IRC SP-20

Rural Roads Manual

Ancillary Material

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LIST OF SYMBOLS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AIV	Aggregate Impact Value
ALD	Average Least Dimension
AWR	All Weather Road
BC	Black Cotton
BIS	Bureau of Indian Standards
BM	Bituminous Macadam
BMM	Block Making Machine
BT	Black Top
CADP	Command Area Development Programme
CBP	Concrete Block Pavement
CBR	California Bearing Ratio
CC	Cement Concrete
CD	Cross Drainage
CR	Coarse Rubble
CRF	Central Road Fund
CRM	Crusher Run Macadam
CRMB	Crumb Rubber Modified Bitumen
CRRI	Central Road Research Institute
CTB	Cement Treated Base
CVPD	Commercial Vehicles Per Day
DBM	Dense Bituminous Macadam
DLC	Dry Lean Concrete
DLFC	Dry Lean Fly Ash Concrete
DPDC	District Planning and Development Committee
e	Superelevation
EAS	Employment Assessment Scheme
EIA	Environmental Impact Assessment
FWR	Fair Weather Road
GBFS	Granulated Blast Furnace Slag
GI	Galvanised Iron
GIS	Geographic Information System
GL	Ground Level
GSB	Granular Sub-Base
H:V	Horizontal : Vertical
HFL	Highest Flood Level
HQ	Headquarters
ICBP	Interlocking Concrete Block Pavement
IMD	Indian Meteorological Department
IRC	Indian Roads Congress
IRDP	Integral Rural Development Programme

IS	Indian Standards
ISD	Intermediate Sight Distance
JGSY	Jawahar Gram Samridhi Yojna
JRY	Jawahar Rozgar Yojana
LBL	Low Bed Level
LFBM	Lime Fly Ash Bound Macadam
LL	Liquid Limit
LWL	Low Water Level
MC	Medium Curing Cut-Back
MCE	Medium Curing Emulsion
MDD	Maximum Dry Density
MDR	Major District Road
MLA	Member of Legislative Assembly
MNP	Minimum Needs Programme
MOC	Magnesium Oxichloride Cement
M/o.RT&H	Ministry of Road Transport and Highways
MP	Member of Parliament
MPa	Mega Pascal
MPC	Magnesium Phosphate Cement
MPM	Modified Penetration Macadam
MSE	Medium Setting Emulsion
MSS	Mix Seal Surfacing
NABARD	National Bank for Agricultural and Rural Development
NH	National Highway
NP_3	Non Pressure Pipe Specified by BIS
NREP	National Rural Employment Programme
ODR	Other District Road
OFL	Ordinary Flood Level
OGPC	Open Graded Pre-Mix Carpet
OMC	Optimum Moisture Content
OPC	Ordinary Portland Cement
OSD	Overtaking Sight Distance
PBL	Protected Bed Level
PCC	Plain Cement Concrete
PI	Plasticity Index
PL	Plastic Limit
PM	Penetration Macadam
PMB	Polymer Modified Bitumen
PMC	Pre Mix Carpet
PMGSY	Pradhan Mantri Gram Sadak Yojana
PPC	Portland Pozzolana Cement
PQC	Pavement Quality Concrete
PWD	Public Works Department
R	Radius of Curve in m

RCC	Roller Compacted Concrete
RCC	Reinforced Cement Concrete
RCE	Rapid Curing Emulsion
RCCP	Roller Compacted Concrete Pavement
RCCP	Roller Compacted Concrete
RCFC	Roller Compacted Fly Ash Concrete
RHA	Rice Husk Ash
RIDF	Rural Infrastructure Development Fund
RL	Reduced Level
RLEGP	Rural Landless Employment Generation Programme
ROW	Right of Way
RR	Random Rubble
RSE	Rapid Setting Emulsion
RTL	Road Top Level
SBC	Safe Bearing Capacity
SC	Seal Coat, Slow-Curing Cut-Back, Scheduled Caste
SD	Surface Dressing
SH	State Highway
SP	Special Publication
SSC	Super Sulphate Cement
SSD	Stopping Sight Distance
SSE	Slow Setting Emulsion
ST	Scheduled Tribe
TI	Traffic Intensity
TRL	Transport Research Laboratory
UCS	Unconfined Compressive Strength
UV	Utility Value
V	Design Speed in km/hr
VR	Village Road
WBM	Water Bound Macadam

Appendix-1.6

LEGEND/COLOUR CODES FOR PREPARATION OF MAPS

A. Roads/Railways

National Highways	NH
State Highways	SH
MDRs	MDR
ODR/VRs	ODR/VR
Any Other VRs	
Railways	

The MDR, ODR and VR should be coloured with the following colours as per their surface conditions:

BT	Red
WBM	Green
Gravel/Brick soling	Violet
Earthen	Grey
Cross drainage	
Water Bodies	Blue

B. Boundaries

District Boundary

Block Boundary

C. Habitations

Habitation (Number indicates (three digit code) numerical serial number of habitation in the Block)

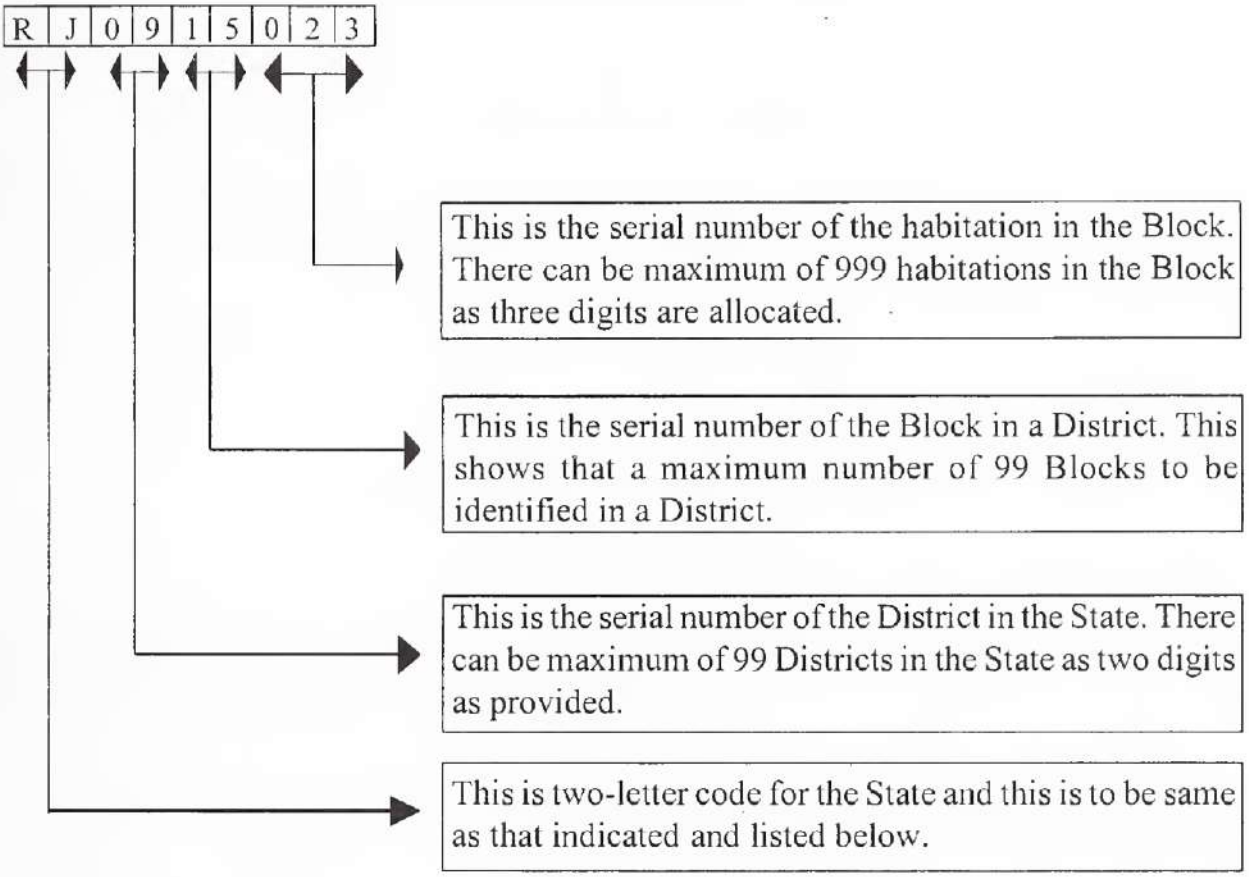
(i) > = 1000 persons	● Black
(ii) 500 - 999 persons	● Red
(iii) 250-499	● Blue
(iv) < 250 persons	● Yellow
District Headquarter	■ (Name)
Block/Tehsil Headquarter	▲ (Name)

D. Other Features

(i) Places of tourist, religious and historical importance

(ii) Quarry site QS

CODING FOR HABITATION



State/Union Territory codes

Name of the State	Code	Name of the State	Code
Andhra Pradesh	AP	Orissa	OR
Arunachal Pradesh	AR	Punjab	PB
Assam	AS	Rajasthan	RJ
Bihar	BR	Sikkim	SK
Chattisgarh	CG	Tamilnadu	TN
Goa	GA	Tripura	TR
Gujarat	GJ	Uttaranchal	UT
Haryana	HR	Uttar Pradesh	UP
Himachal Pradesh	HP	West Bengal	WB
Jammu & Kashmir	JK		
Jharkhand	JH		
Karnataka	KN	**Name of the Union Territory**	
Kerala	KR	Andaman & Nicobar Islands	AN
Madhya Pradesh	MP	Chandigarh	CH
Maharashtra	MH	Dadar and Nagar Haveli	DN
Manipur	MN	Daman & Diu	DD
Meghalaya	MG	Delhi	DL
Mizoram	MZ	Lakshadweep	LK
Nagaland	NG	Pondicherry	PD

Chapter 2

GEOMETRIC DESIGN STANDARDS

2.1. Introduction

These guidelines relating to geometric design standards are intended to be applied to rural roads. For these guidelines, the rural roads shall include Other District Roads (ODR) and Village Roads (VR). These roads provide accessibility to the villages in the rural area of the country. Geometric design standards of the rural roads need not be restricted to the minimum values set out and milder values than the minimum should be preferred where conditions are favourable and the cost is not excessive. Higher standards right in the initial stages may be warranted in cases where improvement of road geometric (like, widening of formation width) at a later date is anticipated due to increased traffic.

The following codes have been published by IRC for providing guidelines on the Geometric Design Standards of Rural Roads.

(i) IRC:73 Geometric Design Standards for Rural (Non-Urban) Highways
(ii) IRC:52 Recommendations About the Alignment Survey and Geometric Design of Hill Roads
(iii) IRC:SP:23 Vertical Curves for Highways
(iv) IRC:38 Guidelines for Design of Horizontal Curves for Highways and Design Tables
(v) IRC:SP:48 Hill Road Manual

Above IRC publications deal with geometric design features for all categories of roads including National Highways. This Chapter exclusively deals with geometric design standards for rural roads and other relevant features. These guidelines can be adopted to new roads as well as improvement of existing rural roads.

2.2. Classification of Rural Roads

The rural roads in India are commonly referred to:

(i) Other District Roads (ODR)
(ii) Village Roads (VR)

Other district roads are the roads serving rural area of production and providing them with outlet to market centres, taluka headquarters, block development headquarters or major district roads, and would serve to connect villages with population 1000 and above or cluster of villages. Village roads are roads connecting villages or cluster/group of villages with each other and to the nearest road of a higher category. These two categories of roads are proposed to be called together as 'rural roads' with uniform standards.

2.3. Terrain Classification

The general slope of the country classifies the terrain across the area. The terrain is an important parameter governing the geometric standards and the criteria given in Table 2.1 should be followed. While classifying a terrain short isolated stretches of varying terrain should not be taken into consideration.

TABLE 2.1. TERRAIN CLASSIFICATION

Terrain Classification	Cross Slope of the Country	
Plain	0-10 per cent	More than 1 in 10
Rolling	10-25 per cent	1 in 10 to 1 in 4
Mountainous	25-60 per cent	1 in 4 to 1 in 1.67
Steep	Greater than 60 per cent	Less than 1 in 1.67

2.4. Design Speed

Design speed is a basic criterion for determining all geometric features of horizontal and vertical alignments. The design speeds for the rural roads should be taken as given in Table 2.2.

TABLE 2.2. DESIGN SPEED

Road Classification	Design Speed (km/h)							
	Plain Terrain		Rolling Terrain		Mountainous Terrain		Steep Terrain	
	Ruling	Min.	Ruling	Min.	Ruling	Min.	Ruling	Min.
Rural Roads (ODR and VR)	50	40	40	35	25	20	25	20

Normally ruling design speed should be the guiding criterion for the purpose of geometric design. Minimum design speed may, however, be adopted where site condition and cost does not permit a design based on "Ruling Design Speed".

2.5. Basic Principles of Geometric Design

These guidelines are intended for uniform practices to achieve optimum design standards for rural roads. As a general rule, geometric features of a road do not allow for stage construction. Improvement of features, like grade, curvature and widening of cross drainage works at a later date can be very expensive and sometimes impossible in remote and hilly area. It is, therefore, necessary that ultimate geometric requirement of rural road should be kept in mind right in the beginning.

If stage construction is unavoidable, the permanent works, like, retaining walls, breast wall, and drain, which may have to be altogether rebuilt, may be constructed using dry masonry. Interceptor drains may be located well at the beginning and culverts provided to full width to avoid the need for their widening subsequently.

The design standards recommended are absolute minimum. However, the minimum values should be applied only where serious restrictions are implied from technical or economical considerations. General effort should be to exceed the minimum values as far as possible. Road should be designed so as to have minimum turns and the total number of curves in one kilometer should generally be less than 6.

2.6. Cross-Sectional Elements

2.6.1. Road Land Width : Road land width (also termed the right-of-way) is the width of land acquired for road purposes. The desirable land width for rural roads in different terrain is given in Table 2.3.

TABLE 2.3. RECOMMENDED ROAD LAND WIDTH

Road Classification	Plain and Rolling Terrain				Mountainous and Steep Terrain			
	Open Area		Built-up Area		Open Area		Built-up Area	
	Normal	Range	Normal	Range	Normal	Exceptional	Normal	Exceptional
Rural Roads (ODR and VR), (m)	15	15-25	15	15-20	12	12	12	9

Note: (i) Additional land width as per requirement may be acquired at locations involving deep cuts, high banks and unstable or landslide prone areas.

(ii) The lower values of land width may be adopted where the traffic intensity is less than 100 vehicles per day, and where the traffic is not likely to increase due to situation, like, dead end, low habitation and difficult terrain conditions.

2.6.2. Building and control lines : In order to prevent overcrowding and preserve sufficient space for future road development, it is advisable to lay down restrictions on building activity along the rural roads. Fig. 2.1 shows road land boundary, building line, control line, roadway and carriageway for rural roads. Recommended standards for building lines and control lines are given in Table 2.4.

TABLE 2.4. RECOMMENDED STANDARDS FOR BUILDING AND CONTROL LINES

Road Classification	Plain and Rolling Terrain		Mountainous and Steep Terrain		
	Open Area	Built-up Area	Open Area	Built-up Area	
	Overall Width Between Bldg. Lines	Overall Width Between Control Lines	Distance Between Bldg. Line and Road Boundary (set-back)	Distance Between Building Line and Road Boundary (set-back)	
Rural Roads (ODR and VR), (m)	25/30*	35	3-5	3-5	3-5

Note: *If the land width is equal to the width between the building lines indicated in Section 2.6.1, the building lines should be set-back by 2.5 m from the road land boundary.

2.6.3. Roadway width : Roadway width inclusive of parapet, side drains for rural roads for different terrain shall be as given in Table 2.5.

TABLE 2.5. RECOMMENDED ROADWAY WIDTH

Terrain Classification	Roadway Width (m)
Plain and Rolling	7.5
Mountainous and Steep	6.0

Notes: (i) For rural roads, where the traffic intensity is less than 100 motor vehicles per day, and where the traffic is not likely to increase due to situation like dead end, low habitation and difficult terrain conditions the roadway width may be reduced to 6.0 m in case of plain and rolling terrain.

(ii) The roadway width given in the Table 2.5 for mountainous and steep terrain is inclusive of parapet.

(iii) The roadway width for Rural Roads is on the basis of a single lane carriageway of 3.75 m.

(iv) On horizontal curves the roadway width should be increased corresponding to the extra width of carriageway for curvature.

(v) On roads subjected to heavy snowfall and landslides, where regular snow or debris clearance is done over long period to keep the road open to traffic, roadway width may be increased by 1.5 m.

2.6.4. Carriageway width : The standard width of carriageway for both plain and rolling as well as mountainous and steep terrain shall be as given in Table 2.6. Typical cross-sections of rural roads are given in Figs. 2.2 and 2.3.

TABLE 2.6. RECOMMENDED CARRIAGEWAY WIDTH

Road Classification	Carriageway Width (m)
Rural Roads (ODR and VR)	3.75

Note: For rural roads, the carriageway width may be restricted to 3.0 m, where the traffic intensity is less than 100 motorised vehicles per day, and where the traffic is not likely to increase due to situation, like, dead end, low habitation and difficult terrain conditions.

As per DO#P-10021/2/2007-Tech, Dt. 5/11/2018 of the Joint Secretary (RC) & DG, NRRDA, New Delhi, the carrigeway of CC pavement in habitations can be laid between edge-to-edge of building lines (subject to a maximum of 6.0 m) along with hard shoulders and side drains. See Appendix 2.1 for reference and details

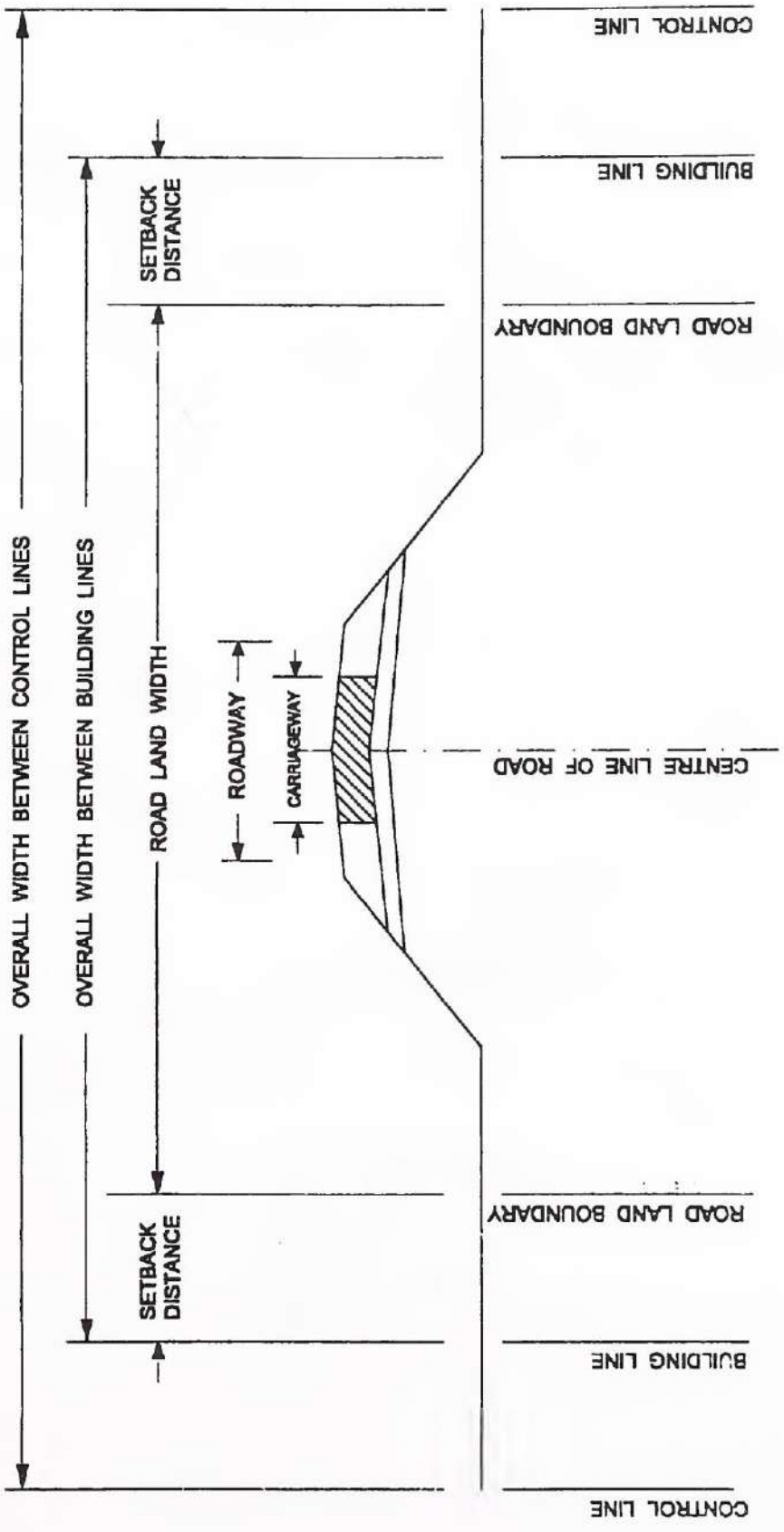


Fig. 2.1. Road Land Boundary, Building Lines and Control Lines

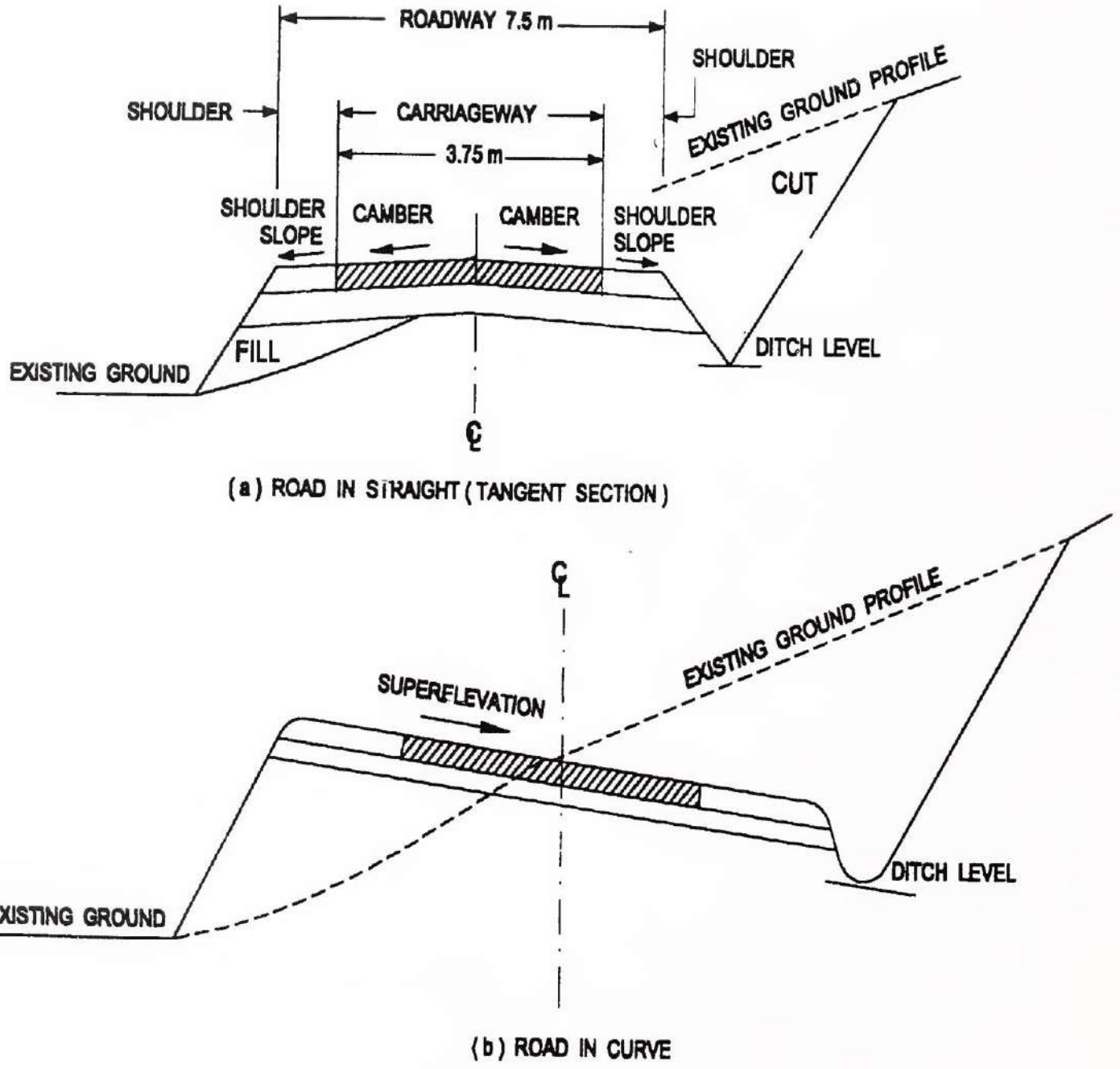


Fig. 2.2. Typical Cross-Section in Plain and Rolling Terrain

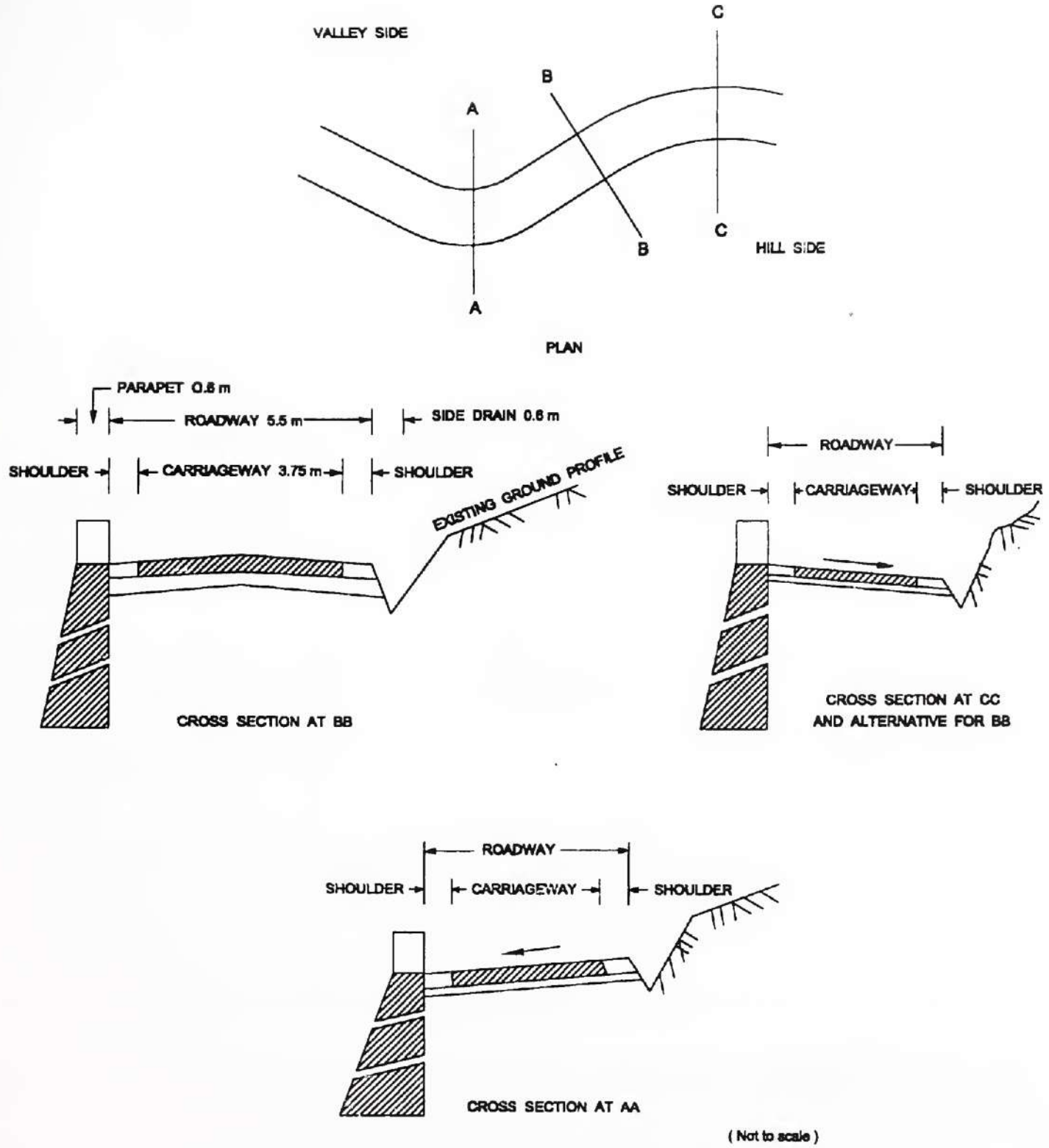


Fig. 2.3. Typical Cross-Sections in Mountainous and Steep Terrain

2.6.5. Shoulder width : The width of shoulder for rural roads in different terrain can be directly obtained using Tables 2.5. and 2.6. Shoulder width will be one half the difference between the roadway width and carriageway width.

2.6.6. Side slopes : Side slope for rural road where embankment height less than 3.0 m is given in Table 2.7.

TABLE 2.7. SIDE SLOPE FOR RURAL ROADS

Condition	Slope (H:V)
Embankment in silty/sandy/gravelly soil	2:1
Embankment in clay or clayey silt or inundated condition	2½ :1 to 3:1
Cutting in silty/sandy/gravelly soil	1:1 to ½ :1
Cutting in disintegrated rock or conglomerate	½:1 to ¼:1
Cutting in soft rock like shale	¼:1 to 1/8 :1
Cutting in medium rock like sandstone, phyllite	1/12 :1 to 1/16:1
Cutting in hard rock like quartzite, granite	Near vertical

2.7. Roadway Width at Cross-Drainage Structures

It is difficult to widen cross-drainage structure at a later stage. Therefore, the roadway width should be decided very carefully at the planning stage itself. Causeway and submersible bridge are usually provided on rural roads. High-level bridge on rural roads shall be provided only in exceptional cases on merit.

2.7.1. Culvert : The roadway width at culvert (measured from outside to outside of the parapet walls) shall be as given in Table 2.8.

TABLE 2.8. ROADWAY WIDTH AT CULVERT

Road Classification	Terrain (m)	
	Plain and Rolling	Mountainous or Steep
Rural Roads (ODR and VR)	7.5	6.0

2.7.2. Bridge : The roadway width between the kerb for minor and major bridges shall be as given in Table 2.9.

TABLE 2.9. ROADWAY WIDTH AT BRIDGE

Road Classification	Clear Roadway Width (m)
Rural Roads (ODR and VR)	5.5

The roadway width specified in Table 2.9 is exclusive of parapet.

For rural roads, where the traffic is less than 100 motorised vehicles per day and it is not likely to grow due to situation, like, dead end, low habitation and difficult terrain conditions, the roadway width at bridge may be reduced to 4.25 m.

2.7.3. Causeway and submersible bridge : Roadway width at causeway and submersible bridge shall be as given in Table 2.10.

TABLE 2.10. ROADWAY WIDTH AT CAUSEWAY AND SUBMERSIBLE BRIDGES

Road Classification	Overall Roadway Width (m)	
	Plain and Rolling	Mountainous and Steep Terrain
Rural Roads (ODR and VR)	7.5	6.0

2.8. Camber

The camber on straight section of road should be as recommended in Table 2.11.

TABLE 2.11. CAMBER FOR DIFFERENT SURFACE TYPES

Surface Type	Camber (per cent)	
	Low Rainfall (Annual Rainfall < 1000 mm)	High Rainfall (Annual Rainfall > 1000 mm)
Earth road	4.0	5.0
WBM and gravel road	3.5	4.0
Thin bituminous pavement	3.0	3.5
Rigid pavement	2.0	2.5

At super-elevated road sections, the shoulder should normally have the slope of same magnitude and direction as the pavement slope subject to the minimum cross-fall allowable for shoulder. The camber for earth shoulder should be at least 0.5 per cent more than that for the pavement subject to the minimum of 4 per cent. However, 1 per cent more slope than the camber for pavement is desirable.

2.9. Sight Distances

Visibility is an important requirement for the safety of travel on roads. For this, it is necessary that sight distance of adequate length should be available in different situations to permit drivers enough time and distance to control their vehicles so that chances of accidents are minimised. Three types of sight distance are relevant in the design of road geometry: Stopping Sight Distance (SSD); Intermediate Sight Distance (ISD) and Overtaking Sight Distance (OSD).

2.9.1. Stopping sight distance : The stopping sight distance is the clear distance ahead needed by a driver to bring his vehicle to a stop before collision with a stationary object in his path, and is calculated as the sum of braking distance required at the particular speed plus the distance travelled by the vehicle during perception and brake reaction time.

2.9.2. Intermediate sight distance : Intermediate sight distance is defined as twice the stopping sight distance.

2.9.3. Overtaking sight distance : Overtaking sight distance is the minimum sight distance that should be available to a driver on a two-way road to enable him to overtake another vehicle. The provision of overtaking sight distance is by and large not feasible on hill roads and also not considered for single lane roads.

The design values for these sight distances and criteria for their measurement are given in Tables 2.12 and 2.13 respectively.

TABLE 2.12. DESIGN VALUES OF STOPPING, INTERMEDIATE AND OVERTAKING SIGHT DISTANCE

Speed (km/h)	Design Values (m)		
	Stopping Sight Distance	Intermediate Sight Distance	Overtaking Sight Distance
20	20	40	-
25	25	50	-
30	30	60	-
35	40	80	-
40	45	90	165
50	60	120	235

TABLE 2.13. CRITERIA FOR MEASURING SIGHT DISTANCE

Sight Distance	Driver's Eye Height (m)	Height of object (m)
Safe Stopping Sight Distance	1.2	0.15
Intermediate Sight Distance	1.2	1.2
Overtaking Sight Distance	1.2	1.2

In addition to these, on valley curves, the design is governed by night visibility also. Application of sight distance criteria for geometric design is covered in the following sections.

2.10. Horizontal Alignment

2.10.1. General guidelines

(i) The alignment should be as directional, fluent and matching well with the surrounding topography as possible and also to avoid abrupt changes.

(ii) On new roads the curves should be designed to have the largest practical radius generally not less than the ruling value corresponding to ruling design speed given in Table 2.2.

(iii) Absolute minimum values based on Minimum Design Speed may be used where economics of construction and site condition so dictates. The radii below the absolute minimum should not be provided.

(iv) Straight section exceeding 3 km length should be avoided. A curvilinear alignment with long curve is better from point of safety and aesthetic.

(v) Sharp curves should not be introduced at the end of long tangents, since these can be extremely hazardous.

(vi) Curve should be sufficiently long and have suitable transition curves at either end to eliminate the shock due to application of centrifugal force. For deflection angle less than 1 degree no curve is required to be designed.

(vii) Reverse curves may be needed in difficult terrain. Sufficient length between two curves shall be provided for introduction of requisite transition curve.

(viii) To avoid distortion in appearance, the alignment should co-ordinate with the longitudinal profile.

2.10.2. Horizontal curve : In general, horizontal curve should consist of a circular portion flanked by spiral transition at both ends. Design speed, super elevation and coefficient of side friction affect the design of circular curves. Length of transition curve is determined on the basis of rate of change of centrifugal acceleration or the rate of change of super elevation.

2.10.3 Superelevation : Superelevation to be provided on curve is calculated from the following formula:

$$e = \frac{V^2}{225R}$$

Where e = Superelevation in metre per metre

V = Design speed in km/ hr

R = Radius of the curve in metres

Superelevation obtained from the above expression should, however, be kept limited to the following values:

Plain and rolling terrain	7 per cent
Snow bound area	7 per cent
Hilly area but not snow bound	10 per cent

Fig. 2.4 indicates the super-elevation rates and radius of curvature for various design speeds on this basis. For safety reasons superelevation should be used for all roads regardless of traffic volumes. The only exception may be for very large radius curve. When the superelevation calculated is less than the minimum camber required for drainage of surface water no superelevation need be provided. Table 2.14 shows the radii of horizontal curve for different camber beyond which extra superelevation is not required. The change over from normal section to superelevated section should be achieved gradually over the full length of the transition curve. In case where the transition curve cannot be provided for some reason, two-third superelevation may be attained on the straight and the balance one-third on the circular curve. Keeping in view pavement surface drainage, superelevation should not be less than the rate of camber appropriate for the type of wearing surface.

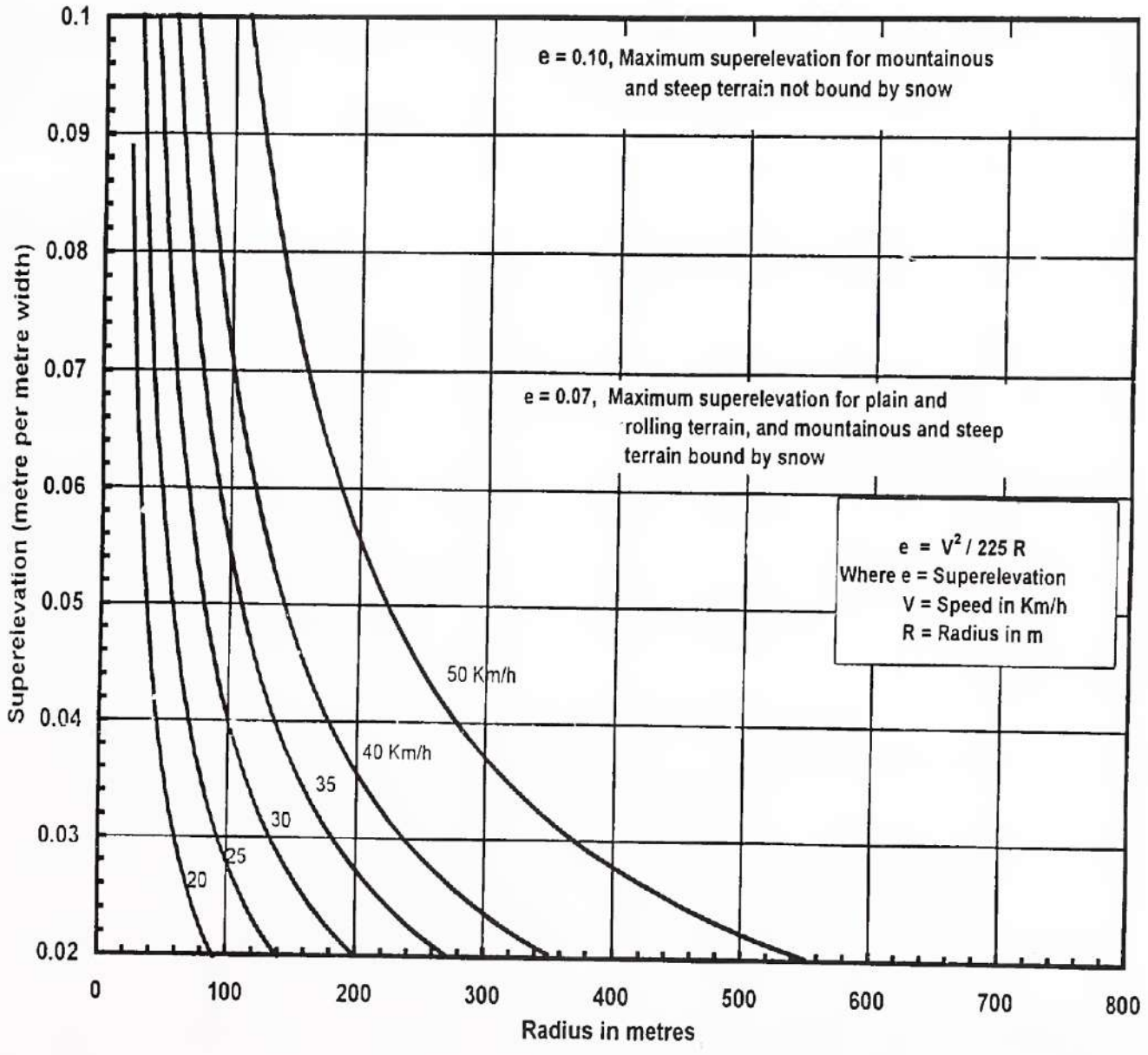


Fig. 2.4. Superelevation Rates for Various Design Speeds

TABLE 2.14. RADII BEYOND WHICH SUPERELEVATION NOT REQUIRED

Design Speed (km/h)	Radius (m)			
	4 per cent Camber	3 per cent Camber	2.5 per cent Camber	2.0 per cent Camber
20	50	60	70	90
25	70	90	110	140
30	100	130	160	200
35	140	180	220	270
40	180	240	280	350
50	280	370	450	550

The change from normal cross-section to a superelevated section should be made gradually. The normal cambered section of the road is changed into superelevated section in two stages. First stage is the removal of adverse camber in outer half of the pavement. In the second stage, superelevation is gradually built-up over the full width of the carriageway so that the required superelevation is available at the beginning of the circular curve. There are three different methods for attaining the superelevation:

(i) Revolving pavement about the centreline
(ii) Revolving pavement about the inner edge of the pavement
(iii) Revolving pavement about the outer edge

For rural roads, the first method, i.e., revolving pavement about the centreline will be suitable in most of the situations. Since vehicles have to frequently use the shoulders in the case of single lane roads, the shoulder slope on superelevated sections should be of the same magnitude and direction as the pavement slope. The required superelevation on shoulders should be attained simultaneously with the pavement in the same manner. In case transition curves are provided, superelevation is attained over length of transition curve.

2.10.4. Minimum curve radii : On new roads, horizontal curve should be designed to have the targeted practical radius generally more than the values corresponding to the ruling design speed. However, absolute minimum values based on minimum design speed might be resorted to if economics of construction or the site conditions so dictate. While improving existing roads, curves having radii corresponding to absolute minimum standard may not be flattened unless it is necessary to realign the road for some other reasons. The minimum curve radii for horizontal curves corresponding to ruling minimum and absolute minimum design speeds are given in Table 2.15.

TABLE 2.15. MINIMUM RADII OF HORIZONTAL CURVES

Road Category	Plain Terrain		Rolling Terrain		Mountainous Terrain				Steep Terrain			
					Areas not Affected by Snow		Areas Affected by Snow		Areas not Affected by Snow		Areas Affected by Snow	
	Ruling Minimum	Absolute Minimum	Ruling Minimum	Absolute Minimum	Ruling Minimum	Absolute Minimum	Ruling Minimum	Absolute Minimum	Ruling Minimum	Absolute Minimum	Ruling Minimum	Absolute Minimum
Rural Roads (ODR & VR), (m)	90	60	60	45	20	14	23	15	20	14	23	15

Note: Ruling minimum and absolute minimum radii are for ruling design speed and *minimum design speed respectively vide Table 2.2.*

2.10.5. Transition curve : Spiral curve should be used for transition. This is necessary for a vehicle to have smooth entry from a straight section in to a circular curve. The transition curve also improves aesthetic appearance of the road besides permitting gradual application of the superelevation and extra widening of carriageway needed at the horizontal curve. Transition curve is provided at both ends of horizontal curve. Minimum length of transition curves for various radii are given in Table 2.16. For deriving values of the individual elements like shift, tangent distance, apex distance, etc., and working out co-ordinates to lay the curves in the field, it is convenient to use curve tables. For this, reference may be made to IRC:38.

2.10.6. Widening at curves : At sharp horizontal curve, it is necessary to widen the carriageway to facilitate safe passage of vehicles. The extra width to be provided to horizontal curve are given in Table 2.17. By increasing the width at an approximately uniform rate along the transition curve required widening should be achieved; the extra width should be continued over the full length of the circular curve. The widening should be done on both sides of the carriageway, except that on hill roads it will be preferable if the entire widening is done only on the inner side of the curve.

TABLE 2.16. MINIMUM LENGTH OF TRANSITION CURVE FOR DIFFERENT SPEEDS AND CURVE RADII

Plain and Rolling Terrain				Mountainous and Steep Terrain				
Curve Radius (m)	Design Speed (km/h)			Curve Radius (m)	Design Speed (km/h)			
	50	40	35		40	30	25	20
	Transition Length (m)				Transition Length (m)			
45		NA	70	14			NA	30
60	NA	75	55	20			35	20
90	75	50	40	25		NA	25	20
100	70	45	35	30		30	25	15
150	45	30	25	40	NA	25	20	15
170	40	25	20	50	40	20	15	15
200	35	25	20	55	40	20	15	15
240	30	20	NR	70	30	15	15	15
300	25	NR		80	25	15	15	NR
360	20			90	25	15	15	
400	20			100	20	15	15	
500	NR			125	15	15	NR	
600				150	15	15		
700				170	15	NR		
800				200	15			
900				250	15			
1000				300	NR			

NA Not applicable NR Transition not required.

TABLE 2.17 WIDENING OF PAVEMENT AT CURVE

Radius of Curve (m)	Upto 20	21-60	Above 60
Extra Widening for 3.75 m Wide Single Lane Carriageway, (m)	0.9	0.6	Nil

2.10.7. Set-back distance at horizontal curves : Requisite sight distance should be available across the inner side of the horizontal curve. Lack of visibility in the lateral direction may arise due to obstruction, like, wall, hill cut, wooded area, high slope, etc. The sight distance is measured along the middle of the inner

lane. However, on single lane road, sight distance is measured along the centre line of the carriageway. The set-back distance is calculated using the following equation :

$$m = R - (R-n)\cos\phi$$

Where $\phi = \frac{S}{2(R-n)}$ radians

m = the minimum set-back distance from the centre line of the road in metres

R = radius of the centre line of the road in metres

n = distance between the centre line of the road and the inside lane in metres

S = required sight distance in metres

Utilising the above equation the design values of the set-back distance corresponding to safe stopping distance for single lane carriageway are given in Table 2.18.

TABLE 2.18. RECOMMENDED SET-BACK DISTANCE FOR SINGLE LANE CARRIAGEWAY

Radius of Circular Curve (m)	Set-Back Distance (m)				
	S=20 m (V=20 km/h)	S=25 m (V=25 km/h)	S=30 m (V=30 km/h)	S=45 m (V=40 km/h)	S=60 m (V=50 km/h)
14	3.4	-	-	-	-
15	3.2	-	-	-	-
20	2.4	3.8	-	-	-
23	2.1	3.3	-	-	-
30	1.7	2.6	3.7	-	-
33	1.5	2.3	3.4	-	-
50	1.0	1.6	2.2	5.0	-
60	-	1.3	1.9	4.2	-
80	-	1.0	1.4	3.1	5.6
100	-	0.8	1.1	2.5	4.5
120	-	0.7	0.9	2.1	3.7
150	-	0.5	0.8	1.7	2.3

Set-back distance for overtaking or intermediate sight distance can be computed similarly but the clearance required is usually too large to be economically feasible except on very flat curves. Where there is hill slope on the inner side of the horizontal curve, the average height of sight line for stopping sight distance can be used as 0.7 m for deciding the extent of clearance. Cut slope should be kept lower than the height of the sight line demarcating the set-back distance, either by cutting back the slope or benching suitably. In the case of intermediate or overtaking sight distance, height of sight line above the ground should be taken as 1. 2 m. Where horizontal and vertical curve overlap, the design should provide for the required sight distances both in the vertical direction along the pavement and in the horizontal direction on the inner side of the curve.

2.11. Vertical Alignment

The designer has to always keep an eye on economy in selecting the alignment and the longitudinal profile. It is general practice to follow as closely as possible the natural terrain profile. Desirably there should be no change within the distance of 150 m. Two vertical curves in same direction with a short tangent should be avoided. The longitudinal profile should be co-ordinated suitably with the horizontal alignment.

Decks of small cross drainage structures (culverts and minor bridges) should follow the same profile as the flanking road section without any break in the grade line.

2.11.1. Gradient : The rate of rise or fall with respect to the horizontal along the length of road expressed as ratio or a percentage is termed as the "gradient". Gradient should be carefully selected keeping in view the design speed and terrain. Various levels of gradients which are generally adopted for roads are as given below:

(a) **Ruling gradient:** It is a gradient, which in the normal course must never be exceeded in any part of road.

(b) **Limiting gradient:** It is a gradient steeper than the ruling gradient, which may be used, in restricted lengths where keeping within the ruling gradient is not feasible.

(c) **Exceptional gradient:** It is a gradient steeper than the limiting gradient, which may be used in short stretches only in extraordinary situation.

Gradient upto the 'ruling gradient' may be used as a normal course in design. The 'limiting gradients' may be used where the topography of a place compels this or where the adoption of gentler gradients would involve additional cost. In such case also, the length of continuous grades steeper than the ruling gradients should be as short as possible.

'Exceptional gradients' are meant to be adopted only in very difficult situations and for short length not exceeding 100 m at a stretch. In mountainous and steep terrain, successive stretches of exceptional gradients must be separated by a minimum length of 100 m having gentler gradients. Recommended gradient for different classes of terrain except at hair-pin bends are given in Table 2.19. The rise in elevation over a 2 km length shall not exceed 100 m in mountainous terrain and 120 m in steep terrain. In hilly terrain, gradient should be such that it can be negotiated with the least change of gears by heavier vehicles to save time and operation cost.

TABLE 2.19. RECOMMENDED GRADIENTS FOR DIFFERENT TERRAIN CONDITIONS

Terrain	Ruling Gradient	Limiting Gradient	Exceptional Gradient
Plain and rolling	3.3 Per cent (1 in 30)	5 Per cent (1 in 20)	6 Per cent (1 in 16.7)
Mountainous terrain and steep terrain having elevation more than 3,000 m above the mean sea level	5 Per cent (1 in 20)	6 Per cent (1 in 16.7)	7 Per cent (1 in 14.3)
Steep terrain having elevation more than 3,000 m above the mean sea level	6 Per cent (1 in 16.7)	7 Per cent (1 in 14.3)	8 Per cent (1 in 12.5)

In the plain area, as the road is used by slow moving bullock carts and motor vehicles, gradient adopted should be such that it will not have adverse effect on bullock cart traffic.

2.11.2. Grade compensation at curves : At horizontal curves, the gradients should be eased by an amount known as the 'Grade Compensation' which is intended to offset the requirement of extra tractive effort at curves. This may be calculated from the following formula:

Grade compensation (per cent) = $(30 + R)/R$

Subject to a maximum of $75/R$, where R is radius of the curve in meters.

Since grade compensation is not necessary for gradients flatter than 4 per cent, while compensation of the grady they need not be eased beyond 4 per cent.

2.11.3. Vertical curve : Vertical curves are introduced for smooth transition at grade changes. Both summit curves and valley curves should be designed as parabola. The length of the vertical curve is controlled by sight distance requirements, but curves with greater length are aesthetically better. Curves should be provided at all grade changes exceeding those given in Table 2.20. For satisfactory appearance, the minimum length should be as given in the Table 2.20.

TABLE 2.20. MINIMUM LENGTH OF VERTICAL CURVE

Design Speed km/h	Maximum Grade Change (per cent) Not Requiring a Vertical Curve	Minimum Length of Vertical Curve (meter)
Upto 35	1.5	15
40	1.2	20
50	1.0	30

2.11.3.1. Summit curve : The length of summit curve is governed by the choice of sight distance according to the operating condition of the road. The required length may be calculated from the formulae given in Table 2.21.

TABLE 2.21. LENGTH OF SUMMIT CURVE

Case	Length of Summit Curve	
	For Stopping Sight Distance	For Intermediate Sight Distance
When the length of the curve exceed the required sight distance, i.e., L is greater than S	$L = \frac{NS^2}{4.4}$	$L = 2S - \frac{4.4}{N}$
When the length of the curve is less than the required sight distance, i.e., L is less than S	$L = \frac{NS^2}{9.6}$	$L = 2S - \frac{9.6}{N}$

Where

N = deviation angle, i.e., the algebraic difference between the two grades
L = length of parabolic vertical curve in metres
S = sight distance requirement in metres

2.11.3.2. Valley curve : The length of valley curves should be such that for night travel, the headlight beam distance is equal to the stopping sight distance. The length of curve may be calculated using formulae given in Table 2.22.

TABLE 2.22. LENGTH OF VALLEY CURVE

Case	Length of Valley Curve
When the length of the curve exceed the required sight distance, i.e., L is greater than S	$L = \frac{NS^2}{1.5+0.035S}$
When the length of the curve is less than the required sight distance, i.e., L is less than S	$L = 2S - \frac{1.5 + 0.035S}{N}$

Where

N = deviation angle, i.e., the algebraic difference between the two grades
L = length of parabolic vertical curve in metres
S = stopping sight distance in metres

2.12. Alignment Compatibility

As a general rule, changes in horizontal and vertical alignment should be phased to coincide with each other, i.e., the vertical curve should roughly extend from the commencement to the end of the corresponding horizontal curve. Preferably, the horizontal curve should be somewhat longer than the vertical curve. Sharp horizontal curve should not be introduced at or near the top of the summit vertical curve or the lowest point of valley curve.

2.13. Hair- Pin Bends

A hair-pin bend may be designed as a circular curve with transition at each end. Alternatively, compound circular curves may be provided. The following design criteria should be followed normally for the design of hair pin bends :

Minimum design speed	20 km/hr
Minimum roadway width at apex	7.5 m
Minimum radius for the inner curve	14.0 m
Minimum length of transition curve	15.0 m
Gradient	
Maximum	1 in 40 (2.5 per cent)
Minimum	1 in 200 (0.5 per cent)
Superelevation	1 in 10 (10 per cent)

The inner and outer edge of the roadway should be concentric with respect to centre line of the pavement. Where a number of hair-pin bends have to be introduced, a minimum intervening length of 60 m should be provided between the successive bends to enable the driver to negotiate the alignment smoothly. Widening of hair-pin bends at a later date is a difficult and costly process. Moreover, gradients tend to become sharper, as widening can be achieved generally only by cutting the hillside. These points should be kept in view at the planning stage, especially where a series of hair-pin bends is involved. At hair-pin bends, preferably the full roadway width should be provided with surfacing.

2.14. Passing Places

On hill roads passing places are required to facilitate crossing of vehicles. These should be provided at the rate of 2 to 3 per kilometre. The exact location should be judiciously decided on the basis of site conditions. The length of passing place should be about 20 to 30 m long with a carriageway width of 5.5 m.

2.15. Later and Vertical Clearance

2.15.1. Lateral clearance : It is desirable that the full roadway width at the approaches should be carried through the underpass. This implies that the minimum lateral clearance (i.e., the distance between the extreme edge of the carriageway and the face of the nearest support whether a solid abutment, pier or column) should be equal to the normal shoulder width.

2.15.2. Vertical clearance : The minimum vertical clearance of 4.5 m should be ensured over the full width of the roadway at all underpasses, and similarly at overhanging cliffs. The vertical clearance should be measured in reference to the highest point of the carriageway, i.e., the crown or the superelevated edge of the carriageway as the case may be. Due allowance for any future raising/strengthening of the pavement should also be made.

2.16. Traffic Engineering Requirements

The rural roads are low volume (traffic) low speed roads with maximum design speed of 50 kmph. The geometric designs are detailed in this Chapter adequately fulfils the requirements of traffic that is likely to use rural roads. However, a few features need careful considerations to maintain safety and convenience of the vehicles using these roads.

2.16.1. Intersection with other road : A rural road quite often meets or crosses another road of higher category. In such situation the junction layout is required to be provided in such a way that the safety of the vehicles leaving the higher category of road and joining the rural road or those which join the higher category of road from the rural road is maintained adequately. As the higher category of the road will normally have wider right-of-way provision, the intersection is to be flared along the higher category of road as shown in the Fig. 2.5. The figure also shows that the rural road should not meet the other road at an angle other than 90°. Thus, wherever such condition prevails, effort should be made to realign the road near the junction and make it a right angled junction.

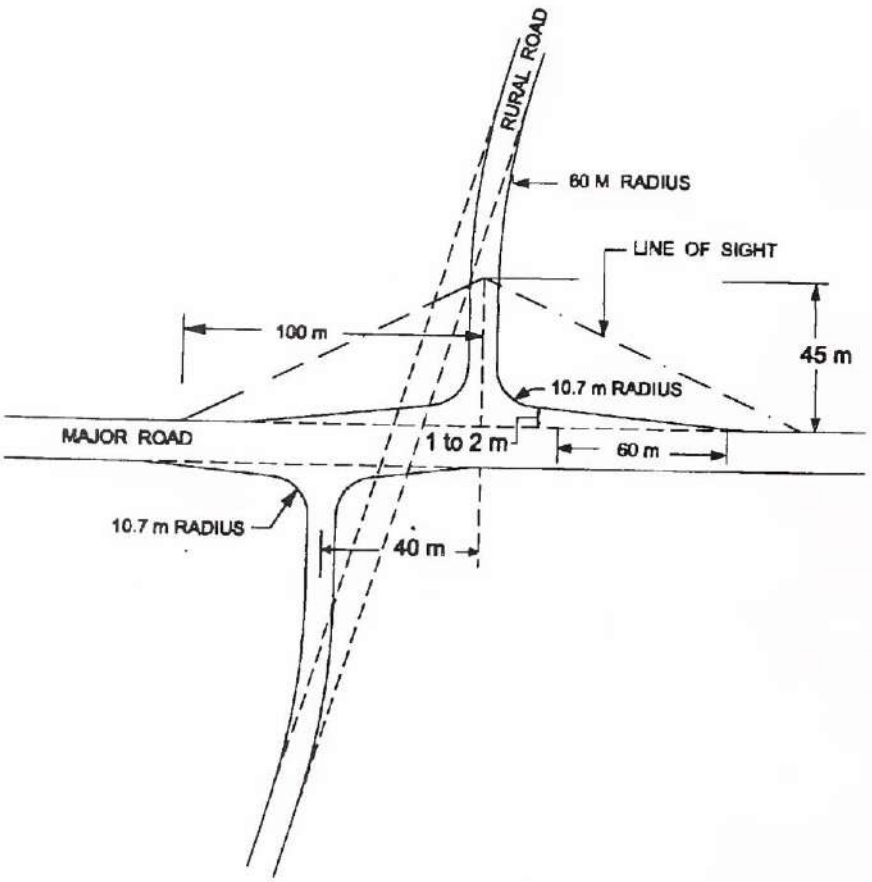


Fig. 2.5. Intersection of Rural and Major Road

2.16.2. Other traffic engineering features : The rural roads are designed and constructed as single lane road with sealed or unsealed surface depending on traffic and other criteria. Thus, there is no requirement of pavement marking. Regarding the signs, the following requirements should be met.

Stop Sign: When rural roads meet each other, the junction should be a stop sign controlled junction, and minor road of the two should be provided with stop signs. In case of rural road meeting any higher category of roads, the traffic joining the higher type road shall be controlled by a stop sign.

Direction Sign: The rural road shall have all the necessary direction signs as per the requirement of road signages recommended by IRC.

Kilometre Stone: The rural road shall have kilometre stone of standard size as given by IRC with top rounded portion painted in orange colour.

Socio-economic: Road projects can provide beneficial impacts through increased access, which in turn can lead to proliferation of related developmental activities and employment generation. The quality of life value, public health and other related aspects may be evaluated.

The degree of impact of road construction on the different environmental aspects vary depending on factors such as the types of area, the terrain (plain, rolling or hilly), and the land use pattern of the area. For example, road construction in the hills is associated with problems like landslides, soil erosion, etc. which are of serious environmental consequences. Where a road has to pass through forest land, obtaining necessary clearance from the Department of Forests and Wildlife is important. Thus, depending on the situation, the aspects requiring detailed study should be identified and the investigations organized accordingly.

3.4.3. Road construction in hilly areas : Construction of a road in the hills is a human necessity for providing the basic communication facility, but this activity invariably disturbs the natural setting and creates conditions conducive to large-scale landslides in the first few years of construction. Even dense forests are not immune to this problem. With the removal of vegetative cover, destructive action of water gets further pronounced and accelerates the process of soil erosion and formation of deep gullies. Consequently the hill faces are bared of soil and vegetative cover and enormous quantities of soil and rock move down the rivers, and in some cases the road itself is washed out.

While the adverse effects of hill road construction on the environmental/ecological system cannot be eliminated altogether, counter measures must be taken by the road construction agencies to bring down the adverse effects to the barest minimum possible. This calls for careful attention right from the stage of conception of the road to surveys and investigations, alignment selection and project formulation, construction, and subsequent maintenance. To ensure that best results are achieved and expensive maintenance is avoided, measures taken should not be considered in isolation but built into the road project itself as an integral part with all necessary provisions for the purpose.

3.5. Erosion Control

There are numerous instances where many embankment slopes made up of different types of soils suffered a high degree of damage due to erosion from rain and wind. Denudation of vegetation from soil slopes or the lack of vegetation cover on embankment slopes is often responsible for the formation of rills and rain-cuts, eventually leading to a surficial slide or even to undermining of the edges of the road pavement structure. When vegetation is established on slopes, there becomes available an effective dense network of root system, penetrating to a depth of about 0.5 to 0.75 m into the slope, which serves to anchor down the soil mantle and render resistance to erosion. There are a number of techniques to prevent erosion of slopes and are discussed below.

3.5.1. Simple vegetative turfing : This is most economical method of providing vegetation on embankment slopes which generally support the growth of vegetation. The method consist of preparing a slope area into seed beds by grading it to the extent possible and then broadcasting seeds or planting root slips of the promising types of locally available plants. One recommended variation of this technique is that instead of treating the whole of the slope in poor soils, plantation could be encouraged by putting in seedling in isolated pockets of specially enriched soil.

There are limits to the successful application of this method. The method is apt to fail in the following situations:

(i) On very erodible slopes where seeding or sprigging is liable to be washed before they have had time to take root.

(ii) When work is done immediately preceeding or during very heavy downpour.

(iii) In places where no artificial supply of water is available for promoting growth of vegetation or where adequate supply of moisture to the slopes by light rain or drizzle is not available outside of the monsoon season.

Only under these circumstances, it is advisable to go in for a special technique, such as, the ones recommended in the succeeding paras of this Chapter.

3.5.2. Transplantation of ready made turfs of grass : It is also possible to provide vegetative turfing by 'sodding' which involves the bodily transplantation of blocks of turfs of grass (with some 5-8 cm of soil covering the grass roots) from the original site to the side slopes of the embankment to be treated. If found necessary, pegs or nails could be used to hold down the grass sods in the initial stage.

3.5.3. Straw with cowdung or wood shavings or sawdust as mulch : In case of embankments which are less than 3 m high, where the severity of the erosion problem is not of a high order, the use of straw mixed with cowdung, or wood shavings or sawdust mixed with cowdung is recommended as a mulch. The approximate thickness of wood shavings or sawdust cover should be 25 mm. The organic mulch covering the soil slopes can be held in place and made resistant to being washed downhill or blown away by pegging them down with bamboos, at suitable intervals, on a grid pattern and also laying bamboos horizontally connecting the pegs and thus forming the grids.

3.6. Special Techniques

3.6.1. Asphalt mulch technique : The slope proposed to be treated should be demarcated and fenced by local prickly bushes or by barbed wire. The slopes should be then prepared into vast seedbeds by rounding off the tops, regarding or reshaping the slope and by finally raking the topsoil to about 5 cm thickness. If the slopes are entirely raw and infertile, and if the soil happens to be slightly acidic, calcium ammonium nitrate should be applied at the rate of 50 kg per 500 sq. metres. The root slips of the most promising types of locally available grasses should then be dibbled, 15 to 25 cm apart, root to root and row to row. The asphaltic film gradually disintegrates, its place being gradually taken up by a carpet of green vegetation, penetrating through the asphaltic film. The carpet of grass that supplants the asphaltic film acts as an immediate cover for the slope till the more deep-rooted species of shrubs and trees develop and take root. After planting of grass roots, etc., these should be watered. An asphalt emulsion (Mulch) is then sprayed by a suitable sprayer. The optimum rate of application of the emulsion shall be 0.7-1.0 kg. per sq.m. By and large, on the basis of requirement of this technique, it would be preferable to use a medium to slow breaking emulsion. If required water may be added to the bituminous emulsion to give a 50:50 composition of binder and water. The thickness of the emulsion coating should be optimum because thicker applications would tend to retard the growth of plants and seeds, whereas application thinner than optimum would not be effective in controlling erosion. The advantages resulting from the application of the asphalt emulsion are:- (i) susceptibility to erosion is cut down, (ii) the moisture content as well as the nutrients in the soil mantle are conserved and (iii) the soil temperature is raised by absorbing the light rays, promoting the emergence of tiny saplings.

The method proves particularly successful if it is so timed that advantage is taken of the increased moisture content in the soil resulting from the first couple of monsoon showers. However, neither a continuous heavy downpour nor a long spell of dry weather occurring immediately after the completed treatment is desirable since in such an eventuality the process will perhaps have to be repeated partially or fully.

3.6.2. Vegetative turfing using jute/coir netting : It has been found that if a heavy mesh of jute/coir fabric is firmly laid on loose earth and sown upon with suitable grass seeds, it gives maximum protection to the soil until the grass takes root and furnishes a permanent coverage. After the soil is thus stabilised, the netting

decomposes and provides nourishment to the grass growing on a soil medium, which hardly possesses any nutrient. The netting can have 2.5 to 5 cm square openings between the threads, giving the grass plenty of room to grow and at the same time providing a large number of check dams per unit area of the material. The netting is just rolled out on the areas to be treated and is properly secured over the ground where a concentrated flow of water is liable to occur, and where there is danger of under cutting of the soil. The netting is firmly secured on to the sloping surface by means of special staples at specified intervals. Control of erosion is effected immediately after the netting is laid. One half of the normal amount of seeding is broadcast prior to the placement of the netting and the other half is broadcast after the netting is in place.

3.6.3. Slope in cohesionless sands : In a purely granular material, it is rather difficult to establish vegetation. Even if it were possible, the sand drains in between the network of root-system are most susceptible of being piped out or washed out, since the distant roots can hardly afford resistance to the movement of individual grains at the surface. Once the movement starts, it can become progressively unconfined and is most liable to 'flow'. The remedial treatment is thereby to provide 0.25 m to 0.3 m thick layer of clayey soil (but not heavy clays) as a blanket covering to the slope of the embankment, tamp it well on the slope and subsequently provide the simple vegetative treatment. If the circumstances are unfavourable for the ordinary method, one may resort to the use of special techniques such as those described above.

3.6.4. Slopes in black cotton soils : Invariably there does not appear to be any need for any special treatment against erosion on black cotton soil slopes since most black cotton soil slopes are seen to promote natural growth of grass and other types of vegetation. The main problem seems to be the formation of shrinkage cracks. Therefore, it is recommended that these slopes may be managed with the simple method of providing vegetative turfing if the natural growth of grass happens to be inadequate. In case the soil does not support vegetation directly, a blanket soil, 0.3 metres thick of clayey soil (but not heavy clays) should be provided to support the vegetative turfing.

Appendix-2.1

एक कदम स्वच्छता की ओर

Alka Upadhyaya
Joint Secretary (RC)
& DG, NRRDA
Tel No: 23384707
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सत्यमेव जयते

ग्रामीण विकास मंत्रालय
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Ministry of Rural Development
Deptt. of Rural Development
Government of India
Krishi Bhavan, New Delhi-110114

DO# P-10021/2/2007-Tech. **05th November, 2018**

Dear Sir / Madam,

The PMGSY Guidelines provide that, ***'where the road passes through a habitation, the road in the built-up area and for 50 m on either side may be appropriately designed preferably as a Cement concrete road or with Paved Stones, besides being provided with side drains. Appropriate side drains and cross drainage will be provided, so that improper drainage does not damage the road or the dwellings alongside'***.

Cement concrete roads are provided only in habitation area, where houses are existing on both sides of roads, raising of road formation is not possible due to land constraints and effective drainage is difficult. Also, in water logged / flood prone areas.

Though the initial cost of CC pavement is much higher than the Bituminous surfacing, the intention is to create better and hygienic standard in the habitation areas by utilizing the inherent advantages of CC pavements, which include low maintenance requirements, long life and better performance under repeated wear and tear. These are the overriding factors in spite of the comparative higher initial cost.

However, it has been observed during the field visits by Secretary, MoRD, Joint Secretary (RC) & DG, NRIDA and Directors of NRIDA, that the shoulders, along the Cement concrete pavements, have not been constructed properly. This leads to poor un-drained and slushy shoulders thus causing inconvenience to the inhabitants during rainy season. In certain places, it was noticed that there is no bond between Cement concrete pavement and shoulders and the level of shoulders are much below the Cement Concrete pavement which raises concerns about safety of road users especially two wheeler users. This may also lead to breaking away of edges, unhygienic conditions within the habitation etc and finally negating the entire purpose of providing CC pavement.

In order to avoid such issues, the following instructions are issued.

i. Cement concrete pavement may be laid edge to edge of the houses (upto building line) with adequate side drains, where the width of the road is less than 6 m. Only closed drains are to be provided within habitations with necessary perforations for rain water entry.
ii. In case of roads more than 6m, both sides of cement concrete pavement should be filled up with wll compacted unscreened gravel equal to CC pavement thickness or minimum 200 mm for 1 m width from the edge of the carriageway on either side to serve as hard shoulders for better shoulder management with smooth traffic mobilization.
iii. Interlocking concrete block pavements of suitable thickness may be provided as shoulders along the CC pavement, wherever adequate drainage is not provided or the soil is clayey in nature.
iv. Shoulders should never be allowed to be higher than the road pavement.
v. Required camber may be provided as per specification so that the water will drain easily.

....2

I, therefore, request you to send suitable instructions to the filed officers and supervising authorities to adhere to the above instructions scrupulously and it must also be ensured that necessary provisions for hard shoulders are made in the DPR stage itself.

Further, I also request you to verify the quality of shoulders constructed in PMGSY roads during the course of your inspections.

with Best Wishes

Yours sincerely

Alka

(Alka Upadhyaya)

To,
All Principal Secretaries/ Secretaries I/c of PMGSY

Chapter 4

ROAD MATERIALS

4.1. Introduction

The most important pavement materials are soils, mineral aggregates, bituminous binders, and stabilisers like lime, cement, water etc. Mineral aggregates constitute bulk of total volume of road construction materials used. All roads have to be founded on soil and are required to make optimum use of the locally available materials, if it is to be constructed economically. Materials used in the structural layers of the pavement should be selected based on availability, economy and previous experience. This aspect must be considered at the design stage so that the materials can be selected which are the most economical and best suited to the prevailing conditions.

This chapter covers soil and material survey for proper identification of materials, details about soil and granular materials including marginal materials which can be used for road construction purposes, their availability in different parts of the country and their important physical characteristics to assess suitability as road construction material in different pavement layers. In addition, information has also been provided about bitumen and cement, their characteristics and suitability for use in bituminous and cement bound bases and surfacing layer.

4.2. Soil and Material Surveys

After selection of the final centre line of the road, investigations for soil and other materials required for construction are carried out in respect of the likely sources and the availability and suitability of materials. Some other investigations, for example, in respect of landslide prone locations may also be conducted at this stage. In particular, soil and material surveys are required for various reasons as follows.

(i) To determine the nature and physical characteristics of soil and soil profile for design of embankment and pavement

(ii) To determine the proper method(s) of handling soils

(iii) To classify the earthwork involved into various categories such as rock excavation, earthwork in hard soil, etc.

(iv) To gather information regarding subsoil water level and flooding

(v) To locate sources for pavement construction materials and to ascertain their availability and suitability for use in the different pavement courses.

The soil and material location surveys should start from study of all available information such as geological maps, data published by the various authorities regarding location of construction materials and the information available with ground water authorities regarding depth of water table. Soil maps prepared by the local agricultural department and records of existing highways may also provide useful information. A study of these data, if available, will be of great help in planning and conducting surveys and investigations. This information should be studied in conjunction with general information gathered during the preliminary survey. IRC:SP:19 for survey, investigation and preparation of highway project may be referred for further details.

After studying the available information, detailed programme of survey can be drawn up. A comprehensive district-wise report on survey of locally available materials had been prepared by various State PWDs under Research Scheme R-1 "Survey and Evaluation of Locally Available Materials" sponsored by Ministry of Road Transport and Highways, Govt of India. These reports should be referred, while selecting pavement materials.

The field work consists essentially in identifying different types of subgrade soils encountered along the alignment and the various other locally available materials, like, moorum, gravel, soft aggregate, etc., that can be usefully incorporated in road construction. In regard to subgrade soils, representative samples should be

collected wherever there is a visible change in soil type. In case the same soil type continues, at least two representative samples from each kilometre length of road alignment should be collected. Since sampling is considered as important as testing, it is not only desirable but absolutely necessary to make sure that the samples collected are truly representative of the materials to be evaluated. A certain amount of training and engineering judgement is necessary to be able to carry out the sampling process effectively. The needed quantities of soil samples to be collected will depend upon the types of tests to be conducted and will vary from about 2 kg to 20 kg. For visual classification, gradation and simple plasticity tests, a small quantity (2-5 kg) will generally be enough while for detailed strength tests like the CBR, etc., as much as 20 kg will be required.

For manufactured items like lime, cement, bitumen, information about their sources of supply and the distance of the nearest rail/road station from the location of works should be gathered during the survey. The information should also be collected about the availability of water suitable for road construction works. Where the use of brick aggregates is envisaged, a survey should be made to identify the location and average lead from the work site of existing kilns capable of supplying overburnt bricks/ brickbats.

4.2.1. Soil investigations for low embankment : The first operation in the detailed soil survey is to demarcate the possible borrow areas along or off the road alignments. The extent of borrow areas should commensurate with the volume of work involved in the embankment. Test pits 0.5 to 1.0 metre square should be dug in the borrow areas from where the embankment material is to be obtained. For borrow-pits along the road land, the test pits should be at intervals of 200 m but the intervals may be varied depending on the uniformity or variability of the soil. When embankment material is to be obtained from off-road locations, adequate number of samples should be taken from each such area. The depth of test pits should not exceed the likely depth of the borrow-pits by more than 15 cm where the type of material varies in a single pit, the tests should be conducted on each type of soil separately and the location of soil types should be noted.

The general character of material excavated from the test pits should be recorded and tests conducted on it in the laboratory for properties as mentioned below:

(i) Gradation test based on wet sieve analysis test [IS:2720 (Part 4)-1985]

(ii) Liquid limit and Plastic limit [IS:2720 (Part 5)-1985]

(iii) Standard Proctor density and optimum moisture content [IS:2720 (Part 7)-1980

(iv) Deleterious constituents (only in salt infested areas, where presence of salt is suspected) [IS:2720 (Part 27)-1977]

In case of highly plastic, poorly draining and unstable soils, some additional soil tests (e.g. consolidation test, shear strength test) may also be performed. The results of the laboratory investigations should be summarised in a convenient form, for which a format is suggested in Format 4.1. Usually the information should be enclosed in full with the project report. Based on results of the tests, sand content and classification of the soil should also be determined. The final selection of the borrow areas whether for the body of the embankment or the subgrade can then be made in accordance with the norms recommended in Section 4.4. Great caution should be exercised to ensure and mark, as far as possible, homogeneous soils only for this purpose. Heterogeneous or variable soils should be avoided. In making the selection it should be ensured that the best available homogeneous soil is reserved for use in the subgrade (i.e. top 300 mm portion of the embankment). After completing the analysis of the results, borrow area details should be prepared as shown in Format 4.2.

Format 4.1

Laboratory Investigation of Soil for Embankment Construction

Route : **Date :**

Section :

Location (km)	Type of Soil	Sieve Analysis, per cent Passing				Sand Content	Atterberg Limits			IS Soil Classification	Standard Proctor test		Deleterous content	Remark
		4.75mm	2mm	425 μ	75 μ		L.L (%)	P.L. (%)	P.I		MDD (gm/cc)	OMC (%)		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Format 4.2

Sources for Procuring Material for Earth Works

Route : **Date :**

Section :

Reach	Estimated Fill		Source of Procurement of Earth				Remarks
	For Subgrade	For Body of Embankment	For Subgrade and Shoulder		For Body of Embankment		
			From borrow areas	From reaches of cutting	From borrow areas	From reaches of cutting	
Km-Km	Cum	Cum	Cum	Cum	Cum	Cum	
1	2	3	4	5	6	7	8

4.2.2. Special investigations for high embankment : The basic objective of investigations in such cases is to obtain engineering data for soil and rock that are necessary for a quantitative design of embankment at the chosen sites. The details of investigations depend upon the requirements of design. Generally for checking stability against slip failures, the basic properties to be investigated are shear parameters, unit weight and moisture conditions. For safety against excessive settlement, consolidation properties are important. For investigation of such cases, services of specialists will often be needed. Reference may also be made to IRC:75 "Guidelines for the Design of High Embankments", in case height of embankment exceeds 3 m. IRC:SP:58 on "Guidelines for Use of Fly Ash in Road Embankments" may be referred, if fly ash is used in making embankments.

4.2.3. Soil investigations for cut sections : In the same manner as described for embankment material, for soil in cut sections along the centre line of the proposed road at an elevation corresponding to the design subgrade level should be tested for the following general properties:

(i) Gradation test based on wet sieve analysis test [IS:2720 (Part 4)-1985]

(ii) Atterberg limits [IS:2720 (Part 5)-1985]

(iii) Standard Proctor density and optimum moisture content [IS:2720 (Part 7)-1980]

(iv) Field density and moisture content [IS:2720 (Part 28)-1974]

In the case of rock cuts where necessary, trial pits or boreholes should be carried out at the foundation level to make realistic estimates of the type of cutting involved. The interval of trial bores may be 30-50 metres or as otherwise decided by the Engineer-in-Charge depending on specific requirements. Information collected during preliminary survey would normally identify the landslide prone areas along the alignment and every effort should be made to avoid such areas while fixing the alignment of the road. However, in cases where it is not feasible, further investigations would be required to study the extent of the problem and plan appropriate remedial measures. For this purpose, services of a geologist or soil specialist may often be needed.

4.2.4. Soil investigations for subgrade : For new roads, the soil data already collected in earlier phases of the survey should be studied in detail for ascertaining the variability/homogeneity of the soil profile, and plan further investigations. Where pavement design relates to strengthening of an existing road, the road should be divided into more or less similar sections on the basis of actual testing.

For pavement design, apart from the general soil tests referred to earlier, CBR test should be conducted for soaked condition unless the annual rainfall is less than 500 mm and subgrade is of well drained material. Frequency of CBR tests should normally be such that roughly one set of results (each consisting of three samples are available for every one half to one-kilometre section of the road). The interval could, however, be increased or decreased depending on the discretion of the Engineer-in-Charge. Overall objective should be to get strength results for all radical changes in soil type or each demarcated section of similar performance. A suggested format for presenting soil investigation data pertinent to flexible pavement design is given in Format 4.3.

4.2.5. Survey for marginal materials and aggregates : The locally available materials that can be used in embankment, subgrade and pavement construction should be thoroughly and judiciously explored. In this class of materials various types of soils are encountered: sands from streams/river beds and other sources; moorums which may even be available at shallow depths below the ground level or from other quarries; gravels, soft aggregate, like, laterite, kankar, dhandla, river sand-gravel mixes, etc. While locations of PWD/Zilla Parishad approved quarries for locally available materials, like the ones listed above, may not be available but local enquiries from villagers can help a great deal in this regard. Special care has to be exercised in collection of samples of these locally available materials since these are generally quite variable in their engineering properties.

Format 4.3

Soil Investigation for Flexible Pavement Design

Route : **Date :**

Section :

Location (km).	Type of Soil	Sieve Analysis, per cent Passing				Sand Content (%)	Atterberg Limits (%)			Field density of Subgrade (for existing roads or new roads in cutting) (gm/cc)	Field Moisture content (%)	Standard Proctor test		C.B.R. at Standard Proctor density/ Field density (%)	Depth of Water Table (m)	Remark
		4.75 mm	2mm	425 µ	75 µ		LL (%)	PL (%)	PI			MDD (%)	OMC (%)			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Experiences show that the locally available moorums and gravels from the same source can give widely different strength values. This, naturally has significant implication in the design, construction and performance of roads. The site quality control of materials can be exercised meaningfully only if sampling and testing of these locally available materials has been carefully done and design values arrived at judiciously based on the laboratory strength values. Besides the variable quality of materials, another important factor is that of the quantities available from each source which should be carefully estimated and invariably noted down during field surveys.

The tests to be conducted and format for presenting the test results are shown in Formats 4.4 and 4.5 Format 4.4 is for aggregates while Format 4.5 is for naturally occurring materials like moorum, gravel and soil gravel/moorum mixtures. For every quarry source, at least three specimens should be tested for each type of material met with. Sample for the tests should be representative and collected in accordance with the procedure set forth in IS:2430-1986. Quarry charts showing the location of quarries and the average lead of materials should also be prepared.

4.3. Soil and Marginal Materials

4.3.1. General : Subgrade soil is an integral part of the road pavement structure as it provides support to the pavement as its foundation. The main function of the subgrade is to give adequate support to the pavement and for this the subgrade should possess sufficient stability under adverse climatic and loading conditions. The formation of waves, corrugations, rutting and shoving in black top pavements are generally attributed to poor subgrade conditions. When soil is used in embankment construction, in addition to stability, incompressibility is also important as differential settlement may cause failure. Soil is used in its natural form (gravel and sand) or in a processed form (stabilised layer) for pavement construction. Soil is also used as a binder in water-bound macadam layers. Soil is, therefore, considered as one of the most basic highway materials. The foundation of other cross-drainage structures (culverts, bridges and retaining walls) rests on soils and their stability depends on the soil strength. Knowledge of soil properties is necessary to select the embankment material, pavement structure, drainage system and foundation of structures. When a high embankment rests on soft ground, its stability can be predicted by studying the properties of soil. Frost action, common in high altitudes, can be taken care of if the soil properties are well known. Soil consists mainly of mineral matter formed by the disintegration of rocks, by the action of water, frost, temperature, pressure or by plant or animal life. Based on the individual grain size of soil particles, soils have been classified as gravel, sand, silt and clay. The BIS gives the following limits of particle size:

Gravel	**80 – 4.75 mm**
Sand	
Coarse	4.75 – 2.00 mm
Medium	2.00 – 0.475 mm
Fine	0.475 – 0.075 mm
Silt	0.075 - 0.002 mm
Clay	Less than 0.002 mm

4.3.2. Types of soils : Soils occur in a fairly wide variety in our country, as will be seen from the soil map of India given in Fig. 4.1. Some of the major soil types found in the country are:

Alluvial soils: These are mostly found in the Indo-Gangetic plain. Generally, these are composed of broadly matching fractions of sand, silt and clay, and make fair to good subgrade material.

Fine sand: It is confined mostly to desert areas in the north-western part of the country. This soil lacks binder fraction and is not well graded.

Coastal soils: The sands/sandy soils forming the coastal alluvium usually make good subgrades.

Format 4.4

Test of Aggregates/Stone Metal

Route : **Date :**

Section :

Location and Name of Quarry (km)	Type of Stone Metal	Specimen no.	Los Angeles Subgrade Value (IS:2386-Part IV) (%)	Aggregate Impact Value (IS:2386-Part 4) (%)	Water Absorption (IS:2386-Part 3) (%)	Flakiness Index (IS:2386-Part 1) (%)	Stripping Value (IS:6241)	Remarks regarding the performance of the aggregate, wherever a systematic study has been made	Additional Remarks like old/new quarry, approximate quantity available, existing access to quarrry, etc.
1	2	3	4	5	6	7	8	9	10

FORMAT 4.5

Test of Moorum/Soil-Gravel-Moorum Mixtures, etc.

Format 4.5

Date :

Section :

General Description of the Material	Location (km)	Type of Material	Sieve Analysis, per cent Passing				Atterberg Limits			Standard Proctor test		C.B.R. (%)	Additional remarks like new/old quarry, approx. quantity, access to quarry, etc.
			4.75 mm	2 mm	425 µ	75 µ	LL (%)	PL (%)	PI	MDD (gm/cc)	OMC (%)		
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Black Cotton (BC) soils: Black cotton soils occur in parts of Madhya Pradesh, Maharashtra, Andhra Pradesh and Karnataka. These soils are characterised by pronounced volume changes (swelling upon wetting and shrinkage after drying) and low strength at high moisture content.

Red gravelly soils: The moorums and red gravelly soils are found in various pockets and are generally less problematic.

The wide range of soil types available as highway construction materials have made it obligatory on the part of the highway engineer to identify and classify the different soils. The classification of soil as per IS nomenclature (IS:1498-1970), the general range of the maximum dry densities of these materials and their approximate CBR values are given at Table 4.1.

TABLE 4.1. CLASSIFICATION OF SOILS AS PER IS SYSTEM

Soil Group Description	Symbol	Unit dry weight, gm/cm³ [IS:2720 (Part 7)-1980 IS Light Compaction	CBR % at IS Light Compaction Density
Well graded gravels and gravel sand mixture (fines < 5 per cent)	GW	2.00-2.24	60-90
Poorly graded gravel and gravel sand mixture (fines < 5 per cent)	GP	1.76-2.24	25-60
Silty gravel and gravel sand mixture (fines >12 per cent)	GM	2.08-2.22	20-80
Clayey gravels and gravel sand silt mixtures (fines >12 per cent)	GC	1.92-2.24	20-80
Well graded sand and gravely sand (fines < 5 per cent)	SW	1.76-2.08	20-60
Poorly graded sands and gravely sand (fines < 5 per cent)	SP	1.59-1.92	10-30
Silty sand and sand-silt mixtures (fines >12 per cent)	SM	1.92-2.16	10-4 0
Clayey sands and sand-clay mixtures (fines >12 per cent)	SC	1.68-2.08	15-50
Inorganic silt, very fine rock floor,	ML	1.60-2.00	5-20
Clayey silt or fine sand, inorganic clay, gravelly, sandy or silty	CL	1.60-2.00	5-15
Organic silt and silty clays	OL	1.44-1.60	3-8
Inorganic silt elastic and micaceous silts	MH	1.28-1.60	3-8
Inorganic fat clays	CH	1.44-1.76	3-5
Organic silt and clays	OH	1.28-1.68	2-4

4.3.3. Marginal/low grade materials : Surveys carried out in the country for different types of low-grade material encountered in the country reveal that there is a wide variety of marginal/low grade materials, which can be used for advantage in road construction. Usually marginal materials can be adopted for construction of sub-base/base courses and for shoulders. The distribution of a wide variety of naturally occurring low-grade materials/soft aggregates can be broadly categorised as:

(i) Moorum/Gravel

(ii) Kankar

(iii) Dhandla

(iv) Laterite

(v) Soft Stone/Sand-Stone

Soft Stone/Sand Stone: The soft stone namely sand stone, limestone, etc. are found all over the country. These are sedimentary rocks softer than hard rocks like granite and quartzite. These aggregates are more susceptible to stripping when they come in contact with water. Therefore, these aggregates should not be used under heavy rainfall areas.

River Gravel: River gravel found in stream and river bed are normally rounded in shape. This material can be used in sub-base course.

River Shingle: They possess smooth surface and are rounded in shape. When used in base/surface coarse river shingle should possess at least two broken faces.

Compressed Shale Aggregates: The aggregates produced from stratified shale rock are quite tough when dry but their strength fall appreciably once they come in contact with water. Care should be taken under humid and cold climate.

Brick Aggregates: These are suitable for all climatic conditions.

4.4. Embankment and Subgrade Materials

4.4.1. Physical requirements : The materials used in embankment, subgrades and earthen shoulders shall be soil, moorum, gravel, a mixture of these or any other material approved by the engineer. Such material shall be free from logs, roots, stumps, rubbish or any other ingredient likely to deteriorate or affect the stability of embankment/subgrade.

4.4.2. Specification for embankment and subgrade material : Following types of material shall be considered unsuitable for embankment/subgrade:

(a) Materials from swamps, marshes and bogs
(b) Peat, log, stump and perishable material; any soil that is classified as OL, OI, OH in accordance with IS:1498-1970
(c) Materials susceptible to spontaneous combustion
(d) Materials in frozen conditions
(e) Clay having Liquid Limit (LL) exceeding 70 and Plasticity Index (PI) exceeding 45
(f) Materials with salts resulting in leaching in the embankment
(g) Expansive clays, 'Free swelling index' exceeding 50 per cent when tested as per IS:2720 (Part 40)-1977, shall not be used as fill material
(h) Materials with a sulphate content (expressed as SO_3) exceeding 0.5 per cent by mass, when tested accordance with BS:1377-1975 Test 9, shall not be deposited within 500 mm from concrete surface.

The size of the coarse material in the mixture of earth shall ordinarily not exceed 75 mm when being placed in the embankment and 50 mm when placed in the subgrade. Ordinarily only the materials satisfying the density requirements given in Table 4.3 shall be employed for the construction of the embankment and the subgrade.

TABLE 4.3. DENSITY REQUIREMENTS OF EMBANKMENT AND SUBGRADE MATERIALS

Type of work	Maximum laboratory dry unit weight when tested as per IS: 2720 (Part 7)-1980
Embankments upto 3 metres height, not subjected to extensive flooding	Not less than 1.44 gm/cc
Embankments exceeding 3 metres height or embankments of any height subject to long periods of submergence	Not less than 1.52 gm/cc
Subgrade and earthen shoulders	Not less than 1.65 gm/cc

Notes:(i) This Table is not applicable for lightweight fill material, e.g., cinder, fly ash, etc. for which IRC:SP:58 may be referred

(ii) The Engineer may relax these requirements at his discretion taking into account the availability of materials for construction and other relevant factors.

4.4.3. Specifications for granular sub-base (GSB) : The material to be used for the work shall be natural sand, moorum, gravel, crushed stone, crushed slag, granulated slag, crushed concrete, brick metal and kankar, etc. The material shall be free from organic or other deleterious material. The material shall have 9 per cent fines value of 50 kN or more (for sample in soaked condition) when tested in compliance with BS: 812 (Part 3)-1975. The water absorption of the aggregate shall be determined as per IS:2386 (Part 3)-1963; if this value is greater than 2 per cent, the soundness test shall be carried out on the material delivered at the site as per IS:383-1970. The CBR requirement for sub-base layer should be at least 15 per cent when tested in soaked condition. The material for sub-base shall be preferably non-plastic. Otherwise, the plasticity index (PI) of material passing 425 micron sieve shall be less than 6 and liquid limit less than 25 per cent. The material shall conform one of the gradations specified below in Table 4.4. For the construction of gravel roads gradation of granular material specified in Table 4.5 can be adopted. In case of unsurfaced roads, the PI value of the gravel should not exceed 9 per cent.

TABLE 4.4. GRADATION REQUIREMENT FOR COARSE GRADED GRANULAR SUB-BASE

IS Sieve	Per cent by weight passing the IS sieve (By wet sieve analysis)		
	Grading I	Grading II	Grading III
75.0 mm	100	-	-
53.0 mm	-	100	-
26.5 mm	55-75	50-80	100
4.75 mm	10-30	15-35	25-45
2.36 mm	-	-	-
0.425 mm	-	-	-
0.075 mm	<10	<10	<10

TABLE 4.5. GRADATION REQUIREMENT FOR CLOSE-GRADED GRANULAR SUB-BASE

IS Sieve	Per cent by weight passing the IS sieve (By wet sieve analysis)		
	Grading I	Grading II	Grading III
75.0 mm	100	-	-
53.0 mm	80-100	100	-
26.5 mm	55-90	70-100	100
9.5 mm	35-65	50-80	65-95
4.75 mm	25-55	40-65	50-80
2.36 mm	20-40	30-50	40-65
0.425 mm	10-25	15-25	20-35
0.075 mm	3-10	3-10	3-10

Note: The material passing 425 micron sieve for all the three grading when tested according to IS:2720 (Part 5)-1985 shall be having liquid limit and plasticity index not more than 25 and 6 respectively. The material with CBR greater than 15 per cent shall be accepted for construction of GSB course.

4.5. Stabilised Soils

Sometimes soil/soil-gravel/aggregates and waste materials such as fly ash, iron and steel slag and other such materials, available in the near vicinity of the construction sites do not conform to the grading, PI and strength requirements. Such inferior materials can be improved by adopting soil stabilisation technique. The methods of stabilisation can be broadly grouped as:

- Mechanical stabilisation
- Lime stabilisation
- Cement stabilisation
- Bituminous stabilisation

4.5.1. Mechanical stabilisation : This work consists of improving the inferior soils/low grade aggregates like kankar, laterite, brick aggregates, moorum, etc. by blending them with locally available suitable materials. Different methods of proportioning two materials on the basis of the gradation or/and plasticity index are given in ***Appendix-4.1.***

4.5.2. Lime stabilisation : When the local soil, moorum cannot be economically and effectively stabilised by mechanical methods, the chemical stabilisation of these materials are resorted to. Lime stabilisation is normally adopted for silty clays and clayey soils including black cotton soil. The development of strength in soil lime mixes depends on the type of clay and its quantity in soils. Thus, lime stabilisation is recommended for soils having PI > 8. It is desirable that the calcium hydroxide content (available lime) in lime for stabilisation should be more than 70 per cent. In case of inferior lime the quantity of lime for stabilisation has to be increased proportionately. Lime with purity less than 50 per cent should not be normally used. Lime shall be properly stored to avoid prolonged exposure to the atmosphere. The quantity of lime to be added as percentage by weight of the dry soil shall be specified in the contract. The mix design shall be done to decide the optimum quantity of lime to be added to obtain required test value. Before stabilisation soil shall be pulverised by using disc harrow, rotavator till 100 per cent material passes through 26.5 mm sieve and 80 per cent through 5.6 mm sieve.

4.5.3. Lime-Fly ash stabilisation : This method is suitable for areas where good quality of fly ash and lime are locally available and the local soils respond to these techniques. Normally, soils having medium plasticity index (5-20) and clays that do not respond to lime can be improved by this technique. Details of this technique are given in Chapter 9.

4.5.4. Cement stabilisation : Gravelly, sandy, clayey type of soils can be stabilised using cement, when comparatively higher and faster development of strength, and durability characteristics are needed especially for waterlogged and high rainfall areas. The material used for stabilisation by cement shall be gravelly or sandy type of soil. Marginal materials like kankar, laterite, brick aggregate, crushed rock or slag or any combination of these can also be stabilised using cement. For use in sub-base and base course, the material shall have grading as shown in Table 4.6. It shall have a uniformity coefficient not less than 5 so that it can produce a well closed surface finish.

Cement shall comply with the requirement of IS:269-1989, 455-1989, 8112-1989 or 1489-1991 details of which are presented later in this chapter. The quantity of cement to be added as per centage by weight of the dry soil shall be specified in the contract. Also if lime is used as pre-treatment for highly clayey soil, the quantity as per centage by weight of dry soil shall be specified in the contract. The quantities of lime and cement must be determined on the basis of unconfined compressive strength and durability tests under 12 cycles of wet-dry conditions. Generally cement concrete ranges from 3 to 5 per cent by weight of dry soil.

TABLE 4.6. GRADING OF MATERIALS FOR STABILISATION WITH CEMENT

IS Sieve Designation	Per centage by weight passing	
	Sub-base (Finer than)	Base (Within the range)
53.0 mm	100	100
37.5 mm	95	95-100
19.0 mm	45	45-100
9.50 mm	35	30-100
4.75 mm	25	25-100
600 micron	8	8-65
300 micron	5	5-40
75 micron	0	0-10

If the material passing 425 micron sieve is plastic, it shall have a liquid limit not greater than 45 per cent and plasticity index not greater than 20 per cent as per IS:2720 (Part 5)-1985. For the treatment of the plastic soil, the stabilisation shall be as per Section 4.5.3. For further details reference may be made of IRC:50.

4.6. Road Aggregrates

4.6.1. General : Aggregates form the major portion of pavement structure and they are the most voluminous ingredient used in pavement construction. Aggregates have to bear the stresses due to the wheel loads on the pavement and on the surface course. They also have to resist wear due to abrasive action of traffic. Most of the road aggregates are obtained from natural rocks. The conventional road aggregates in India are obtained by crushing of rocks. There are three main groups of rocks: igneous, sedimentary and metamorphic. Within these three broad geological classes, there are hundreds of different types of rocks. Many of these rocks differ little from each other with regard to their road making qualities. The map showing rocks and minerals found in India is given in Fig. 4.2. The desirable properties of road aggregates are given below:

Strength: The aggregates to be used in road construction should be sufficiently strong to withstand the stresses due to traffic wheel loads; hence they should possess sufficient strength to resist crushing.

Hardness: The aggregates used in the wearing course are subjected to constant rubbing or abrasion due to moving traffic. They should be hard enough to resist wear due to abrasive action of traffic.

Toughness: Aggregates in the pavements are also subjected to impact due to moving wheel loads. The resistance to impact or toughness is hence another desirable property of aggregates.

Durability: The stones used in pavement construction should be durable and should resist disintegration due to action of weather. The property of stones to withstand the adverse action of weather is called soundness.

Shape of the aggregates: Aggregates which happen to fall in a particular size range may have rounded, cubical, angular, flaky or elongated shape of particles. It is evident that the flaky or elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of same stone. Hence too flaky and too much elongated particles should be avoided as far as possible.

Adhesion: The aggregates used in bituminous pavements should have less affinity to water.

4.6.2. Natural aggregates : The most commonly available rocks in India from which road aggregates can be obtained are given in Table 4.7.

4.6.3. Artificial aggregates : Artificial or manufactured aggregates have been used widely for road construction in the developed countries. In some parts of India, brick soling or WBM construction using brick ballast have been widely used. As the properties of these artificial aggregates are dependent on various factors, the quality of final products vary too much necessitating elaborate evaluation of their properties before utilisation. The types of artificial aggregates available in the country are :

Brick ballast: It is the hand broken aggregates of well burnt or over burnt bricks free of extraneous materials.

Cinder: It is well burnt furnace residue, which has been fused or sintered into lumps of varying sizes.

4.6.4. Waste materials : There are a large variety of waste materials, which can be used effectively for road construction works. The following waste materials have been successfully tested in the lab and also used in field trials:

- Fly ash
- Iron and steel slag
- Processed municipal wastes
- Rice husk ash
- Marble slurry dust wastes
- Recycled concrete
- Quarry waste/mine waste.

Details regarding usage of waste materials are presented in Chapter 9.

TABLE 4.7. PROPERTIES OF ROCKS AVAILABLE IN INDIA

Types of Rocks	Geological Group	Properties	Suitability	Location/Availability
Basalt	Igneous (Volcanic type)	Hard and durable, resistant to abrasion, fine grained	Good for base and surface courses	Maharashtra, Bihar, Gujarat, W.B. & M.P.
Granite	Igneous (Plutonic)	Hard, durable resistant to abrasion, coarse grained and quite brittle	Very good for bituminous courses and WBM	J&K, Tamil Nadu, Punjab, Rajasthan, U.P., M.P., Rajasthan, Assam, Karanataka, W.B., Maharashtra, Bihar, Orissa, Kerala and Gujarat
Lime stone	Sedimentary (Calcareous)	Reasonably hard and liable to polish to a smooth surface under traffic, fine grained high water absorption, excellent adhesion to bitumen	Good for base course	Maharashtra, W.B., Rajasthan, A.P., Andaman Islands, Bihar, H.P., M.P., & U.P.
Quartzite	Sedimentary (Siliceous) and metamorphic	Hard, durable, but is liable to be brittle and adhesion to bitumen is rather poor	Good for base courses	W.B., A.P., H.P., Tamil Nadu, U.P., Karanataka, Gujarat, Punjab & Rajasthan
Sand stone	Sedimentary rock (Siliceous)	Moderately hard and durable, fine to medium grained	Good for road bases	A.P., M.P., W.B., Punjab, Bihar, Rajasthan, H.P., Andaman Islands, J&K, U.P. & Tamil Nadu

4.7. Aggregate for Base Course

4.7.1. General : WBM is one of the commonly used pavement layers. It can be used for construction of sub-base or base course. The size of the coarse aggregate depends upon the thickness of the layer. The strength of the layer depends on the interlocking and lateral confinement of the layer. The grading requirements of the screening are given in the Table 4.8.

TABLE 4.8. PHYSICAL REQUIREMENTS FOR WBM

Lay	AIV (%) not more than [IS:2386 (Part 4)-1963]	Flakiness Index [IS:2386 (Part 1)-1963	Moisture or water absorption [IS:2386 (Part 3)-1963] (%)
Sub-base course	50	40	6
Base course	40	30	3

AIV = Aggregate Impact Value

4.7.2. Aggregate grading requirements for WBM : The grading required for the coarse aggregates are given in Table 4.9 as per IRC:19. The larger size of the aggregates will give higher thickness of the WBM layer.

TABLE 4.9. GRADING OF COARSE AGGREGATES FOR WBM

Grading No	Size range	IS Sieve (IS: 460)	Per cent by weight passing the sieve
I	90 mm-45 mm	125 mm	100
		90 mm	90-100
		63 mm	25-60
		45 mm	0-15
		22.4 mm	0-5
II	63 mm-45 mm	90 mm	100
		63 mm	90-100
		53 mm	25-75
		45 mm	0-15
		22.4 mm	0-5
III	53 mm-22.4 mm	63 mm	100
		53 mm	95-100
		45 mm	65-90
		22.4 mm	0-10
		11.2 mm	0-5

Note: The minimum compacted thickness for a layer with grading I shall be 100 mm while for layer with grading II and III shall be 75 mm. Grading II and III shall be preferably used for construction of WBM as base course. Grading I shall be used for sub-base only.

4.7.3. Grading requirements for screening material : The quality of screening material shall conform to MoRT&H Specifications/IRC:19. The material used for screening includes stone grit, coarse sand, hard moorum, etc. The permissible grading is given in Table 4.10.

TABLE 4.10. GRADING FOR SCREENING MATERIAL

Grading Type	Size Range	IS Sieve Designation	Per cent by Weight Passing
A	13.2 mm	13.2 mm	100
		11.2 mm	95-100
		5.6 mm	15-35
		180 micron	0-35
B	11.2 mm	11.2 mm	100
		5.6 mm	90-100
		180 micron	15-35

Note: (i) For further details on conventional water bound macadam specifications and construction, reference may be made to MoRT&H Specifications for Road and Bridge Works.

(ii) The binding material shall have PI value between 4 to 6 per cent. Non plastic binding material may also be used in case Engineer-in-Charge approves the same.

4.7.4. WBM as wearing course : When WBM is used as wearing course, WBM Grade III shall be adopted. The plasticity requirements for binding material are given in Table 4.11.

TABLE 4.11. PLASTICITY REQUIREMENTS FOR WEARING COURSES

Climate (Range)	Liquid Limit not to exceed	Plasticity Index
Moist temperate and wet tropical	35	4-9
Seasonal wet tropical	40	6-15
Arid	55	15-30

The materials for this layer shall be either crushed or broken stone, crushed slag, over burnt brick aggregates or any other naturally occurring aggregates such as kankar and laterite of suitable quality. Aggregates like brick, stone metal, kankar, laterite, etc., which get softened in presence of water shall be tested for impact value under wet conditions. The requirement of flakiness index shall be enforced only in case of crushed broken stone and crushed slag.

4.8. New Materials and Stabilisers

4.8.1. Geotextiles : Synthetic materials in the form of strong flexible sheets either woven or non-woven and permeable or water tight membranes have been used for several years to improve soil quality and performance in different branches of geotechnical engineering, e.g., lining, drainage and protection of slopes and embankments. Such materials are called geotextile. Natural man made textiles, such as, jute fabrics, coir mats are also being used extensively in many civil engineering projects and such materials can also be adopted in rural road construction. The geotextiles are generally classified by the manufacturing process, and are often separated into two sub-categories, namely non-woven and woven. Other types of geotextiles include (i) Knitted geotextiles (ii) Directionally structured filament (iii) Composite geotextiles.

In a given application, a geotextile can perform one or several functions to improve the mechanical and/or hydraulic behaviour of the structure in which it is incorporated. Filtration/Drainage and separation functions, which are two important functions of geotextiles, are described in the following lines. The separation function refers to the separation of two dissimilar materials. The primary geotextile responsibility is to prevent intermixing of the two different soil layers or dissimilar materials; throughout the design life of the structure. Normally geotextiles provided for separation in road pavement prevent intrusion/pumping of soil particles into the base/sub-base course. Geotextile are commonly used for this function when pavements are constructed over soft soils. Roadway pavements are basically structures for taking the high contact pressure from the vehicle tyres and reducing that pressure through the depth of the pavement to a level, which can be handled by the underlying soil. Pressure dissipation occurs down through the various layers of materials within the pavement. Over a period of time, especially in presence of water, repeated vehicle load applications cause subgrade soils to migrate into the aggregate base of the pavement section. Contamination of the aggregate base by the subgrade results in the reduction of the effective base thickness to a value, which is less than what was the design value. Reduction of the base thickness results in a decrease in the load carrying capability of the aggregate base and leads to a reduction in the pavement life. Geotextile prevent the subgrade materials from migrating into the aggregate base, while maintaining the desired strength over a much longer period and as a consequence the quality and the life of the pavement is increased substantially.

Filtration is one of the most widely used geotextile functions. For centuries, Engineers have constructed filter systems using conventional graded aggregates. A geotextiles provides filtration function which serves the same role in soil structures as were the various gradation of aggregates conventionally used. The filtration

function has two concurrent objectives. These are to retain the particles of the soil while permitting water to pass freely through the plane of the geotextile from the soil. These two parallel roles are the key to filtration design. For the filtration function, a geotextile must be able to convey a certain quantity of water across the plane of the fabric throughout its design life to prevent the build up of water pressures. Further details regarding Detailed specifications of geosynthetics, geotextiles etc. and their use in sub-surface drains with installation specifications are given in MoRT&H Specification and IRC:59.

Natural fibres, like, jute and coir are also used for making Geotextiles. Availability of natural jute in India in abundant quantity gives the natural fiber based fabrics an advantage in terms of cost. Jute is a lignocellulosic natural fiber and as such is biodegradable. There are various application areas where the presence of fabrics is either required for a short duration or where the degradation of fabric does not hinder its application function. In such cases, it is advisable to go for natural materials rather than synthetic materials, as they are available locally and cheap. Fibre drains made up of jute composites are used for consolidation of soft clays. Jute being 100 per cent biodegradable is the only environmental friendly drain and is acceptable even in the developed countries. These drains are versatile and can be used as:

(i) Vertical drains for consolidation of clays
(ii) Horizontal drains for stabilisation of slopes and
(iii) Horizontal drains to counter the problems arising due to seepage

When jute geotextiles is laid over the subgrade it reduces the possibility of failure by performing the following functions:

(i) The fabric acts as a separator between the subgrade and the granular sub-base and prevents the migration of the particles from subgrade to the sub-base material
(ii) The highly permeable nature of geotextiles helps in rapid removal of water from the road section and thus prevents the pumping action of the pavement

In the same manner, coir is also used for drainage and erosion control. The resistance to biodegradability of coir is better than jute.

4.8.2. New stabilisers : Many type of new stabilisers are now available. Some of these are chemical/ enzyme based compounds. Use of such materials can be taken up initially on experimental basis to establish its efficacy.

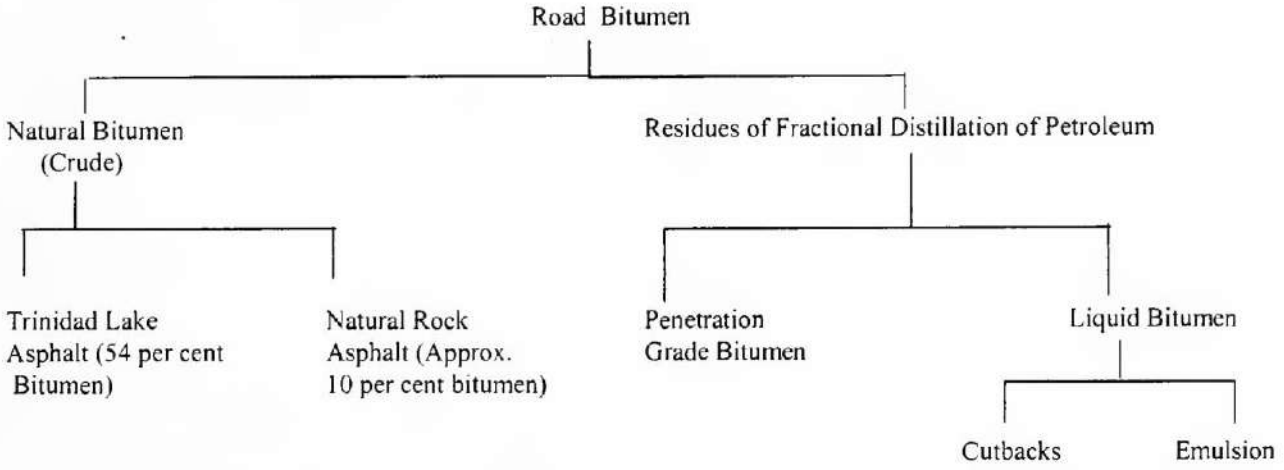
4.9. Materials for Desert Areas

Road construction in sandy areas is confronted with many serious problems notable among them being the non-availability of hard stone metal. Since stone has to be brought from long distances, the cost of construction at such places is very high. It has been observed that in desert areas, on account of non-cohesive nature of sandy subgrade, the oversize metal has a tendency to sink in the subgrade resulting in the deformation of road surface. It is, therefore, essential to provide adequate support to prevent deformation.

The detailed survey of soils and road construction materials carried out in sandy areas has shown that a variety of materials, such as, Dhandla (a calcareous material), Kankar, soil gravel mixes and Bentonite (heavy clays) are available at many locations. Research work carried out at various laboratories and subsequent laying of test tracks and its field performance have shown that these materials can be used both in the sub-base and base course of road pavement in place of hard stone metal.

4.10. Material for Bituminous Construction

4.10.1. General : Bitumen is a viscous liquid, semi-solid or solid material, colour varying from black to dark brown, having adhesive properties, consisting essentially of hydrocarbons derived from distillation of petroleum crude or natural asphalt and soluble in carbon disulphide. Bituminous materials used for paving purposes can be grouped as illustrated below:



4.10.2. Requirements for good bituminous binder : The bituminous binder should posses the following qualities as per IS:73-1992:

- Adequate viscosity at the time of mixing and compaction
- Not highly temperature susceptible
- Should not strip off from aggregate in presence of water

4.10.3. Tests for bituminous binders : To ensure that the required properties are available in the bituminous materials standard tests are performed. These tests can be divided into four categories :

- Consistency tests
- Composition tests
- Specific gravity tests
- Flash and fire point tests

These tests as required for quality control are described in Chapter 10.

Consistency tests : By consistency is meant the resistance of a material to flow. Temperature changes for bitumen ranges from its processing temperature (177°C) to the road surface temperature during winter. As a single test cannot be adequate for evaluating all bituminous binder, a number of tests have been developed; each of which has certain advantages and disadvantages.

The consistency tests of importance are:

- Penetration test (IS:1203-1978)
- Viscosity test (IS:1206-1978)
- Softening point test ((IS:1205-1978)
- Ductility test (IS:1208-1978)

Composition tests : Most bituminous binder specification includes criteria regarding composition. To ensure these compositions are met, a number of tests have been developed to determine the proportion of

specific fractions and components of the bituminous binders. The more common tests in this category are:

- Loss on heating test (IS:1212-1978)
- Solubility test (IS:1216-1978)
- Water content test (IS:1211-1978)
- Distillation test (IS:10512-1983)
- Spot test (AASHTO T:102-74)

Specific gravity test : The specific gravity of refinery penetration grade bitumen varies between 1.00 and 1.05. Specific gravity data are required to calculate the percentage of voids in an aggregate-binder mix. Moreover, while the specifications provide the quantities in weight, the material supplied and measured in use by volume. The test may be performed as per IS:1202-1978.

Flash and fire point test : These are primarily safety tests, but also indicate the volatile substances present in the binders indirectly. Of the two tests, fire point test is more important as it indicates the maximum temperature to which bituminous material can be safely heated. The test may be performed as per IS:1209-1978.

4.10.4. Bitumen emulsion : Bitumen emulsion is a liquid product in which a substantial amount of bitumen is suspended in a finely divided condition in an aqueous medium and stabilised by means of one or more suitable materials. In India normally cationic type of emulsion is used. An emulsion is a two-phase system consisting of two immiscible liquids; bitumen being dispersed as fine globules in water. A small proportion of an emulsifier is used to facilitate dispersion and to keep the globules of dispersed binder in suspension. The function of this emulsifier is to form a protective coating around the globules of binder resisting the coalescence of the globules. The bitumen content in emulsions is around 60 per cent and the remaining is water. When emulsion is applied on the road, it breaks down resulting in release of water and the mix starts to set. The time setting time depends upon the grade of emulsion. The first sign of breakdown of emulsion is indicated by the change in colour of the film from chocolate brown to black. Three types of bituminous emulsions are available, (i) Rapid Setting (RS), (ii) Medium Setting (MS), (iii) Slow Setting (SS). If the bitumen emulsion is intended to break rapidly, the emulsion is said to possess rapid set quality. Emulsions which do not break spontaneously on contact with stone, but break during mixing or by fine mineral dust are medium set grades. When special types of emulsifying agents are used to make the emulsion relatively stable, they are called slow setting. The viscosity values of bitumen emulsions when tested using Sabolt Furol Viscometer are given in Table 4.12. IS:8887-1995 may be referred for specification on bitumen emulsion for roads.

TABLE 4.12. VISCOSITY OF BITUMINOUS EMULSIONS

Temperature	Type of Emulsion		
	RS	MS	SS
At 25°C (secs)	-	-	20-100
At 50°C (secs)	50-400	50-400	-

4.10.5. Polymer modified bitumen/crumb rubber modified bitumen : Certain additives or blend of additives called as bitumen modifiers can improve properties of bitumen and bituminous mixes. Bitumen treated with these modifiers is known as modified bitumen. Polymer modified bitumen (PMB)/crumb rubber modified bitumen (RMB) should be used only in wearing course depending upon the requirements of extreme climatic variations as given in Table 4.13. The detailed specifications for modified bitumen are given in IRC:SP:53. It must be noted that the performance of PMB and RMB is dependent on strict control on temperature

during construction. The advantages of using modified bitumen are as follows:

- Lower susceptibility to daily and seasonal temperature variations
- Higher resistance to deformation at high pavement temperature
- Better age resistance properties
- Higher fatigue life for mixes
- Better adhesion between aggregates and binder
- Prevention of cracking and reflective cracking.

TABLE 4.13. SELECTION CRITERIA FOR PMB AND RMB BASED ON ATMOSPHERIC TEMPERATURE

Minimum Atmospheric Temperature °C	Maximum atmospheric temperature °C			
		<30	30 to 40	>40
	<-15	PMB-120*	PMB-70	PMB-70
		RMB-50**	RMB-55	RMB-60
	-15 to 15	PMB-120	PMB-70	PMB-40
		RMB-55	RMB-55	RMB-60
	> 15	PMB –70	PMB-40	PMB-40
		RMB-55	RMB-60	RMB-60

* Average penetration value ** Softening point is not less than this value

4.10.6. Physical requirements of aggregate for bituminous surfacing layers : The quantities of the aggregate required for different bituminous treatments can be obtained from the standard/specifications of MoRT&H. The aggregates should be tough, durable and sound as per the required specifications. The requirements and test are listed in Table 4.14. If the stripping value of the aggregate exceeds the specified value of 15 per cent, anti-stripping agent may be used.

TABLE 4.14. PHYSICAL REQUIREMENTS OF AGGREGATE FOR BITUMINOUS SURFACING

Sr. No.	Test	Test Method	Requirement (Per cent max.)
1.	Los Angeles abrasion value	IS:2386 (Part 4)-1963	40
2.	Aggregate impact value	IS:2386 (Part 4)-1963	30
3.	Combined flakiness and elongation index	IS:2386 (Part 1)-1963	35
4.	Stripping value	IS:6241-1971	15
5.	Soundness Loss with sodium sulphate (5 cycles) Loss with magnesium sulphate (5 cycles)	IS:2386 (Part 5)-1963	 12 18
6.	Water Absorption	IS:2386 (Part 3)-1963	2

4.10.7. Modified penetration macadam (MPM) : The material is similar to WBM except that some key aggregates and lean dose of bitumen replace the moorum and water. In this treatment, 40 mm hand broken metal is used. Though hand broken metal is preferred about 30 per cent quantity can be replaced with 40 mm crusher broken metal. The gradation for 40 mm metal has to conform to 100 per cent passing 50 mm sieve and fully retained on 25 mm sieve. Also, 12 mm size key aggregates are used. The gradation for 12 mm metal has to conform to 100 per cent passing 20 mm sieve and fully retained on 10 mm sieve. Bitumen of 30/40 or 60/70

penetration grade can be used for grouting. The selection of the grade of bitumen shall depend upon the climatic condition, traffic intensity, etc. The detailed specifications and construction method is given in Chapter 8.

4.11. Materials for Bituminous Surfacing

4.11.1. Prime coat over granular base : This work shall consist of application of single coat of low viscosity liquid bituminous material to an absorbent granular surface preparatory to any superimposed bituminous treatment or construction. The choice of bituminous primer shall depend upon the porosity characteristics of the surface to be primed as classified in IRC:16. These are:

(i) Surface of low porosity; such as wet mix macadam and water bound macadam.
(ii) Surface of medium porosity; such as cement stabilised soil base.
(iii) Surface of high porosity; such as a gravel base

The different ranges of viscosity requirements for the primers to be used for different type of surfaces to be primed are given in Table 4.15.

TABLE 4.15. BITUMINOUS MATERIAL REQUIREMENTS FOR PRIME COAT

Type of Surface	Kinetic Viscosity of Primer at 60°C (Centistokes)	Quantity per 10 sqm. (kg)
Low porosity	30-60	6 to 9
Medium porosity	70-140	9 to 12
High porosity	250-500	12 to 15

The primer shall be bitumen emulsion, complying with IS:8887-1995 of a type and grade as specified in the contract or as directed by the Engineer. The use of medium curing cut-back as per IS:217-1988 shall be restricted only for sites at sub-zero temperature or for the emergency applications as directed by the Engineer.

4.11.2. Tack coat : Tack coat application consists of a single coat of low viscosity liquid bituminous material to an existing road surface preparatory to another bituminous construction over it. It is used to create a bond between an existing surface and a bituminous overlay. The binder used for a tack coat shall be bitumen emulsion complying with IS:8887-1995. The cut-back being environmentally hazardous, its use should be limited to exceptional cases where emulsion cannot be used due to sub-zero temperature.

4.11.3. Surface dressing : The binder shall be straight run bitumen or bituminous emulsion of a suitable grade appropriate to the region, traffic, rainfall and other environmental conditions and conforming to IS:73-1992. The details of the choice and construction method are given in Chapter 8. The physical requirements of aggregates shall remain the same as given in Table 4.15. The size of stone chipping shall be in accordance with Table 4.16.

TABLE 4.16. SIZE REQUIREMENTS OF STONE CHIPPING FOR SURFACE DRESSING

Type of construction	Normal size of stone chipping	Specifications
Single coat surface dressing or the first coat of two-coat surface dressing	13.2 mm	100 per cent passing through 22.4 mm sieve and retained on 11.2 mm sieve.
Second coat of two-coat surface dressing (also used as a renewal coat)	11.2 mm	100 per cent passing through 13.2 mm sieve and retained on 5.6 mm sieve.

(i) A less viscous paving grade bitumen such as 80/100 is normally used for easy and uniform spraying and providing sufficient time during which viscosity does not build up. This ensures proper coating and embedment of aggregates sprayed on hot bitumen.

(ii) In many parts of India, the period of bituminous construction, specially surface dressing work is confined mainly to dry summer months. The working period is thus often limited to six to seven months in a year. However, it can be extended for construction in winter months by controlling viscosity of bitumen according to prevailing atmospheric/pavement temperatures.

(iii) Paving grade bitumen 60/70 may be used for roads in coastal region where temperature variation is less than 20°C.

(iv) Paving grade bitumen 80/100 may be used for rural roads in entire north India and part of peninsula excluding coastal regions.

More viscous grade of bitumen is advantageous in reducing stripping of bitumen film from aggregates in the presence of water. With rounded river shingles, more viscous grade of bitumen compensates to some extent for poor mechanical interlock.

4.11.4. Premix carpet : The binder shall be bitumen of a suitable grade appropriate to region, traffic, rainfall and other environmental conditions as directed by the Engineer and satisfying the requirements of IS:73-1992, 217-1988, 454-1994 or other approved emulsion and cut-back as applicable. The physical requirements of aggregates shall remain the same as given in Table 4.14. The stone polishing value as measured by BS: 812 (Part 114)-1989 shall not be less than 55. Large scale field trials conducted on premix carpet under different climatic condtions have given a broad indication for selection of appropriate grade of paving bitumen as follows:

(i) For traffic intensity of less than 500 CVPD (commercial vehicles per day) and temperature variation through out the year is less than 25°C, paving bitumen 60/70 may be preferred.

(ii) In areas where difference between maximum and minimum atmospheric temperatures is more than 25°C and traffic intensity is less than 500 CVPD, paving bitumen 80/100 may be used.

(iii) Paving bitumen 80/100 may be used in high altitude and snow-bound regions irrespective of traffic intensity.

(iv) For premix work in cold weather with atmospheric temperature below 20°C use of cut-back bitumen MC-3 is suggested. Cut-back bitumen MC-3 may be used in mixes with less quantity of fine aggregate, while cut-back bitumen SC-3 may be used in mixes with appreciable quantity of fine aggregates.

4.11.5. Seal coat : The characteristics of binder for seal coat should be the same as specified above for premix carpet. In case of open graded premix carpet construction, the surfacing layer should always be sealed with a layer of seal coat. Seal coat may be either liquid seal coat (Type A) or sand seal coat (Type B). Type A seal coat shall be used for high rainfall areas (over 1000 mm rainfall per annum) and type B seal coat for other climatic conditions.

4.11.6. Climatic suitability of bituminous material : Suitability of bitumen and emulsion for different types of bituminous work is given in tabular form in Tables 4.17 to 4.21.

TABLE 4.17. SUITABILITY OF TYPE OF BITUMEN USED FOR CLOSE GRADED PREMIX CARPET/MIX SEAL SURFACING AS BITUMINOUS COURSE FOR DIFFERENT CLIMATIC CONDITIONS IN INDIA

Type of bitumen/ Binder	Temperature variation throughout the year ° C		Hot climatic condition throughout the year	Coastal region	North-East States of India	High Altitude/ Cold Climate/ snow bound area, temp < 20°C
	<25	>25				
60/70	*	-	*	*		
80/100					*	*
Cut-back						SC-3
Emulsion	MS	MS	MS	MS	MS	MS

* Represent the suitability of binder for the climatic condition

TABLE 4.18. SUITABILITY OF TYPE OF BITUMEN USED FOR OPEN GRADED PREMIX CARPET WITH SEAL COAT AS BITUMINOUS COURSE FOR DIFFERENT CLIMATIC CONDITIONS IN INDIA

Type of bitumen/ Binder	Temperature variation throughout the year in °C		Hot climatic condition throughout the year	Coastal region	North-East States of India	High Altitude/Cold Climate/snow bound area, temp < 20°C
	<25	> 25				
60/70	*		*	*		
80/100		*			*	*
Cut-back						MC-3
Emulsion	MS	MS	MS	MS	MS	MS

* Represent the suitability of binder for the climatic condition

TABLE 4.19. SUITABILITY OF TYPE OF BITUMEN USED FOR SURFACE DRESSING AS BITUMINOUS COURSE FOR DIFFERENT CLIMATIC CONDITIONS IN INDIA

Type of bitumen/ Binder	Temperature variation throughout the year in °C		Hot climatic condition throughout the year	Coastal region	North-East States of India	High Altitude/Cold Climate/Snow Bound Area, temp < 20°C
	<25	>25				
60/70	*		*	*		
80/100		*			*	*
Cut-back						RC-3
Emulsion			RS	RS	RS	RS

* Represent the suitability of binder for the climatic condition

TABLE 4.20. SUITABILITY OF TYPE OF BITUMEN USED FOR MODIFIED PENETRATION MACADAM FOR DIFFERENT CLIMATIC CONDITIONS IN INDIA

Type of bitumen/ Binder	Temperature variation throughout the year in °C		Hot climatic condition throughout the year	Coastal region	North-East States of India	High Altitude/Cold Climate/Snow Bound Area, temp < 20°C
	<25	>25				
60/70	*		*	*		
80/100		*			*	*
Cut-back						
Emulsion			MS	MS	MS	MS

* Represent the suitability of binder for the climatic condition

TABLE 4.21. SUITABILITY OF TYPE OF BITUMEN USED FOR MAINTENANCE/PATCH REPAIR WORK FOR DIFFERENT CLIMATIC CONDITIONS IN INDIA

Type of bitumen/ Binder	Temperature variation throughout the year in °C		Hot climatic condition throughout the year	Coastal region	North-East States of India	High Altitude/Cold Climate/Snow Bound Area, temp < 20°C
	<25	>25				
60/70	*		*	*		
80/100		*			*	
Cut-back						SC-3
Emulsion	MS	MS	MS	MS	MS	SS

* Represent the suitability of binder for the climatic condition

4.12. Materials for Semi-Rigid Pavement

4.12.1. Dry lean concrete : Dry lean concrete (DLC) is a semi-rigid material used for base course construction having distinctly superior load dispersion characteristics as compared to conventional granular bases and sub-bases, like, WBM. As such, smaller thickness of this material can be used to replace the conventional base and sub-base courses in flexible and rigid pavement construction. Besides superior load dispersing properties DLC is resistant to softening action of water and can serve as a good working platform on softer foundations. It would be particularly useful as a base/sub-base course in areas where good quality aggregates are not available.

4.12.1.1. Materials for DLC

Cement: Ordinary Portland Cement conforming to IS:269-1989 or IS:8112-1989 or Portland pozzolana cement (PPC) covered by IS:1489 (Part 1)-1991 can be used.

Aggregates: Coarse aggregates shall consist of clean, hard, strong, and durable pieces of crushed stone or crushed gravel and shall be complying with IS:383-1970. Brick bats and low grade aggregates can also be used in DLC, however in selecting the aggregates, strength requirement stipulated in (mix design criteria) should be kept in view. The maximum size of the coarse aggregate in the mix is limited by the thickness of DLC layer to be laid, and should not exceed 40 mm for 10 cm layer thickness. The maximum size of the aggregate should preferably be 20 mm. Use of higher size aggregates may lead to segregation of the concrete mix. Restricting the higher size of the aggregate to 25 mm would yield better results. The fine aggregate shall consist of clean natural sand or crushed stone grit or a combination of the two and shall conform IS:383-1970. Fine aggregate shall be free from soft particles, clay, shale, loam, cemented particles, mica, organic and other foreign matter. Continuously graded or gap graded aggregates may be used, depending on the grading of fine aggregates. The combined grading of coarse and fine aggregate should be within the limits given in Table 4.22. In case of marginal aggregates, higher per centage of fine aggregates is desirable to act as a cushion for weak aggregates during rolling.

TABLE 4.22. AGGREGATE GRADATION FOR DLC

I.S. Sieve Size	Per cent passing the Sieve (By weight)
26.5 mm	100
19.0 mm	80-100
9.5 mm	55-75
4.75 mm	35-60
600 micron	10-35
75 microns	0-8

Water: Water is an essential ingredient used in mixing of concrete. It should be free from harmful oil, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. The pH value of water shall generally be between 6 to 8. Potable (drinking water) is generally satisfactory for mixing and curing of concrete. Water found suitable for mixing is also suitable for curing, pH shall not be less than 6. Permissible limits of solids in water are given in Table 4.23.

TABLE 4.23. PERMISSIBLE LIMITS FOR SOLIDS IN WATER (IS:456-2000)

Solids	Permissible, Maximum
Organic	200 mg/litre
Inorganic	3000 mg/litre
Sulphates(as SO_4)	400 mg/litre plain concrete
Chloride (as Cl)	2000 mg/litre for plain concrete
Suspended matter	2000 mg/litre

Fly ash: Fly ash can be used to replace a part of fine aggregate in DLC. Details of fly ash usage in DLC are given in Chapter 9.

4.12.1.2. Proportioning of dry lean concrete : The mix proportions of DLC are designed by trial and error method. As compaction is to be done by rolling, workability shall be kept low, 0-10 mm slump. The cement content in DLC shall not be less than 150 kg per cubic metre of concrete. The average compressive strength of a group of 5 cubes shall not be less than 10.0 MPa at 28 days. In addition, the minimum compressive strength of any individual cube shall not be less than 7.5 MPa at 28 days. While selecting the trial mix proportions, allowance should be made for the maximum size and shape of the aggregate, as increase in the maximum size of the aggregate and its surface area requires reduction in water content; similarly change from angular crushed aggregates to rounded aggregates and increase or decrease in fineness modulus of sand requires a change in sand content.

The design mix complying with the strength requirements shall be got approved by the engineer and demonstrated in the trial length construction. The optimum water content (OMC) shall be determined and demonstrated by rolling during trial length construction. The right amount of water for DLC shall be decided so as to ensure full compaction under rolling. Too much water will cause DLC to be heaving up before the wheel and picked up on the wheels of the roller and too little water will lead to inadequate compaction, low in-situ strength and open textured surface. While laying DLC should have moisture content within OMC + 1 per cent, keeping in view the effectiveness of compaction and to compensate for water absorption and evaporation losses.

4.12.2. Lime fly ash concrete : Details of usage of lime fly ash concrete are presented in Chapter 9 in accordance with IRC:60.

4.13. Materials for Rigid Pavement

4.13.1. Cement concrete pavement : Cement is a material obtained by pulverising clinker formed by calcining raw materials, primarily consisting of argillaceous and calcareous materials. The argillaceous materials used are shale or clay. The calcareous material commonly used is limestone. These materials supply the essential components such as lime (CaO), Silica (SiO_2), Alumina (Al_2O_3) and iron oxide (Fe_2O_3). Cement, when mixed with water, forms a paste, which hardens and binds the particles of aggregates together, to form a hard durable mass called concrete. Ordinary cement is called Portland cement because of the resemblance of set cement to rock found on the English island of Portland. Cement shall be stored in a dry place and subjected to acceptance tests prior to its immediate use. Cement to be used may preferably be obtained in bulk form. Cement shall be stored in a covered place to prevent its deterioration or contamination by foreign matter and to ensure its satisfactory quality and fitness for work. If a lot or batch of cement is not used for two months, fresh tests shall be carried out to ascertain its suitability for use. As per IS:456-2000, a part of cement to the extent of 10-25 per cent can be replaced with fly ash provided required compressive strength is achieved. Before using any cement it would be advisable to get the cement tested for the following main properties to determine whether these properties meet the requirements as per IS standards:

- Fineness [IS:4031 (Part 1,2 & 15)-1996, 1999, 1991]
- Setting time [IS:4031 (Part 5)-1988]
- Soundness [IS:4031 (Part 3)-1988]
- Compressive strength [IS:4031 (Part 6)-1988]

The pavement design shall conform to the provisions of IRC:58 and IRC:15.

4.13.1.1. Types of cement : In India, the BIS has classified Ordinary Portland Cement (OPC) into three grades. Grade of cement refers to 28 days compressive strength in MPa. The specifications of three different grades are given below:

Ordinary Portland Cement (OPC) Grade 33

1. Compressive strength of cement sand mortar (IS:269-1989) not less than

72 ± 1 hours	= 16 MPa
168 ± 2 hours	= 22 MPa
672 ± 4 hours	= 33 MPa

2. Fineness (sqcm/gm) not less than = 2250

Ordinary Portland Cement (OPC) Grade 43

1. Compressive strength of cement sand mortar (IS:8112-1989) not less than

72 ± 1 hours	= 23 MPa
168 ± 2 hours	= 33 MPa
672 ± 4 hours	= 43 MPa

2. Fineness (sqcm/gm) not less than = 2250

Portland Pozzolana Cement (PPC) Grade-I (Fly ash Based)

This cement may be used in construction of base or sub base course under flexible or rigid pavement. This type of cement is preferable to use in mass concrete works and under coastal environment for longer life of the pavement. The specification for this cement is given below:

1. Compressive strength of cement sand mortar [IS:1489 (Part 1)-1991] not less than

168 ± 2 hours	= 22 MPa
672 ± 4 hours	= 33 MPa

2. Fineness (sqcm/gm) not less than = 3000
3. Fly ash/calcined clay = 10-25 per cent

Blast Furnace Slag Cement

This type of cement is preferable to use in concrete works under coastal environment. The specifications for such cement are given below:

1. Compressive strength of cement sand mortar (IS:455-1989) not less than

72 ± 1 hours	= 15.7MPa
168 ± 2 hours	= 21.6 MPa

2. Fineness (sqcm/gm) not less than = 2250
3. Slag (Ground granulated slag) = 25-65 per cent

4.13.1.2 Aggregates for concrete : The bulk of the material that forms concrete, is stone aggregates. Thus, the properties of concrete and its costs are controlled very closely by the quality and cost of aggregates. Aggregates for concrete are classified as fine aggregates and coarse aggregates. Fine aggregates are those which pass 4.75 mm sieve, and coarse aggregates are those which are retained on 4.75 mm sieve. The Indian Roads Congress specifies that the maximum size of the aggregates should not exceed 1/4th of the pavement thickness. Fine aggregates are generally obtained as natural sand from river beds. They can also be obtained by crushing stone and gravel. Coarse aggregates can either be (i) uncrushed gravel, or (ii) crushed stone or gravel,

or (iii) a blend of the two. As per IS:456-2000 other types of aggregate such as slag and overburnt brick, which may be found suitable with regard to strength and durability of concrete as well as free from harmful contents may be used for plain concrete. The aggregate should not contain more than 0.5 per cent of sulphate as SO_3 and should not absorb water more than 2 per cent of their own weight.

The aggregates should be hard, strong, dense, durable, clean and free from adherent coating; they should not have injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As far as possible, flaky and elongated pieces should be avoided. Aggregates should not contain harmful quantities of materials such as pyrites, coal, lignite, mica, shale or similar laminated material, clay alkali, soft fragments, seashells as these can affect the strength or durability of concrete. Generally fly ash and Lithium Chloride to some extent prevent harmful alkali-aggregate reaction. Aggregates are typically stored in separate piles according to gradation and the area must be free draining and free from deleterious matter. In case the engineer considers that the aggregates are not free from dirt, the same shall be washed and dried for atleast 72 hours before batching.

Cement concrete in pavements is subjected to high flexural stresses and abrasion. The aggregates must therefore be able to provide the needed strength and quality, to resist these external forces. Strength is measured by the aggregates crushing test and the aggregates impact test. Abrasion is measured by the Los Angeles Abrasion test [IS:2386 (Part 4)-1963]. The strength requirements of coarse aggregates are as given in Table 4.24. In case of concrete having reinforcement, maximum size of aggregate should also not exceed 1/4th of the minimum clear spacing between reinforcing bars. The maximum size commonly used should preferably be 20-25 mm.

TABLE 4.24. STRENGTH REQUIREMENTS OF COARSE AGGREGATES FOR CONCRETE

Property	For Wearing Surfaces (%)	Other than Wearing Surfaces (%)
Aggregate Impact value	Not more than 30	Not more than 45
Los Angeles Abrasion value	Not more than 30	Not more than 50

4.13.1.3. Water : Water used for mixing and curing of concrete pavement shall conform to the requirements given in Section 4.12.

4.13.2. Roller compacted concrete pavement (RCCP) : Roller compacted concrete is a zero-slump Portland cement concrete which is compacted using a road roller. There are several differences between roller compacted concrete (RCC) and conventional Portland cement concrete. The most apparent is the lower water content of RCC. The lower water to cement ratio results in higher strength than conventional Portland cement concrete. In addition, it allows the use of roller for compaction, which would otherwise get bog down in wetter concrete. Other notable differences are that RCC usually has a lower paste content. When used as an alternative material in pavements, RCC has several advantages like:

- Speed of construction
- Lower cost
- Use of fly ash as an essential ingredient
- Expansion joints not required

Early uses of RCC pavements were primarily for heavily loaded pavements such as parking lots, goods shed, etc. This is because RCC can provide a suitable surface tolerance, adequate for moderate traffic speeds. If it is to be used as wearing course, it is best suited for low and medium traffic volume roads. In case smoother overlay is proposed to be laid as wearing course, RCC can be used for construction of all categories of roads.

Materials for Roller Compacted Concrete are given below:

Cement: Cement conforming to IS:269-1989 or IS :8112-1989 or IS:12269-1987 can be used. Portland pozzolana cement (PPC) covered by IS:1489-1991 can also be used, however in that case, fly ash or any other pozzolanic material shall not be used to replace part of cement.

Aggregates: Coarse aggregate for RCC shall be from natural aggregates complying with IS:383-1970. They shall consist of clean, hard, strong, dense, non-porous and durable aggregates derived from crushed stone or crushed gravel and shall be devoid of pieces of disintegrated stone, soft, flaky, elongated and highly angular pieces. The maximum size of coarse aggregate should be preferably limited to 20 mm in order to avoid a harsh pavement surface and segregation during transport and placement. The engineer may permit use of aggregate of upto 25 mm size, if field trials are satisfactory

The fine aggregate shall consist of clean natural sand or crushed stone grit or a combination of the two and shall conform IS:383-1970. Fine aggregate shall be free from soft particles, clay, shale, loam, cemented particles, mica, organic and other foreign matter. The combined grading of coarse and fine aggregate shall conform to gradation given in Table 4.25.

TABLE 4.25. AGGREGATE GRADATION REQUIREMENTS FOR RCC

Sieve Designation	Percentage of material by weight
26.5 mm	100
19.0 mm	80-100
9.50 mm	55-80
4.75 mm	35-60
600 micron	10-35
75 micron	0-8

Fly ash: Eventhough roller compacted concrete can be made without using fly ash, use of fly ash in roller compacted concrete has many advantages. Details of usage of fly ash usage in roller compacted concrete are given in Chapter 9.

Water: Water used for mixing and curing of roller compacted concrete shall be clean and free from injurious amounts of oils, salts, acid, etc. It shall meet the requirements given in Section 4.12.

4.14. Materials for Special Pavements

4.14.1. Concrete block pavement (CBP)/interlocking concrete block pavement (ICBP) :CBP/ICBP consists of a surface layer of brick-sized concrete blocks paved on a thin, compacted bedding sand layer of specified grading, which is spread over a properly profiled base course and is bounded by edge restraints. The joints are sealed with joint filling sand, also of specified grading. The block layer is embedded into the bedding sand by vibratory compaction. In CBP rectangular blocks are used which are non-interlocking when paved, while in ICBP blocks with curved vertical faces are used, which have enhanced interlocking effect when paved. Paving quality concrete is used for production of precast blocks and edge restraints. Ordinary Portland Cement/Portland Pozzolana Cement/Portland Slag Cement meeting relevant specifications are used as binder. Good quality natural coarse and fine aggregates meeting the specification requirements as per IS:383-1970 should be used in concrete. Industrial waste products like fly ash, slag, etc. meeting relevant specifications can also be used as additives. Potable water should be used for making concrete mix. Concrete blocks are normally produced using properly designed cement concrete mix. However, the blocks so produced should have equivalent 28-days strength as per design requirements.

Concrete blocks are produced using properly designed cement concrete mix and using electro-hydraulically operated Block Making Machines (BMMs), in which heavy metallic moulds are used in combination with compaction heads. Different moulds are used for different shapes of blocks. The desired density and strength is achieved by vibratory compaction and hydraulic pressing. Fresh blocks are produced on metallic or wooden pallets. In the context of rural roads, wherever BMMs are available, the same can be used for production of

blocks. Where such infrastructure cannot be arranged, manual or semi-automatic hydraulic presses can be utilised for the same. In such cases the choice of block shapes should be based on simplicity in fabrication of moulds. Manual or power-driven mixers can be used for preparation of concrete mix. For curing of blocks, curing tanks with adequate capacity for holding 2 weeks' production of blocks are required. When such facility cannot be arranged, curing by wet gunny bags or hessian cloths can be adopted. Blocks produced in BMMs/ hydraulic presses should be allowed to self-cure under ambient temperature for 24 hours during mild season and 12 to 18 hours during summer. After that they should be transferred to curing tanks or stacked in neat rows and cured with wet gunny bags/hessian cloths. It is necessary to cure the blocks for 28 days to achieve the full strength potential of blocks. However, under inevitable circumstances curing for 14 to 28 days may also be allowed. Proper quality control should be exercised in production of blocks, so that they achieve the expected strength and durability requirements. The pavement design requirements for CBP/ICBP are given in Chapter 5.

4.14.2. Stone-sett pavement/brick-on-edge pavement : Stone-sett pavement consists of hard stones paved on a bedding sand layer provided over compacted subgrade of base course, bounded by edgestones. Locally available hard stones are generally used for the purpose. Irregular quarry stones or stones cut to regular sizes can be used, provided the surface evenness requirement is not a precondition. The types of stones normally used are granite, basalt, sandstone and limestone. Depending upon the quality of stones used, stone-sett pavement can be expected to have a life of 20 years or more. Brick-on-edge pavement consists of a layer of burnt-clay bricks (placed on edge) paved over a thin bedding sand layer provided over compacted subgrade or base course in the desired paving pattern, and bounded by edge restraints for which the bricks themselves can be used. High quality bricks can be produced by preparing clay with high (20 per cent) lime content, moulding them in steel forms and firing at high temperatures. While normal brick pavements can be expected to serve for 10 years, pavements constructed with lime-mixed bricks can have a life of upto 20 years.

4.15. Climatic Suitability of Concrete Materials

4.15.1. Selection of constituents of concrete : Cement concrete is the major component of semi-rigid and rigid pavement and special pavement construction. Concrete is mainly composed of sand and crushed rock or other aggregates, held together by a hardened paste of hydraulic cement and water. The ingredients of concrete are thoroughly mixed in pre-selected proportions, resulting in a plastic mass which can be cast/moulded into a predetermined shape and dimension to construct semi-rigid and rigid pavement for rural roads. Semi-rigid and pavement quality concrete and roller compacted concrete pavements are suitable for the regions where annual rainfall is more than 1000 mm and soil is very clayey/silty (CBR 2-3 per cent). Depending upon the availability of funds, as the semi-rigid or rigid pavements are about 50 to 70 per cent costlier than flexible pavements, the choice must be exercised with extreme caution for any extreme condition.

Further, to reduce the cost of these pavements, fly ash shall be used as replacement of portland cement by 10-25 per cent (by weight) in semi-rigid and rigid surface. For use in the wearing course 50 per cent sand can be replaced by fly ash (by weight) in semi-rigid pavement construction (either for base/sub-base or wearing course), if fly ash is available in a reasonable reach. The use of fly ash shall be guided by IRC:68 and IRC:SP:58. The details of such construction are given in Chapter 9. However, it is indicated that use of fly ash in concrete is more advantageous in tropical, arid and semi-arid environment. Use of fly ash in concrete gives better performance than plain conventional concrete in coastal regions where chances of chlorides and sulphates in the ground water or soil are more and air temperature is reasonably high.

Cement is the binding material for most of semi-rigid and rigid pavements. A wide variety of cements are available now-a-days, and their suitability in relation to five different exposure conditions is given in

IS:456-2000. Minimum amount of cement in concrete and maximum w/c (water/cement) ratio to be adopted may also be refered in IS:456-2000. As semi-rigid base course materials such as pozzolanic concrete, lean cement concrete, lime fly ash concrete, soil cement etc. can not withstand the attrition and impact due to road traffic, a suitable bituminous surfacing/wearing course has to be laid over such base course material. Limits of chlorides, sulphate and cement content in the concrete (adopted from IS:456-2000) required for road construction is given in Table 4.26.

TABLE 4.26. LIMITS OF CHLORIDES, SULPHATE AND CEMENT CONTENT IN THE CONCRETE FOR RCCP AND SEMI-RIGID PAVEMENT (IS:456-2000)

Type of Concrete	Cement Content kg/cum	Total Soluble Chloride Content in kg/cum of concrete	Total Soluble Sulphate Content in Concrete	Minimum Grade of Concrete in Coastal Region
Plain concrete	Maximum= 450** Minimum= Refer IS:456-2000	3.0	4.0* % by mass of cement	M-30

* Does not apply with SSC (IS:6909-1990), ** Not including fly ash/slag

Note: In case of reactive aggregates, use of at least 20 per cent fly ash or at least 50 per cent slag is recommended.

Appendix 4.1

Mechanical Stabilisation

Correctly proportioned material (aggregate and soil) can be adequately compacted to form a mechanically stable pavement layer. This method is called mechanical stabilisation. Thus the basic principles in this method of stabilisation are: a) Proportioning and b) Compaction. If a granular soil containing negligible fines is mixed with a certain proportion of binder soil, it is possible to increase the stability. Similarly the stability of a fine-grained soil can be considerably improved by mixing a suitable proportion of granular material to get a desired gradation.

Mechanical stabilisation has been successfully applied for sub-base and base course construction. It has also been used as a surface course for low cost roads such as village roads when the traffic and rainfall are low. The desirable properties of soil aggregate mixtures are strength, incompressibility, less changes in volume and stability with variations in moisture content, good drainage, less frost susceptibility and ease of compaction. It is generally believed that the stability of a soil-aggregate mix can be increased by increasing its dry density. Hence proportioning of mixes is done to attain maximum dry density.

The following are the recommended values of the liquid limit and plasticity index for the material passing 425 micron sieve, to be used for mechanical stabilisation

	Base Course	Surface Course
Liquid limit	25 per cent max.	35 per cent max.
Plasticity index	6 per cent max.	5 to 10 per cent

Design of mechanically stabilised mixes

The factors to be considered in the design of mix are gradation, density, index properties and stability. Of these, the gradation is the most important factor. The particle size distribution that gives maximum density is generally aimed at. Fuller's formula may be used to obtain the theoretical gradation for maximum density and is given by:

$$P = 100\,(d/D)^{1/2}$$

where, P = per cent finer than diameter 'd' (mm) in the material.

D = diameter of the largest particle, mm

Combining two materials based on sieve analysis

A simple method for proportioning two materials to obtain a mix of specified gradation is outlined below:

(i) Column 3, 4 and 5 of Table below, show the details of specification limits for a particular pavement course.

(ii) Column 2 and 6 in the Table give the particular size distribution of materials A and B which do not satisfy the gradation requirement of the specification.

(iii) The inverse ratio of the totals in columns 1 and 7 gives the proportion of the materials to be mixed to obtain the desired mix.

A:B = 45:139 (1:3)

(iv) Mixing 25 per cent of the material A and 75 per cent of material B would give the desired gradation as shown in Table 4.1.1.

TABLE 4.1.1. MIXING OF AGGREGATES FOR DESIRED GRADATION

Numerical difference between material A and average per cent passing	Material A per cent passing	Sieve size	Limits per cent passing	Average per cent passing	Material B per cent passing	Numerical difference between material B and average per cent passing
1	2	3	4	5	6	7
-	100	40 mm	100	100	100	-
8	98	20 mm	80-100	90	73	17
26	94	10 mm	55-80	68	55	13
33	83	4.75 mm	40-60	50	42	8
32	72	2.36 mm	30-50	40	35	5
33	55	600 μ	15-30	22	21	1
7	17	75μ	5-15	10	9	1
Total = 139						Total= 45

Combining two materials based on plasticity properties

Let there be two soils A and B which are to be mixed to get a soil of required plasticity index P. Determine the plasticity index of the two soils. Let these be P_A and P_B for soil A and soil B. Determine from sieve analysis for each soil, the percentage of material passing 425 micron sieve. Let these be S_A and S_B for the soil A and soil B respectively. Then the percentage of soil A in the mix having plasticity index P is given by the relation:

$$\text{Material A\%} = \frac{S_B (P-P_B)}{S_B (P-P_B) - S_A (P-P_A)}$$

Chapter 5

PAVEMENT DESIGN

5.1. Introduction

The road structure may be divided into four major components, viz., land, earthwork, pavement and cross drainage works. The pavement constitutes nearly one-third to one-half of the total cost of the road. Therefore, very careful consideration should be there for the choice of the type of pavement and its design. The factors which govern the selection of the type of the pavement are:

(a) Initial (construction) cost
(b) Availability of good materials locally
(c) Cost of maintenance or rehabilitation during service
(d) Technology of construction required and its availability

The options available are: (a) flexible pavement, (b) cement concrete pavement, (c) composite pavement with semi-rigid base with suitable bituminous surfacing, (d) semi-rigid base with surfacing of inter connected concrete paving blocks, and (e) roller compacted concrete. In India most of the roads are with flexible pavement; however, the recent trend is of concrete pavement, specially for high density traffic corridors and expressways.

In case of rural roads, in view of the stage development strategy and the initial cost advantage, the flexible pavement may be the appropriate choice. However, in special cases, in short sections or in some rural road projects where the ground conditions and material availability may pose restriction for use of flexible pavement, the other options like roller compacted concrete, block pavements and composite pavements may be cost effective. Generally the choice of pavement will be further guided by several other factors, such as

(a) Rainfall and temperature
(b) Type and strength of soil along the alignment
(c) Availability of good aggregates
(d) Availability of industrial wastes (like, fly ash, slag, etc.) in the proximity

Thus, based on the above guiding principles, practically the choice can be exercised by the Engineer appropriately to economise in the overall cost of the project without compromising the quality in any manner.

The importance of pavement design, even for rural roads, cannot be overemphasized. While it appears that rural roads will not have traffic intensity or axle loads as compared to higher categories of road, even small number of commercial vehicles (or tractor-trolley) with heavy axle loads or iron-tyred animal drawn cart may cause heavy damage to an underdesigned pavement. It is due to this single most important reason that a considerable length of rural roads built every year using resources of different rural development programmes failed prematurely.

Any design using conventional, marginal or waste material must follow standard procedure based on material property, traffic and design life. There are many associated factors like rainfall, ground water table, etc. which are also to be taken into account for evolving durable pavement design. In all designs, economy in the initial cost as well as in life cycle cost are crucial and very important. These aspects assume extra emphasis in case of rural roads.

5.2. Design Parameters

5.2.1. General : The principal criterion for determining the thickness of a flexible pavement with a thin bituminous surfacing is the vertical compressive strain on top of the subgrade imposed by a standard axle load of magnitude 8.17 kN (8170 kg). Excessive vertical subgrade strain causes permanent deformation in the subgrade, which is manifested in the form of rutting on the pavement surface. The maximum rutting that can be accepted in village roads may be taken as 50 mm before rehabilitation work is needed. Analytical evaluation of performance of other district roads and village roads on the basis of the vertical subgrade strain criterion has indicated that the design curves as per IRC:37 are generally valid for the design traffic from 0.1 million standard axles (msa) to 2 msa. However, for design of rural roads, the design charts have to be simple and convenient for the grass-root level agencies. Road Note 29 of TRL, IRC:37 and experience in India suggests that the charts may be for the traffic in the range upto 450 CVPD. Since subgrade CBR may be as high as 20 per cent, design curves are also prepared for subgrade CBR up to 20 per cent. The minimum recommended pavement thickness is 150 mm even when design chart gives lower thickness. For rigid and semi-rigid pavements tensile stress is taken as the design criteria to prevent fracture of the concrete layer within the design period. In case of concrete block pavements, vertical subgrade strain is the critical criterion to limit rut depth due to traffic loading.

5.2.2. Traffic : For the purpose of structural design, only the number of commercial vehicles of laden weight 3 tonnes or more should be considered. To obtain a realistic estimate of design traffic, due consideration should be given to the existing traffic and its rate of growth. In case of new construction, anticipated traffic, possible changes in the road network and land use of the area served as well as the probable growth of traffic over design life are to be carefully accounted for. If adequate data is not available, an average value of 6 per cent may be adopted for traffic growth rate. The traffic study for the road may be carried out as per the IRC:9.

5.2.3. Design life : Design life is usually defined as the number of years until the first major reconstruction is anticipated. For unsurfaced roads, aggregates are displaced on either side of the wheel path and frequent blading is necessary to maintain a good riding surface. For unsealed/unsurfaced roads aggregates are often lost due to traffic action as well as erosion by rains, and the pavements become thinner with time. Material lost must be replenished periodically to maintain the rideability. It is necessary that sufficient thickness is provided to prevent rutting failure during the design life due to high vertical subgrade pressure. It is considered appropriate that roads in rural areas should be designed for a design life of 10 years. The thin bituminous surfacing that is commonly provided on the low volume roads has a life of about 5 years.

5.2.4. Computation of design traffic : The design traffic is considered in terms of the future traffic to be carried during the design life of the road. Its computation involves estimates of the initial volume of commercial vehicles per day, traffic growth rate and design life in years. In case of rural roads the commercial vehicles will be trucks (small and big), buses and tractor-trolley. The traffic for the design life is computed as:

Where $A = P(1+r)^{n+x}$

A = Number of commercial vehicles per day for design

P = Number of commercial vehicles per day at last count

r = Annual growth rate of commercial traffic

n = Number of years between the last count and the year of completion of construction

x = design life in years

Since the width of rural roads will be single lane, design traffic should be based on total number of commercial vehicles per day in both directions. Bullock carts with iron rims are still in use in different parts of

the country and the total weight including the pay load of a bullock cart may range from 1.0 tonne to 1.5 tonnes. Though the designed pavement as a whole will be safe from shear failure, the iron rims damage the top layer of the pavement because of high concentration of stress. Thus the wearing course must be made up of good quality aggregates with aggregate impact value not exceeding 30 per cent to reduce degradation of the aggregates by crushing.

5.3. Pavements Components

5.3.1. Subgrade : In rural roads, the top 30 cm of the cutting or embankment at the formation level shall be considered as subgrade. The subgrade, whether in cut or fill, should be well compacted to utilise its inherent strength and prevent permanent deformation because of additional compaction by traffic. A minimum of 100 per cent of Standard Proctor compaction should be attained in the top 30 cm of the subgrade. For clayey soil, the minimum compaction for subgrade should be 95 per cent of Standard Proctor compaction and the compaction should be done at moisture content 2 per cent in excess of the optimum value. For embankments, the soil below 30 cm of subgrade shall be compacted to minimum 97 per cent of Standard Proctor compaction [IS:2720 (Part 7)-1980]. For pavement design, the subgrade strength should be determined in terms of CBR at the most critical moisture conditions likely to occur. The CBR test should be conducted on remoulded samples prepared at optimum moisture content and dry density corresponding to Standard Proctor compaction [(IS:2720 (Part 7)-1980] and soaked in water for four days prior to testing. If the annual rainfall is of the order of 500 mm or less and the water table is too deep, soaking for four days may not be necessary.

One or two CBR tests should be done per kilometre depending on the variation of soil type. If there is no variation in soil type, mean CBR value should be adopted for the design of pavements. In case of existing roads requiring strengthening, the soil should be moulded at the existing moisture content and field density, and soaked for four days prior to testing for CBR.

Where the CBR of the subgrade is less than 2 per cent a capping layer of 100 mm thickness of material with a minimum CBR of 10 per cent is to be provided in addition to the sub-base required for CBR of 2 per cent. If the subgrade CBR is more than 15 per cent, there is no need to provide a sub-base. WBM base can be laid directly over the subgrade after providing a drainage layer (inverted choke).

5.3.2. Sub-base : Sub-base is a layer of selected material placed on the subgrade compacted to 98 per cent of the IS heavy compaction. Generally it consists of locally available, relatively low strength inexpensive material. The principal function of the sub-base is to distribute the stresses over a wide area of the subgrade imposed by traffic and to ensure that no subgrade material intrude into the base course and vise versa. There are a large number of locally available aggregates and industrial waste materials that can be utilised for sub-bases of pavements. These are discussed in Chapters 4 and 9.

The sub-base material should have minimum soaked CBR of 15 per cent. Material component of sub-base passing 425 micron IS sieve when tested in accordance with [IS:2720 (Part 5)-1985] should have liquid limit and plasticity index not more than 25 and 6 respectively. These requirements should be enforced to achieve desired quality.

When the subgrade is silty or clayey soil and the annual rainfall of the area is more than 1000 mm, a drainage layer of 100 mm over the entire formation width should be provided conforming to the gradation given in Chapter 6. This layer will form a part of the designed thickness of sub-base.

5.3.3. Base : The base course materials should be of good quality so as to withstand high stress concentrations which develop immediately under the wearing surface. Since bituminous surfacing consists

only of a thin wearing course, the upper surface of the base must be sufficiently smooth and true to profile to provide a good riding surface. The different types of base course which are commonly used are:

(a) Water Bound Macadam (WBM)
(b) Crusher-Run Macadam
(c) Dry Lean Concrete
(d) Soft Aggregate Base Course
(e) Lime-Fly Ash Concrete

Thickness deduced from the design charts are appropriate to pavements with unbound granular bases which comprise of conventional WBM or any other equivalent granular construction. For cement treated or stabilised materials, thorough laboratory investigations are necessary and the pavement design can be done using analytical method. In some situations where good quality aggregates are not available, cement treated low grade aggregates or soils may also be used. Appropriate agency may be approached for laboratory investigations and design.

It is recommended that normally no material with CBR value less than 100 per cent should be used in base courses. Since base course will be affected by water, their strength should be determined in soaked condition. Where a substantial part of the base material consists of particles larger than 20 mm size, the CBR test will not be applicable and their strength will have to be estimated from experience. WBM of adequate thickness over a properly designed sub-base will be assumed to satisfy the CBR requirements of 100 per cent. The design of base courses of different types are given in subsequent Sections.

5.3.4. Pavement surface : Pavement can be with a sealed or unsealed surface. The unsealed surface means a granular surface where percolation of water into the pavement layers is possible, whereas in sealed surface it is prevented by appropriate surfacing layer. Details of the design or choice of surfacing are given in Section 5.4.2.

5.4. Design of Flexible Pavement

5.4.1. Pavement thickness : The thickness of pavement is designed on the basis of projected number of commercial vehicles for the design life using the current commercial vehicles per day and its growth rate. Further, it requires the subgrade strength value in terms of CBR. It is expected that rural road will not have more than 450 CVPD in any case. The design chart given in Fig. 5.1 may be referred to obtain the total pavement crust thickness (granular crust thickness) required over the subgrade for the design life of the pavement. Based on the strength of granular materials that are used, the total design thickness is divided into base and sub-base thicknesses. However, any other higher type of bituminous layer can be part of the designed thickness, with the exception of thin bituminous surfacings (PMC, MSS, etc.). In case of rural roads, with low volume of traffic, structural layer of bituminous mix need not be provided, generally except in very special cases where the traffic volume is so high that the design suggests it.

For the convenience of engineers the whole range of traffic and CBR that exist for rural roads in various States of the country have been considered and flexible pavement thickness catalogues are given in Figs. 5.2, 5.3 and 5.4 for ready reference. A worked out example for design of flexible pavement for rural road is given in section 5.4.3.

5.4.2. Surfacing : A gravel road or WBM layer can serve adequately as a surfacing depending on traffic volume. However, it is to be clearly understood that granular materials (like, soil-gravel mixture) will be lost gradually by traffic action and thickness will be reduced. Therefore, for gravel roads extra thickness should be provided. Further, for similar reasons, only WBM Grade-III should be used as a surfacing course for an unsealed WBM road. Other granular surfacings, like, Moorum, Kankar, etc. will have to be bladed as and when required to provide smooth riding surface.

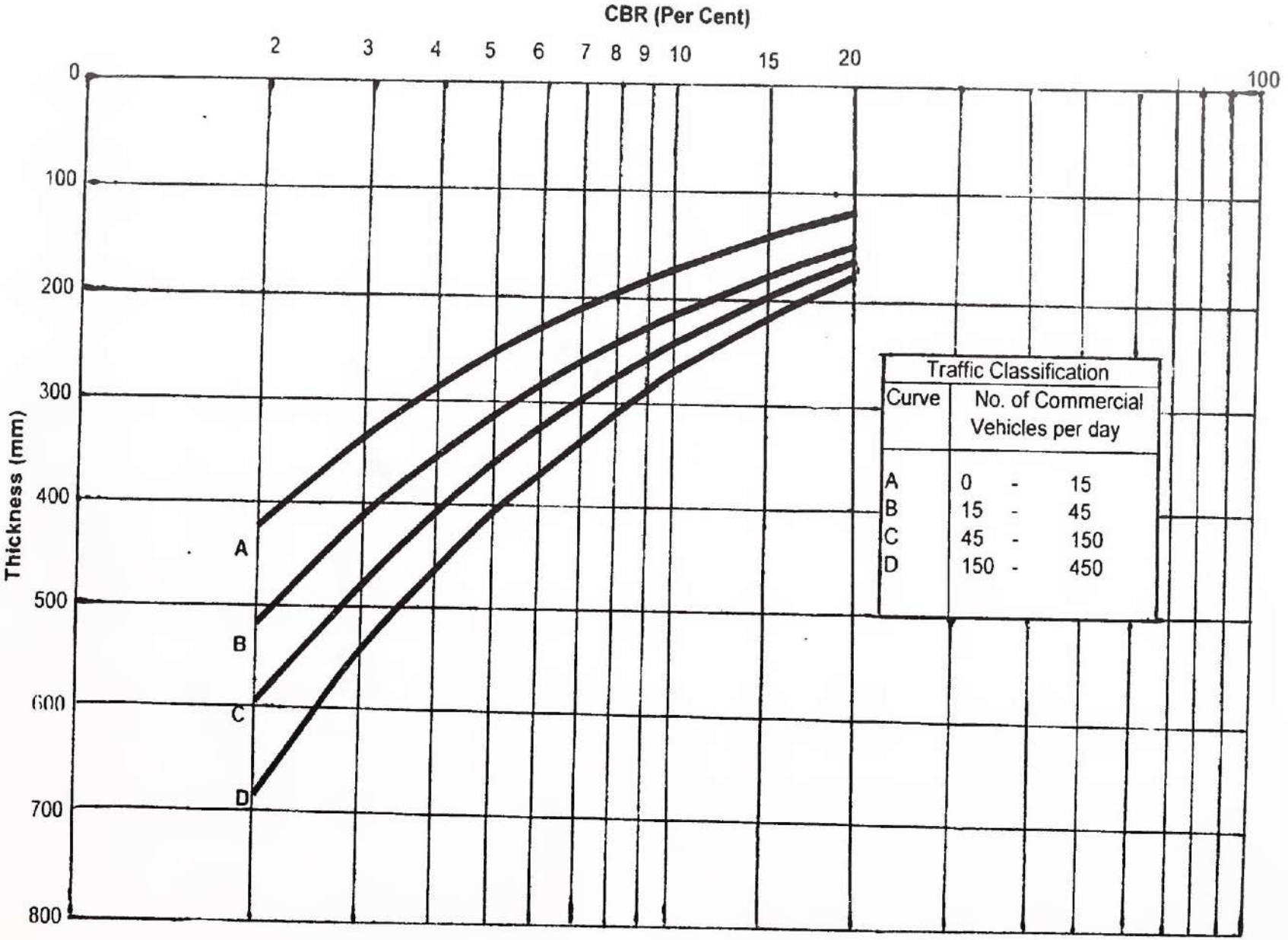


Fig. 5.1. CBR Curves for Flexible Pavement Design

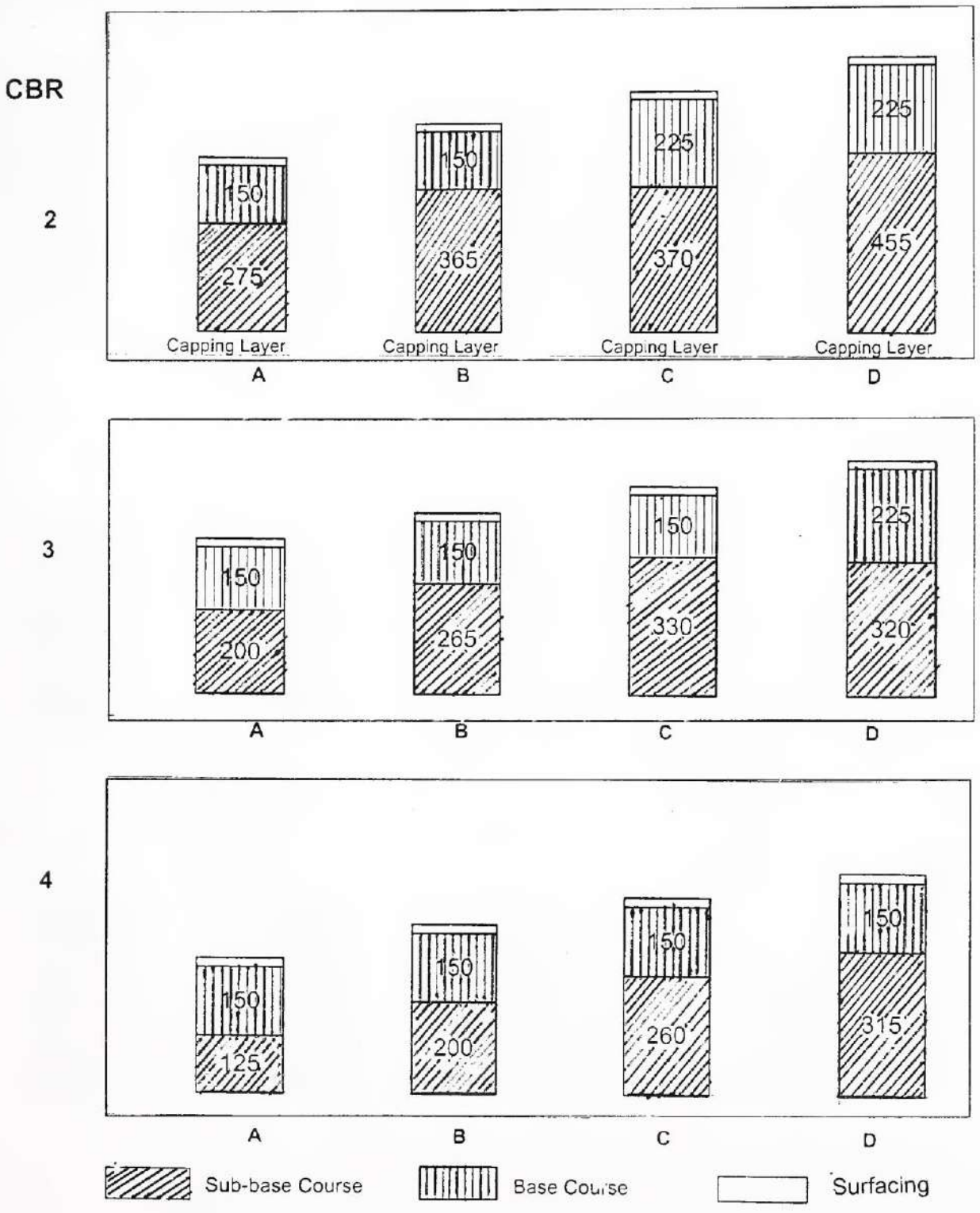


Fig. 5.2. Thickness of Crust Required for Different Traffic (CBR 2 to 4)

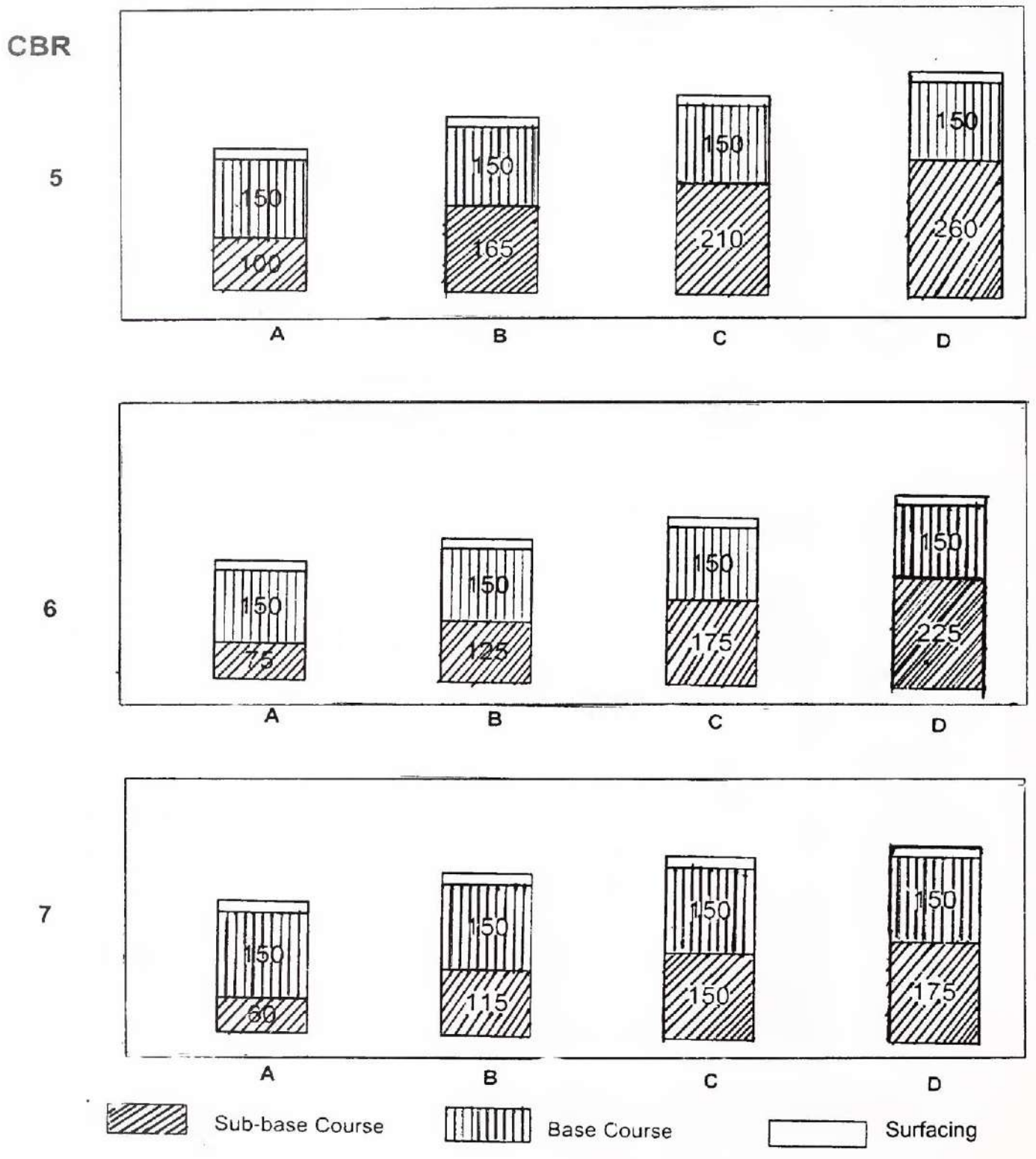


Fig. 5.3. Thickness of Crust Required for Different Traffic (CBR 5 to 7)

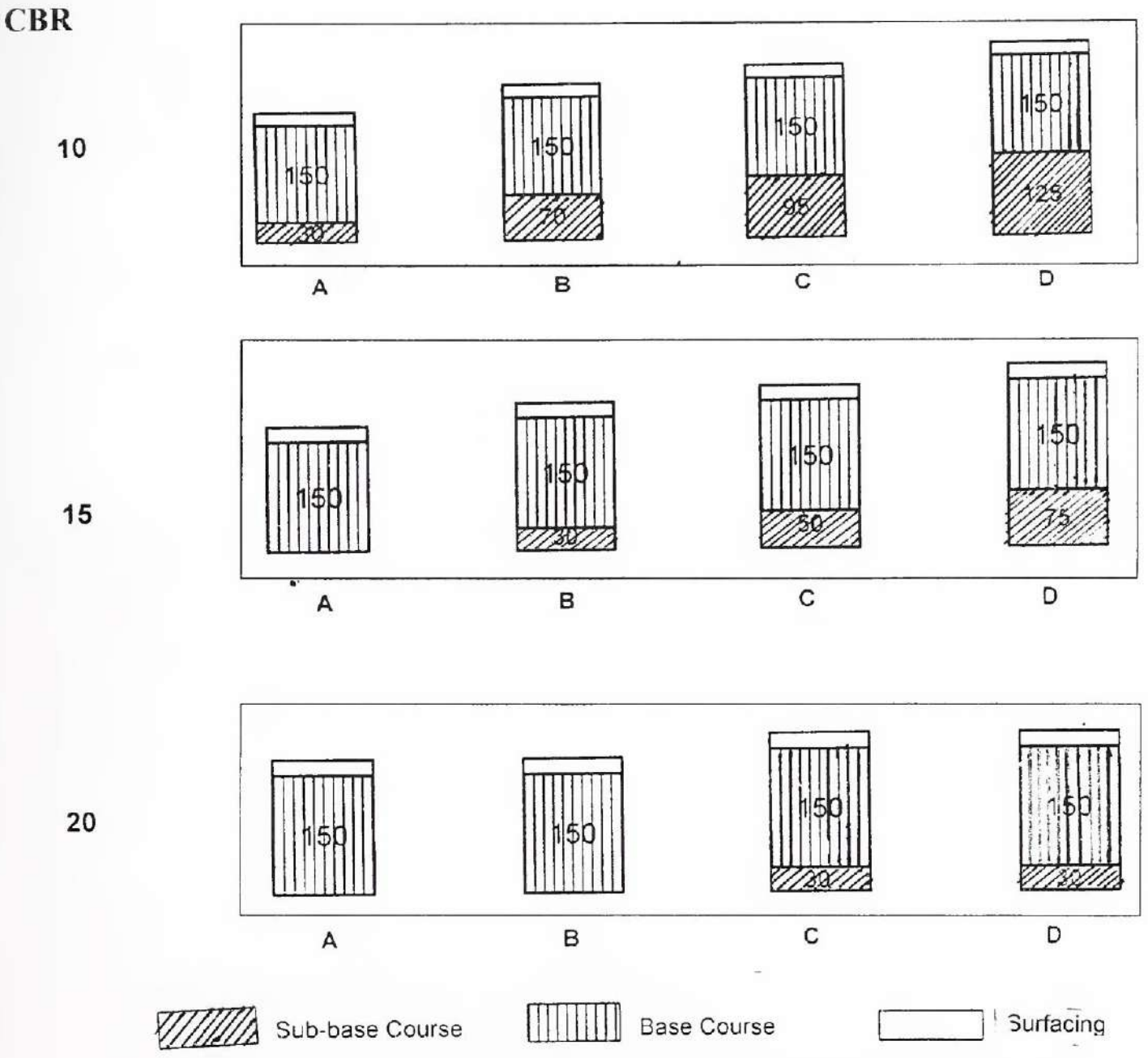


Fig. 5.4. Thickness of Crust Required for Different Traffic (CBR 10 to 20)

The bituminous wearing course will generally consist of premix carpet with seal coat or two coat surface dressing laid over WBM base course or other type of bases. Bituminous wearing course must be made up of good quality aggregates with aggregate impact value not exceeding 30 per cent in order to reduce degradation of the aggregates by crushing. Use of bituminous emulsion for such work may give good surfacing because of processing of material at ambient temperature. Maintaining the right mixing temperature of the hot mix is not easy when the dampness of aggregates stacked at the sites varies. Based on the total motorised traffic and rainfall, an appropriate surface course can be chosen from Table 5.1.

TABLE. 5.1. GUIDELINES ON SURFACING FOR RURAL ROAD

Annual Rainfall (mm)	0-50	50-150	150+
1500+	Thin Bituminous Surfacing (2-Coat S.D.)	Bituminous Surfacing (PMC + Seal Coat)	Bituminous Surfacing (PMC + Seal Coat)
1000-1500	Single Coat Surface Dressing	Thin Bituminous Surfacing (2-Coat S.D.)	Bitumouns Surfacing (PMC+ Seal Coat)
500-1000	Unsealed Surface (Gravel Road)	Single Coat Surface Dressing	Thin Bituminous Surfacing (2-Coat S.D.)
0-500	Unsealed Surface (Gravel Road)	Unsealed Surface (Gravel Road)	Thin Bibtuminous Surfacing (2-Coat S.D.)

Motorised Traffic (Except 2-Wheeler) Per Day

Note: S.D. = Surface Dressing
PMC = Premix Carpet

5.4.3. Worked out Example : A pavement is to be designed for a subgrade CBR of 4 per cent, with an initial traffic of 70 motorised vehicles per day (except 2-wheelers) in both direction of which commercial vehicle is 30 CVPD, with a growth rate of 6 per cent per annum for a location having annual rainfall of 1200 mm. The design life is 10 years. Determine the pavement thickness.

Initial traffic in both direction : 30 CVPD. Using equation given in Section 5.2.4.

Design Traffic $=30*(1+.06)^{10}$

$= 54$ CVPD

Designed pavement crust thickness :	405 mm (refer Fig 5.1)
Provide :	Sub-base 260 mm
	Base course 150 mm
Sub-base :	Layer 1: 100 mm
	Layer 2: 160 mm
Base Course :	Layer 2: WBM Grade 2 = 75 mm
	Layer 3: WBM Grade 3 = 75 mm
Surfacing :	2 Coat Surface Dressing (from Table 5.1 for projected 125 veh/day motorised traffic in design year and 1200 mm rainfall)

The designed cross-section of the pavement is shown in Fig. 5.5.

5.5. Design of Semi-Rigid Pavement

5.5.1. General : Semi-rigid materials have modulus of elasticity less than pavement quality concrete (rigid pavement material), but more than bituminous materials. The flexural strength of semi-rigid materials is generally between 1.0 to 1.2 MPa. These materials are used as base course under flexible or rigid pavements. In case of rural roads, 20 mm thick bituminous layer of premix carpet with seal coat or 20 mm thick mix seal surfacing or surface dressing may be applied over the semi-rigid base as the abrasion resistance of semi-rigid materials is very less as compared to pavement quality materials. The 28-days compressive strength of semi-rigid material varies from 5 to 10 MPa. These materials have better capability of load distribution and more

flexural rigidity than WBM. Therefore, these are suitable for heavy rainfall areas or where soil is very weak. In areas where good quality aggregates are not available, DLC made from pit-run gravel, river gravel and other low grade aggregate may provide an economical solution. Commonly used semi-rigid materials are dry lean concrete, lime-fly ash concrete and other cementitious materials. The maximum single layer thickness of DLC to be compacted should be 100 mm.

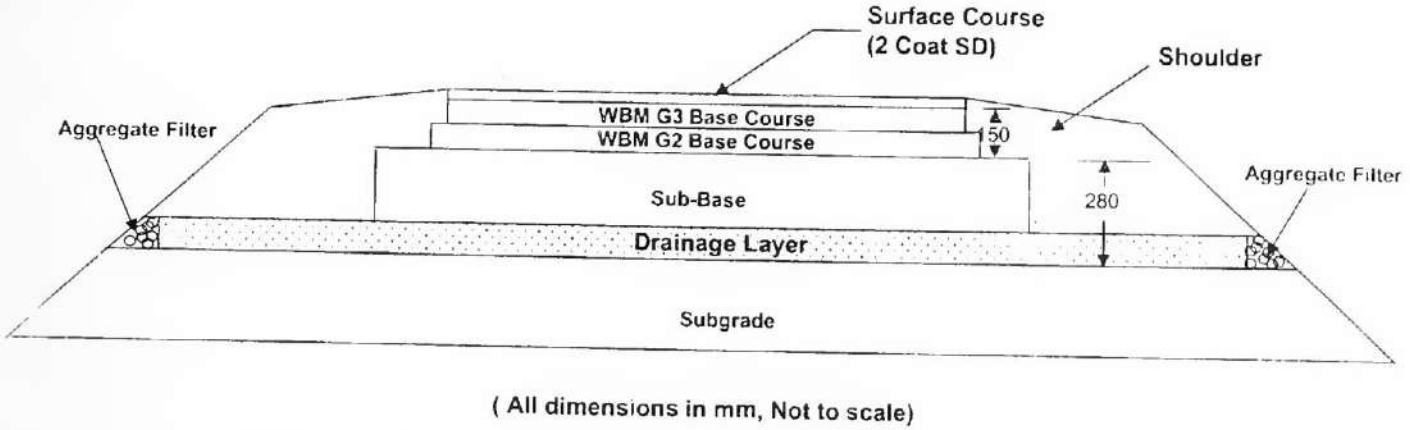


Fig. 5.5. Designed Cross-Section of Road as per Worked out Example in Section 5.4.3

5.5.2. Dry lean concrete base : Dry lean concrete base is subjected to flexural fatigue under traffic loading. Design charts of semi-rigid bases for different subgrade CBR and various traffic levels are shown in Fig. 5.6. A granular sub-base, 100 to 150 mm thickness to full width of formation should be laid below the cement bound layer to provide a working platform and also to act as a drainage/filter layer. The DLC is likely to be eroded under traffic and requires bituminous wearing course of premix carpet with seal coat or two coat surface dressing.

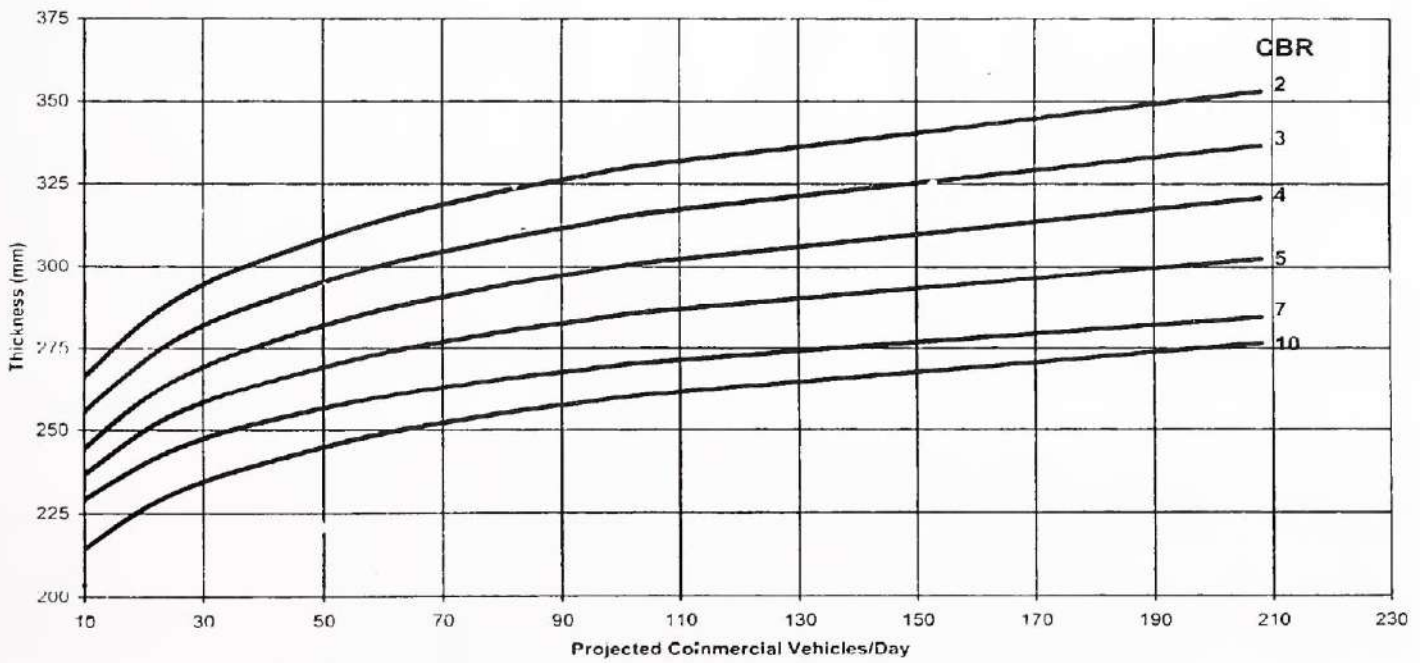


Fig. 5.6. Design Chart for Dry Lean Concrete/Cementitious Semi-Rigid Base

Worked out Example

A pavement is to be constructed in an area where only pit-run gravel is available at a low cost. Design data is the same as in the worked out example in Section 5.4.3. A mix consisting of cement, sand and aggregates in the ratio of 1:6:12 has a 28-days flexural strength of 1.1 MPa.

Design traffic (projected) = 54 CVPD

For subgrade CBR = 4

From Fig. 5.6, thickness of cement treated base = 285 mm

The pavement section will consist of a thin bituminous wearing course and 285 mm cement treated base over 100 mm of drainage/filter layer.

5.5.3. Lime-fly ash concrete and other cementitious bases : In areas close to thermal power plants where fly ash is available in plenty, fly ash stabilised bases can give a low cost pavement. Pozzolanic materials are known for their durability. They gain in strength with time. Various properties of different types of fly ash aggregate mixtures are given in Chapter 9. Combinations which give flexural strength higher than 1.0 MPa may be used. Lime-rice-husk-ash mixtures as described therein may also be used. Marginal aggregates can also be used in these mixes. These types of base courses require a drainage layer below it. A bituminous wearing course is necessary to prevent erosion of the stabilised bases. Compaction shall be done till the density achieved is at least 98 per cent of the maximum dry density as per IS:2720 (Part 8)-1983. Method of construction of these fly ash bases and their curing shall be as per the requirements specified in Chapter 9. The design chart given in Fig. 5.6 can be used to design the thickness of lime fly ash concrete. A wearing course of premix carpet with seal coat or surface dressing shall be provided on such bases.

5.6. Design of Rigid Pavement

5.6.1. Cement concrete pavement : Design of cement concrete pavement shall be as per IRC:58 and construction including detailing of joints shall be as per IRC:15. Strict quality control shall be exercised during construction. Cement concrete pavement may be used in special cases only where drainage problem is acute and continuous. In cases of deficient design and construction, their design life is likely to be greatly affected. The cement concrete pavement may be used in limited length within the village portion. However, drainage arrangements should be ensured even for concrete pavement.

5.6.2. Roller compacted concrete pavement (RCCP) : RCCP is a technique which makes use of laying zero slump concrete manually and compacting with vibratory or static road roller of 8-10 tonnes capacity.

RCCP may be used in areas where there is drainage problem. These roads must be constructed under strict supervision and quality control. In cases of deficient design and construction, their design life is likely to be greatly affected. Construction of RCCP is a faster technique than the construction of plain cement concrete using conventional method of compaction, i.e., screed vibrator/needle vibrator.

The mix design shall be based on flexural strength. Flexural strength achieved usually exceed those for conventional concrete with similar cement contents. Flexural strengths of even 4.5 MPa can be achieved. Initial rate of strength gain of RCC may be slower when compared to the same mix of plain cement concrete. Consequently, designs based on more than 28 days strengths would be appropriate depending on the available lead time prior to opening to traffic. While designing the mix in the laboratory, correlation between flexural and compressive strengths of concrete shall be established on the basis of tests on samples for use at a later date to verify the in-situ flexural strength of RCC though testing on cores. Considering the variations in the field,

the laboratory mix shall be designed for atleast 1.25 times the required 28 days field strength. Laboratory mix design can be carried out as per IRC:44. Due to low water content of RCC, amount of fines required is more than normal concrete. This helps to reduce segregation. The fines are typically supplied by fly ash. An additional benefit is gained from the pozzolanic property of fly ash, which contributes to strength of RCC. Generally the fly ash content in RCC pavements has been upto 25 per cent of total cementitious ingredients, with typical contents being about 15-20 per cent.

The concrete used in RCC work would be usually having zero slump. Modified Proctor compaction test can be used for determining the optimum moisture content for compaction or trials may be made with RCC to have optimum strength. This test would also indicate maximum achievable density of the mixture, against which field densities can be compared. The right amount of water for the RCC pavement work shall be decided for ensuring full compaction. Excess water will cause the concrete to heave in front of the roller wheels, resulting in uneven compacted surface while too little water will lead to inadequate compaction, low in-situ strength and an open textured surface. The optimum water content, as determined in laboratory trials, shall be adjusted during construction at field by trial rolling a small stretch. The variations in water content in the mix shall be $\pm$ 1 per cent from the specified value.

The design of RCCP and DLC (which is almost similar to RCCP except for strength of concrete) are based on IRC:58. Construction of RCCP shall be as per IRC:15. The main difference in construction using pavement quality concrete (conventional concrete pavement) and RCCP is of compaction and making of joints. In RCCP, the compaction of zero slump concrete is done by road roller of 8-10 tonnes capacity. The methodology for construction, design, placing, curing are the same as compared to conventional concrete pavement. The slump of concrete is always kept as minimum as possible so the RCCP can take the load of moving roller even during construction. A worked out example of RCCP is given in ***Appendix-5.1.***

5.7. Design of Special Pavements

5.7.1. Concrete block pavement/interlocking concrete block pavement (CBP/ICBP) : The general features and requirements of CBP/ICBP are given in Chapter 4. The concrete mix for production of blocks shall be properly designed. M-30 or higher grade concrete shall be used for production of blocks meant for paving roads carrying traffic. For non-traffic areas like footpaths, 60 mm thick blocks using M-25 or higher grade concrete may be used. For convenience in design of mix, one or two ready mixes can be used by trial and error method. For precast edge restraints, M-25 or higher grade concrete shall be used. A typical dimension of precast edge restraint is 150 x 150 x 300 mm. The top surface area of blocks shall ideally be in the range 200-500 cm^2. The breadth-to-length ratio for rectangular blocks may be 1:2. Rectangular blocks should have length in the range of 200 to 220 mm and width in the range of 100 to 110 mm. The colour of the blocks can be natural cement colour, or special colours can be effected by using organic or inorganic pigments. This technique will give a distinct and beautiful look to the paved area. The thickness of blocks for use in trafficked areas shall be 80 mm.

The thickness of granular base course for CBP/ICBP can be obtained from Fig. 5.7. Cement treated marginal aggregates may also be used as a base course, the thickness of which shall be 67 per cent of the granular base course required. Lime-fly ash bound macadam and lime-fly ash concrete may also be used as base layer, the thickness of which also shall be 67 per cent of the base course. Minimum thickness of base course shall be 100 mm. A good drainage layer must be provided over the compacted subgrade for satisfactory performance of CBP/ICBP.

Worked out example

Design of CBP/ICBP for the data in the worked out example in Section 5.4.3.

Design traffic (projected): 54 CVPD

From Fig: 5.7, thickness of granular base layer = 250 mm

Hence provide 100 mm of granular drainage/filter layer, and 150 mm WBM Grade-III in two layers.

Bedding sand and joint filling sand shall meet the requirements of IS:383-1970. Zone-II sand shall be used as bedding sand and Zone-IV sand as joint filling sand. These gradings are given in Table 5.2. The thickness of bedding sand shall be 30 mm.

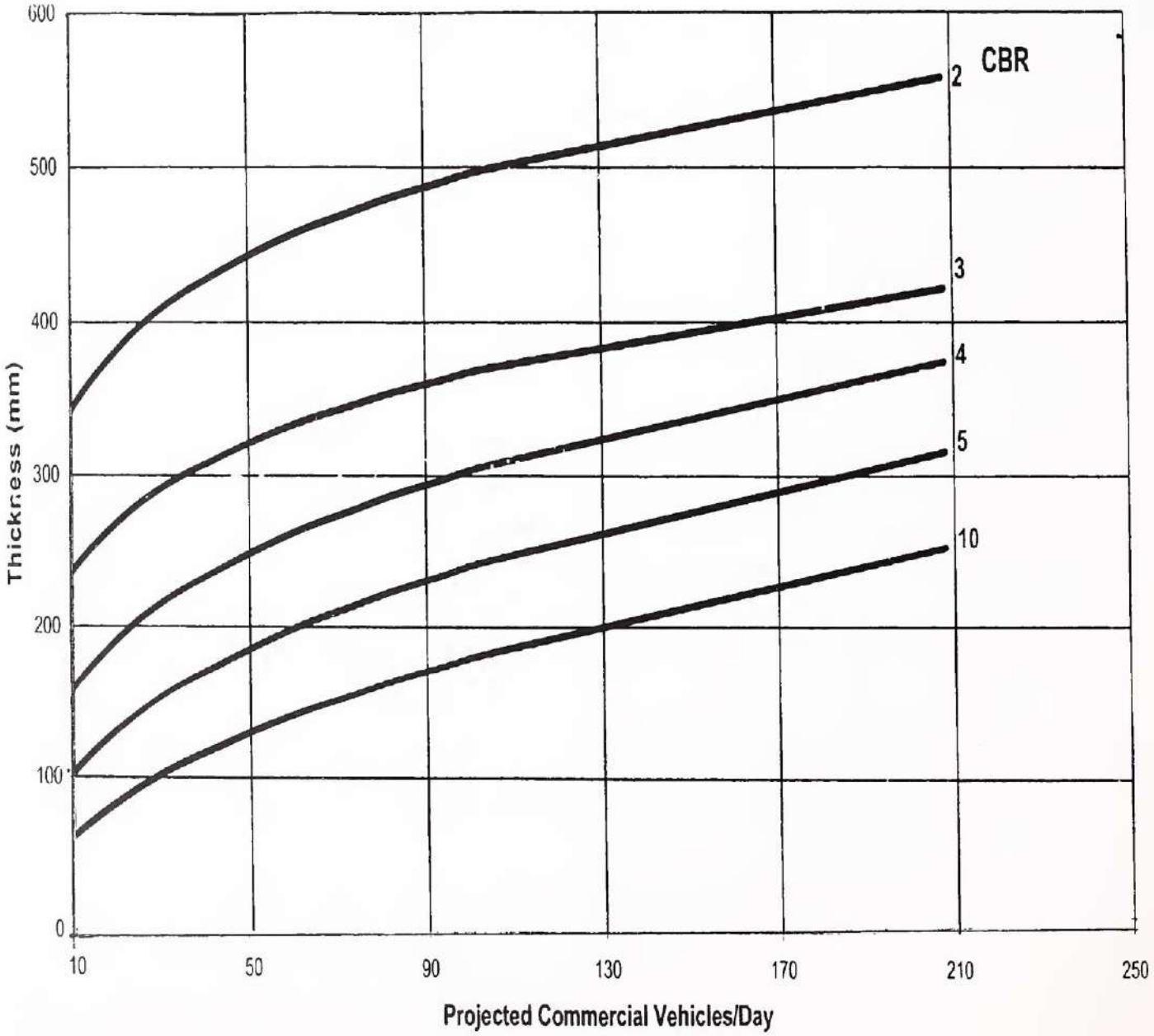


Fig. 5.7. Design Chart for Granular Base for CBP/ICBP

TABLE 5.2. RECOMMENDED GRADINGS FOR BEDDING AND JOINT FILLING SAND

IS Sieve Size (mm)	Per Cent Passing	
	Zone-II (IS:383-1970) (For Bedding Sand)	Zone-IV (IS:383-1970) (For Joint Filling Sand)
10.00	100	100
4.75	90-100	95-100
2.36	75-100	95-100
1.18	55-90	90-100
0.60	35-59	80-100
0.30	8-30	15-50
0.15	0-10	0-15
0.075	0-3	0-5

5.7.2. Stone-sett pavement/brick-on-edge pavement : For stone-sett/brick-on-edge pavement, stones cut to regular sizes should normally have dimensions of 100 to 150 mm diameter and 90 to 100 mm thickness. Cobblestones available from river beds can also be used for paving. The type of stones normally used are granite, basalt, sandstone and limestone. For brick pavement, burnt clay bricks or bricks having minimum 28 days compressive strength of 7 MPa can be used. Bricks are laid on edge over bedding sand. The stones/ bricks themselves can be used as edge restraints. Stone sett/brick-on-edge pavement as surfacing layer shall be used only for areas having very poor drainage and pedestrian pathways.

5.8. Drainage and Shoulders

The performance of a pavement can be seriously affected if internal drainage measures (sub-surface drainage) to prevent accumulation of moisture in the pavement structure are not provided, particularly when rainfall is more than 1000 mm per annum. Though elaborate drainage measures are not warranted for low traffic volume, it is advisable to provide a drainage layer of dust-free coarse to medium sand of 100 mm to 150 mm thickness over the subgrade if the subgrade is clayey (and impermeable) particularly in areas having higher rainfall (more than 1000 mm), as illustrated in Fig. 5.8. The washed coarse to medium sands have permeability values in the range of 10^{-2} to 10^{-4} centimeter per second respectively. Crushed aggregates, Jhama bricks or crushed gravels as per typical grading given in Chapter 6 may also be used as a drainage layer. Particles finer than 0.075 mm should be less than 5 per cent to ensure adequate permeability.

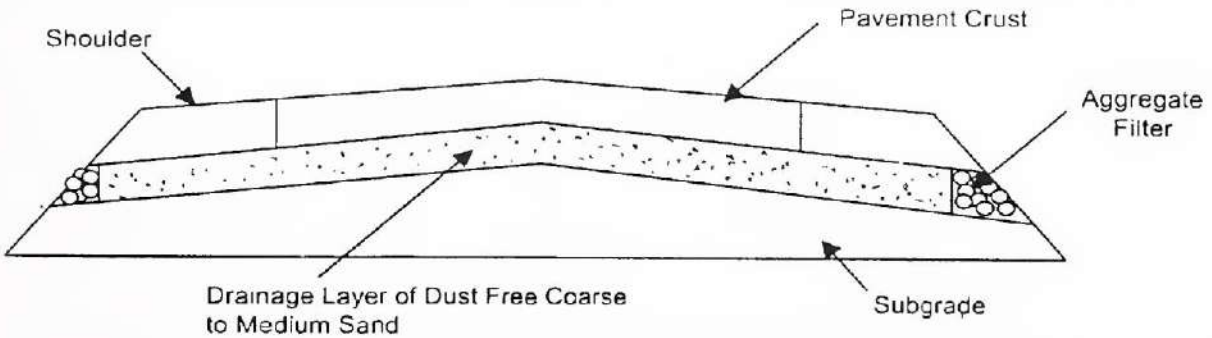


Fig. 5.8. Drainage Layer of Pavement on Clayey Subgrade

Earthen shoulder shall be compacted to density not less than 100 per cent of laboratory dry density, adopting Standard Proctor compaction [IS:2720 (Part 7)-1980]. Maximum laboratory dry unit weight of the material for the shoulder shall not be less than 16.5 kN/m^3. Plasticity Index and Liquid Limit shall not exceed 6 and 25 respectively.

Appendix 5.1

Worked Out Example of Roller Compacted Concrete Pavement (RCCP)

Criteria and Design stipulation for RCCP over 15 cm thick WBM is that flexural strength to be achieved at 28 days should be not less than 40 kg/cm² (4 MPa)

(i)	Traffic, $T = P(1+r)^{n+20}$	50-100 commercial vehicles/day
(ii)	Design wheel load :	5100 kg
(iii)	Tyre pressure :	7 kg/cm² (0.7 MPa)
(iv)	Design flexural strength of concrete for RCCP :	40 kg/cm² (4 MPa)
(v)	Poisson's ratio of concrete, μ :	0.15
(vi)	Modulus of elasticity of concrete, E :	$3x10^5$ kg/cm² ($3x10^4$ MPa)
(vii)	Subgrade CBR value:	4 per cent
(viii)	Corresponding K value:	3.46 kg/cm³ (34.6 MN/m³)
(ix)	Base course, compacted WBM	(7.5 +7.5 cm) = 15 cm or dry lean concrete of 10 cm thickness
(x)	Modulus of subgrade reaction, K :	4.36 kg/cm³ (43.6 MN/m³)
(xi)	Width of pavement	3.75 m

Design of thickness

Start with Trial thickness :	23 cm
Radius of relative stiffness, l :	$[3x10^5 x23^3/12x4.36(1-0.15^2)]^{0.25}$ = 87.71 cm
Radius of contact area, a :	15.02 cm
Ratio a/h :	15.02/23 = 0.65<1.724, so
Radius of resisting section, b :	$(1.6 \times 15.02^2 + 23^2)^{0.5} - 0.675 \times 23$ = 14.30 cm
Edge Temperature Stress, σ_{Tec}	= (E x α x dt x C)/2
Designing the pavement for Delhi region	
α = Coefficient of thermal expansion of concrete	= $10x10^{-6}$ per°C
d_t = Maximum temperature differential during 24 hours between top and bottom of slab	= 13.82 °C
CL= CW = C= Bradbury's coefficient	
Providing dummy contraction joint spacing	= 450 cm c/c
Lane width, w	= 375 cm
L/l = 375/87.71	= 4.27
B/l = 400/87.71	= 4.56
From IRC:58.	

C = 0.75

Temperature (Warping stress), σ_{tc} = $(3x10^5 \times 10x10^{-6} \times 13.82 \times 0.75)/2$

= 15.54 kg/cm² (1.554 MPa)

Residual strength = 40 - 15.54

= 24.46 kg/cm² (2.446 MPa)

Calculation of Edge Wheel Load Stress

$\sigma_{te} = (0.529\ P/h^2)\ (1+0.54\ \mu)\ [4 \log_{10}(l/b) + \log_{10} b - 0.4048]$

$= (0.529 \times 5100/23^2)\ (1+0.54x0.15)\ [4 \log_{10}(87.71/14.30) + \log_{10} 14.30 - 0.4048]$

= 21.50 kg/sq.cm

Factor of safety = Residual strength/Edge load stress

= 24.46/21.50

= 1.13 >1

Hence, the design is safe for RCCP of thickness of 23 cm.

Check for Corner Load Stress

$$S_c = \frac{3P\ [1-(a \times 1.414)^{1.2}]}{h^2 \qquad l}$$

$= (3 \times 5100/23^2)\ [1-(21.24/87.71)^{1.2}]$

= 23.6 kg/sq.cm < 40 kg/sq.cm, so design is safe.

Thickness adjustment for future traffic

Design life of the pavement = 20 years

Design traffic intensity at the end of design life in commercial vehicles per day:

$T = P\ (1+r)^n$

P is the traffic intensity at last traffic count = 50-100 CVPD

Annual rate of increase of traffic = 6.0 per cent

$T = 50(1+0.060)^{20}$ = 160 to 320 CVPD

Pavement thickness adjustment factor, h_t, may be taken as = 1 cm

Therefore, final pavement thickness = 23 – 1 = 22 cm

Contraction joints in RCCP may be provided as per IRC:15, (but dowel bars are not required at contraction joints) after an interval of 4 to 10 m centre-to-centre upto a depth of 4 to 5 cm and width 6 to 8 mm. Expansion joints may be provided by providing a wooden board or ply board for full depth after an interval of 50 m centre-to-centre but without dowel.

Chapter 6

ROAD DRAINAGE

6.1. Introduction

The main objective of drainage is to prevent early damage of the pavement due to entry of excess of water and preventing saturation upto a depth of 1 meter below the top of the subgrade. This can be achieved by proper design of the pavement which includes effective drainage system. An adequate drainage design includes the control of rain or surface flow and also the underground seepage or water held by capillary action (soil suction).

Various types of damages arising due to inadequate drainage are:

- Considerable reduction in the bearing capacity of subgrade soil due to excess of moisture, resulting in premature failure of pavement.
- Pavement failures like potholes, rutting, waviness and corrugation in flexible pavement.
- Reduction in strength of many pavement materials, like, stabilised soil and water bound macadam due to increase of moisture content.
- Damages to shoulder and pavement edges from surface water.
- Considerable erosion of the soil from the substrata, slopes of embankment, cut and hillside due to surface water.

Therefore, an adequate drainage is required for maintaining the structural and functional adequacy of the road. In India, unfortunately not as much attention is being paid to drainage, as it deserves, with obvious dangerous consequences. It has been conclusively established that if drainage of the pavement is improved, the cost of the maintenance/repair goes down considerably. It is estimated that cost of drainage measures works out to 3 to 5 per cent of the total cost of the construction. This small investment for drainage provisions at the initial stage pays rich dividend in the service period. Providing drainage measure at latter stage is both difficult and expensive, and therefore, proper provisions for adequate drainage should be made at the initial construction stage itself.

6.2. Types of Road Drainage

The road drainage woks may be broadly classified as under:

(i) Interception and drainage of surface water (Surface Drainage)

(ii) Interception and rapid removal of seepage or subsurface water (Sub-surface Drainage)

These guidelines deal with drainage of rural roads running through plain, rolling and hilly terrains. The aspects covered are influence of alignment and geometric of the road, surface drainage, sub-surface drainage and internal drainage of pavement structures. For rainfall less than 500 mm per annum, no internal drainage of pavement is required. It may be noted that some aspects of hill road drainage are also covered for the details of which relevant IRC specifications/guidelines may be referred. Moreover, detailed design and specifications on CD works have been presented in Chapter 7.

6.3. General Criteria for Road Drainage

Alignment of Road : The alignment of road has vital influence on the problem of drainage. The ideal alignment should avoid steep and heavy cut/fill, as these locations are vulnerable to drainage problems.

Embankment Height : The road subgrade level in fill section is to be fixed so that the difference between formation level and highest water table/high flood level is not less than 0.6 meter, and between formation level and ground level not less than 1.0 meter.

6.4. System of Drainage

In general the road drainage is catered by both surface and sub-surface drainage systems, for which a survey and field investigation should be carried out. It may include:

(i) Preparation of alignment plan, longitudinal section, contour map
(ii) Hydrological data, such as, rainfall and estimation of runoff
(iii) Hydrographical survey
(iv) Geotechnical investigation

6.5. Surface Drainage System

The fast disposal of runoff on the road surface is achieved by surface drains or roadside drains or catch water drains.

6.5.1. Geometric design of road : Providing camber on one side or both sides, proper slope to the shoulder and providing requisite longitudinal gradients, etc. disposes water from road surface.

6.5.1.1. Longitudinal gradient : The longitudinal gradient serves the natural means for drainage of rainwater collected over the road surface. Internal drainage through granular layers needs, a longitudinal gradient of 0.3 per cent for its effectiveness.

6.5.1.2. Pavement cross slope/camber : If a road is to perform adequately, care must be taken to remove the surface runoff by suitable cross falls, which will be helpful in minimizing ponding of the water. Therefore, higher than minimum cross fall/camber should be adopted where possible by the following means:

- Cross fall or camber may be made to slope on one side in case of hilly areas to drain the surface water on the carriageway towards the hillsides where the gutters on both sides are not feasible.
- When the road is on a gradient, it is desirable that the camber should not be less than 50 per cent of the longitudinal gradient subject to minimum of specified camber. This is essential to ensure the surface water to reach the shoulders quickly.

Recommended camber or cross slope on straight section of roads is given in Table 6.1.

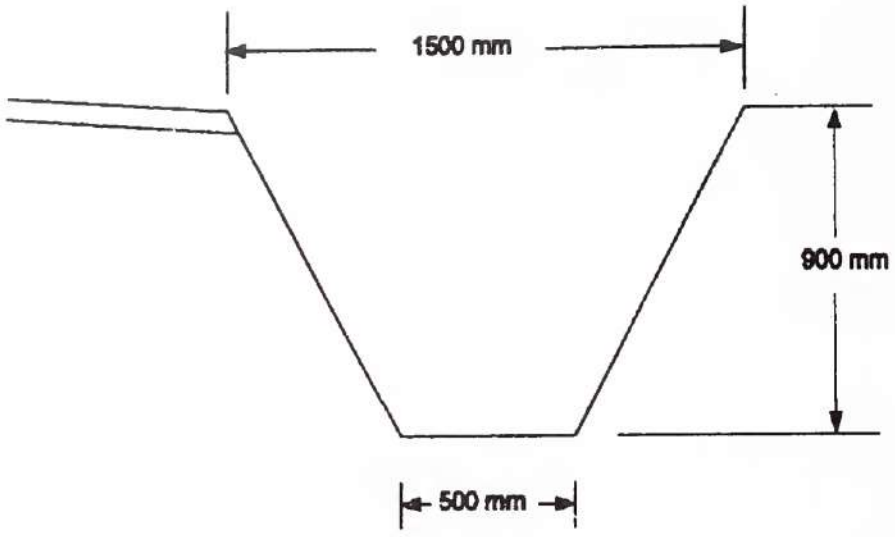
TABLE 6.1. CROSS SLOPE/CAMBER FOR DIFFERENT SURFACE TYPES

Surface Type	Camber (per cent)	
	Annual Rainfall (less than 1000 mm)	Annual Rainfall (more than 1000 mm)
Earth	4.0	5.0
W.B.M. and Gravel	3.5	4.0
Thin Bituminous Surface	3.0	3.5
Rigid Surface	2.0	2.5

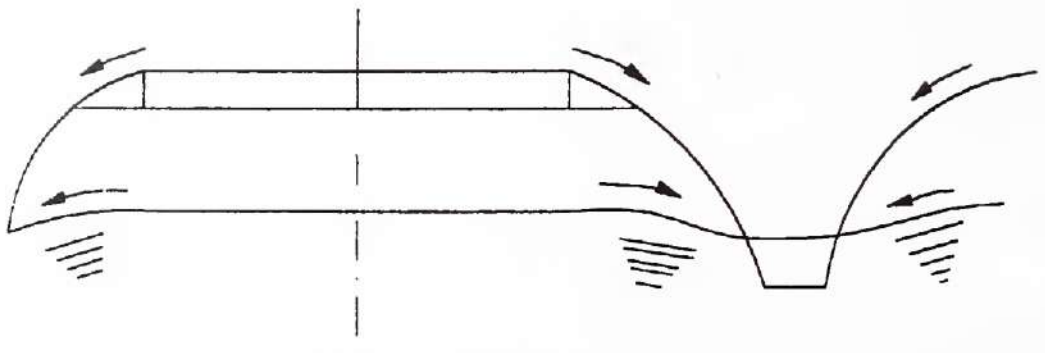
6.5.2. Surface drains : The water from road and adjacent area shall be collected and lead away to natural out falls. This is achieved by surface drains:

(i) Drain along the side of the road (gutter)
(ii) System of suitable drains, such as, shoulder drains
(iii) Deep catch water surface drain on the hillside

6.5.2.1. Road side drains : The function of roadside drain is to collect surface water from the roadway and lead it to an outlet. Another function of roadside ditches is to drain out the base course of the roadway structure so as to prevent its saturation and consequent loss in load bearing capacity as illustrated in Fig. 6.1. In absence of properly designed roadside ditches, the surface water from the roadway, as well as water collected from cut slopes accumulates, causing serious damage by erosion to the roadway, as well as formation slopes.



(a) Typical Cross-Section of Side Drain in Soil

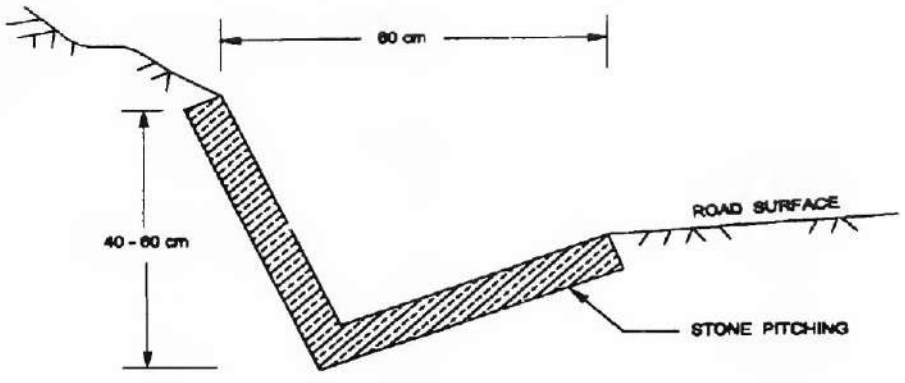


(b) Function of Side Drains

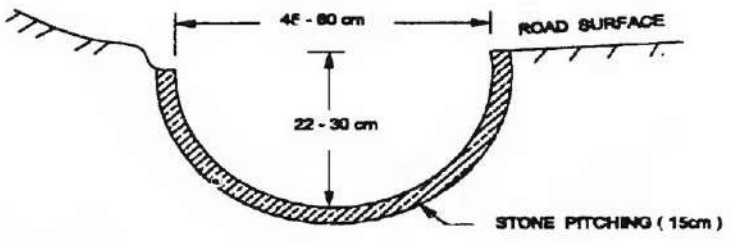
Fig. 6.1. Cross-Section and Function of Side Drains

The side drains are designed on the principles of open channel flow, and generally provided on both sides of the road. In case of hilly terrain, side drains on hillside are made when road is built in cut section. They should be provided below the subgrade of the road.

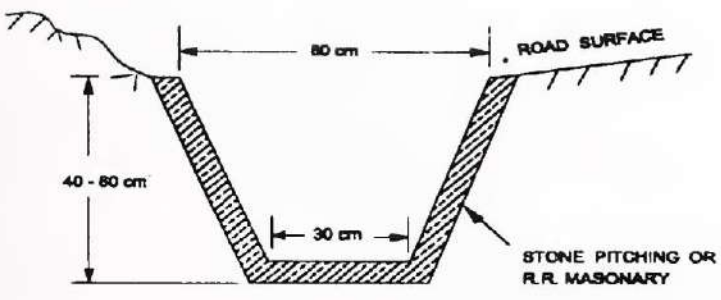
Roadside drains in hilly terrain are constructed to parabolic (saucer shape), trapezoidal, triangular, V-shape, kerb and channel or U-shaped cross-sections. The parabolic section is hydraulically the best and most erosion resistant. However, the trapezoidal section is easier to construct and is generally adopted. U-shaped drains are generally deep drains and are provided where higher discharge has to be catered and road width is available. Extra width will be available when kerb and channel drains are provided. Details of various types of side drains are shown in Figs. 6.2 and 6.3.



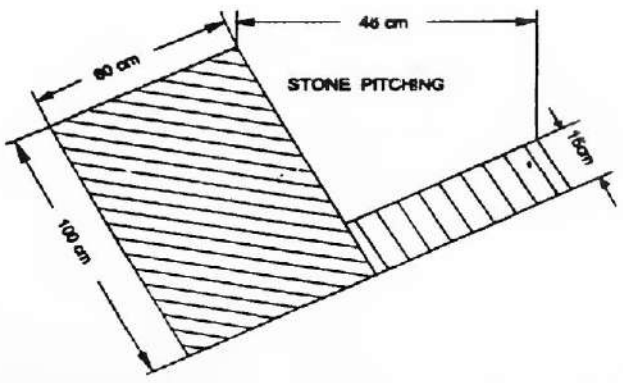
(a) V - SHAPED DRAIN



(b) PARABOLIC OR SAUCER TYPE DRAIN

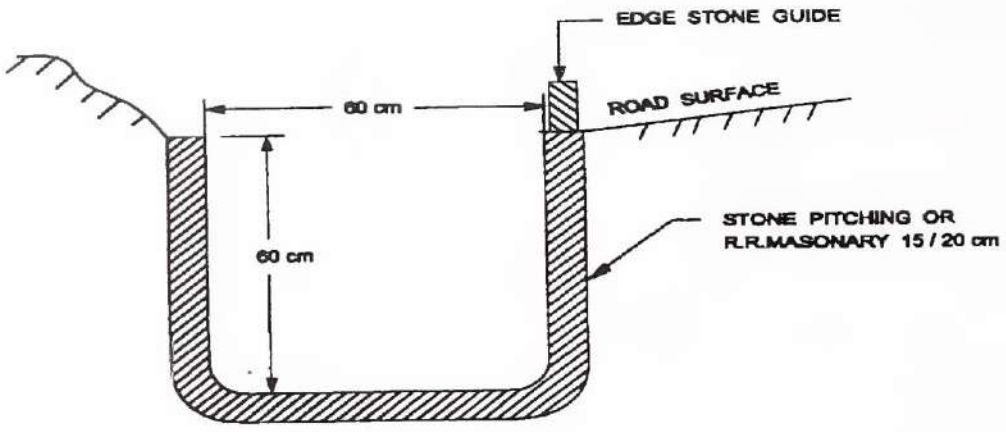


(c) TRAPEZOIDAL DRAIN

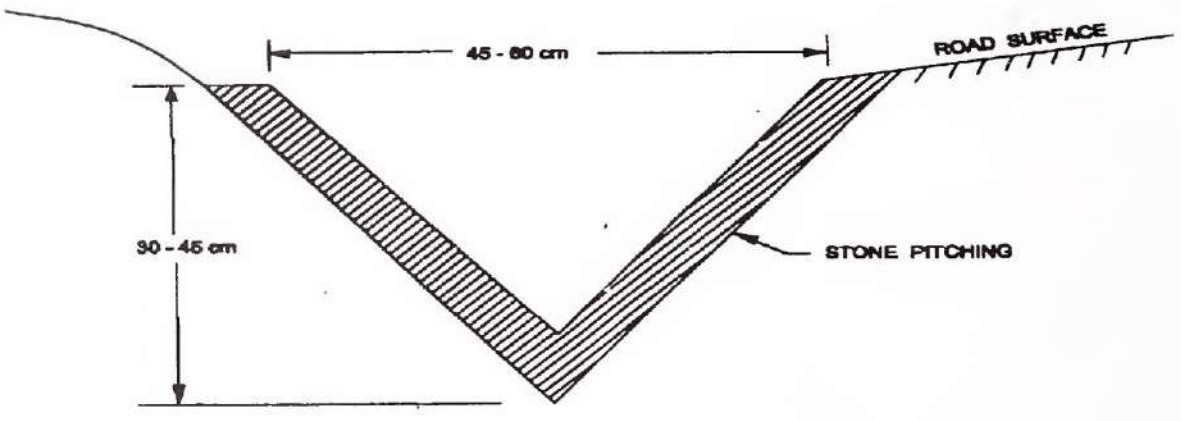


(d) TYPICAL SECTION OF TOE WALL AND DRAIN

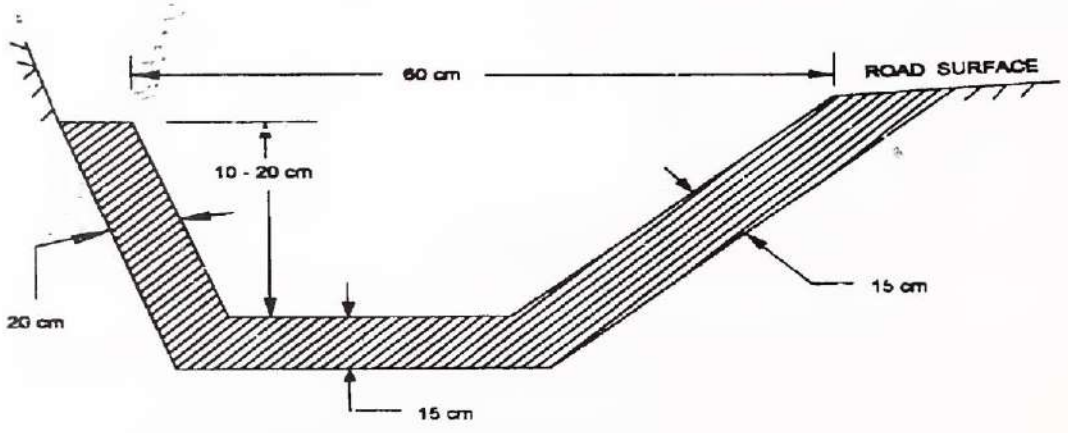
Fig. 6.2. Side Drains



(e) U - SHAPED DRAIN



(f) TRIANGULAR DRAIN



(g) KERB AND CHANNEL DRAIN

Fig. 6.3. Side Drains

The lining of side gutters is a costly proposition, and therefore, judicious selection of the type of lining is very essential. It is more cost effective and desirable to provide bigger size gutter (section) than any lining. Bigger section reduces damages to the pavement and also reduces the maintenance liabilities.

To estimate the runoff at a given location, the Rational formula relating rainfall to runoff is used for catchment areas not exceeding 50 sq.kg. The formula states that:

$$Q = 0.028\ PA\ I_c$$

Where

Q	=	Discharge (Peak runoff) in cum/sec
P	=	Coefficient of runoff for the catchment characteristics
A	=	Area of catchment in hectares from toposheet
I_c	=	Critical Intensity of rainfall in cm per hour for the selected frequency and for the duration equal to the time of concentration

The coefficient of runoff for different surfaces is provided in Table 6.2.

TABLE 6.2. SUGGESTED VALUES OF COEFFICIENT OF RUN-OFF

Sl. No.	Description of Surface	Coefficient of runoff (P)
1.	Steep bare rock and watertight pavement surface (concrete or bitumen)	0.90
2.	Steep rock with some vegetative cover	0.80
3.	Plateau areas with light vegetative cover	0.70
4.	Bare stiff clayey soils (Impervious soils)	0.60
5.	Stiff clayey soils (impervious soils) with vegetative cover and uneven paved road surfaces	0.50
6.	Loam lightly cultivated or covered and macadam or gravel roads	0.40
7.	Loam largely cultivated or turfed	0.30
8.	Sandy soils, light growth, parks, gardens, lawns and meadows	0.20
9.	Sandy soil covered with heavy bush or wooded/forested areas	0.10

The selection of roadside drain is based on magnitude and duration of flow. The hydrological data required for design of gutter are drainage area, water shed delineation, direction of flow, location of outfalls, ditches, other surface drainage facilities, ground surface condition, rainfall and flood frequencies. The roadside drains are designed on the principle of flow in open channel based on Manning's formula which states that:

$$Q = AV$$

where $V = (1/n)\ R^{2/3}\ S^{1/2}$,

and

Q	=	Discharge in cum/sec
V	=	Mean Velocity in m/sec
n	=	Manning's Roughness coefficient
R	=	Hydraulic radius in m which is area of flow cross-section divided by wetted perimeter
S	=	Energy slope of the channel, which is roughly taken as slope of drain bed
A	=	Area of the flow cross-section in m^2

The value of Manning's coefficient and permissible velocity of flow to prevent erosion are given in Table 6.3.

TABLE 6.3. MANNING'S 'n' AND MAXIMUM PERMISSIBLE VELOCITY OF FLOW

Sl. No.	Ditch Lining	Manning's 'n'	Permissible Velocity m/sec
Natural Earth Drain			
A.	**Without Vegetation**		
	(i) Rock		
	(a) Smooth & Uniform	0.035-0.040	6.0
	(b) Jagged & Irregular	0.04-0.045	4.5-5.5
	(ii) Soils (Extended Casagrande classification)		
	GW	0.022-0.024	1.8-2.1
	GP	0.023-0.026	2.1-2.4
	GC	0.020-0.026	1.5-2.1
	GF	0.024-0.026	1.5-2.1
	SW	0.020-0.024	0.3-0.6
	SP	0.022-0.024	0.3-0.6
	SC	0.020-0.023	0.6-0.9
	SF	0.023-0.025	0.9-1.2
	CL & CT	0.022-0.024	0.6-0.9
	MI & ML	0.023-0.024	0.9-1.2
	OL & OI	0.022-0.024	0.6-0.9
	CH	0.022-0.023	0.6-0.9
	MH	0.023-0.024	0.9-1.5
	OH	0.022-0.024	0.6-0.9
	Pt	0.022-0.025	0.6-0.9
B.	**With Vegetation**		
	(i) Average turf		
	(a) Erosion resistant soil	0.050-0.070	1.2-1.5
	(b) Easily erode soil	0.030-0.050	0.9-1.2
	(ii) Dense turf		
	(a) Erosion resistant soil	0.070-0.090	1.0-2.4
	(b) Easily erode soil	0.040-0.050	1.5-1.8
	(c) Clean bottom with brush sides	0.050-0.080	1.2-1.5
	(d) Channel with tree stumps		
	No sprouts	0.040-0.050	1.5-2.1
	With sprouts	0.060-0.080	1.8-2.4
	(e) Dense weeds	0.080-0.012	1.5-1.8
	(f) Dense Brush	0.100-0.140	1.2-1.5
	(g) Dense willows	0.150-0.200	2.4-2.7

Paved Drain			
A.	**Concrete with all surfaces**		
	Good or Poor		
	(i) Trowel finished	0.012-0.014	6.0
	(ii) Float finished	0.013-0.015	6.0
	(iii) Formed, no finish	0.014-0.016	6.0
B.	**Concrete bottom, float finished with sides of**		
	(i) Dressed stone in mortar	0.015-0.017	5.4-6.0
	(ii) Random stone in mortar	0.017-0.020	5.1-5.7
	(iii) Dressed stone or smooth concrete rubble (Rip-rap)	0.020-0.025	4.5
	(iv) Rubble or random stone (Rip-rap)	0.025-0.030	4.5
C.	**Gravel bottom with sides of**		
	(i) Formed Concrete	0.017-0.020	3.0
	(ii) Random stone in mortar	0.020-0.024	2.4-3.0
	(iii) Rubble or random stone (Rip-rap)	0.023-0.033	2.4-3.0
D.	**Brick**	0.014-0.017	3.0
E.	**Bitumen (Asphalt)**	0.013-0.016	5.4-6.0

Procedure for design of side drain is generally in the following steps:

- Find discharge using rational equation
- Find area of cross-section using allowable velocity of side drain
- Find slope of side drain using Manning's formula
- Longitudinal slope should not be less than minimum slope of 0.5 per cent if side drains are lined and 1.0 per cent if they are unlined as specified in IRC:73-1980 "Geometric Design Standards for Rural Highways"

IRC:SP:42 "Guidelines on Road Drainage" may be referred for detailed hydraulic design of the drain. However, the tentative salient design features of roadside drains (gutters) given below may be adopted in absence of any data.

Location	300 mm deeper than the bottom of road crust
Minimum width at bottom	450 mm
Minimum longitudinal grade	0.5 per cent
Discharge	0.50 cum/sec
Shape	Triangular, Rectangular and Trapezoidal
Side slope	Generally not exceeding 1 in 4

The rectangular or trapezoidal section causes a sense of danger to the motorist travelling close to it, but triangular section is most appropriate and widely used.

An unlined drain can withstand only a limited amount of discharge without erosion problem. The problem will be severe in silt and sand when the velocity of flow is between 0.3 to 1.0 m/sec. In stiff clay this velocity may be 1.5 m/sec. But in all cases the permissible velocity of flow can be increased significantly by lining the drain. Also by lining the side slopes (of drain) can be made steep. An unlined cross-section of drain may require 4:1 to 2:1 side slope, but a section with brick lining can be rectangular. Generally, in rural roads turfing is done in the roadside drains to prevent (soil) erosion of unlined drains. However, suitability can be improved by adopting different types of lining in side drains as given in Table 6.4.

TABLE 6.4. SUITABILITY OF DIFFERENT TYPES OF LINING IN SIDE DRAINS

Types of Lining	Brief Description	Suitable for	Unsuitable for
Turfing	Turfing is useful in humid area for preventing erosion	Triangular drain having 4:1 to 3:1 slopes	Rectangular, Trapezoidal drains since maintenance is difficult
Stone	Brick masonry stone/bricks can be laid dry or bedded in concrete with joints fitted in cement mortar	(i) When drains are required to carry a large amount of debris (ii) Velocity is high	In known unstable area
Concreting	— do —	— do —	— do —
Stone slab lining		(i) Useful in triangular section drains and in other section in combination with masonry/ concreting (ii) In areas where flat stone is easily available	
Boulder pitching		Area with stable slopes	In unstable loose strata
Bituminous treatment	It is primary quick sealing of the surface. 10 to 15 cm impregnated with bitumen cutback or emulsion on the sides and base	Used in conjunction with boulder pitching in catch water drains for prevention of seepage flow	

6.5.2.2. Shoulder drainage : Drainage from shoulder is ensured by properly maintaining the surface of the shoulder with specific camber. Shoulder should be shaped regularly before and during the monsoon, in order to avoid damages to the road pavement. A shoulder normally consists of granular material. However stabilised shoulders are preferred in case of clayey soil. Alternatively, following measures may be adopted when shoulders are of impervious material, like, clay or black cotton soil, such as:

(i) Laying of continuous drainage layer of 75 mm to 100 mm thick under shoulder at the bottom level of sub-base as shown in Fig. 6.4.

(ii) Extending the sub-base/base course with drainage material in the entire formation width upto the edge of formation and provide a generous cross slope to permit rapid drainage as shown in Fig. 6.5.

(iii) Provision of shoulder drains at 4 to 10 metres centre to centre as shown in Fig. 6.6.

(iv) Shoulder with hard material, like, granular or stabilised soil to affect good drainability.

The cross slope of the shoulder should be 1 per cent steeper than the cross slope of carriageway subject to minimum of 4 per cent. At times super elevation creates certain problems for the shoulder slopes on horizontal curve. In such stretches, shoulder on inner side of the curve should have a somewhat steeper slope than the pavement and shoulders on the outer side of the curve through shoulder drains. In case of earth shoulders with low permeability, i.e., black cotton soil, the drainage should be improved by providing shoulder drains. Shoulder drains provided at a spacing of 5 to 10 metre centre to centre as shown in Fig. 6.6 are preferred.

6.5.2.3. Catch water drains : These drains are provided on hill slopes to intercept water flowing from upper reaches and guide such flow towards culverts. Such drains should be provided in suitable hill slopes as shown in Figs. 6.7 to Figs. 6.9. The catch water drains may be simple gutters at suitable location at top of the slope and leading to natural watercourses. These drains of trapezoidal shape should be stone lined and cement pointed with a stone masonry wall to retain the slopes.

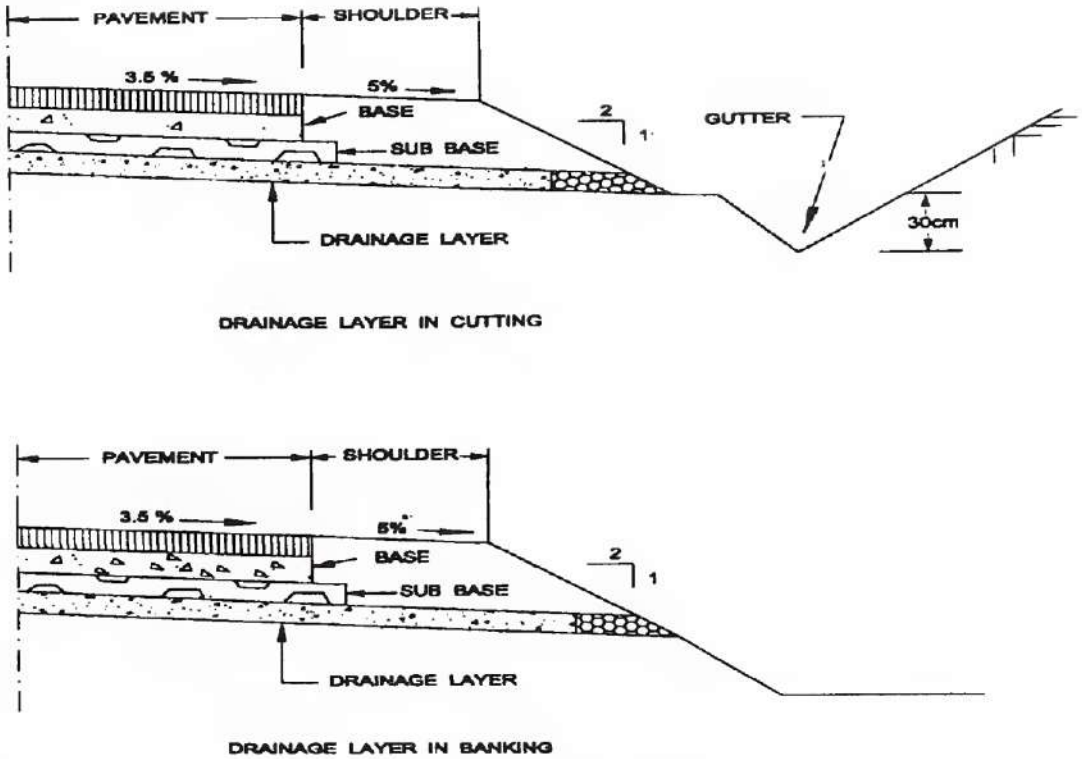


Fig. 6.4. Provision of Drainage Layer

6.6. Sub Surface Drain

Changes in moisture content of subgrade are caused by fluctuations in ground water table, seepage, percolation of rainwater and movement of capillary water and even water vapour. Hence, it should be ensured that variation in moisture content in the subgrade is kept as minimum as possible. The type of subsurface drainage depends on the topography, depth and fluctuations in the ground water level and the type of subgrade.

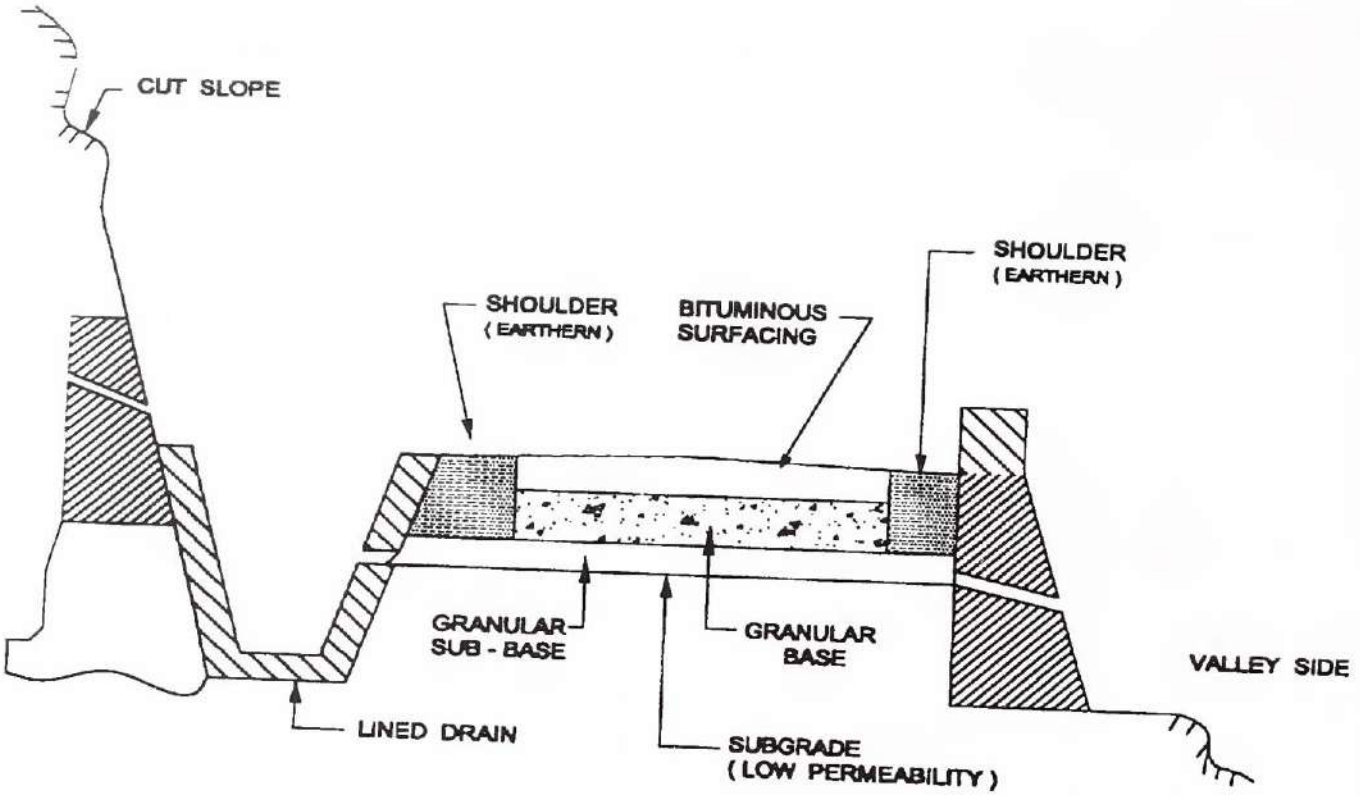
Various measures that can be adopted at a specific situation are described below:

Continuous drainage layer should be laid over the entire formation width below the sub-base/base course as per gradation specified in Table 6.5. In case of fine sand or silt or clayey subgrade or if annual rainfall is more than 1000 mm, a continuous layer of drainage material is required for the entire width of the formation as shown in Fig. 6.4.

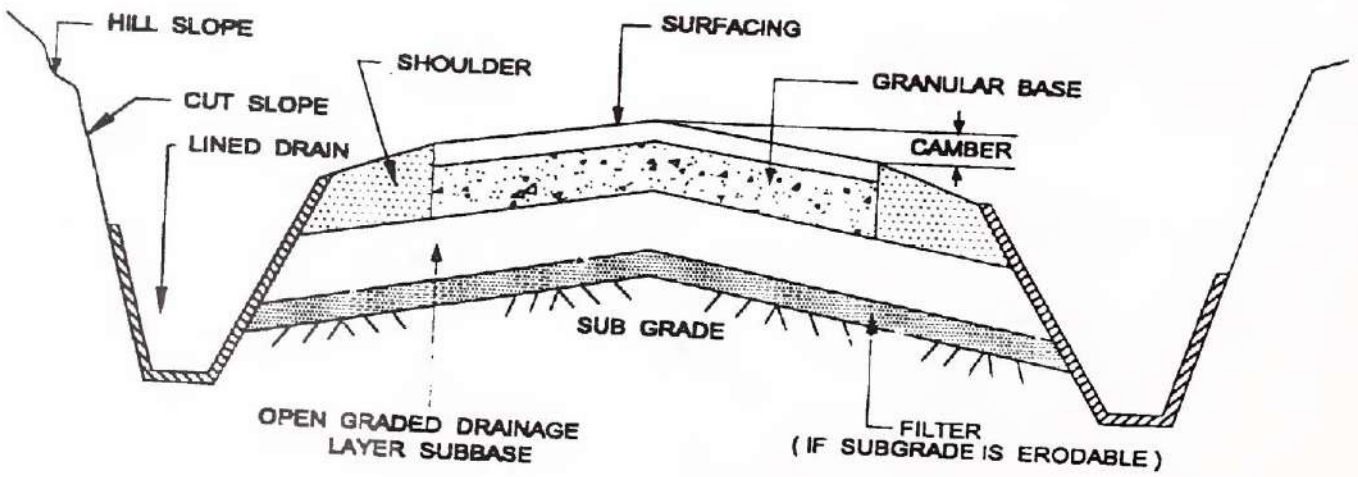
TABLE 6.5. GRADATION OF MATERIAL FOR DRAINAGE LAYER

IS Sieve Designation	Per cent by Weight Passing the IS Sieve
75.0 mm	100
53.0 mm	-
26.5 mm	55-75
9.5 mm	-
4.75 mm	10-30
2.36 mm	-
0.425 mm	-
0.075 mm	<5*

Note: *In drainage layer, fine sand should not be used and the portion passing 75 micron should be restricted to 5 per cent. However, in exceptional situations the engineer should apply discretion and it should be restricted to maximum of 10 per cent.



(a) Road in Side Hill Cut



(b) Through Road in Hill Cut

Fig. 6.5. Drainage Through Opengraded Sub-base

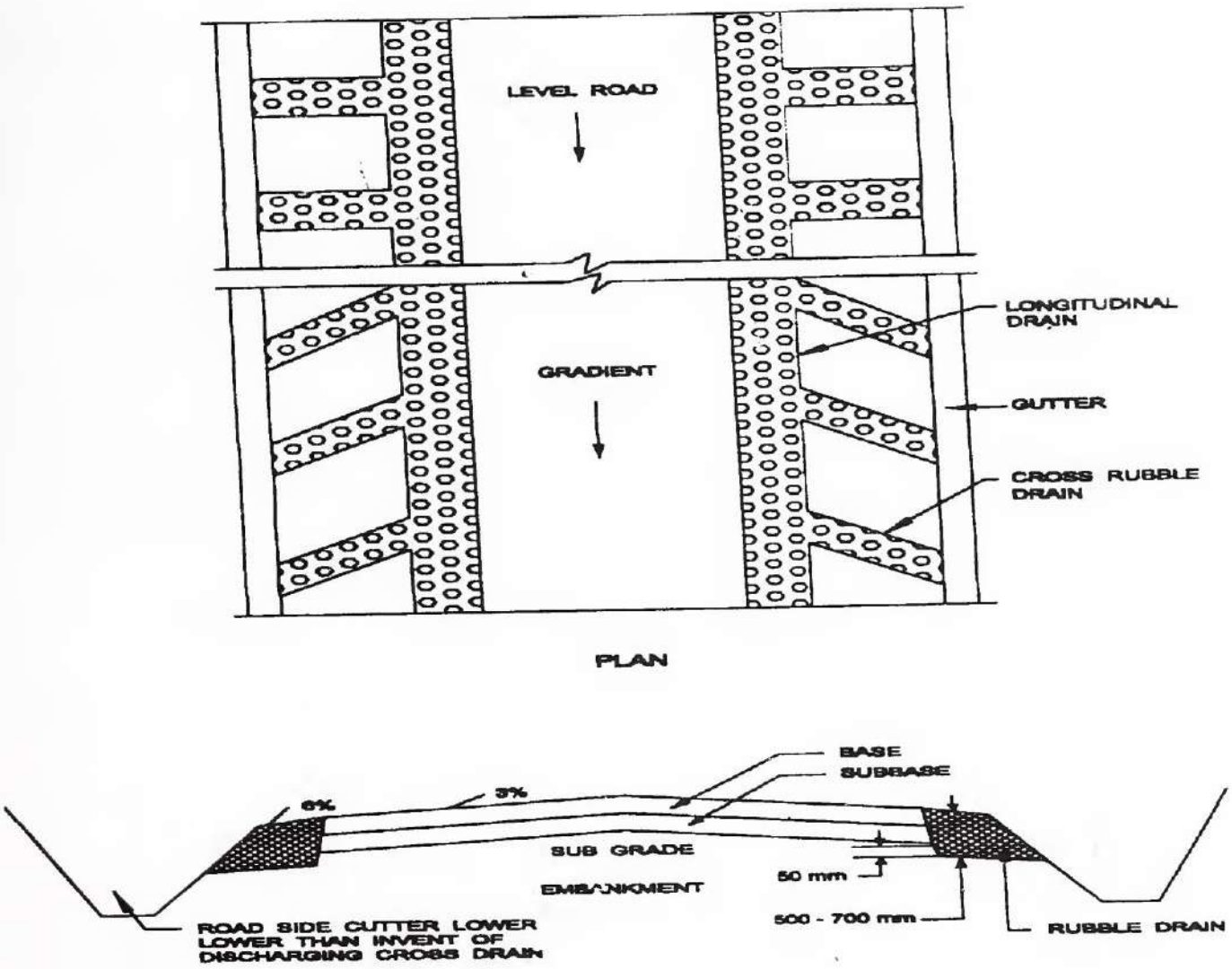


Fig. 6.6. Shoulder Drainage by Longitudinal and Diagonal Drains

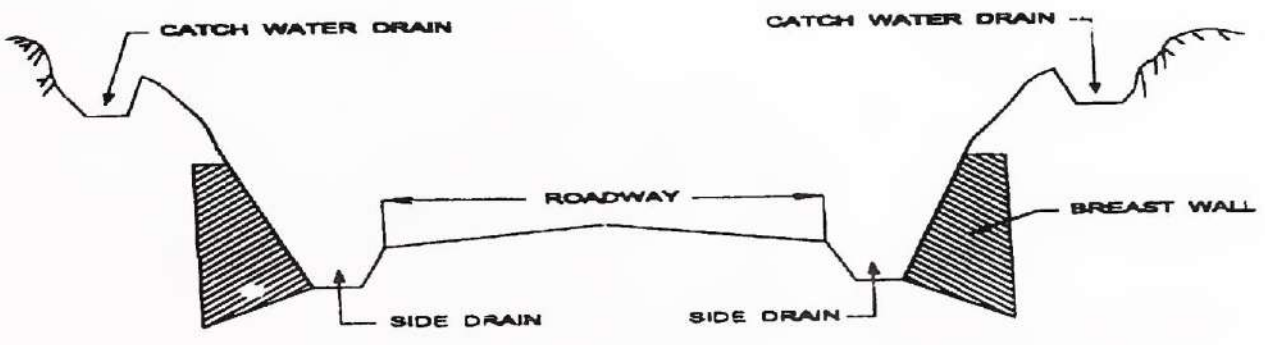


Fig. 6.7. Typical Box Cut

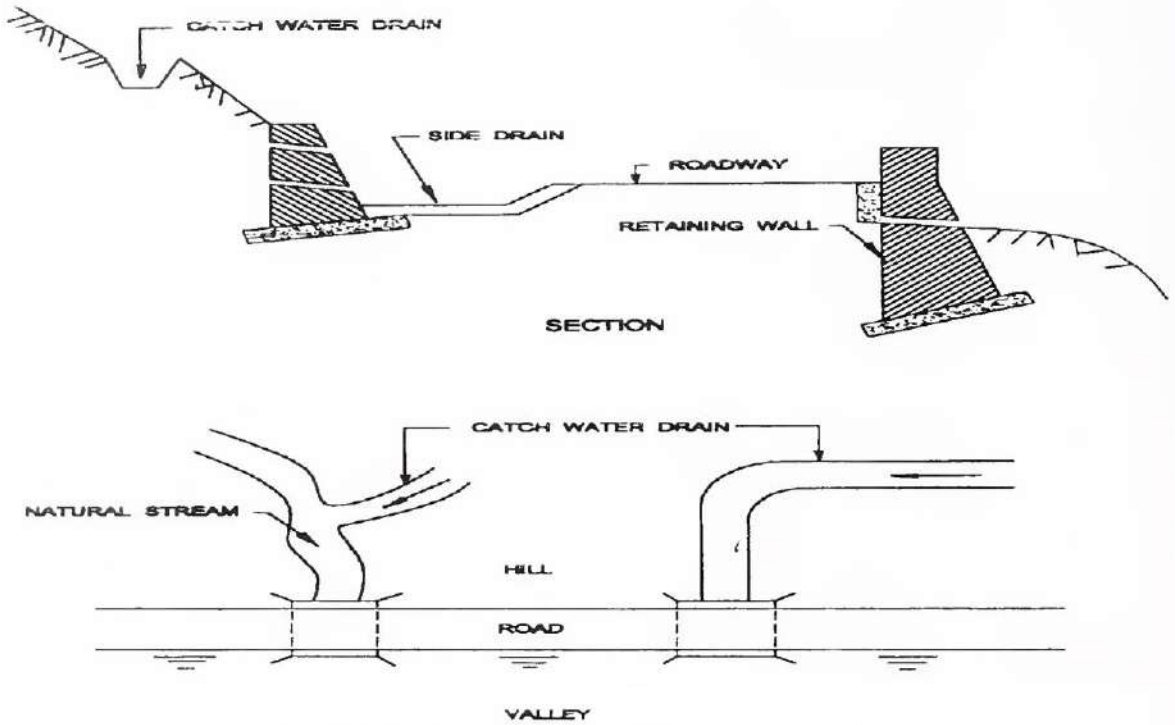


Fig. 6.8. Catch Water Drain in Stable Area

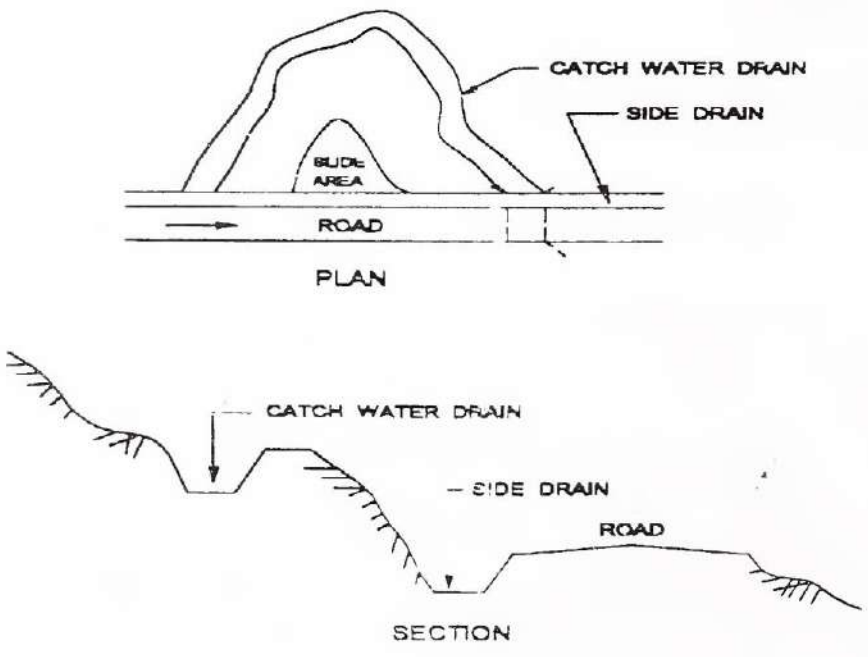


Fig. 6.9. Catch Water Drain in Slide Area

Rural roads with existing water bound macadam/gravel surfaces, drainage may be improved by providing aggregate drains in the shoulder as per Clause 309.3.7 of MoRT&H Specifications for Road and Bridge Works.

It is recommended to lower the water table by providing subsurface drain (longitudinal) for relatively permeable soil subgrade and transverse drains for relatively less permeable soil subgrade as shown in Fig. 6.10. The subsurface drain may consist of perforated pipe or open jointed solid pipe in trench with backfill around it or it may be simply a free draining material in the trench without any pipe. The perforated pipes may be of metal, asbestos, cement etc. The top of trench is sealed by providing impervious cap so that only sub-surface water may enter the drain. In pipe drain, the internal diameter of pipe should not be less than 150 mm. Holes in the perforated pipes may be formed in one half of the circumference only. Size of the holes may be close to D_{85} size of material surrounding the pipe subject to minimum of 3 mm and maximum of 6 mm. D_{85} denotes size of the sieve that allows 85 per cent of material to pass through it. The backfill may consist of sand-gravel material or crusted stone satisfying the grading of Table 6.6 in case no specific design exercise based on filtration and permeability criteria has been carried out. The filter material (backfill material) should be free of organic material, clay balls and other deleterious material. The filter material is to be laid as per standard practice. The IRC:SP:42 "Guidelines on Road Drainage" may be referred for detail design of the subsurface drains.

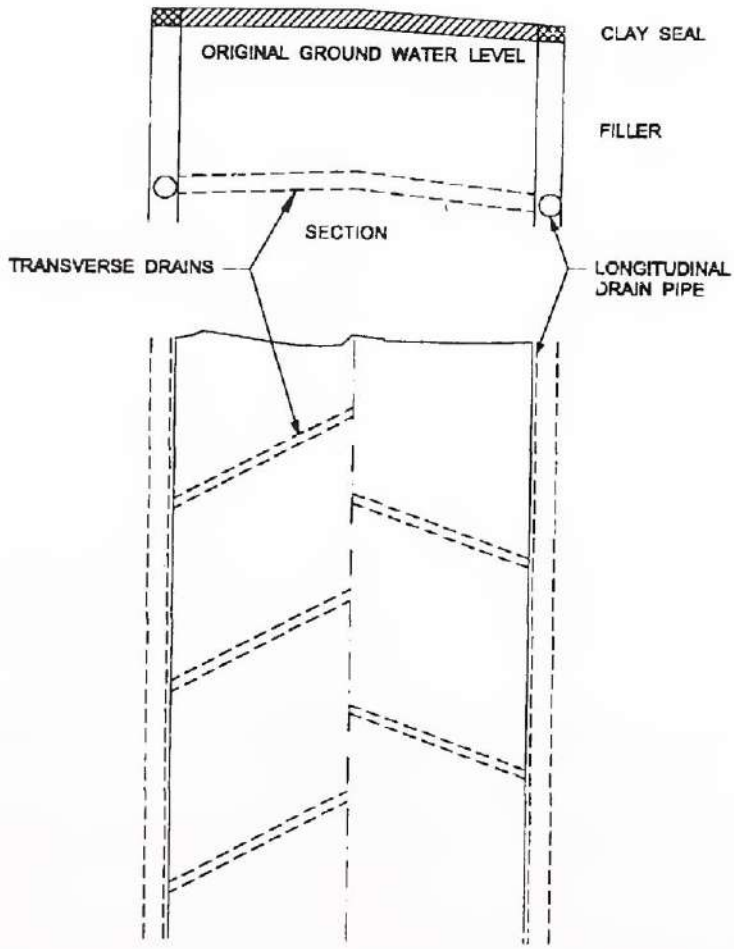


Fig. 6.10. Sub-Surface Drainage System with Transverse Drains

TABLE 6.6. GRADING REQUIREMENT FOR FILTER MATERIAL

Sieve Designation	Per cent by Weight Passing the Sieve		
	Class I	Class II	Class III
53 mm	-	-	100
45 mm	-	-	97-100
26.5 mm	-	100	-
22.4 mm	-	95-100	50-100
11.2 mm	100	48-100	20-60
5.6 mm	92-100	28-54	4-32
2.8 mm	83-100	20-35	0-10
1.4 mm	59-96	-	1-5
710 mm	35-80	6-18	-
355 μm	14-40	2-9	-
180 μm	3-15	-	-
90 μm	0-5	0-4	0-3

Note: 1. When the soil around the trench is fine grained (fine silt or clay or their mixture) adopt Class I grading. When coarse silt to medium sand or sandy soil exists then Class II grading is adopted. When gravelly sand is present then class III grading should be adopted.

2. The thickness of backfill material around the pipe should not be less than 150 mm. Therefore, considering that the minimum diameter of the pipe as 150 mm, the width of the trench should not be less than 450 mm.

When the subsurface consists of only free draining material, the drain may be constructed without any pipe. The trench may be filled with material such as gravel, slag or stone aggregates free from organic and deleterious substances. This drain is known as aggregate drain. Its grading is indicated in Table 6.7.

TABLE 6.7. GRADATION FOR AGGREGATE DRAIN

Sieve Designation, mm	Per cent by Weight Passing
13.2	100
11.2	92-100
5.6	27-46
2.8	3-16
1.4	0-6

The sub-surface drain can be provided with geotextile either along the trench or around the pipe or both. The geotextile acts as both separation and filtration layer. When geotextile is provided, the filtration requirement in the grading is not important as far as material on both sides of it is concerned.

Intercepting a seepage zone as shown in Fig. 6.11 can be done using horizontal drains. Perforated pipes are inserted in the hill cuts for removal of the moisture from the soil mass of up hill slope.

If some portions of road is required to be constructed in heavy clayey soils or passing through an area susceptible to ingress of water, subsoil drains as shown in Fig. 6.12. may be provided in the road.

Sub soil drainage system has to be provided in valley curves as shown in Fig. 6.13. It consists of a trench cut across the body of the embankment/affected portion. The trench is filled with good drainage material such as gravel, sand, shingle, metal etc. A perforated pipe may also be provided in addition to the drainage material. The trapped moisture shall be drained to the trench bottom and discharged into side drain or outside the formation.

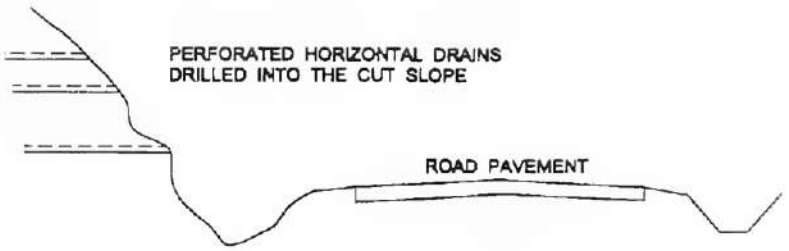


Fig. 6.11. Provision of Horizontal Drains

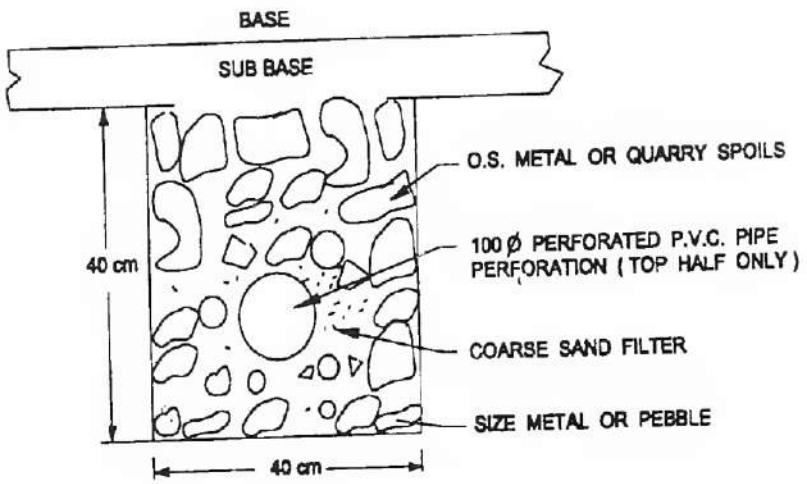


Fig. 6.12. Sub-Surface Drain in Heavy Clayey Soil

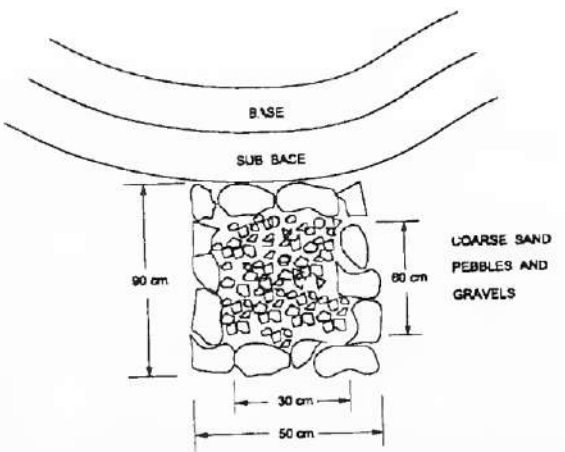


Fig. 6.13. Sub-Surface Drain at Valley Curve and Change of Grade

If the moisture reaching the subgrade due to capillary rise is likely to be detrimental, it may be checked by providing a layer of granular material of suitable thickness of about 75 mm to 100 mm as cut-off layer during the construction of embankment between the subgrade and the highest level of ground water table or highest flood level as shown in Fig. 6.14.

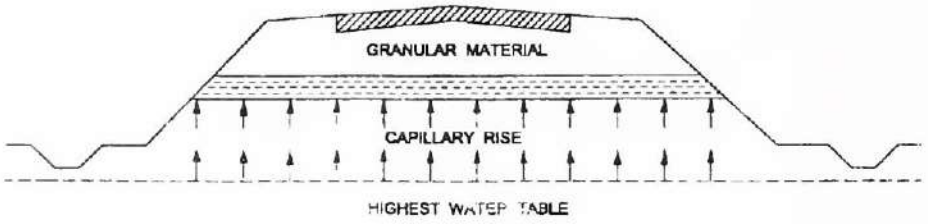


Fig. 6.14. Granular Capillary Cut-Off

Chapter 7

CULVERTS AND SMALL BRIDGES

7.1. Introduction

In order to adopt uniform standards and to assist the field engineers in providing cross drainage works, type designs and estimates of culverts of probable spans and heights for rural roads are given. These designs are based on relevant IRC codes and guidelines. This Chapter generally deals with culverts, small bridges and minor bridges for rural roads, having height from foundation to road top up to 8 m and spans up to 10 m. Information and details of causeways and submersible bridges are also given. Standard design of spans 12 m and 15 m are also given so that unavoidable crossing can be dealt with. The required formation width for rural roads [Other District Road (ODR) and Village Road (VR)] is 7.5 m. In case of roads of short length connecting only one village and hill roads, the formation width can be reduced to 6 m.

7.2. Geometric Standards for Culverts

A Culvert is a cross drainage structure having a total length of 6 m or less between the interface of dirt walls or extreme vent way boundaries. A minor bridge is a bridge having a total length upto 60 m. A small bridge on rural road could be generally taken as a bridge of total length between 6 m and 30 m. Submersible bridges and causeways are the structures, which get submerged during high floods in monsoon for some duration but are available for traffic otherwise.

7.2.1. Overall width of CD works : The overall width of culvert should be equal to the formation width of the road. In rural roads, the roadway width is 7.5 m in plain and rolling terrain. However from cost and low traffic point of view 6.0 m formation (roadway width) can be adopted for such roads, which connect only a small habitation and where length of the road is small. After careful consideration of various issues and with due consideration of traffic and cost, overall width of culverts and small bridges are given in Table 7.1.

TABLE 7.1. OVERALL WIDTH OF CD WORKS

Type of Cross Drainage Works	For 7.5 m Roadway Width		For 6.0 m Roadway Width	
	Overall width, m	Carriageway, m	Overall width, m	Carriageway, m
Culverts	7.5	6.6	6.0	5.5
Small and minor bridges	6.4	5.5	6.0	5.5
Submersible bridges	7.5	6.6	6.0	5.5

The carriageway width of a CD structure is generally the overall width minus the kerbs and railings which should normally allow passage of two trains of IRC Class A Loading. In case of roads with low traffic intensity, and in hilly terrain where overall width is 6 m, it is adequate to provide 0.25 m wide kerb raised from slab. Clear width of carriageway in these cases will be 5.5 m.

For pipe culverts on rural roads it would be desirable to provide 3 pipes of 2.5 m length each, to avoid cutting of pipes. This will mean that clear width on these culverts would be 7.5 m width minus width of guard stone or parapet wall. For buried pipe culverts with embankment of more than 1 m above the pipe, length of pipe should be suitably increased.

7.2.2. Siting of culverts on gradient : The cross drainage works should generally be sited on the straight alignment of a road. If a nalla crosses the road other than at right angle, either a skew culvert should be provided or, if economical, the nalla should be suitably drained. If the road at the culvert is in gradient, the same gradient of road may be provided for deck slab of the culvert. If the culvert is situated at change of

gradient (hump), the profile of vertical curve should be given in the wearing coat on the culvert. In such cases, the levels of the two abutment caps on either side may not be the same. However, the bearing surface of an RCC or Stone slab culvert on the abutment should be horizontal. Drawings for RCC skew slab are not given in this Manual.

7.2.3. Kerb and parapet wall : Parapet walls of culverts generally consist of either Random Rubble (RR) or Coarse Rubble (CR) stone masonry in cement mortar 1:5 or RCC railings of 0.8 m high above kerb. It is observed that these railings get damaged due to impact of vehicles and repair takes time. Where overall roadway is 7.5 m or 6.4 m, the combined width of kerb and parapet is 450 mm as per standards. However, for 6 m wide culverts or bridges, 250 mm wide RCC kerb, 300 mm above road level should be provided. If considered necessary either pipe railing or guard stones of 200 x 200 mm section projecting 300 mm above kerb and spaced at 1200 mm c/c may be fixed. In case of small bridges with 7.5 m and 6.4 m overall width, parapet may be of Plain Cement Concrete (PCC) railing or brick masonry or of guard stones. At the end of parapets and returns, 400x400x600 mm RCC blocks are provided at four corners at the end of returns. Numbering of culverts and direction of flow can be marked on these pillars.

7.3. Design Loading

Culverts and bridges of 6 m, 6.4 m and 7.5 m overall widths on rural roads are normally designed for two lanes of IRC Class A loading with impact Where in exceptional cases single lane bridges are provided, they may be designed for a single lane of IRC Class A loading with impact.

7.4. Wearing Coat

Concrete wearing coats have been provided extensively in the past. However, when the road is with bituminous surface, it is desirable to provide 20 mm thick Premix Carpet (PMC) with a 5 mm thick seal coat as wearing coat on culverts. If the rural road is not black topped, concrete wearing coat can be adopted for CD works. For submersible structures, like, arch/vented causeways, cement concrete wearing coat of 75 mm thickness must be provided.

7.5. Name Plates and Numbering of Culverts

Two name plates or plastered surfaces should be provided on the roadside faces of 0.6 m high guard stone. Numbering of culverts should be done as per practice prevalent in the State. Number of culvert, description of type and the direction of flow should be inscribed on the left-hand side end faces of returns in both directions. In case of pipe culverts, 2 guard pillars of 400x400x600 mm size are provided on left-hand side in either direction for recording the number of culvert. It is desirable to refer the relevant IRC standards for this purpose.

The culverts are designated in the form of a fraction, the numerator denoting the number of kilometer and the denominator to indicate the kilometer wise serial number of the structure. For example 11/3 indicates the 3rd culvert between 10th and 11th km stone. The methodology for inscribing numbers on parapets, railings and on stone/RCC posts has been given, in IRC:7 'Recommended Practice for Numbering of Bridges and culverts. The size of letter shall not be less than 100 mm high and shall conform to IRC:30 'Standard Letters and Numerals of Different Heights for Use on Highway Sign's.

7.6. Design of Culverts (Hydraulic Aspects)

The topography of the land across the country varies widely and conditions may be dissimilar even within the same State, depending on the annual rainfall and nature of terrain. The hill streams are flashy in nature, which need tall substructures to span them. The natural streams in plains and rolling terrains are usually wide and need longer superstructures with relatively shorter substructures. The man made drains both for irrigation and industrial use could be low cost structures such as pipe culverts. Since the catchment area varies

widely, it is suggested to estimate discharge of a natural stream by direct measurement. If it is not possible to measure, some of the empirical formulae (like, Dicken's and Inglis) listed in IRC:SP:13 may be referred to fix the waterway. In the plains of north-eastern States, the CD works may be expected to carry a very heavy discharge necessitating deeper foundations and/or adoption of longer span lengths.

7.6.1. Waterway area : The waterway of culvert is given by:

$$A = Q/10.9$$

Where Q = Catchment area in hectares
A = Waterway in sq. m.

This formula is generally suitable for culverts with catchment upto 100 hectares. 1 Sq. km It is, however, advisable to determine the actual discharge of the stream by a suitable method, where the catchment is more than 100 hectares.

7.6.2. Linear waterway : It is generally found that the linear waterway for catchment area of 1 square km will be between 4 to 6 m. Statistical data shows that the relationship between linear waterway and the catchment area is given by the following empirical formula.

$$L_w = K\sqrt{Q},$$

L_w = Linear waterway in metre.
Q = Catchment area in sq. km.
and K varies from 4 to 6

This formula is not suitable for culverts with a catchment area of less than 1 sq. km.

On the basis of formula in Section 7.6.1, for a catchment area of 1.25 sq. km. (125 hectares) the waterway works out to be 6 m for a depth of flow of 2 m, as follows:

A	=	125/10.9	=	11.46 sq.m.
L_w	=	11.46/2.0	≈	6.0 m

Thus for catchment area less than 1.25 sq. km (125 hectares), a culvert is required and for catchment area more than 1.25 sq. km, a minor bridge is to be provided. If the depth of water is more say 3.0 m, a culvert of 6 m waterway can be provided up to a catchment area of 2 sq. km, i.e., 200 hectares. These figures are meant for guidance. The States may fix their own criteria based on statistical data.

7.6.3. Hydraulic data : Following data needs to be collected for the design of a culvert :

(i) Catchment area of the stream in hectares.
(ii) Cross-section of the stream at proposed crossing alongwith L-section of road upto 200 m on either side of the culvert.
(iii) L-section of nalla (for catchment area more than 125 hectares) about 200 m upstream and 200 m down-stream to ascertain if straightening of the stream is necessary to fix the location of the culvert.
(iv) High flood level (HFL).
(v) Road top level (RTL).

In case of long bridges, the road top level is fixed on the basis of HFL after providing prescribed vertical clearance and calculated afflux. In case of culverts, the RTL should not be fixed on the basis of HFL and vertical clearance alone. The gradient of road 200 m on either side should be examined and the road top level (RTL) should be fixed such that RTL is not less than the minimum requirement on the basis of HFL.

When the mean velocity of flow is more than 2.6 m/sec protection of entry and exit end is desirable. Otherwise, stone pitching of bed would be adequate. As per IRC:5 the vertical clearance for CD works varies from 150 mm to 600 mm as indicated in Table 7.2.

7.6.4. Road top level : Most of the work of construction of culvert will be generally on new roads. Some works may, however, be on the existing roads. Culvert should be constructed simultaneously when the earthwork of road is in progress, whereby the geometrics of the road can be properly provided. In many cases culverts are taken up after providing the road crust. This has two disadvantages:

(i) Practically every culvert becomes a hump on the road and geometrics of the road are affected.
(ii) Duplication of work of consolidation of approaches causes extra cost.

The road top level at culvert should be fixed in advance.

7.6.5. Minimum span and clearance : From the consideration of maintenance of culverts, it is preferable that the clear waterway of slab culvert is minimum 1.5 m and diameter of pipe in case of pipe culvert is 1000 mm (900 mm internal dia). Culverts of small span or diameter get choked due to silt. It is not possible to enter the pipe and carry out inspection and repairs in span or diameter less than the ones given above as the requirements. Irrigation pipes do not come under the purview of pipe culverts. Minimum height of soffit of slab should be 1.5 m above lowest bed level from the consideration of inspection and maintenance. Table 7.2 indicates clearance required for different spans.

TABLE 7.2. SPANS AND CLEARANCE

Span, m	Vertical Clearance, mm
1.0 and 1.5	150
2.0 and 2.5	300
3.0 and 4.0	450
5.0 and 6.0	600

(IRC:SP:13 provides more detailed hydraulic calculations)

7.6.6. Number of culverts per kilometre : It is observed that about 2-3 culverts are required per km length of road depending on the topography. This may also vary from region to region and guidance can be taken from statistical data of existing roads. When the ground generally slopes from one side to another, the embankment intercepts natural flow of rainwater. In such cases balancing culverts are provided at the rate of one per 500 m length of road to avoid water logging. The balancing culvert could be a pipe culvert of minimum 900 mm internal diameter.

7.7. Types of Culvert

Following types of culverts are generally provided:

(a) RCC Pipe Culvert
(b) RCC Slab on Masonry or Plain Concrete Abutment
(c) RCC Box Types Culvert
(d) Arch Culvert
(e) Cut Stone Slab Culvert
(f) Stone Masonry Scupper
(g) Vented Causeway
(h) Submersible Bridge

The first three types of culverts are most popular across the country. The brick/stone masonry arch culvert is less common these days since the skills necessary to undertake the construction are on the decline. However, this form of construction is quite suitable for CD works on rural roads. The design of RCC slab bridges is well established and many ready to use charts are available with State Governments and IRC:SP:13

also provides a large number of them. The design of box culvert is simple and the form of construction is sound from both hydraulic and structural considerations. In Maharashtra, an attempt was made for adoption of PCC block arch culvert with pre-fabricated concrete blocks of uniform size. A few such arch culverts both in single and multiple spans were built in the State and their performance appears to be satisfactory. The stone slab culverts could be adopted for a clear span upto 1.8 m at locations where suitable material is locally available. Stone masonry scuppers are adopted in the hill States of Jammu and Kashmir, Himachal Pradesh, Jharkhand and Uttaranchal. In many States the vented causeways and submersible bridges are used for wide streams with low seasonal discharge. Cost per running metre being low, they are considered to be low cost CD works although the total length could be as much as 100 m including ramps. Some States, particularly the north-eastern States, use steel or timber bridges which are not covered in this Manual.

7.7.1. Height of culvert : The minimum height of the formation level of the road from the bed level is required to be as per Table 7.3 in case of pipe culvert.

TABLE 7.3. MINIMUM HEIGHT OF FORMATION

Diameter (NP_3 pipes), mm	Height of Formation, m
For 1000 (900 mm internal dia)	1.75
For 1200	2.15

Minimum height in slab culvert will be 1.775 m which include height of abutment (1.5 m) thickness of RCC deck slabs (0.2 m), wearing coat respectively (0.075 m). There is no difference in height in either slab or pipe culverts.

7.7.2. Pipe culvert

7.7.2.1. Diameter of pipe : The cost of slab culvert is less if the foundation is within 2 m from the bed level, otherwise, pipe culvert is chosen. Although use of 450 mm, 600 mm diameter pipes in CD works was more popular in low to moderate rainfall regions, from inspection and maintenance point of view, a minimum of 900 mm (internal) diameter is recommended. However, taking into consideration the smaller length of barrel and low embankment heights, pipes of lesser dia, viz, 600 mm or 750 mm may also be used in exceptional situations. RCC pipes of 300 and 450 mm dia, used for purposes, such as, irrigation/agriculture are to be considered as mere buried conduits and not as culverts. The pipes for culverts of rural roads shall be of NP_3 type, which conform to IS:458-1989 and can be chosen as per Table 7.4.

TABLE 7.4. DIAMETER OF PIPE

Catchment Area (Hectares)	Diameter of Pipe (mm)
Up to 10	1000 single row
10 to 20	1200 single row
20 to 50	1000 or 1200 (2 to 3 rows)
50 to 60	1000 or 1200 (4 rows)

Where the height of embankment on account of geometric consideration of the road is more than 5 m but the catchment area of the stream is less than 40 hectares, it would be economical to provide a pipe culvert with 2 rows or 4 rows of pipes. The main advantage in pipe culverts is the speed of construction and good quality of factory produced pipes. A pipe culvert can be constructed in 15 days. The only time consuming and costly item is stone masonry headwall.

7.7.2.2. Headwall : In order to reduce the quantum of masonry wall and the cost, the headwalls are raised up to top of the pipe and 0.5 m parapet wall is provided above it. The length of headwall is equal to four

times the diameter of pipe for retaining the slope of earthen bank within 1 (Vertical) to 1.5 (Horizontal). By restricting the height, the length and section of headwall is considerably reduced. Longer headwalls are provided for wider streams as per site requirements. Pipes are generally 2.5 m or 3 m long. It shall be ensured that the invert of the pipe is placed 150 mm below the average bed level. Suitably designed RCC face wall (150 mm thick) can also be used for a single row pipe culvert.

Pipe culvert may prove to be economical where foundation of culvert is likely to be deeper or in predominantly black cotton soil area; and where foundations are required to be taken to more than 2.5 m below the bed level. In heavy rainfall area and for stream with high velocity, protection of scourable bed on downstream side should be ensured. This protection is usually in the form of a launching apron using large size stones.

7.7.2.3. Design aspects : The pipes shall be conform to IS:458-1989 (Specification for concrete pipes) and shall be laid as per relevant IS:783-1985 (laying of concrete pipes). The structural design of pipe culvert requires calculations of probable maximum load on the pipe, inherent strength of pipe and selection of bedding for the pipe. The load factor of a pipe depends on different conditions of bedding as well as laying of pipes. It is desirable to use type A, i.e., concrete cradle bedding for pipes of 1000 mm diameter and above and those with fills higher than 4 m. The minimum compressive strength of concrete should be 20 MPa. The type B bedding is adopted for height of fill between 0.6 m and 4 m. It consists of a continuous layer of compacted sand or moorum, with minimum thickness of 75 mm below the pipe. The fill material shall be free from clay lumps retained on 75 mm sieve and from stone retained on a 26.5 mm sieve. Fig. 7.1 shows different field conditions in foundation. It may be ensured that the minimum height of fill above pipe including road crust shall be 1000 mm. The relevant MoRT&H Specifications may be followed for laying and back filling of pipes.

7.7.2.4. Jointing of pipe : The pipes shall be joined either by collar joint or the flush joint. The collar shall be of RCC 150 mm to 200 mm wide having strength as that of pipes. Caulking space shall be between 13 to 20 mm according to the diameter of the pipe. The collar shall be properly placed over the joint of the pipe to cover the joint evenly. Caulking material shall be a wet mix of cement and sand in the ratio of 1:2 rammed with caulking irons.

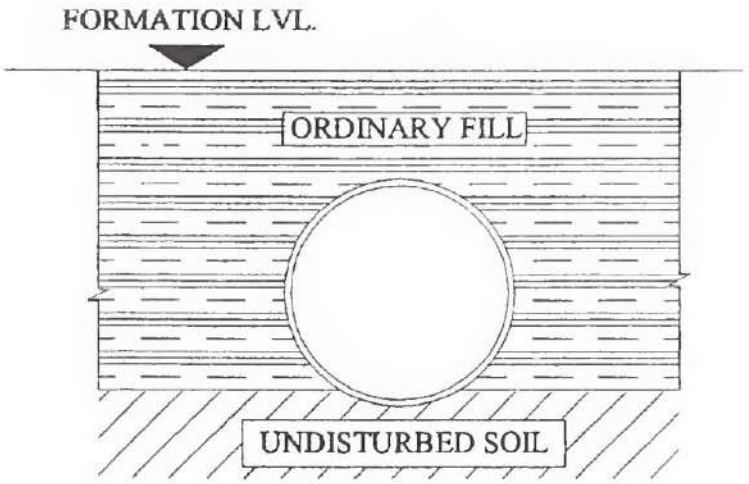
In case of flush joint the ends of pipes are specially shaped to form a self-centering joint with jointing space 13 mm wide. The jointing space shall be filled with cement mortar (cement:sand 1:2) mixed sufficiently dry to remain in position when forced with a trowel or rammer. Care shall be taken to fill all voids and excess mortar shall be removed.

7.7.3. RCC slab culvert

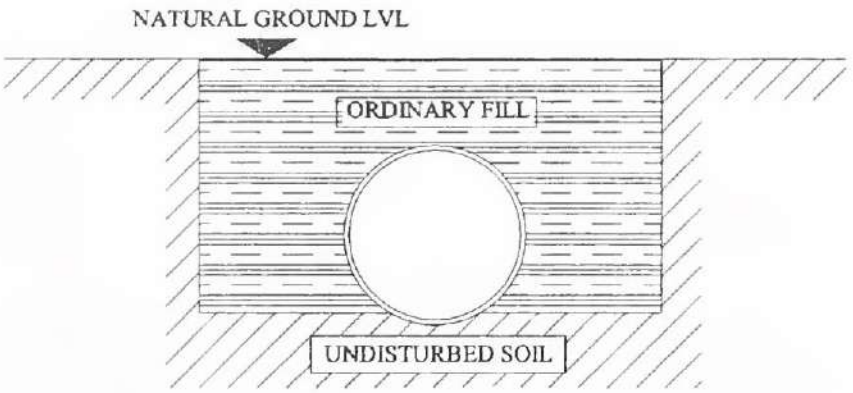
7.7.3.1. Catchment area and span requirement : RCC slab culvert is one of the common types of culvert. For catchment area more than 60 hectares, RCC slab culvert offer an economical and convenient proposal. The approximate relationship between the catchment area and the span is given in Table 7.5.

TABLE 7.5. CLEAR SPAN OF CULVERTS

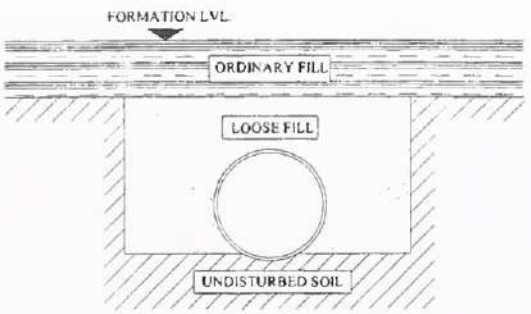
Catchment Area in Hectares	Clear Span of Culvert, m
Up to 15	1.5
16 to 25	2.0
26 to 50	3.0
51 to 75	4.0
76 to 100	5.0
101 to 125	6.0
126 to 200 (deep channels)	6.0



Positive Projection



Trench Condition



Negative Projection

Fig. 7.1. Different Conditions of Pipe Culverts in Foundations

7.7.3.2. Minimum depth from lowest bed level : Minimum depth from lowest bed level to soffit is 1.5 m. Normally a small bridge will not be required for catchment area less than 125 hectares. Most of the culverts on roads can be adjusted according to catchment area indicated in Table 7.5.

7.7.3.3. Detailing : M25 concrete and High Strength Deformed bars are specified for usage in deck slab. A nominal 1:1.5:3 concrete mix with 43 grade cement and a water cement ratio restricted to 0.45 can produce this strength. In case of simply supported slabs, it is a common practice to crank alternative bars at 1/ 7th clear span. Similar practice can be adopted for solid slab culvert of 4.0 m span and above. But in case of 3.0 m span and below, only one bar in every four bars is to be bent. Alternatively, cranking may be avoided. The plates showing the type designs indicate the exact number of bars to be cranked.

The shear force at the support of a deck slab is large. In slab with small spans of 3.0 m or less, local bond stress exceeds permissible limit when alternate bars are bent. Therefore alternate bars are not bent in such small spans. The standard designs of RCC slab issued by Ministry of Road Transport and Highways for spans of 3.0 m to 10 m are meant for a carriageway of 12 m width and designed for Class 70 R loading. These drawings are not applicable to CD works on rural roads. The design live load adopted for the type design of solid slab on rural road is two lanes of Class A with impact. Although bearings are required for 12-15 m spans, they may be avoided with the stipulation that the substructures are appropriately designed by considering horizontal forces. Plates 7.7 to 7.16 give details of RCC deck slab for span 1.5 to 15 m and an overall width of 6 m, 6.4 m and 7.5 m.

7.7.4. RCC box type culvert

7.7.4.1. Section of box culvert : Box section of size less than 2 x 2 m is not practicable to implement. Box type culverts are suitable for a situation where the catchment area is more than 30 hectares. An isolated box culvert is economical in such cases where either the depth of foundation is more than 4 metres below bed level or where the total embankment is very high, as in the case of approaches of a long bridge. Normal sections of box culverts adopted for different catchment areas are given in Table 7.6. Box culverts of smaller sections or arch culverts are cost effective at most of the locations particularly in strata with low bearing capacity and where founding strata is deep seated.

TABLE 7.6. SECTIONS OF BOX CULVERTS

Catchment Area, Hectares	Sections of Box Culverts
30 to 40	2.0 m x 2.0 m
41 to 60	2.5 m x 2.5 m
61 to 81	3 m x 3 m
Upto 200	3 m x 3 m (2 boxes)

The loads that are considered in the design of a box culvert are the live load and dead loads such as self weight, load due to earth fill (if any) on the top slab, soil reaction on the bottom slab, and those due to lateral earth pressure on the vertical walls. The hydrostatic pressures due to standing water are also considered in the design. The moments per unit width of box are calculated by the moment distribution method, or any other analytical method. Some design offices resort to the usage of design coefficients, which depend on length to width ratio, and the thickness of the top, bottom and side slabs. Most design offices now use computer aided analytical methods supported by various structural analysis software. The type designs of box cells given in Plates 7.18 and 7.19 may be referred to. Details of lesser cross Section, such as, 1x1 m, 1.5 x 1.5 m, etc. can be used when ready-to-use charts are available.

Trautwine suggested that Fs should be taken as 10 to account for unknowns in geological formation of stones used. The value could be taken as 3 for igneous and metamorphic rocks. Cut stones of 300 mm width could be placed side by side spanning across CR or brick masonry abutments and about 100 mm thick RCC slab is provided to interconnect the stone slabs and serve as wearing coat.

Substituting $b = 0.3$ m, $w^{I} = 27$ kN/m³, $h = 0.1$ m, $w^{II} = 24$ kN/m³, $Fs = 3$, $q = 8450$ kN/m²

$P = 845\ d^2/L - 1.35\ L\ d - 0.12L$, or

$P = 26.8$ kN (with 10 per cent impact) for a single imprint of 114 kN axle of IRC Class A loading,

when d is less than 0.3

$26.8 = 845\ d^2/L$ (approx.)

or $d^2 = 0.0317\ L$

The required thickness of a cut stone slab for different span lengths is given below:

Clear span (m)	1.5	1.8
Thickness (mm)	220	240

A bearing length of 150 mm extra on span is required on either side to seat the stone slab on abutments. Thus a 1.8 m span unit weighs (1.8 + 0.3)x0.3x0.24x2700 = 408 kg which can be handled. It is to note that the IRC:6 does not specify impact factors for masonry bridges.

7.7.7. Stone masonry scupper : This type of CD work is more common in the Himalayan regions of Jammu and Kashmir, Himachal Pradesh and Uttaranchal. In hill roads, it is conventional to cut the roads from the hill face in one working season and open the road immediately to light traffic. The construction of pavements and roadside drains are taken up subsequently. Stone being the locally available material, stone corbelled scuppers are provided as semi-permanent CD works, to carry the water from side drains collected from hill slopes. A typical dry stone masonry scupper of 1 m span is shown in Plate 7.27. The foundations of abutments shall be kept horizontal. The length of scupper may be increased or decreased as per requirement at site. If good stone is not locally available or within 10 km distance, the scupper may be replaced by RCC slab or box culvert with catchwater drains. Since the ventway is small, a scupper can carry only limited discharge. Therefore, they are provided at frequent intervals, like, 4 to 6 numbers per km length depending on the requirement. It is found that stone corbelled scupper is more stable than stone masonry arch, under seismic conditions. Therefore, these are preferable in Himalayan region. Further, construction of a scupper does not need any extra skill. However, dry stone masonry scuppers need periodic examination, since the stones are likely to be dislodged in the event of a high discharge after a cloud burst. Plate 7.27 gives details of stone masonry scupper.

7.7.8. Design aspects and specifications

7.7.8.1. Design considerations : The type designs of pipe culvert and RCC slab culvert are based on some of the following considerations. The CR/RR stone or brick masonry for substructure and parapet walls are found to be economical in comparison to mass concrete sub-structure. The masonry below ground level should be in cement mortar 1:4 and above ground level in cement mortar 1:5. If burnt clay bricks with a crushing strength of 7 MPa are available, they can also be used for culverts. Fly ash bricks can also be used instead of burnt clay bricks when the strength is more than 7 MPa. Where bricks of specified strength are not available, CR/RR stone masonry could be attempted.

7.7.8.2. Foundation concrete

(i) Foundation concrete for masonry abutment and return shall be M10, otherwise it shall be M15. If the foundation level is below water table, 10 per cent extra cement should be added in concrete.

(ii) The thickness of PCC footing below abutment should be minimum 200 mm. In case of pipe culvert, it is not necessary to provide concrete bedding below the entire length and width of pipe.

(iii) A moorum cushion consolidated to 200 mm thickness is adequate. However, 200 mm thick cushion below pipe and 300 mm wide M15 concrete bedding is necessary at all the joints of pipes. The guidelines given in IS:783-1985 should be followed; 20 mm size aggregate should be used for foundation concrete and 40 mm size aggregate for abutment and return walls.

7.7.8.3. Return wall or wing wall : Length of return and splayed wing wall are generally found to be better than straight returns. However, straight returns are easy for construction and standardisation. The layout and construction of wing wall is also difficult. It is, therefore, proposed to provide straight return walls for culverts. The length of return walls beyond the faces of abutments should be as given in Table 7.8.

TABLE 7.8. LENGTH OF RETURN

Height of formation at abutment above bed level, m	Length of Return, m
2.5	3.75
2.5 to 3	3.75 to 4.5
3.5	5.25
4	6

The Sections of return wall are given in Plates 7.2, 7.3, and 7.5. Normally the length of return should be 1.5 times the height of abutment above lowest bed level. For the purpose of standardisation common lengths of returns are proposed. A toe wall may be provided at the end of earth slopes at abutments for protection of slopes. If the height of road top from the bed level at abutment is more than 4 m, the length of returns should be suitably worked out. Foundation level of returns may be stepped up to reduce the cost, if suitable founding strata are available at shallow depth. But at such change of foundation level, continuity between two parts may be broken by a vertical joint.

7.7.8.4. Section of abutment, pier and return

(a) Section of abutment and returns : Following sections are given in plates:

Height 2 m to 4.5 m	Masonry Section	Plate 7.2
Height 4.5 m to 8.0 m	Masonry Section	Plate 7.3
Abutment for height upto 8 m	PCC M15	Plate 7.4
Return for height upto 8 m	PCC M15	Plate 7.5

The abutment cap and cap on return wall and dirt wall for culverts will be of plain concrete of M20 grade with surface reinforcement. Where bearings are provided the cap will be reinforced. For dirt wall of spans more than 6 m the dirt wall shall be reinforced. Stepped piers and abutments are chosen for ease of shuttering since tapered sections are likely to pose construction problems in rural areas. Plates 7.2 and 7.3 give cross sectional details of masonry abutments and returns for spans 1.5 to 3.0 m and 4.0 to 6.0 m respectively. Quantity of abutment and returns in both masonry and PCC are indicated in Plate 7.24 for guidance.

(b) Piers : The sections of PCC pier and the method of designing a pier are given in the Plates 7.4 and 7.6. The sections of PCC return walls and wing walls are given in Plate 7.5. Where bearing capacity of soil is low, the lateral dimensions of the footing could be increased suitably. Type sections for RCC pier and abutment caps besides dirt walls are given Plate 7.25.

(c) Miscellaneous : Stopper, protection around abutment and treatment for the submersible bridge is given in the Plate 7.20.

7.7.8.5. Approach slab : Abutment is designed for surcharge of equivalent height 1.2 m and return walls for an equivalent height of 0.6 m. Therefore, there is no need to provide approach slab. However, it may be desirable to provide a pavement for entire formation width for length of 3.6 m behind abutment, between returns.

7.7.8.6. Design of masonry section : The following considerations are taken into account:

(a) Abutments are designed for a live load surcharge of 1.2 m, (Clause 714.4 of IRC:78).
(b) Granular material filling is provided between return walls. (Appendix 6 of IRC:78 should be followed).

7.7.8.7. Expansion joints/bearing surface

(i) **For span up to 3 m :** Expansion gap may not be provided up to 3 m span. The top of abutment cap and the face of dirt wall (on slab side) are however coated with a layer of bitumen.

(ii) **For span between 3 to 6 m :** For spans between 3 m to 6 m a pre-moulded bituminous sheet such as Shalitex board of 12 mm thickness may be provided. In the parapet wall it is desirable to provide a vertical joint in the masonry wall at the location of end of deck slab. Thus the parapet wall shall have three parts, viz. , the central part over deck portion and two side parts over return walls. Corresponding joint is also necessary in the coping over parapet wall.

(iii) Tar paper (bearing) should be provided on all supports of deck slab upto 10 m spans.

7.7.8.8. Weep hole and water spout : Weep holes are provided to prevent building up of hydrostatic pressure behind abutments and wing walls.

(i) There may not be any need for weep holes and waterspouts in small span culverts. However, local practices prevails on size and spacing of weep holes, which may be followed.

(ii) If the height of abutment and return over bed level is more than 2 m, weep holes should be provided 150 mm above low water level (LWL) or ground level (GL) whichever is higher. In case of stone masonry, weep holes of 150 mm dia or 80x150 mm size in 1:20 slope should be provided at required intervals (Refer: IRC:40).

(iii) For 5 m and 6 m span one waterspout of 100 mm dia should be provided in the centre of slab on either side of the deck.

7.7.8.9. Grade of concrete : In the past, M10 and M15 grades of cement concrete were extensively used in CD works. As per IRC:21, the minimum grade of structural concrete is M20 (design mix). Where the quantum of concrete work is small as in CD works of rural roads, it is suggested to use nominal mix based on volumetric proportion of cement, sand and aggregate with a low water cement ratio up to 0.45. The minimum quantity of cement shall be 310 kg/m^3. Superplasticizers could be used to improve workability.

7.7.8.10. Pre-cast construction for culvert : This type of construction has certain advantages. Construction time could be reduced considerably, if precast concrete blocks or other RCC units are adopted for abutments, in place of CR/RR stone masonry. Due to non-availability of good masons, present trend is to adopt cast-in-situ PCC M15. These works are likely to be handled by small inexperienced contractors, and in remote areas the quality of concrete is likely to be poor. It would, therefore, be desirable if factories manufacturing pre cast concrete block of M15 strength are set up to produce blocks of 200x200x400 mm and 200x100x400 mm sizes. Such units can be easily handled manually.

Pre cast blocks of 0.6 m width for spans upto 2 m weighing about 600 kg can also be easily handled manually; and can be considered for adoption in suitable cases. Such blocks shall conform to IS:2185 (Part 1)-1979 concrete masonry units.

7.7.8.11. Cost of culvert : From the data available from various States, the cost of culverts constructed recently follow the break-up of cost given in Table 7.9. The height of culverts were between 2.4 to 3.2 m and spans 1.5 to 2.5 m.

TABLE 7.9. COST OF CULVERTS

Items	Percentage of Total Costs
(i) Excavation and dewatering etc.	5-10
(ii) Foundation concrete	10-15
(iii) Stone masonry substructures (piers, abutments, caps, returns, coping, etc.)	40-50
(iv) RCC deck slab	15-20
(v) Parapet wall and wearing coat	5-10

Items (i), (ii) and (iii) constituting 75 per cent of the total cost are governed by following parameters:

(a) Height (H) from top of foundation to the top of slab

(b) Overall width (W) and the length of returns

But the cost of items (iv) and (v) consisting 25 per cent of overall cost is governed by:

- Span of culvert (L)
- Width of culvert (W)

In case of culvert, the span is not a function of height. Hence, cost of culvert cannot be calculated on the basis of span.

7.7.8.12. Minor bridges on rural roads : For rural roads only such minor bridges are normally taken up where the height from the low bed level (LBL) to road top is within 8.0 m and where span is within 15 m. For such bridges, the same sections of abutment and returns provided for culverts may be adopted. Type designs for these spans are available. If heights of the small bridge from bed level is more than 8.0 m design of abutments and piers is called for. Similarly, abutments/piers of 12-15 m span bridges are to be designed separately, if bearings are not provided. If the bearing capacity of soil is poor the footing need to be suitably widened. The Plates given in this Chapter consider a safe bearing capacity of 30 T/m^2 which could be suitably modified for lower values of SBC, wherever required.

7.8. Causeway and Submersible Bridge

A causeway may not be a small bridge (length less than 30 m) but is a low cost cross drainage work of longer length. These are so built that the period of interruption to traffic during rainy season is short. The outer width of causeway should be equal to roadway width. A submersible bridge is a bridge, which gets submerged during monsoon in high floods of short duration, but is available for use of traffic during the rest of the times.

7.8.1. Criteria for submersible bridge : All culverts and small bridges (upto 30 m length) may be of high-level type. However, high-level minor and major bridges, are not considered on rural roads due to their high cost. They may also not be necessary for traffic requirements. Therefore, causeways or submersible bridges instead of major bridges could be provided on rural roads after comparing relative costs.

The period of permissible interruptions to the traffic due to submergence of a bridge could be 6 times in a year the period not exceeding 24 hours if no alternative access road is available. For this, it is necessary to correctly ascertain the Ordinary Flood Level (OFL). The OFL when cleared under the bridge provides permissible interruption to traffic. Such OFL and Reduced Level (RL) is to be arrived at considering the frequency of flood above that RL so that submergence consequent to higher floods do not exceed permissible frequency of interruption to traffic. If there is a considerable difference in OFL and HFL then it will be adequate to provide

bridge clearing the OFL and submersible for HFL. The soffit level of the bridge should be fixed so as to clear the OFL with some free board.

From streams with a velocity of flow more than 6 m/sec., causeways and submersible bridges may be avoided. If the cost of a submersible bridge with its approaches is more than about 70 per cent of the cost of a high level bridge with approaches at the same site, it is advisable to adopt a high level bridge. The decision of construction of a high level bridge should be taken after careful consideration of bridge site and related parameters. In case of causeway and submersible bridge, the RCC kerb of 250 mm width should not be continuous. After 1.5 m continuous length of kerb there should be a gap of 300 mm so that flood water is discharged expediously from the top of riding surface. The size of kerb stone used could be 500x250x300 mm.

7.8.2. Special aspects of submersible bridges and causeways : Since submersible bridges and causeways have been constructed extensively in several States in the past, guidelines and practices may be available in the States. Extract of guidelines adopted in Maharashtra PWD are enclosed for reference, ***Appendices-7.1 and 7.2.*** These may vary from region to region. Therefore, local guidelines and practices with due modifications may be adopted.

The sections of piers given in the Plate 7.06 can be adopted for submersible bridges as well. The approaches of causeways and submersible bridges should be preferably without banking. It has also to be ensured that height of submersible embankment shall not be excessive and hence, correct ascertaining of OFL, is important. The road level for a submersible bridge should never be below OFL unless only causeway is intended to be provided. While fixing the level of submersible bridge, consideration is also required to be given to OFL, vis-à-vis, terrace level on riverbanks, which occasionally get over topped. Where adequate flood frequency and gauging records are not available, thorough local inquiries are to be made to fix the OFL.

If the mean velocity of flow is more than 4.0 m/sec deck of submersible bridge must be suitably anchored. The stopper needs to be provided in cap of all submersible bridges. Part of the approach of a submersible bridge, which goes in submergence, needs protection. Protection could be done with precast cement concrete (interlocked) blocks or stone blocks. The required protection at submersible bridge has been shown in Plates 7.20 and 7.21. Provision of return walls on both sides and a pacca drain as shown in the Plates can serve the purpose. For submersible bridges discontinuous kerbs and removal/collapsible railings may be provided. Alternatively pipe railings can also be provided. Plates 7.20, 7.22, 7.23, 7.26.1, 7.26.2, 7.26.3 and 7.26.4 give details of causeways/submersible bridges.

7.8.3. Inspection and maintenance of small bridge and culvert : Although there is no special publication on maintenance of culverts, nevertheless, the IRC:SP:35 may be followed for inspection and use may be made of the inspection proformae given in *Appendices-4 and 5* of the publication. It is pertinent that an inventory of CD works be prepared both for existing as well as new CD works on rural roads. Since the waterway is usually small they tend to get clogged due to accumulation of silt and debris. In addition, the growth of vegetation should be checked lest the life of CD works would be curtailed. Small bridges and culverts will not last the expected life unless inspected and repaired frequently-normally twice in a year.

Timely and proper maintenance of culverts is very important for their upkeep. The maintenance covers three aspects:

(i) Maintenance of Channel
(ii) Maintenance of Structure
(iii) Maintenance of Approaches

The inlet of channel should preferably be on a straight alignment so that accumulation of debris or occurrence of eddy currents is minimal. The bed of the stream should be suitably protected to prevent erosion or scour.

It is expedient to carry out repairs to the substructure to prevent their early deterioration. The headwalls and wing walls should be inspected for cracks, settlement and unusual backpressures and rectification undertaken where required. The timely maintenance of wearing coat prevents occurrence of potholes in the earth cushion or the damage to RCC slab or the structure.

The sinking of approaches is quite common in rural areas. This is primarily due to movement of cattle from approach roads to the stream and also improper compaction of the earth fill. Occurrence of potholes due to undermining is also common. All the above things are to be attended to make the movement of traffic safe.

Maintenance of culverts and causeways is elaborated in ***Appendix-11.4*** of Chapter on Maintenance.

7.9. Quality Control

7.9.1. General aspects : Although the work of culvert is simple, it is necessary to have proper quality control in the work of stone masonry and concrete in deck slab, bar-bending, etc. The specifications for culvert should be in accordance to "Specifications for Road and Bridge Works" of Ministry of Road Transport and Highways. The testing of various construction materials and other tests during construction should be carried out as per the Ministry's specifications. Quality Control aspects for concrete have been covered in Chapter 10 in this Manual.

Formwork and False work: The considerations of formwork and false work aspects in bridges and culverts should be as per IRC:87 Guidelines for the Design and Erection of Falsework for Road Bridges.

7.9.2. Stone masonry

(i) For the work of culvert course rubble (second sort) masonry is stipulated.

(ii) Face stones shall be hammer dressed on all beds and joints so as to give them approximately rectangular shape. The bed joint shall be chisel drafted for at least 80 mm backs from the face and at least 40 mm for the side joints. No portion of the dressed surface shall show a depth or gap more than 10 mm from a straight edge placed on it.

(iii) The hearting or interior filling of the wall shall consist of flat-bedded stone carefully laid on their proper beds in mortar. The use of chips shall be restricted to the filling of interstices between the adjacent stones in hearting and these shall not exceed 15 per cent of the quantity of masonry.

(iv) Bond stones or headers shall be at 1.5 m or 1.8 m apart clear in every course. The headers shall overlap at least 150 mm.

(v) Face stone shall tail into the work for not less than their heights and at least one third of the stones shall tail into the work for a length not less than twice their height.

(vi) The face joint shall not be more than 20 mm thick.

(vii) The height of course shall depend on locally available size of stone. In no case the height of course should be less than 150 mm. The heights of courses generally adopted are 160 mm, 180 mm and 200 mm.

(viii) The size of face stones for these heights of courses are given in Table 7.10.

TABLE 7.10. SIZE OF FACE STONES

Size	Height of Course (mm)	Minimum Acceptable Size (mm)	Preferable Size (mm)	Size of Longer Stones /3rd of Total Face Stones 1 (mm)
A	160	150 x 150 x 200	150 x 180 x 225	150 x 180 x 300
B	180	170 x 170 x 210	170 x 210 x 255	170 x 210 x 340
C	220	190 x 190 x 225	190 x 225 x 280	190 x 225 x 380

(ix) Size C can be adopted for precast concrete blocks of 1:3:6 (cement:sand:coarse aggregate). Although there is no restriction for adopting the other courses (A and B), it is desirable to adopt 200 mm courses and insist on getting large size stones from quarries.

(x) Sizes of stones as specified above are not cut by labour and generally random sizes are made. With some efforts it should be possible to obtain the size of stones as specified above. On measuring the sizes of stones, the height of course should be fixed by the Engineer-in-Charge and insisted upon in the construction. The length of header should not be less than 400 mm.

(xi) The back batter of abutment is one horizontal to three verticals. The offset should be 1/3rd height, of course, if stepped masonry is provided in place of batter. The front batter below ground level is one horizontal to two verticals, the offset will therefore be ½ the height of course.

(xii) The laying of stone masonry: On fixing the face stones in position, the stones in the hearting should be placed and fixed in mortar and all interstices and stone chips laid in mortar should fill in gaps. In this way each stone in hearting shall be fixed properly in the course. The method of laying hearting between the face stones and pouring mortar and water is not a sound practice and should not be followed. The vertical pin headers shall be provided in each course for attaining bond between the two courses. Generally Grade 33 or blended cement should preferably be used for masonry works. 43 Grade cement causes shrinkage and may be avoided in stone masonry works.

7.9.3. Concrete :

According to IRC:21, M15 is the minimum grade of plain concrete and M25 is the stipulated strength for RCC. The nominal mix adapted in small works and their corresponding strength for different works using 43 grade cement is given in Table 7.11 for guidance.

TABLE 7.11. GRADES OF CONCRETE

Grade	Nominal Mix	Usage
M10	1:4:8	Lean concrete as levelling course
M15	1:3:6	Concrete blocks, PCC Pier, Foundation concrete for masonry works
	1:2½:5	Abutment, Wing/Return Walls, Foundation for RCC works
M20	1:2:4	RCC pier, Abutment caps, Raft foundations, Dirt walls
M25	1:1½:3	RCC superstructure

Note: Mix proportions are by weight

M15 could also be used as foundation concrete below abutments and piers where SBC is low.

The sizes of reinforcement to be used for RCC slabs and the grading of aggregates are specified in the schedule of rates issued by different States. It is advisable to use power driven concrete mixer to produce concrete for all culverts. Similarly, needle and form vibrators should be used for compaction of concrete. Bottom cover of concrete must be ensured by providing precast briquettes of concrete. However, concrete must be suitably vibrated. Water cement ratio must be limited to 0.45 (maximum). With the use of plasticisers, the w/c ratio can be brought down to 0.4. Measurement of volume mix concrete in rural areas is generally done by locally made containers and there is no uniformity in size. It is advisable to key 6 steel boxes each with a volume of half bag, the size being 300x300x195 mm with 2 handles. This can be easily lifted by a male labour. With the usage of these boxes quality of concrete improves. Wherever possible, mix design can be prepared by weigh batching and converted to volume batching by using boxes of appropriate size.

7.9.4. Reinforcement details : Lengths of bars, bending profile and numbers are given in the Plates listed in Section 7.11. Cutting of bars from available stock must be done carefully. Generally the tendency is to cut bars of required lengths and discard pieces of shorter lengths leading to greater wastage. There is no restriction in providing staggered overlaps 1 in every 5 bars (4 bars of full length and one overlapped or welded bar). The calculated quantities of steel are increased by 4 per cent to account for overlaps. However, cranking of reinforcements may be avoided, for spans less than 4 m. In case of welding, the relevant Clauses in IRC:21 may

be adhered to. Steel riders should be provided at cranked bars for maintaining them in correct position and alignment during concreting.

7.9.5. Precast works : As already mentioned, if factories manufacturing concrete blocks of M15 strength and about 0.6 to 1 m wide precast RCC slab (upto 2 m span) are located near by quality products would be available and work can be expedited. For spans larger than 2 m, cast in-situ concreting is resorted to.

7.9.6. Fly ash bricks : These bricks are now manufactured extensively and the minimum strength required is 7 MPa. Such bricks can be used for culverts. The brick masonry work would be faster. On account of restriction in making deep pits in ground for brick, fly ash bricks of strengths more than 7 MPa are manufactured extensively near towns. It would be possible to identify requirements of total quantity of bricks for culverts and establish factories of fly ash bricks in several districts at suitable places and transport them to the sites of culverts.

7.9.7. Setting out of culverts : Setting out of culverts should be done from four masonry pillars, two in the direction of road and two along the drain, all placed along two centre lines. The top of pillars in the direction of road should be at the proposed top level of deck slab. Two lines, one across the road top level of deck slab, two lines, one across the road (zero line) and one along the centre line of road should be inscribed on one of the pillars and all distances along and across be measured from these lines. The pillars should be placed sufficiently away from the zone of excavation.

7.9.8. Protection works : For better performance, protection work at abutment is necessary. Details are given in Plates 7.20 and 7.21.

7.10. Recommendations

(i) For catchment areas upto 20 hectares pipe culverts will be economical in comparison to slab culverts on all types of roads. This criteria will be suitable if the pipe manufacturing factory is situated within a distance of 300 km from the site of work. Availability of pipes should be assessed before specifying pipe culverts; otherwise the work of culverts is likely to be delayed.

(ii) For catchment areas more than 50 hectares, RCC slab culverts offer economical solution. Alternatively box culverts, single or multiple cells can be used. The cost of other CD works are to be worked out separately.

(iii) All the culverts and small bridges upto 15 m span must be of high-level type. Minor bridges could be either high level or submersible type. Submersible bridges are adopted if the cost of bridge and approach is less than 70 per cent of the cost of high-level bridge with approaches. Protection works of approaches are necessary for causeways and submersible bridges and the details for the same are given in Plates. Precast units can also be used for arch form of construction.

(iv) Quality control in the work: Construction of a culvert can be expedited if precast concrete blocks are used instead of masonry for abutments and precast RCC slabs can be adopted for culverts upto 4 m length in rural areas. Fly ash bricks or other bricks having strength more than 7 MPa can also be adopted in the construction of arch culverts and abutments of slab culverts of low heights.

(v) Power driven mixers and vibrators must be used for concrete works and the water cement ratio be restricted to 0.45. It is advisable to use plasticisers and reduce w/c ratio to 0.4 to achieve higher strength of concrete.

(vi) With a view to expedite preparation of estimates, quantities of abutment return and deck slab are given separately. In Plate 7.24 the quantities for an overall width of 7.5 m, 6.4 m and 6.0 m have been given.

(vii) This Manual contains guidelines for raised causeways, anchorages of submersible bridges and details of protection work as well. Width of 7.5 m, 6.4 m and 6.0 m have been given.

(viii) This Manual contains guidelines for raised causeways, anchorages of submersible bridges and details of protection work as well.

Guidelines for Construction of Causeway

7.1.1. Introduction

A road network is never complete till all CD works including minor bridges and major bridges on the same are completed. Due to several constraints on the allocated funds for roads, many a time the CD works and bridges on the road network are taken up later on. However, till these bridges and CD works are completed to make the crossings fordable during monsoon and floods, the causeways or such type of lower level passages have to be constructed at least to make them usable during the post monsoon period. The causeways or paved dips (hard passages) are no substitute for high-level bridges or submersible bridges with permissible interruptions to traffic. Such causeways are essentially low cost solutions designed for floods of frequency much higher than those for submersible bridges. Apart from floods, the causeways are not designed for all such forces, which are considered for design of bridges. Therefore some damages during floods do occur on such causeways. However, if proper precautions are taken in planning and designing of the causeways, some of the damages though cannot be avoided altogether, could at least be minimized. Some of guidelines would enable the field officers in planning, designing and construction of causeways to avert or minimize major avoidable damages.

7.1.2. Definition

Causeway : A causeway is a small submersible structure with or without openings, which allows flood to pass over it. Depending on the type of construction and the road level above the bed of the watercourse, these structures can be classified under, flush, low level and high-level causeways.

Flush causeway : It is a paved dip or road dam of a roadway, built to cross a shallow watercourse. The top level of road dam shall be at the same level as that of the bed of the watercourse.

A low level or a vented causeway : This is a structure provided with a few openings comprising of pipes, short span slabs or small arches etc. with a raised road top level to a moderate height upto 1.20 m. In exceptional cases it may be 1.50 m high.

A high level causeway : This is a submersible structure provided with larger openings comprising of a simply supported/continuous RCC slab or multiple arches or boxes and a raised road top level to a reasonable height upto 1.50 to 3.00 m. The RCC slab may be supported over a series of short masonry piers.

7.1.3. Causes leading to damage : A study of the damages to causeways and their malfunctioning reveal some of the following characteristics:

(i) Outflanking of the causeways.
(ii) Collapse of downstream head wall.
(iii) Damages to road pavement on the causeways.

The probable causes of the above damages could be :

(i) Inadequate or blocked openings;
(ii) Scour on the downstream side;
(iii) Inadequate keying of the headwall in the natural banks.
(iv) Silting on the upstream side and High velocity of steam and inadequate pavement protection.

7.1.4. Precautions to be taken : It is generally observed that the Road Top Level (RTL) selected is abnormally high compared to the vent way provided. This condition causes heading up of water on upstream

side and results in producing high velocities, which lead to structural failure and also out flanking. The road top level of the causeway should be kept as low as possible and be restricted to the heights mentioned in paras 7.2.1 to 7.2.3 of ***Appendix-7.2.***

Area of the Vents : The water way provided in the causeway should not be less than 30 per cent of the area of the stream, measured between the stream bed level and the proposed top level of road. However, larger vent area is desirable in case where the causeway is located on the existing natural crossings. These areas should be calculated at the defined cross-section of the stream. In scanty rainfall areas, i.e., annual rainfall less than 750 mm, the vent area can be brought down to 15 per cent.

The upstream and downstream face walls of the causeway should cover the whole bed width of the watercourse in case of vented and high level causeways. A rising face wall should be provided upto the top level of the protected bed. This face wall serves two major purposes, viz :

(i) It converges the flow and avoids out-flanking.

(ii) It protects the pavement and makes the shape hydraulically efficient.

Foundations of the headwalls should be taken sufficiently deep to avoid exposure due to scouring. Extra care should be taken about the depth of foundation of the downstream head wall in erosive strata, like, soil, soft moorum and sand. In erosive strata, downstream protection by way of apron, should invariably be provided.

It is observed that in causeways with pipe openings, the general tendency is to provide 600 mm thick earth cushion above the pipes. Even though this cushioning is essential for the load distribution and safety of the pipes in general, this provision increases the Road Top Level (RTL) undesirably high and makes the submersible structure hydraulically inefficient. This cushioning should be reduced to the barest minimum by providing Cement Concrete Pavement, Stone Set Pavement or Penetration Macadam, etc. above the pipe openings.

As the causeways are expected to allow the flood water to pass over them and the traffic requirements demand immediate use, the road surface on the causeway should be such that it does not get damaged due to frequent over topping. Sufficiently stable pavement should, therefore, be provided for the full width of the causeway. It should also cover the protected bed portion of the causeway. In case of large submergence, where submersible approaches are provided, similar suitable precautions should be taken while providing the pavement including downstream protection.

It is observed in many washed out and a pavement damaged causeways that the filling between the head walls is done with clayey material. As it is very difficult to ensure proper consolidation around pipes, the use of clayey material should be avoided in causeway construction. Filling between the headwalls should be done with granular material like, sand, hard moorum, pebbles; gravel, small boulders, etc. As the river/steam bed generally consists of such materials, best use of the same should be made of. If required, such material should be brought from outside but in no case clayey material is used.

To increase hydraulic efficiency and structural stability, the following may be considered:

(i) It is preferable that the downstream headwall should have batter on the outside, i.e., on downstream side

(ii) It is also preferable to provide rounding at the outer corners to both the headwalls

(iii) It is preferable to provide slight camber to pavement on one side only, i.e., slopping to downstream side only

(iv) Road top level and top of coping above headwalls should be the same.

In case of streams carrying heavy silt and floating debris, it is desirable to provide a catch pit at the upstream side opening to the vents. In case of streams carrying large floating debris, it is desirable to provide

large openings comprising of slabs or arches rather than small openings of pipes. In case streams carrying large floating material such as small bushes, trees and debris, arresters should be fixed on upstream side.

The work of causeway proper, its approaches, paving and the protective works like apron, paved drains in approaches, pitching for the approaches, etc. should be so planned and undertaken, that all the works are completed before onset of monsoon or else the function of the causeway structure gets impaired and the work may be damaged.

7.1.5. Design aspects : For designing causeway by Engineers in the field, a simple step-by-step procedure is described in ***Appendix-7.2***. It should be noted that while adopting the option of causeway and effecting economy, basis principles of sound engineering practice and minimum technical requirements are not overlooked.

These aspects should be kept in mind and to ensure strict adherence to the guidelines. Specific attention should be paid to the following:

(i) Road top levels above bed should be as low as possible as per guidelines for different types of openings.

(ii) Vent opening below road top level.
Lower limit of 30 per cent of the area below RTL.
And lower limit of 15 per cent for scanty rainfall area.
However, higher vent area is desirable.

(iii) Headwall shape in elevation-trapezoidal, blending smoothly with the natural cross-section of the watercourse with desirable grade 1 in 30.

(iv) Provision of apron for downstream protection in erosive strata.

Appendix 7.2

Guidelines for Design of Causeways (Issued by Govt. of Maharashtra)

7.2.1. General principles : A causeway is a structure midway between a full-fledged bridge (permitting full opening to flood waters) and a natural crossing obstructing no water way at all. A full-fledged bridge provides uninterrupted passage for traffic throughout the year while a natural crossing provides passage only during the dry season of the year.

A Causeway provides passage to the traffic in a major part of the year except during the flood season. An engineer has to understand its shortcomings and take appropriate counter measures to make best utility out of it and effect maximum economy while designing it.

It is expected that a causeway remains undamaged during maximum flood and remains functional during the rest of the time. There is inter-relationship among road top level (RTL), opening provides below RTL (Vent way) and length of the protected bed (Horizontal length of face wall and rising portion of the face wall on both banks). For evolving most economical, stable and hydraulically efficient designs, different trials with the above three parameters (i.e., RTL, Vent way and extent of protected bed) have to be undertaken. For successful prevention of out-flanking, it is necessary to carry out proper calculation of the number of vents and length of rising face walls. It is very important to note that in a vented causeway, the rising face wall plays a very important role in prevention of out flanking. For any natural watercourse, the most efficient hydraulic section is hyperbolic open channel. Nature invariably adapts the same sections. In road geometry, it is difficult to use this section in its true shape. So a modified shape in the form of trapezoid is best adapted amongst all other practicable shapes. This shape is achieved by rising face walls on the flanks and keeping the central porton of the face wall at one level. The entire zone between these face walls should be paved and is generally referred as protected bed.

7.2.2. Component parts : Simply raising the road top level of the causeway never ensures facility to cross at higher floods unless adequate openings are provided. Otherwise it amounts to construction of a road dam raised above the streambed which fails invariably. If due to cost consideration, it is not possible to provide full openings for the floodwaters, the only alternative left is to reduce the height of causeway to the barest minimum. In all flow conditions and the floodwater upto RTL is the most critical condition especially for the submersible bridges. If the construction is low, the flow becomes smooth, and the velocity remains under control, thereby the damages are less. In all the types of causeways, the RTL should, therefore, be kept as low as practicable.

Following recommendations are made:

	Types of Causeway	Preferable Height
(i)	Paved dips or road dam	Same as stream bed level
(ii)	Low level or vented causeway	Maximum height should be 1.2 m above bed in exceptional case 1.5 m
(iii)	High level causeway	Maximum height should be 3 m above the bed.

Openings or vent area : Vent area or openings provided below the RTL plays a great role in operational efficiency and the hydraulic efficiency of the structure. It is desirable to provide vent area of at least 30 per cent of the area obstructed at RTL. Higher values of vent area will reduce the expenditure on the raised face walls and protected bed. In scanty rainfall areas, i.e., annual rainfall less than 750 mm, the vent area could be brought down to 15 per cent.

In case where the causeway is located at the existing natural crossing, the obstructed area should be calculated on the suitable defined cross-section of the steam immediately near the crossing by transferring the road top level on that section.

Openings may be provided by Hume pipes. RCC slabs, Arches or RCC box cells. In erosive strata these openings should be equally spaced through out the channel portion. The spacing could be designed in central zone of causeway. In case of rocks and other non-erosive strata, the spacing may be suitably changed and openings may preferably be provided in the lowest portion.

In case of openings with pipes it is desirable to keep down stream sill of the pipes 300 mm below the average bed level and to lay them to the shape of the stream. In order to keep down the RTL and increase the percentage value of opening, the height of cushion above the pipes should be as low as possible. To enable such reduction from structural point of view, it is desirable to provide cement concrete of M15 grade or stone paving on the top of pipes. In low rainfall areas where frequency of floods is less, a cushion with WBM and Penetration Macadam also serves the purpose. With these specifications the height of cushioning above pipes can be reduced to 225 mm.

Face walls and protected bed : Major portion, of the floodwater has to be allowed to pass over the headwalls of the causeways. The structure should, therefore, be strong enough to avoid damages during the floods. In order to keep velocities at the downstream, in desirable limits and avoid outflanking, cross-section of flow should be adaptable to nature as explained earlier. This is achieved by providing raised face walls to a certain level and protecting the paving upto that level.

It is desirable to keep the obstruction below 30 per cent to ensure sound behaviour of the hydraulic structure. Taking the clue from the same, if the headwalls are raised and anchored into the bank upto a certain level, it will provide additional area over the road top and limit the gross obstruction to flow at 30 per cent. This would result into a stable structure and will not lead to outflank.

It is desirable to provide length of the level portion equal to the width of the stream at RTL at defined cross-section plus 2 to 5 m on either side. The length of rising face walls will be governed by the difference between Protected Bed Level (PBL) and RTL and the gradient for the protected bed. This gradient should preferably be 1 in 30 in a flat terrain or shallow stream and may be steeper in hilly terrain and/or deep gorge but should be limited to 1 in 15.

"For the structural stability and better hydraulic performance", it is desirable that batter should be provided on the outside faces of the headwalls. At least downstream face wall should have batter on downstream side. Road level corners of the headwalls should be provided with suitable rounding. The face walls may be constructed in cement concrete (M15) or random rubble masonry or some suitable material. Care should be taken to keep the top of coping exactly at the same level as that of the road top.

Foundation of the level face wall and 1 to 2 m portion of the raised face wall should be taken sufficiently deep to avoid exposure due to scouring. Extra care should be taken of the downstream face wall in erosive strata.

(a) When the height of causeway is less than 1.2 m above the bed level, the depth of foundations may be within 1.5 m in soils other than purely sandy soils. For sandy soils this may be taken as 1.8 m.

(b) When the height is upto 3m, the depth of foundations may be taken upto 2.5 m. in normal soils.

(c) The general depth of foundations in different strata may be as follows:

Hard Rock	-	300 to 450 mm
Soft Rock	-	600 to 900 mm
Hard Moorum	-	1.20 m
Soft Moorum	-	1.50 m
Expansive Soils, like, Black	-	1.50 to 2.50 m with
Cotton Soil	-	Usual precautions

(d) Further refinement in the depth of foundation can be done by carrying out elaborate scour calculations.

(e) Foundations in erosive strata such as soils, sand, silt, etc. should be protected on downstream side with suitable aprons.

Protective apron : Due to 70 per cent obstruction at road level, a causeway acts, like, a weir and an increase in velocity of flow causes scouring on the downstream side. In soils prone to scouring, protection of the downstream side bed is essential to protect the foundation of the headwall.

Protection may consist of stone apron and toe wall. Protection should be provided for the full width of the stream at the causeway location.

(a) For velocities through pipes upto 2.00 m/sec and an afflux upto 450 mm, a 2.5 m long apron with 450 mm thick rubble mat and toe wall should be provided.

(b) For velocities through pipes more than 2.00 m/sec and an afflux upto 900 mm, a 4.00 m long apron with 900 mm thick stone mat upto 2.00 m and then same reduced to 300 mm at the toe end with toe wall, should be provided.

(c) In no case, the apron length should be less than three times the height of vented causeway above the apron level.

Road crust or paving over causeway : Since a causeway is expected to allow the flood waters to pass over it and is also expected to serve the traffic immediately after the flood recedes, the road surface on the causeway should be so chosen, that it does not get damaged due to frequent overtopping.

Sufficiently stable pavement should be provided for the full width of the causeway and the protected bed portion. For approach in cutting, paved side drains should be provided and portion upto 1.5 m height along the side slopes should be provided with rubble pitching. Similarly, paving over causeway may comprise of:

(i) Cement concrete pavement laid over WBM

(ii) Stone sett pavement on suitable surface

(iii) Rigid pavement with thin carpet

7.2.3. Design procedure : Simple approach in designing the causeways by Field Engineers is given below. As explained earlier, the important components of the vented causeway are vents, rising face walls and paved road surface, which together ensure stability and prevent outflanking. In that case, the flow condition is analysed with respect to top of protected bed and if the percentage obstruction to flow at that level is kept below 30 per cent, then normally no outflanking takes place. Thereafter at subsequent floods with higher levels than PBL, the percentage obstruction will go on reducing and the structure becomes safe in all conditions. For designing, the Field Engineers should find out defined cross-section in the vicinity which represents soil conditions truly and all the calculations as mentioned below should be based on the same.

Step by step procedure :

(i) Normal hydraulic data, such as, catchment area, annual rainfall, HFL, site plan, L Section, tide level, etc. are collected.

(ii) Defined cross-section to a natural scale is plotted.

(iii) The cross-section of crossing at proposed location to the natural scale is plotted.

(iv) The RTL is decided as low as possible and transferred to the same to the defined cross-section.

(v) The area below RTL is calculated at the defined cross-section.

(vi) The vent area is calculated, i.e., 30 per cent of the area "X" [Refer para 7.1.4 "X" of main guidelines *(Appendix-7.1)* in case of scanty rainfall] and arrive at the area "A".

(vii) The length of horizontal portion of the face wall and length of rising face wall are decided by trial with following guidelines:

(a) Length of horizontal portion should be equal to bed width of the channel plus 4 to 10 m additional length
(b) Suitable gradient of rising face wall is assumed between 1:15 to 1:30.
(c) For first trial a 300 mm level difference is assumed between RTL and PBL.

(viii) The RTL and PBL are transferred to defined cross-section. This can be achieved by matching the sill level of the vents with that of the lowest bed level of the defined cross-section.

(ix) The area of flow available at the vented causeway upto protected bed is calculated. This consists of the area of vents and the area between road level and protected bed top level - "X" + = "AC".

(x) The area at the defined cross section is calculated for the corresponding level of protected bed.

$$Y+X = \text{"AN"}$$

(xi) The percentage obstruction to flood shall be:

$$(AN - AC) / AN \times 100$$

If the obstruction is not less than 30 per cent, then steps (vii) to (xi) are repeated by increasing the top level of the protected bed by 200 mm.

(xii) The proposal, which would give percentage obstruction less than 30 per cent is finalised. The worked out example is given below:

Worked out example

Name of work – Construction of a Causeway (16 Rows of 1000 mm diameter)

Hydraulic Data

Parameter	Data	Unit
Catchment Area	11.250	Sq. km
Bed width of define cross-section	25	Metre
Bank width of define cross-section	42	Metre
HFL	102.42	m
LBL (Lowest Bed Level)	98.905	m
Discharge by Inglis Formula	508.00	Cumec
Protected Bed Level	100.90	m
RTL	99.96	m
Annual Rain Fall	1250	mm

Design of Vents

(i) Provide vent area 30 per cent of area on defined cross-section of RTL, i.e., 25x (99.96-98.905) = 26.375 sqm.

$$= \frac{26.375 \times 30}{100} = 7.913 \text{ sqm}$$

(ii) Number of 900 mm diameter pipes

$$= \frac{7.913}{\frac{\pi}{4} \times (0.9)^2} = 12.44$$

Say 13 Numbers

(iii) Provide 16 no. of pipes as pipes can be accommodated in bed width, i.e., 25 m at defined cross-section.

Calculations of Area on defined cross-section at RTL 100.765

Chainage	GL m	RTL m	Difference Between RTL & GL	Mean Difference m	Length m	Wetted Area Sq. m
22.2	101.705	101.705	-	-	-	-
20	1-1.445	101.705	0.261	0.13	2.20	0.286
15	100.695	101.705	1.01	0.635	5.0	3.175
10	100.125	101.705	1.5	1.295	5.0	6.475
5	100.045	101.705	1.66	1.620	5.0	8.10
0	99.955	101.705	1.75	1.705	5.0	8.525
5	99.695	101.705	2.01	1.880	5.0	9.46
10	99.365	101.705	2.34	2.175	5.0	10.875
15	99.995	101.705	1.71	2.025	5.0	10.125
20	100.795	101.705	0.91	1.310	5.0	6.55
25	100.605	101.705	1.1	1.005	5. 0	5.025
30	101.165	101.705	0.54	0.820	5.0	4.1
35	101.615	101.705	0.09	0.315	5	1.575
35.8	101.705	101.705	-	0.045	5.8	0.036

Total : 74.277 Sq. m.

Calculations of Area between RTL and PBL on existing cross-section

Chainage	GL m	RTL m	Difference Between RTL & GL	Mean Difference m	Length m	Wetted Area Sq. m
34	100.9	100.9	-	-	-	-
16	99.96	100.9	0.94	0.47	18	8.46
0	99.96	100.9	0.94	0.94	16	15.04
16	99.96	100.9	0.94	0.94	16	15.04
34	100.9	100.9	-	0.47	18	8.46

Total 47.00 Sq. m.

Percentage Obstruction

A1 = Area provided through vent

= $16 \times 0.7854 \times (0.9)^2$

= 10.18 Sqm

A2 = Area of protected bed,
i.e., Area between road top and top of protected bed

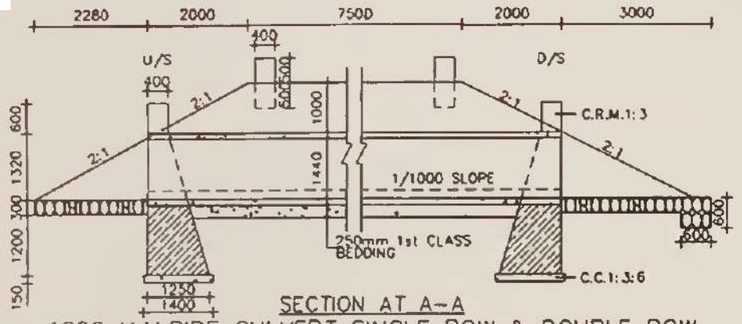
= 47. 00 Sq. m

B = X + Y = Area of define cross-section corresponding to protected bed top

Per cent Obstruction = $\left(1 - \frac{A1+A2}{B}\right) \times 100$

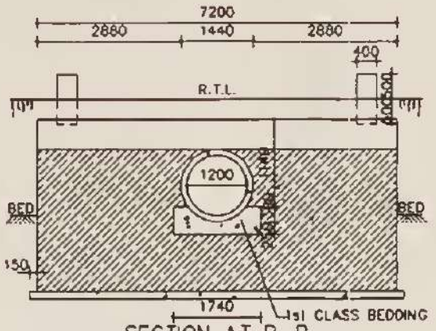
= $\left(1 - \frac{10.18+47.00}{74.24}\right) \times 100$

= 23 < 30 per cent



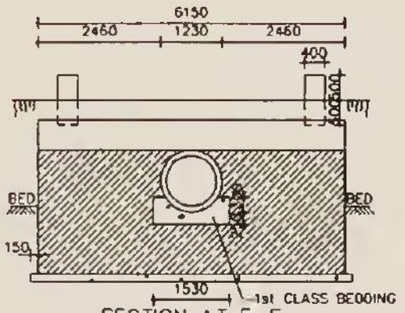
SECTION AT A–A

1200 M.M.PIPE CULVERT SINGLE ROW & DOUBLE ROW



SECTION AT B–B

SINGLE ROW CULVERT 1200 M.M.



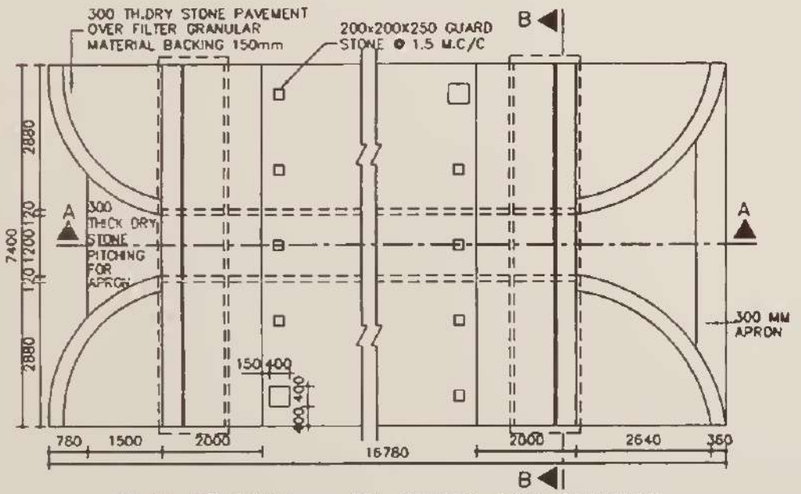
SECTION AT E–E

1000M.M. DIA. CULVERT

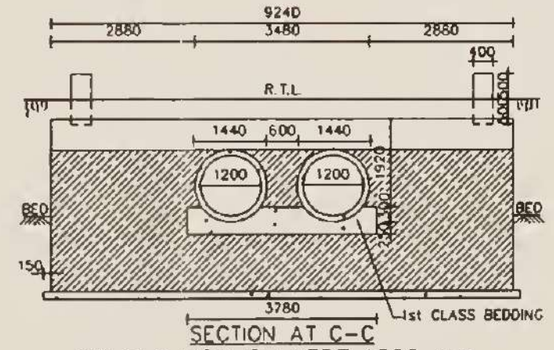
NOTES: –

1. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED.
2. THE PIPES SHALL BE R.C.C. NP.3 NON PRESSURE PIPES. THE SPECIFICATIONS OF PIPES SHALL BE AS PER I.S.458 OF 1988.
3. MINIMUM CUSHION ABOVE PIPE INCLUDING ROAD CRUST SHALL BE 1.0M.
4. QUANTITIES OF ITEMS OF WORK REQUIRED IN THE DESIGN ARE GIVEN IN TABLE NO.1. THE COST OF PIPE WITH TRANSPORTATION COST UPTO SITE EXCLUDED.
5. IN GHATS IF DOWN STREAM IS LOW. SLOPE MAY BE INCREASED UPTO 1:20, IF UP STREAM IS HIGH HALF ROUND WELL BE PROVIDED.
6. CLEAR DISTANCE BETWEEN PIPES MAY BE ADOPTED 500mm FOR 1000ø PIPES (UPTO 6 ROWS) & 600mm FOR 1200ø PIPES (UPTO 5 ROWS), LENGTH OF HEAD WALL WILL BE :–
7. PARAPETS COULD ALSO BE BUILT WITH BRICK MASONRY IN C.M.1:3 OR CEMENT CONCRETE 1:3:6.

ROWS	1000 DIA. PIPE	1200 DIA. PIPE
SINGLE	6150	7400
DOUBLE	7880	9240
THREE	9610	11280
FOUR	11340	13320
FIVE	13070	15360
SIX	14800	–

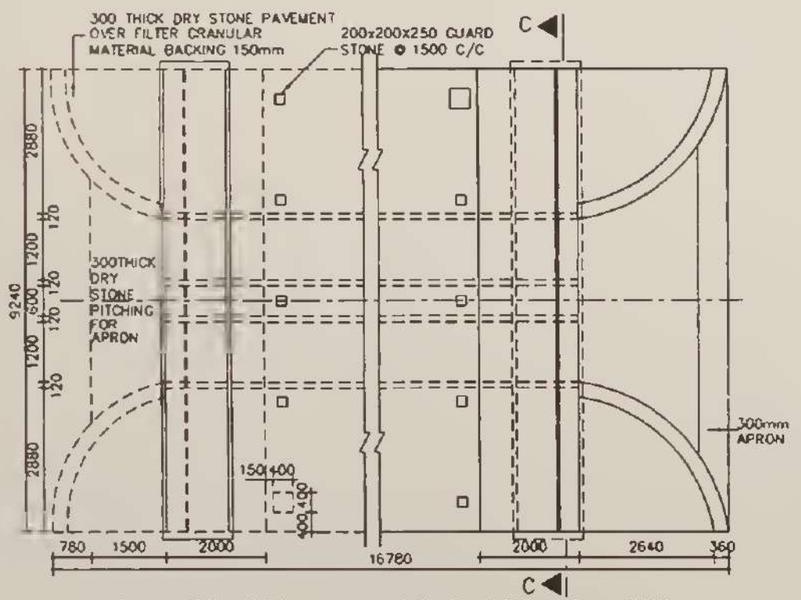


PLAN OF 1200mm DIA SINGLE ROW CULVERT

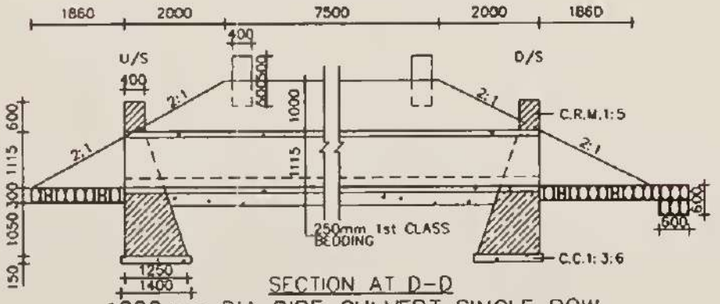


SECTION AT C–C

DOUBLE ROW CULVERT 1200 mm.

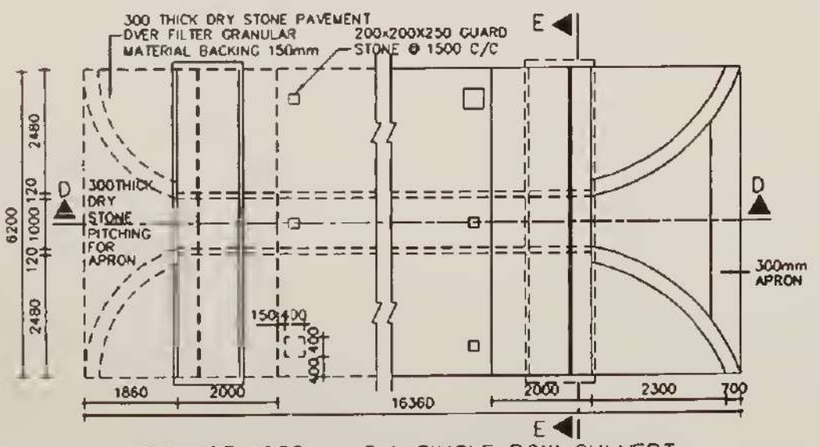


PLAN OF 1200mm DIA DOUBLE ROW CULVERT



SECTION AT D–D

1000mm DIA PIPE CULVERT SINGLE ROW



PLAN OF 1000mm DIA SINGLE ROW CULVERT

SR. NO.	ITEM OF WORK	PARTICULARS	1000mm SINGLE ROW	1200mm SINGLE ROW	1000mm DOUBLE ROW
1.	2.	3.	4.	5.	6.
1.	EXCAVATION	QUANTITY	61.46CU.M.	77.27CU.M.	98.04CU.M.
2.	FOUNDATION CONCRETE M–15	QUANTITY	02.71CU.M.	03.23CU.M.	04.01CU.M.
3.	FORMWORK	QUANTITY	15.82SQ.M.	16.81SQ.M.	30.60SQ.M.
4.	C.R.STONE MASONRY IN CM 1:4/1:5	QUANTITY	24.48CU.M.	34.85CU.M.	39.72CU.M.
5.	CEMENT CONCRETE 1:2:4	QUANTITY	06.26CU.M.	06.32CU.M.	14.54CU.M.
6.	BOULDER PITCHING APRON ETC.	QUANTITY	10.08CU.M.	13.05CU.M.	16.30CU.M.

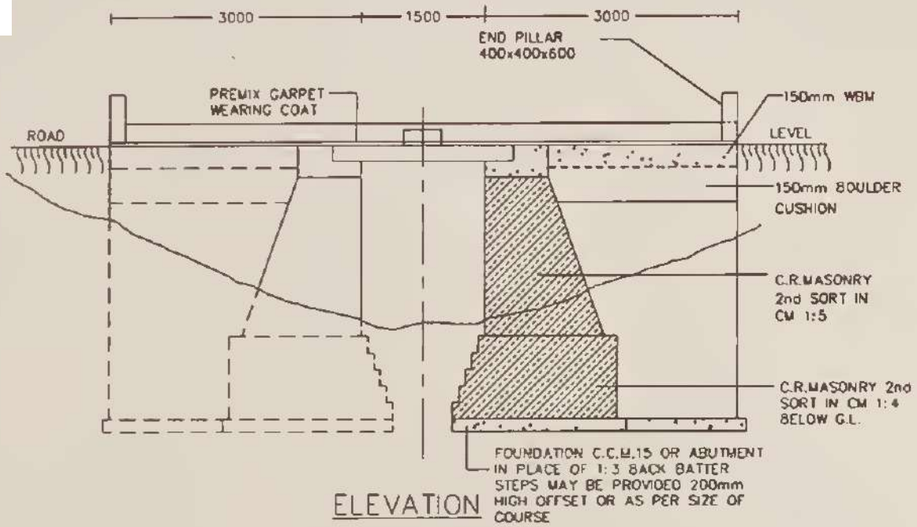
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

DRG.TITLE.

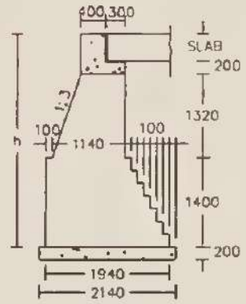
DETAILS OF PIPE CULVERTS 7.5 M. OVERALL WIDTH AT ROAD TOP

PLATE NO.-7.01

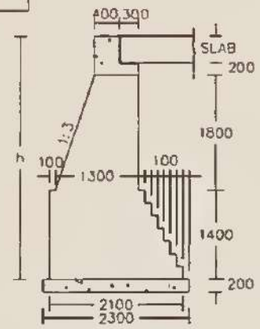


ELEVATION

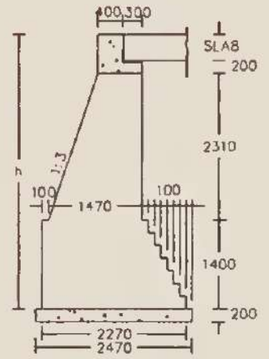
TOP SLAB THICKNESS
FOR 1.5M SPAN = 210
FOR 2.0M SPAN = 240
FOR 3.0M SPAN = 300



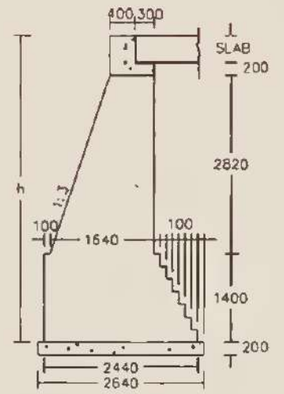
SPAN	HEIGHT
1.5	3130
2.0	3160
3.0	3220



SPAN	HEIGHT
1.5	3610
2.0	3640
3.0	3700

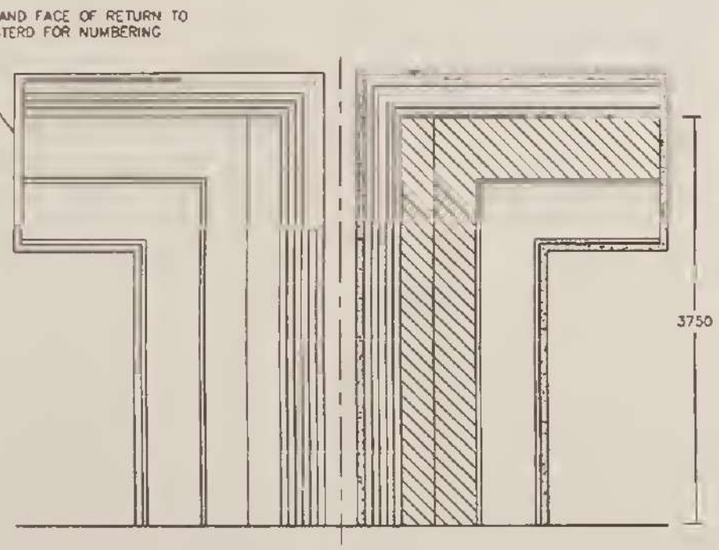


SPAN	HEIGHT
1.5	4120
2.0	4150
3.0	4210

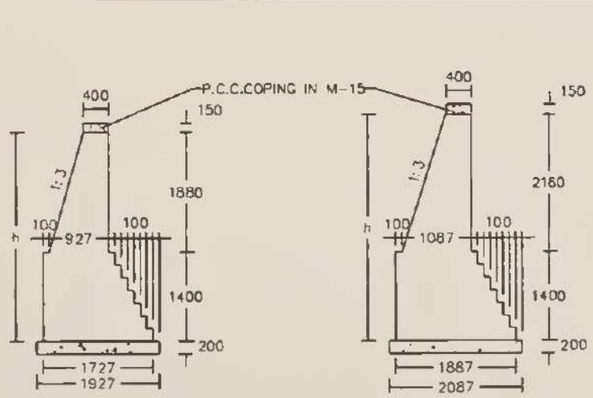


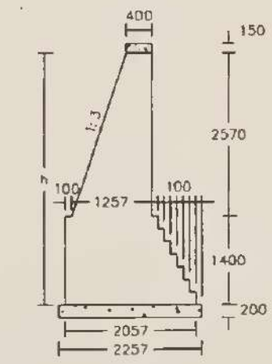
SPAN	HEIGHT
1.5	4630
2.0	4660
3.0	4720

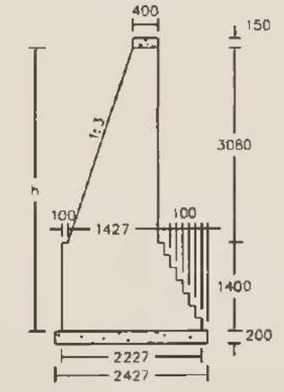
DIFFERENT SECTIONS OF ABUTMENT FOR 1.5M SPAN & HEIGHT 3.0M TO 4.7M



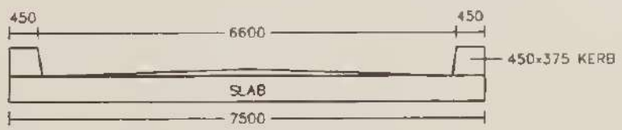
HALF PLAN
(TYPICAL DETAILS OF A CULVERT)



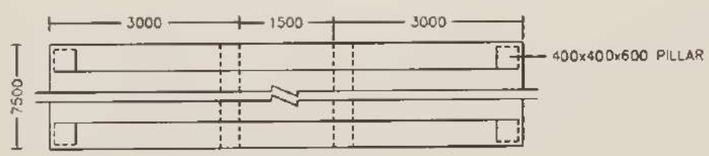




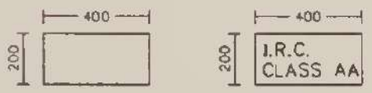
DIFFERENT SECTIONS OF RETURN FOR 2.0M SPAN & HEIGHT 3.0M TO 4.5M

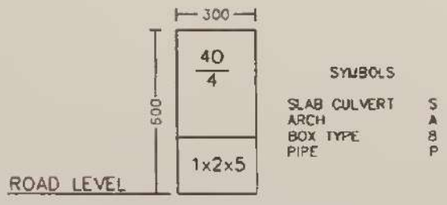


CROSS SECTION



PLAN





NUMBERING OF CULVERT
(ON 400X400X600 RCC PILLARS AT 4 ENDS)

NOTES :

1. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED.
2. COPING, DIRT WALL FOR ABUTMENT & COPING FOR RETURN OF CULVERTS & SMALL BRIDGES IS P.C.C. COPING. PROVIDE SURFACE STEEL 8Φ200 c/c BOTHWAYS ON EXPOSED SURFACE OF ALL PCC MEMBER.
3. THE HEIGHT OF CULVERT SHALL BE FROM THE TOP OF FOOTING TO THE TOP OF DECK SLAB.
4. THE OVER SIZE METAL CUSHION 150mm THICK SHALL BE PROVIDED FOR FULL AREA BETWEEN RETURNS. THIS WILL BE FOLLOWED BY 150mm THICK W.B.M. AND 75mm BITUMINOUS WEARING COAT.
5. THE WEARING COAT OVER THE DECK SLAB AND BETWEEN RETURNS SHALL BE AS: – 20mm PREMIX CARPET WITH SEAL COAT (5mm)
6. THE TOP SURFACE OF ABUTMENT CAP SHALL PAINTED BY BITUMEN AND GAP(EXP.JOINT) BETWEEN SLAB & DIRT WALL SHALL BE FILLED WITH BITUMEN OR OTHER FILLING MATERIAL.
7. SECTIONS CAN BE ADOPTED FOR WIDTHS 7.5M.,6.4M.AND 6.0M.

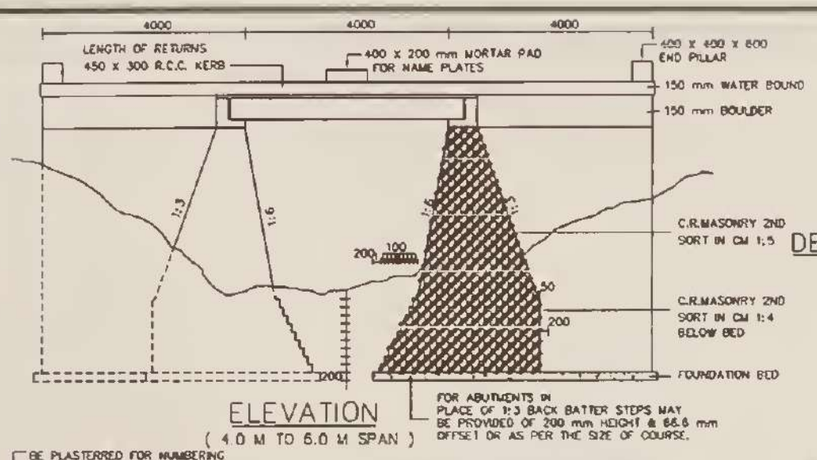
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

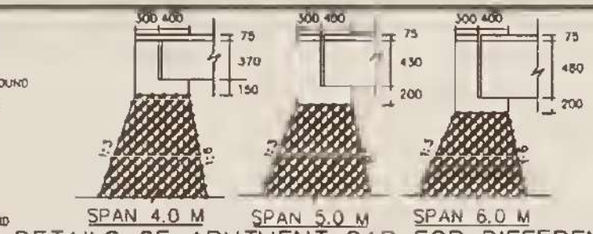
DRG.TITLE:

SECTIONS OF ABUTMENT & RETURN
SPANS 1.5 M. TO 3.0 M. FOR P.C.C./MASONRY

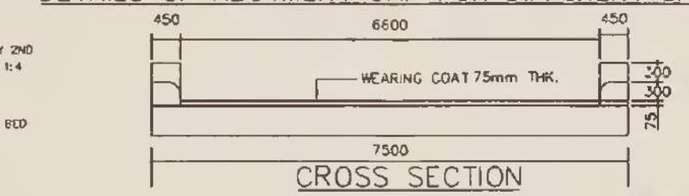
PLATE NO.-7.02



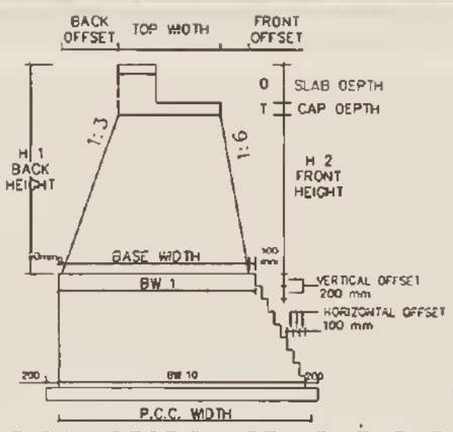
ELEVATION
(4.0 M TO 6.0 M SPAN)



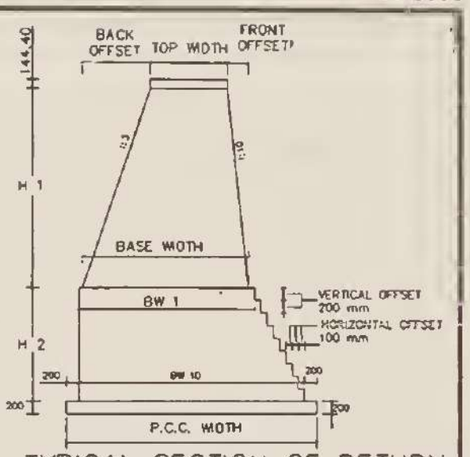
DETAILS OF ABUTMENT CAP FOR DIFFERENT SPAN



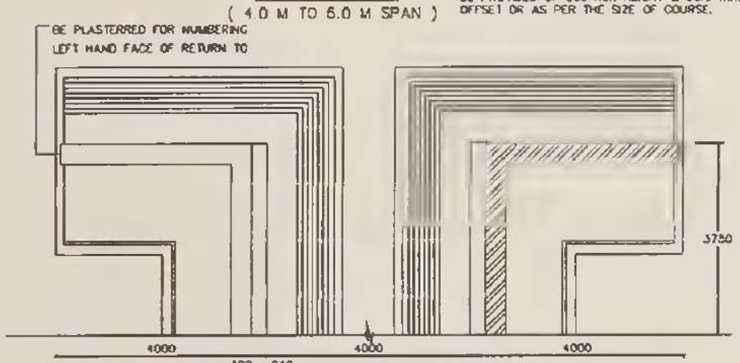
CROSS SECTION

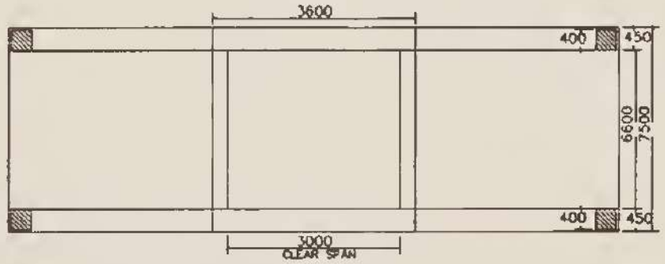


TYPICAL SECTION OF ABUTMENT
(REFER TABLE NO.1.)

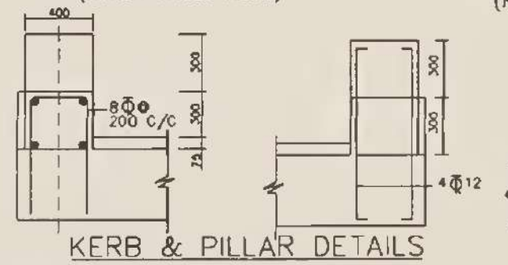


TYPICAL SECTION OF RETURN
(REFER TABLE NO.2.)



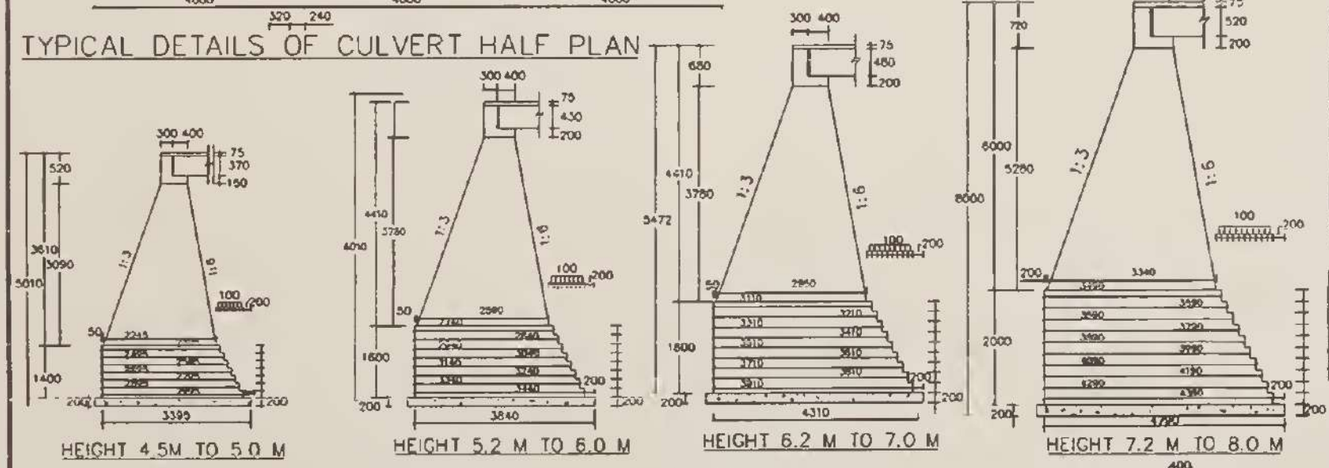


PLAN

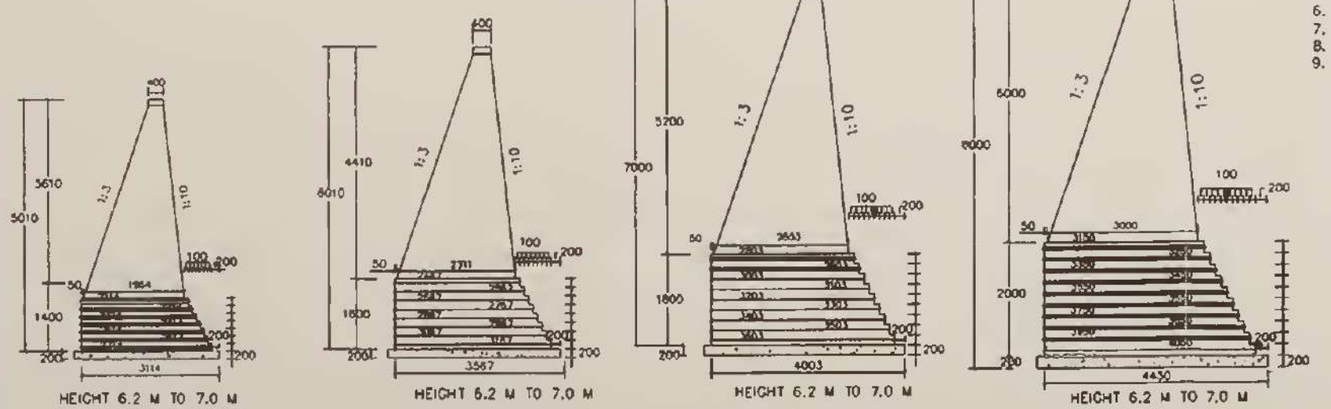


KERB & PILLAR DETAILS

TYPICAL DETAILS OF CULVERT HALF PLAN



SECTION OF ABUTMENTS



SECTION OF RETURN WALL

TABLE NO. 1 ABUTMENT SECTION

SPAN	SPAN DEPTH	CAP DEPTH	TOTAL HEIGHT	BACK OFFSET	FRONT OFFSET	BACK OFFSET	FRONT OFFSET	TOP WIDTH	BASE WIDTH	BW1	BW2	BW3	BW4	BW5	BW6	BW7	BW8	BW9	BW10	P C C WIDTH
4000	370	150	5010	3610	3090	1030	515	700	2245	2395	2495	2595	2695	2795	2895	2995				3395
5000	430	200	5010	3610	2980	933	497	700	2190	2340	2440	2540	2640	2740	2840	2940				3340
6000	480	200	5000	3600	2920	973	487	700	2160	2310	2410	2510	2610	2710	2810	2910				3310
4000	370	150	6010	4410	3890	1297	648	700	2545	2795	2895	2995	3095	3195	3295	3395	3495			3895
5000	430	200	6010	4410	3780	1260	630	700	2590	2740	2840	2940	3040	3140	3240	3340	3440			3840
6000	480	200	6000	4400	3720	1240	620	700	2560	2710	2810	2910	3010	3110	3210	3310	3410			3810
4000	370	150	6010	5210	4690	1563	782	700	3045	3195	3295	3395	3495	3595	3695	3795	3895			4295
5000	430	200	7010	5210	4580	1527	763	700	2990	3140	3240	3340	3440	3540	3640	3740	3840	3940		4340
6000	480	200	7000	5200	4520	1507	753	700	2960	3110	3210	3310	3410	3510	3610	3710	3810	3910		4310
7000	520	200	8000	6000	5280	1760	880	700	3340	3490	3590	3690	3790	3890	3990	4090	4190	4290	4390	4790

TABLE NO.2 RETURN SECTION

COPING DEPTH	HEIGHT H 1	HEIGHT H 2	BACK OFFSET	FRONT OFFSET	TOP WIDTH	BASE WIDTH	BW1	BW2	BW3	BW4	BW5	BW6	BW7	BW8	BW9	BW10	P C C WIDTH
150	3610	1400	1203	361	400	1964	2114	2214	2314	2414	2514	2614	2714				3114
150	4410	1600	1470	441	400	2311	2561	2561	2661	2761	2861	2961	3061	3161			3561
150	5200	1800	1733	520	400	2653	2803	2903	3003	3103	3203	3303	3403	3503	3603		4003
150	6000	2000	2000	800	400	3000	3150	3250	3350	3450	3550	3650	3750	3850	3950	4050	4450

NOTES:

1. THE HEIGHT OF CULVERT SHALL BE FROM TOP OF FOUNDATION CONCRETE TO TOP OF SLAB EXCLUDING WEARING COAT.
2. OVER SIZE METAL PACKING 150mm THICK SHALL BE PROVIDED IN FULL AREA BETWEEN RETURNS THIS WILL BE FOLLOWED BY 150mm THICK WATER BOUND MACADAM AND WEARING COAT.
3. THE WEARING COAT OVER THE DECK SLAB & BETWEEN RETURNS SHALL BE 20mm PRE MIX CARPET WITH 5mm SEAL COAT.
4. PROVIDE 6mm THICK PRE MOULDED BITUMINOUS PAD ON THE ABUTMENT CAP & BETWEEN DECK SLAB AND DIRT WALL FOR EXPANSION JOINT.
5. PROVIDE ONE WATER SPOUT AT THE CENTRE OF SLAB IN PARAPET WALL PROVIDED 1 ROW OF WEEP HOLES AT 2000 C/C AND AT 1000 C/C HEIGHT ABOVE BED LVL FOR ABUTMENT.
6. SPECIFICATION FOR R.C.C. SLAB AS PER ORG. NO. CONCRETE 1:1.5:3. STEEL-HYSD BARS AS PER IS-1786.
7. LENGTH OF RETURN WALL FOR 5.2M TO 6.0M HEIGHT SHALL BE 5.0 AND 6.0M TO 7.0M.
8. ALL DIMENSSIONS GIVEN ARE IN mm UNLESS & UNTILL STATED.
9. COPINGS DIRT WALL FOR ABUTMENT & COPING FOR RETURN OF CULVERTS AND SMALL BRIDGES PCC COPING. PROVIDE SURFACE STEEL 8 ø @ 200 c/c BOTHWAYS ON EXPOSE SURFACE OF ALL PCC MEMBERS.

SPECIFICATION

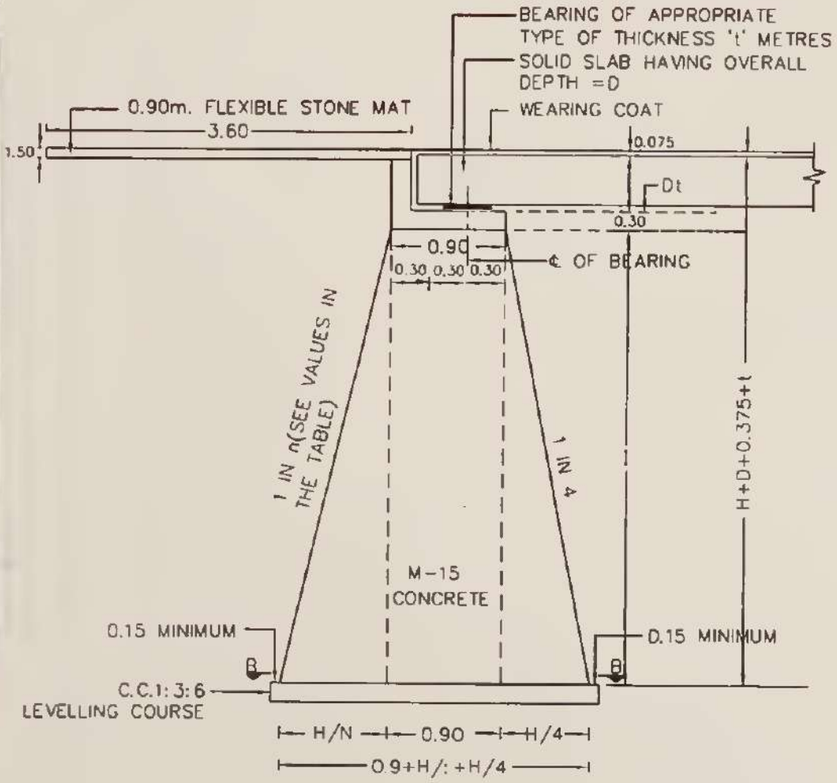
a THESE SECTION FOR CONCRETE M-15
b C.R. STONE MASONRY IN CM 1:5 ABOVE BED LVL. & 1:4 BELOW BED LVL.
c BRICK MASONRY IN CM 1:4
d WITH BRICKS HAVING STRENGTH >70KG/CM
e COPING & CAPS-1:2:4 CONCRETE
f MAXIMUM HEIGHT 8.0 M
g MAXIMUM SPAN 10.0 M

RURAL ROADS MANUAL
CULVERTS AND SMALLL BRIDGES

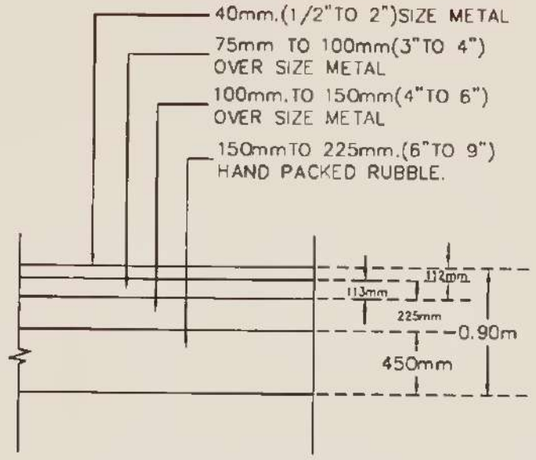
DRG.TITLE.

SECTION OF ABUTMENT & RETURNS WALL FOR 4.0 M. TO 6.0 M. SPAN FOR PCC/MASONRY

PLATE NO.-7.03



TYPICAL SECTION



FLEXIBLE STONE MAT

(SEE NOTE-9)

TABLE-1 DETAILS OF TYPE SECTION

(M-15 CONCRETE)

SR. NO.	HEIGHTS IN METRE "H"	VALUS OF BACK BATTER 1 IN n	
		TAR PAPER BEARING	ELASTOMERIC BEARING
1	UP TO 4.50	1:4	1:6
2	4.51 TO 6.00	1:4	1:6
3	6.01 TO 8.00	1:3	1:4

GENERAL NOTES: -

1. I.R.C. STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES SECTION I TO IV HAVE BEEN USED IN THE DESIGN EXCEPT STATED OTHERWISE BELOW.
2. THE SECTIONS HAVE BEEN DESIGNED AS PER IRC-6 : 2000.
3. BUOYANCY EFFECT TO THE EXTENT OF 15% HAS BEEN CONSIDERED IN THE DESIGN.
4. THE PROPERTIES OF THE BACK FILL HAVE BEEN ASSUMED AS FOLLOWS :-
   A) DRY DENSITY-------1.80T/cu. m.
   B) ANGLE OF INTERNAL FRICTION =30°
   C) ANGLE OF WALL FRICTION = 20°
   D) COHESION (C) = 0.
5. THE HORIZONTAL FORCES ON ABUTMENTS DUE TO BREAKING EFFECT, TEMPERATURE VARIATION ETC. HAVE BEEN TAKEN AS FOLLOWS :-
   A) TAR PAPER BEARINGS OR NO BEARINGS.
      HORIZONTAL FORCE= H/2+u RD WHERE: -
      H= BRAKING FORCE
      u= COEFFICIENT OF FRICTION BETWEEN SOLID SLAB & TAR PAPER OR CONCRETE OVER CONCRETE.
      RD= REACTION DUE TO DEAD LOAD OF SUPERSTRUCTURE.
   B) ELASTOMERIC BEARING.
      HORIZONTAL FORCE =H1+H2 WHERE
      H1=AGd/t Xn
      H1=FORCE DUE TO TEMPERATURE VARIATION AND SHRINKAGE.
      H2=HALF THE BEARING FORCE.
      A= AREA OF EACH ELASTOMERIC BEARING.
      G= MODULUS OF REGIDITY FOR ELASTOMERIC BEARING.
      d= HALF THE TOTAL MOVEMENT DUE TO TEMPERATURE VARIATIONS AND SHRINKAGE.
      t=THICKNESS OF ELASTOMERIC BEARING.
      n=NO.OF BEARINGS ON ABUTMENT.
6. SEISMIC DESIGNS HAVE BEEN DONE AS PER I.S.1893-1970 & PERMISSIBLE STRESSES HAVE BEEN INCREASED BY 50% UNDER SEISMIC CONDITIONS.
7. THE 0.90m THICK FLEXIBLE STONE MAT SHALL BE PROVIDED AS SHOWN IN THE SKETCH.
8. THE TYPICAL SECTIONS ARE WORKED OUT ASSUMING SPANS EQUAL TO 1.25 TIMES THE CORRESPONDING HEIGHTS OF SECTIONS. THESE SECTIONS ARE FOR GUIDANCE FOR ESTIMATION, EXACT STABILITY CALCULATIONS MAY HAVE TO BE DONE FOR DIFFERENT PARAMETRES.
9. BACK FILLING SHALL BE DONE AS PER APPENDIX 6 OF I.R.C. : 78-2000. WEEP HOLES SHALL BE PROVIDED AT 1000 mm C/C HORIZONTALLY & 1000 mm C/C VERTICALLY REGULARLY STAGGERED.
10. THE LEVELLING COURSE BELOW SHOULD BE PROVIDED WITH SUITABLE OFFSET (MINIMUM 0.15m) TO RESTRICT BASE PRESSURE ON SOIL WITHIN IT'S BEARING CAPACITY.
11. IN CASE OF DEEP FOUNDATIONS IF THE SOIL OF REQUIRED BEARING CAPACITY IS NOT MET WITH AT REASONABLE DEPTH THE SECTION B-B SHALL BE JUST BELOW MAXIMUM SCOUR LEVEL AND THE BOTTOM PORTION BELOW SECTION B-B UPTO FOUNDATION LEVEL SHOULD BE TAKEN VERTICALY DOWN WITH SUITABLE OFFSETS & ANULER SPACE REFILLED AND PROPERLY COMPACTED.
12. THE SECTIONS ARE APPLICABLE BOTH FOR HIGH LEVEL AND SUBMERSIBLE BRIOGES.
13. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
14. THE SECTIONS SHOWN APPLY TO SEISMIC ZONE I,II,III & IV.
15. WIDTH AT BASE COULD BE INCREASED/DECREASED AS PER SBC REQUIREMENT.

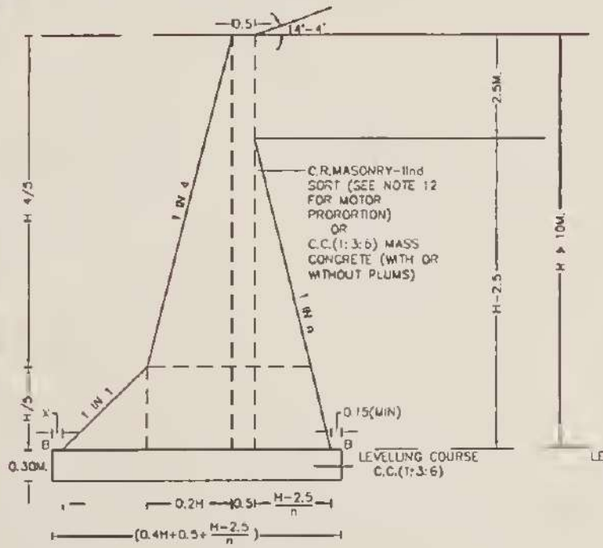
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

DRG.TITLE.

TYPE SECTION FOR ABUTMENTS (WITH SOLID SLAB DECKING)

PLATE NO.-7.04



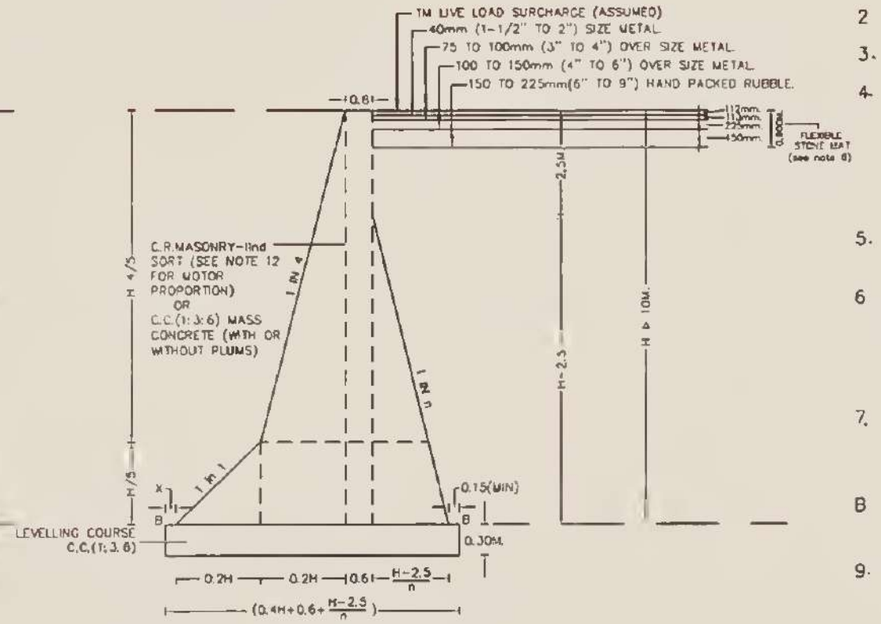
SECTION OF WING WALL

(NOT TO SCALE)

NOTE

THE MAXIMUM COMPRESSIVE STRESS AT SECTION 'B-B' ARE OF THE ORDER OF 30 T / M^2

H IS TOTAL HEIGHT



SECTION OF RETURN WALL

(NOT TO SCALE)

NOTE

THE MAXIMUM COMPRESSIVE STRESS AT SECTION 'B-B' ARE OF THE ORDER OF 30 T / M^2

TABLE VALUES OF n & x FOR DIFFERENT HIGHT OF WING WALL & RETURN WALL SECTIONS

SR. NO.	MATERIAL	HEIGHT IN METRES	VALUE OF BACK BETTER 1 IN n	VALUE OF PRONT OFFSETS 'X' IN METRES (MIN)
1	MASONRY SECTION	LESS THAN 10.00M.	1 IN 4	0.15
2	C.C. (1:3:6) MASS CONCRETE	UP TO 5.00M.	1 IN 5	0.30
		5.01 TO 10.00 M.	1 IN 6	0.50

NOTE

IF THE OFFSET EXCEEDS THE VALUES GIVEN IN ABOVE TABLE NECESSARY REINFORCEMENT SHOULD BE PROVIDED FOR THE SAME.

GENERAL NOTES:-

1. I.R.C. STANDARD SPECIFICATIONS & CODE OF PRACTICE FOR ROAD BRIDGE SECTION-I TO IV HAVE BEEN USED IN THE DESIGN EXCEPT STATED OTHERWISE BELOW.
2. THE SECTIONS HAVE BEEN DESIGNED FOR TWO LANES OF CLASS 'A' LOADING.
3. BUOYANCY EFFECT TO THE EXTENT OF 15% HAS BEEN CONSIDERED IN DESIGN.
4. THE PROPERTIES OF THE BACK FILL HAS BEEN ASSUMED AS FOLLOWS.
   a) DRY DENSITY=1.8 T/Cu. M., b) ANGLE OF INTERNAL FRICTION - 30°,
   c) ANGLE OF WALL FRICTION=20°, d) COHESION (C) - 0.
   e) SURCHARGE ANGLE OF BACKFILL FOR WING WALL (i)=14-4'. CORRESPONDING TO 1.2 BANK SLOPE (VERTICAL . HORIZONTAL)
5. THE SECTIONS PROVIDED FOR FACTOR OF SAFETY OF 2.00 & 1.50 AGAINST OVERTURNING FOR NON-SEISMIC & SEISMIC CONDITIONS RESPECTIVELY.
6. RETURNS ARE DESIGNED FOR AN EQUIVALENT LIVE LOAD SURCHARGE OF 1.00 m. FOR THIS PURPOSE 0.9 m. THICK FLEXIBLE STONE MAT SHOULD BE PROVIDED FOR FULL ROAD WIDTH BEHIND THE RETURN FOR THE ENTIRE LENGTH AS PER SKETCH SO AS TO DISTRIBUTE EFFECT LIVE LOAD.
7. THE ALLOWABLE TENSILE STRESSES UNDER NON-SEISMIC CONDITION HAVE BEEN TAKEN AS 7.0 t/sqm. FOR STONE MASONRY IN CM.(1:5),10t/sqm. FOR BRICK MASONRY IN CM(1:4) & 28t/sqm. FOR C.C. (1:3:6).
8. WING WALLS ARE DESIGNED FOR A SPLAY ANGLE OF 30 TO THE FLOW OF WATER (TO THE FACE OF ABUTMENT)
9. SEISMIC DESIGNS HAVE BEEN DONE AS PER IS:1893-1970 & PERMISSIBLE STRESSES HAVE BEEN INCREASED BY 50% UNGER SEISMIC CONDITIONS (REGARDING APPLICABLE) OF PARTICULAR ZONE TO ANY LOCATION, REFER SEISMIC MAP CORRESPONDING TO THAT OF I.S.:1893-1970)
10. BACKFILLING SHALL BE DONE AS PER APPENDIX 6 OF IRC:78-2000.
11. THE LEVELLING COURSE BELOW SHOULD BE PROVIDED WITH SUITABLE OFFSETS (AS IN TABLE) TO RESTRICT BASE PRESSURE ON SOIL BELOW TO ITS SAFE BEARING CAPACITY & FOR SAFETY AGAINST OVERTURNING.
12. THE PROPORTION OF CEMENT MORTARS FOR STONE MASONRY IS CM (1:5) AND FOR BRICK MASONRY CM (1:4) IN NON- SEISMIC CONDITIONS & CM(1:4) FOR SEISMIC CONDTIONS.
13. THE SECTIONS SHOWN APPLY TO SEISMIC ZONE-I,II,III & IV.
14. IN CASE OF DEEP FOUNDATONS, IF THE SOIL OF REQUIRED BEARING CAPACITY IS NOT MET WITH AT REASONABLE DEPTH, THE SECTION 'B-B' SHALL BE JUST BELOW THE MAXIMUM SCOUR LEVEL & THE BOTTOM PORTION (BELOW SECTION 'B-B' AND UPTO THE FOUNDATION LEVEL) SHOULD BE TAKEN VERTICALLY DOWN IN U.C.R. MASONRY IN CM (1:5) FOR C.R. MASONRY SECTION AND IN C.C. (1:3:6) FOR P.C.C. SECTION WITH SUITABLE OFFSETS AND SIDE TRENCHES REFILLED AND PROPERLY COMPACTED.
15. FOR SECTION WITH C.C.$_2$(1:3:6) NOMINAL SURFACE REINFORCEMENT SHOULD BE PROVIDED AT 2.5 Kg/M AS PER IRC:78-2001
16. ALL DIMENSIONS ARE IN mm UNLESS & UNTILL STATED.

RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

DRG.TITLE:

TYPE SECTION FOR RETURN WALLS AND WING WALLS

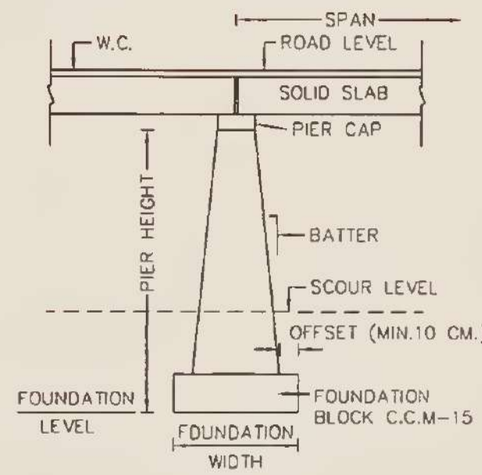
PLATE NO.-7.05

TABLE-I
SECTION DESIGNATION NO. FOR VARIOUS SPAN & HEIGHT.

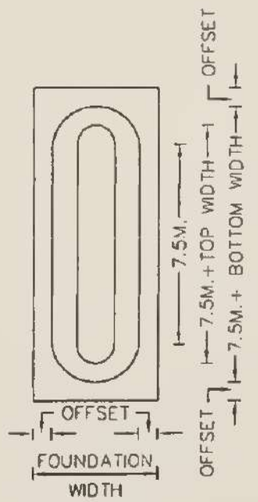
HEIGHT	CR STONE MASONRY IInd SORT IN			P.C.C. M-15	FOUNOATION WIOTH IN mm	
	CM.1:5	CM.1:4	CM.1:3		ON SOIL	ON ROCK
SPAN 5M.						
4.0	9	6	5	3	1850	2030
4.4	10	6	5	2	2000	2200
4.8	10	7	5	2	2100	2300
5.0	10	7	5	2	2200	2300
5.2	10	10	5	2	2200	2400
SPAN 6M.						
4.7	9	6	5	1	2000	2300
5.0	10	7	6	3	2300	2500
6.3	10	8	6	3	2400	2700
6.7	10	8	6	3	2600	2800
7.1	10	8	6	3	2600	2900
SPAN 7M.						
5.6	10	7	5	2	2300	2400
6.4	10	7	5	3	2400	2600
7.2	10	7	6	3	2600	2800
8.0	10	7	6	3	2800	3000
8.8	10	7	6	3	2800	3300
SPAN 8M.						
6.4	10	7	5	2	2300	2600
7.2	10	7	5	3	2400	2700
8.0	10	8	6	3	2400	2700
8.8	10	8	6	3	2700	3200
9.6	10	8	6	3	2800	3300
SPAN 9M.						
7.2	10	7	5	3	2600	2800
8.0	10	7	5	3	2700	3000
8.8	10	7	6	3	3000	3300
9.6	10	7	6	4	3000	3500
10.4	10	7	6	4	3000	3500
SPAN 10M.						
8.0	10	7	5	3	2700	3000
8.8	10	7	5	3	3000	3300
9.6	10	7	5	4	3300	3500
10.4	10	7	6	4	3300	3700
11.2	10	7	6	4	3400	3900

TABLE-II

SECTION OESIGNATION NO.	TOP WIOTH (mm)	BATTER
1	900	VERTICAL
2	1000	VERTICAL
3	1200	VERTICAL
4	750	1 IN 30
5	750	1 IN 25
6	900	1 IN 30
7	750	1 IN 20
8	900	1 IN 25
9	1000	1 IN 30
10	1000	1 IN 25



ELEVATION



PLAN

NOTES :-

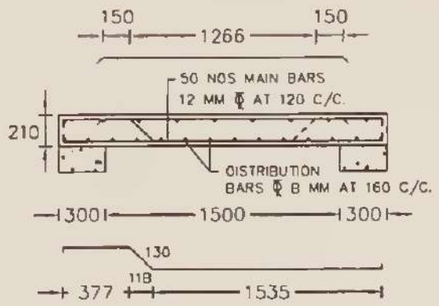
1. OESIGN OATA ASSUMEO FOR OESIGN.
   - 1.1 VELOCITY UPTO 4.5M./SEC.
   - 1.2 LIVE LOAO. I.R.C. CLASS A 2-LANES.
   - 1.3 SUPERSTRUCTURE R.C.C. SOLIO SLAB.
   - 1.4 BUYANCY
     FOUNOATION RESTING ON SOIL 100%
     FOUNOATION RESTING ON ROCK 50%
2. TYPE PLAN IS ALSO APPLICABLE TO SUBMERSIBLE BRIOGE.
3. S.B.C. OF FOUNOING STRATA 30 TON/M^2
4. SEISMIC EFFECT IS NOT CONSIOEREO.
5. FOUNOATION OEPTH
   - 5.1 FOR FOUNOATION ON SOIL THE MINIMUM OEPTH SHOULO BE 2M. BELOW SCOUR LEVEL.
   - 5.2 ANNULAR GAP SHOULO BE FULLY FILLEO IN ANO RAmmEO.
   - 5.3 EMBEOMENT IN SOFT ROCK ANO HARO ROCK SHOULO BE 1.5M. & 0.6M. RESPECTIVELY. FOR EXPOSEO ROCK EMBEOMENT SHOULO BE 1.5M.
6. PROVIOE FOUNOATION BLOCK 0.2M. WITH MINIMUM OFFSET OF 0.1M. AS SHOWN IN FIGURE.
7. ANNULAR GAP AROUNO PIER SHALL BE FILLEO UPTO ROCK TOP LEVEL BY M-10 CONCRETE.

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES

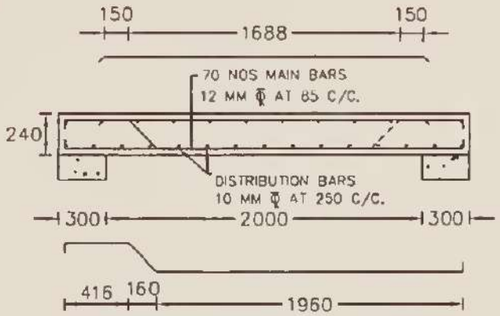
DRG.TITLE.

SECTION OF PIERS FOR HEIGHT UPTO 7.5 M. MASONRY/P.C.C.

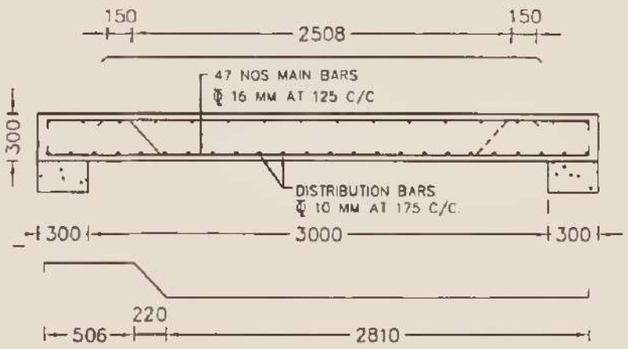
PLATE NO.-7.06



1.5 M. SPAN



2.0 M. SPAN

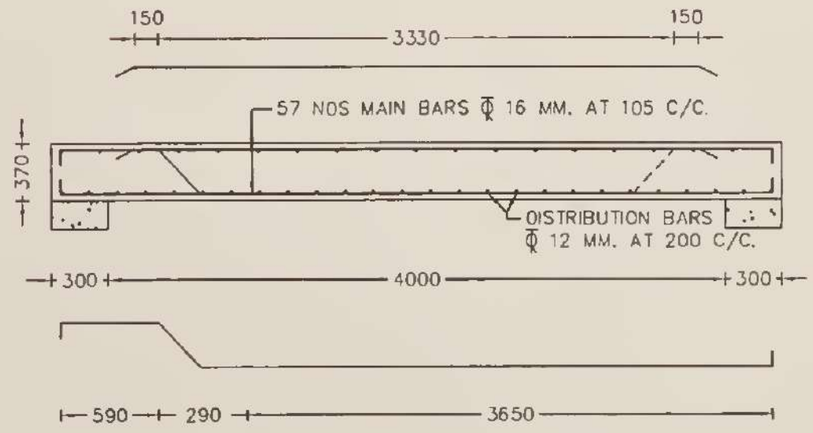


3.0 M. SPAN

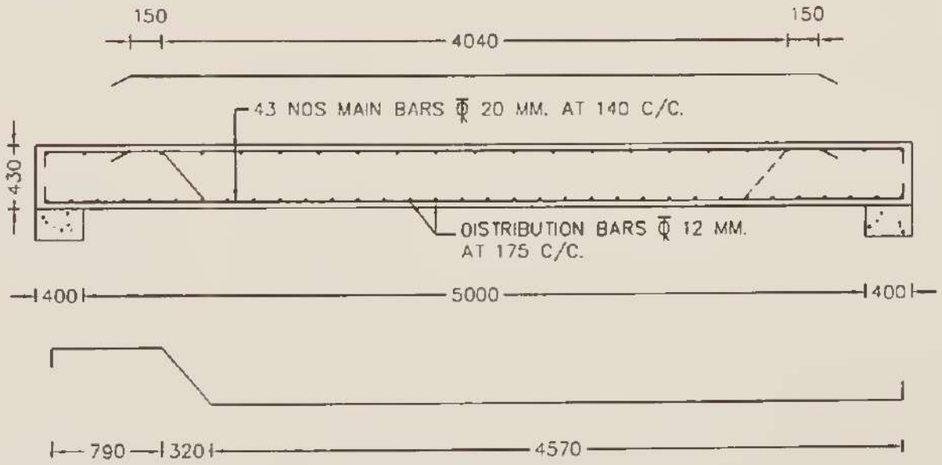
NOTES

1 CONCRETE – 1:1.5:3
2 STEEL – H.Y.S.D. AS PER I.S.1786.
3 COVER – 40mm.AT BOTTOM AND 40mm SIDE.
4 IN 1.5m., 2.0m., AND 3.0m.SPAN ONLY ONE BAR IS TO BE CRANKED, IN EACH SIDE IN FOUR BARS. IN ALL OTHER SPANS CRANK ALTERNATIVE BARS.
5. ALL BARS ARE CRANKED AT ONE END ONLY. THESE ARE PLACED WITH CRANK ON LEFT SIDE AND RIGHT SIDE ALTERNATIVELY.
6 SURFACE STEEL AT TOP LONGITUDINAL–10mm @ 300mm C/C. LENGTH AS SHOWN IN SKETCH
& TRANSVERSE–10mm @ 300mm C/C ALL THROUGHOUT IN LONGITUDINAL DIRECTION PROVIDE STEEL IN THE ZONE WHERE MAIN STEEL IS NOT AVAILABLE PLUS 150mm ON EITHER SIDE.

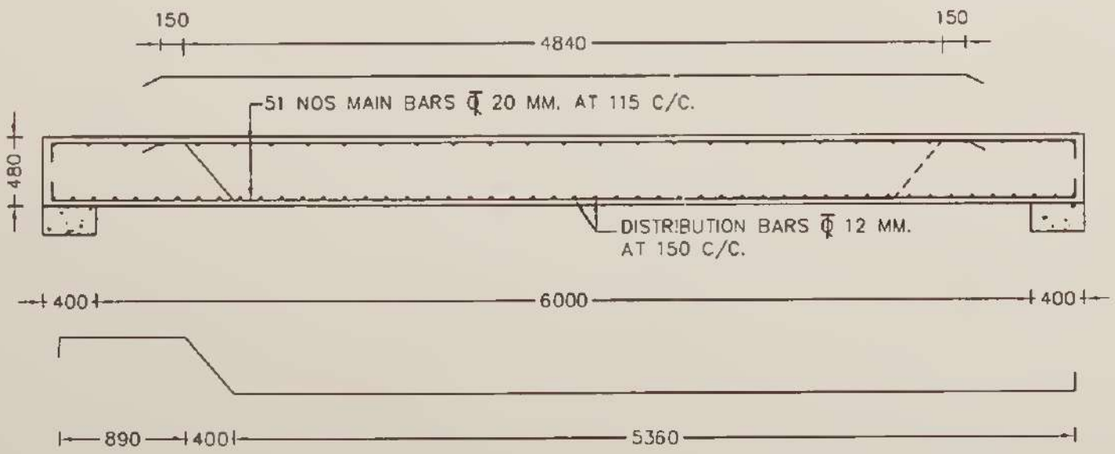
7. ALL DIMENSIONS ARE IN mm UNTILL & UNLESS STATED.



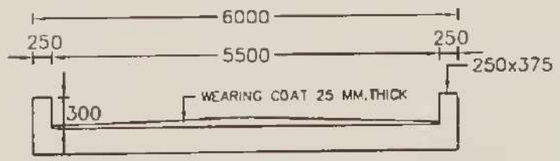
4.0 M. SPAN



5.0 M. SPAN



6.0 M. SPAN



CROSS SECTION OF CULVERT

6.0 M. SPAN

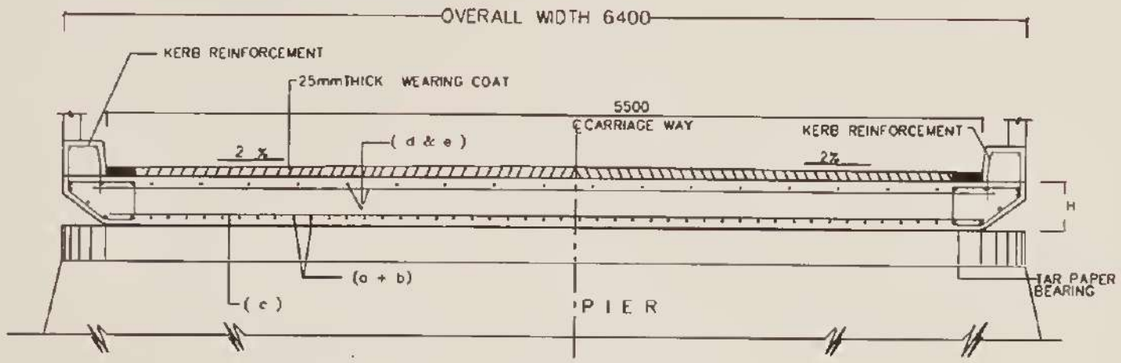
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

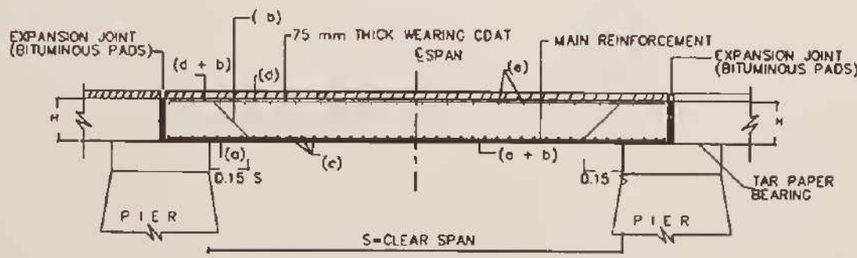
DRG.TITLE.

DETAILS OF SLABS 1.5 M. TO 6.0 M. CLEAR SPANS, OVERALL WIDTH 6.0 M.

PLATE NO.-7.07



CROSS SECTION



LONGITUDINAL SECTION

NOTES:

(A) GENERAL

1 THESE NOTES ARE APPLICABLE FOR THE STANDARD DRAWINGS FOR R.C.C. SOLID SLAB SUPERSTRUCTURE WITHOUT FOOTPATHS.

2 THESE DRAWINGS ARE APPLICABLE ONLY FOR RIGHT ANGLED BRIDGES.

3 ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE MENTIONED. ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED. NO DRAWING SHALL BE SCALED.

4 DESIGN CRITERIA :

I THE DESIGN IS ACCORDING TO THE FOLLOWING CODES
(a) I.R.C.: 5–2000
(b) I.R.C.: 6–2000
(c) I.R.C.: 21–2000

II THE FOLLOWING LOADS HAVE BEEN CONSIDERED IN THE DESIGN:
(a) TWO TRAINS OF CLASS A .
(b) DENSITY OF WEARING COAT IS 2.2t/m^3
(c) DENSITY OF CONCRETE IS 2.4 t/m^3

III THE DESIGNS ARE APPLICABLE FOR 'MODERATE' CONDITION OF EXPOSURE.

5 PUBLIC UTILITY SERVICES eg. WATER SUPPLY AND SEWERAGE PIPES SHALL NOT BE CARRIED OVER THE BRIDGE . IF NECESSARY, SPECIAL PROVISION FOR THE SAME SHALL BE MADE IN THE DESIGN.

6, 25 mm PREMOULDED BITUMINOUS EXPANSION PAD SHALL BE PROVIDED AS EXPANSION JOINT

7 SUPPORT FOR DECK SLAB SHALL PROVIDE A MINIMUM BEARING WIDTH OF
i) AT ABUTMENT – 600 mm
ii) AT PIER – 375 mm

8 TYPE /POSITION OF RETURN WALLS, RAILINGS GUARDS POSTS, RAMP etc. IN APPROACH PORTION SHALL BE DECIDED BY THE ENGINEER-IN-CHARGE.

9 . THERE SHALL BE A CLEAR JOINT BEWEEN PARAPET & KERB ON R.C.C. BOX RETURN/SOLID RETURN AND MAIN BRIDGE & RIDING RETURN.

10 IN CASE OF HIGH LEVEL BRIDGES, WATER SPOUTS OF 150 mm DIA G.I. PIPE SHALL BE PROVIDED AT 3 m c/c.

11 A CAMBER OF 2% SHALL BE PROVIDED IN WEARING COAT FOR BOTH CEMENT CONCRETE AND BITUMINOUES ROADS. THE THICKNESS OF DECK SLAB SHALL BE UNIFORM.

12 FOR THE SUPERSTRUCTURE IN HIGH LEVEL BRIDGE, RAILING SHALL BE OF R.C.C. PARAPETS.

13, TAR PAPER BEARING SHALL BE USED FOR SPANS UPTO 10 m.

14 0.90 m. THICK FLEXIBLE STONE MAT SHALL BE PROVIDED FOR FULL ROAD WIDTH BEHIND THE RETURN FOR A LENGTH OF 3.5 m.

(B) MATERIALS SPECIFICATIONS

Concrete :

1 CONCRETE SHALL BE OF DESIGN MIX AND SHALL HAVE MINIMUM 28 DAYS CHARACTERISTIC STRENGTH ON 150 mm CUBES FOR ALL ELEMENTS OF SUPERSTRUCTURE SHALL BE 25 MPa.

2 . HIGH STRENGTH ORDINARY PORTLAND CEMENT CONFORMING TO IS:8112 OR ORDINARY PORTLAND CEMENT CONFORMING TO IS:269 AND 43 GRADE CEMENT CONFORMING TO IS:12269 CAPABLE OF ACHIEVING THE REQUIRED DESIGN CONCRETE STRENGTH SHALL BE USED.

Reinforcement :

CLEAR COVER TO REINFORCEMENT: –
i) FOR SPANS UP TO & INCLUDING 6m : 25mm AT BOTTOM AND 40mm ON SIDE.
ii) FOR SPANS 7,8,9,10m : 40mm TO ALL REINFORCEMENT

ALL REINFORCING BARS SHALL BE HIGH YIELD STRENGTH DEFORMED BARS (GRADE DESIGNATION Fe 415) CONFORMING TO IS:1786.

Water :
WATER TO BE USED IN CONCRETING AND CURING SHALL CONFORM TO CLAUSE 302.4 OF IRC 21–2000.

(C) WORKMANSHIP/DETAILING

1 FOR ENSURING PROPER COVER OF CONCRETE TO REINFORCEMENT BARS , SPECIALLY MADE POLYMER COVER BLOCKS SHALL ONLY BE USED.

2 Construction Joints

I THE LOCATION AND PROVISION OF CONSTRUCTION JOINTS SHALL BE APPROVED BY ENGINEER-IN-CHARGE. THE CONCRETING OPERATION SHALL BE CARRIED OUT CONTINUOUSLY UPTO THE CONSTRUCTION JOINT.

II THE CONCRETE SURFACE AT THE JOINT SHALL BE BRUSHED WITH A STIFF BRUSH AFTER CASTING WHILE THE CONCRETE IS STILL FRESH AND IT HAS ONLY SLIGHTLY HARDENED.

III BEFORE NEW CONCRETE IS POURED , THE SURFACE OF OLD CONCRETE SHALL BE PREPARED AS UNDER:
a) FOR HARDENED CONCRETE, THE SURFACE SHALL BE THOROUGHLY CLEANED TO REMOVE DEBRIS AND MADE ROUGH.
b) FOR PARTIALLY HARDENED CONCRETE, THE SURFACE SHALL BE TREATED BY WIRE BRUSH FOLLOWED BY AN AIR JET.
c) THE OLD SURFACE SHALL BE SOAKED WITH WATER WITHOUT LEAVING PUDDLES IMMEDIATELY BEFORE STARTING CONCRETING TO PREVENT THE ABSORPTION OF WATER FROM NEW CONCRETE.

IV NEW CONCRETE SHALL BE THOROUGHLY COMPACTED IN THE REGION OF THE JOINT.

3. WELDING OF REINFORCEMENT BARS SHALL NOT BE ORDINARILY PERMITTED. PL. REFFER CLAUSE 30.6.6.5 OF I.R.C. 21–2000

4. LAPS IN REINFORCEMENT:
I MINIMUM LAP LENGTH OF REINFORCEMENT SHALL BE KEPT AS 50 d WHERE "d" IS THE DIAMETER OF BAR.
II NOT MORE THAN 25% OF REINFORCEMENT SHALL BE LAPPED AT ANY ONE LOCATION AND ALL JOINTS SHOULD BE WELL STAGGERED.

5. BENDING OF REINFORCEMENT BARS SHALL BE AS PER IS:2502

6. SUPPORTING CHAIRS OF 12mm DIAMETER SHALL BE PROVIDED AT SUITABLE INTERVALS AS PER IS:2502.

7. CONCRETE SHALL BE PRODUCED IN A MECHANICAL MIXER OF CAPACITY NOT LESS THAN 200 LITRES HAVING INTEGRAL WEIGH-BATCHING FACILITY AND AUTOMATIC WATER MEASURING AND DISPENSING DEVICE.

8. PROPER COMPACTION OF CONCRETE SHALL BE ENSURED BY USE OF FULL WIDTH SCREED VIBRATORS FOR CONCRETE IN DECK SLAB.

9. PROPERLY BRACED STEEL PLATES SHALL BE USED AS SHUTTERING.

10. SHARP EDGES OF CONCRETE SHALL BE CHAMFERED.

(D) PRECAUTIONS FOR SUBMERSIBLE BRIDGES : (SINGLE LANE BRIDGES SHALL BE PREFERABLY HIGH LEVEL ONLY)

i) STOPPERS SHALL BE PROVIDED ON D/S SIDE OF ALL PIERS AND ABUTMENTS.

WITH DISCONTINUOUS KERBS.

iii) WEARING COAT SHALL BE IN R.C.C.

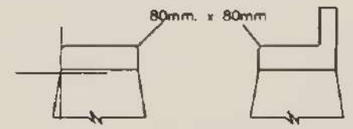
(E) GENERAL SPECIFICATIONS

THE WORK SHALL BE EXECUTED IN ACCORDANCE WITH MORT&H'S SPECIFICATION FOR ROAD AND BRIDGE WORKS (FOURTH REVISION) EXCEPT WHEREVER OTHERWISE MENTIONED.

(F)

FOR SPANS OF 12m. AND 15m. PIER CAPS AND

CHAMFER OF 80mm x 80mm AS SHOWN.



REINFORCEMENT TABLE (CONC. M 25, STEEL–Fe 415)

CLEAR SPAN (m)	OVERALL DEPTH H (mm)	MAIN SLAB: LONGITUDINAL a	a	a	a	b	b	b	b	TRANSVERSE c	c	c	c	d	d	d	d	KERBS: LONGITUDINAL e	e	e	e	f	f	f	f	g	TRANSVERSE g	g	g	QUANTITY STEEL (MTon)	QUANTITY CONCRETE (Cum)
		CLR. (mm)	SPACING (mm)	MAIN BARS	l (mm)	CLR. (mm)	SPACING (mm)	MAIN BARS	n (mm)	h (mm)	d (mm)	CLR. (mm)	SPACING (mm)	MAIN BARS	r (mm)	CLR. (mm)	SPACING (mm)	MAIN BARS	q (mm)	CLR. (mm)	SPACING (mm)	MAIN BARS	s (mm)	CLR. (mm)	SPACING (mm)	MAIN BARS	t (mm)	CLR. (mm)	SPACING (mm)	MAIN BARS	y (mm)		
2.0	260	16	280	21	2700	16	280	20	–	210	2700	10	300	20	2700	10	180	17	5500	10	300	11	5600	10	300	22	585	210	250	563	70	16	–	14	2700	0.404	4.3553
3.0	320	16	240	24	3700	16	240	23	–	280	3700	10	300	20	3700	10	160	25	5500	10	300	14	5600	10	300	28	585	260	250	396	70	16	–	14	3700	0.5935	7.2609
4.0	380	20	280	21	4700	20	280	20	820	487	2800	10	300	20	4700	10	120	41	5500	10	300	17	5600	10	300	34	585	330	250	424	70	16	–	14	4700	0.8215	10.872
5.0	430	20	240	24	5700	20	240	23	750	495	3500	10	300	20	5700	10	110	53	5500	10	300	21	5600	10	300	42	585	380	250	457	70	18	–	14	5700	1.0979	14.849
6.0	490	20	220	27	6700	20	220	26	810	623	4200	10	300	20	6700	10	100	69	5500	10	300	24	5600	10	300	48	585	440	250	500	70	16	–	14	6700	1.4157	19.811
7.0	560	20	200	29	7670	20	200	28	905	679	4900	10	300	20	7670	12	130	61	5500	10	300	27	5600	10	300	54	585	480	250	630	70	16	–	14	7670	1.7962	25.933
8.0	620	25	280	21	8670	25	280	20	995	764	5600	10	300	20	8670	12	120	74	5500	10	300	30	5600	10	300	60	585	540	250	578	70	16	–	14	8670	2.2047	32.364
9.0	690	25	240	24	9670	25	240	23	1075	863	6300	10	300	20	9670	12	110	89	5500	10	300	34	5600	10	300	68	585	610	250	656	70	16	–	14	9670	2.7277	40.073
10.0	800	25	200	29	10670	25	200	28	1115	1019	7000	10	300	20	10670	12	100	108	5500	10	300	37	5600	10	300	74	585	720	250	732	70	16	–	14	10670	3.4857	51.130
12.0	930	28	220	27	12670	28	220	26	1285	1203	8400	10	300	20	12670	16	150	86	5500	10	300	44	5600	10	300	88	585	850	250	849	70	16	–	14	12670	4.7430	70.380
15.0	1180	32	220	27	15670	32	220	26	1485	1556	10500	10	300	20	15670	16	120	132	5500	10	300	54	5600	10	300	108	585	1100	250	1084	70	16	–	14	15670	7.3720	110.07

TYPE 'a' | SHAPE ONLY FOR SPAN 2m. & 3m. TYPE 'b' | TYPE 'a' | TYPE 'c' | TYPE 'e' | TYPE 'f' | TYPE 'g'

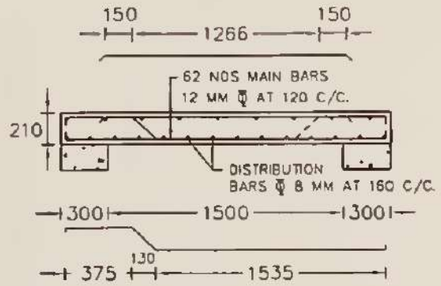
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

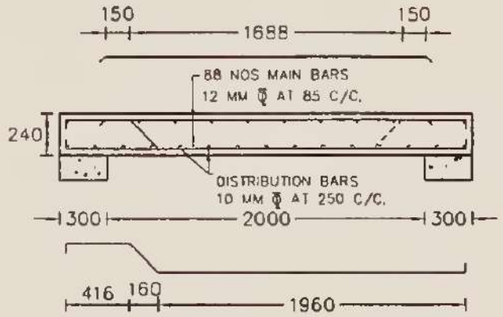
DRG.TITLE.

TYPE PLAN FOR DETAILS OF R.C.C. SOLID SLAB, 5.50 M. CARRIAGEWAY
(WITHOUT FOOTPATH)
(CONCRETE - M-25, STEEL - Fe 415)

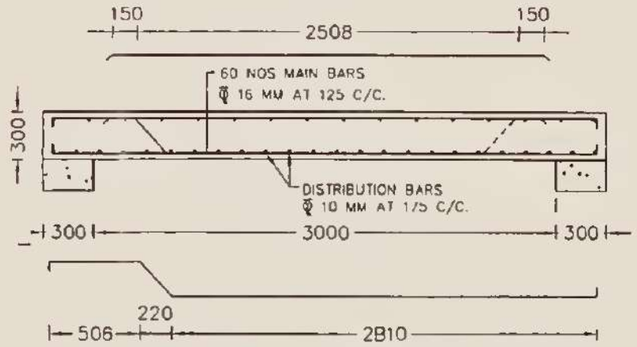
PLATE NO.-7.08



1.5 M. SPAN



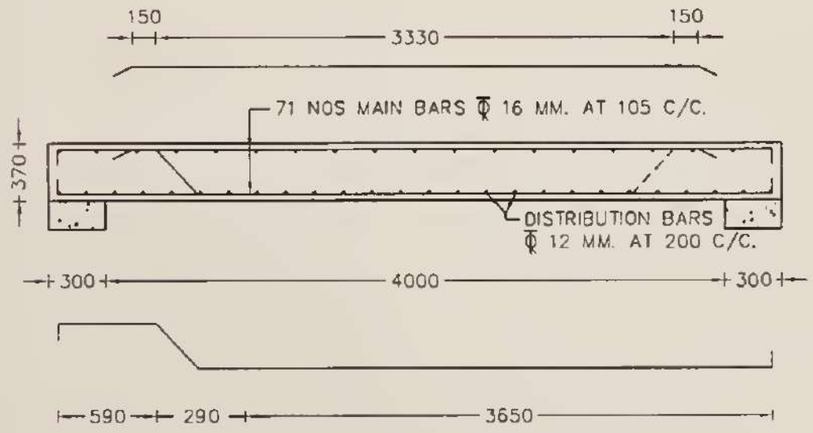
2.0 M. SPAN



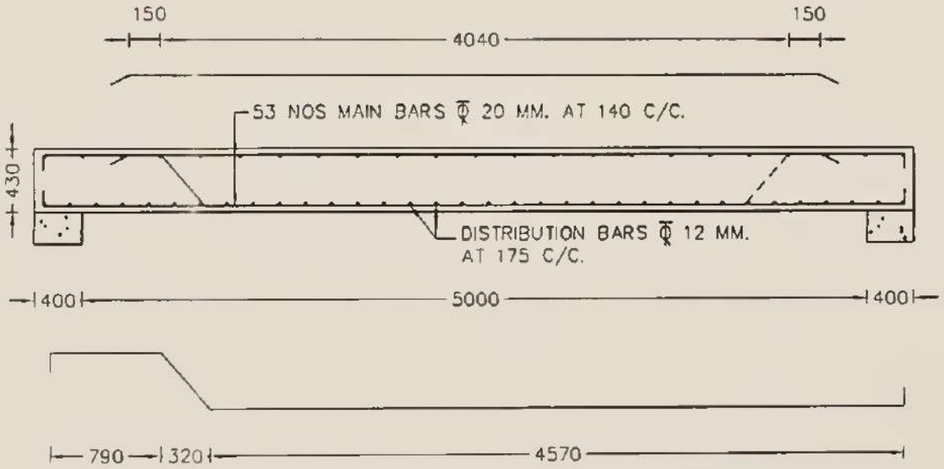
3.0 M. SPAN

NOTES

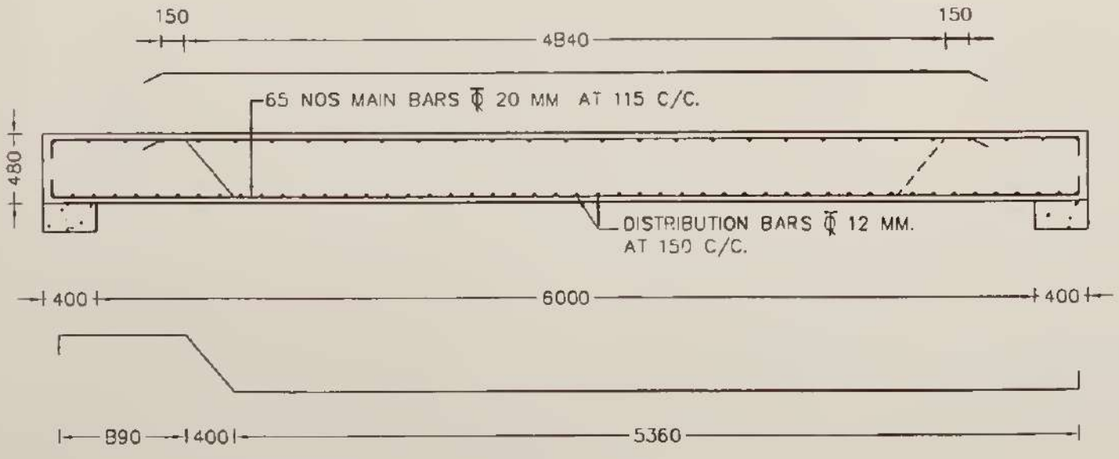
1. CONCRETE – 1:1.5:3
2. STEEL – H.Y.S.D. AS PER I.S.1786.
3. COVER – 40mm.AT BOTTOM AND 40mm SIDE.
4. IN 1.5m.,2.0m.,AND 3.0m.SPAN ONLY ONE BAR IS TO BE CRANKED. IN EACH SIDE IN FOUR BARS. IN ALL OTHER SPANS CRANK ALTERNATIVE BARS.
5. ALL BARS ARE CRANKED AT ONE END ONLY. THESE ARE PLACED WITH CRANK ON LEFT SIDE AND RIGHT SIDE ALTERNATIVELY.
6. SURFACE STEEL AT TOP LONGITUDINAL – 10mm Φ 300mm C/C. LENGTH AS SHOWN IN SKETCH.
   & TRANSVERSE – 10mm Φ 300mm C/C ALL THROUGHOUT IN LONGITUDINAL DIRECTION PROVIDE STEEL IN THE ZONE WHERE MAIN STEEL IS NOT AVAILABLE PLUS 150mm ON EITHER SIDE.
7. ALL DIMENSIONS ARE IN mm. UNTIL & UNLESS STATED.



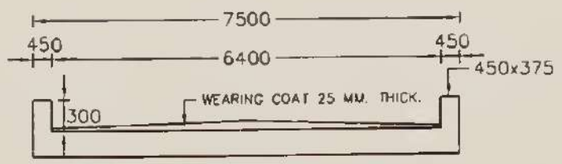
4.0 M. SPAN



5.0 M. SPAN



6.0 M. SPAN



CROSS SECTION OF CULVERT

6.0 M. SPAN

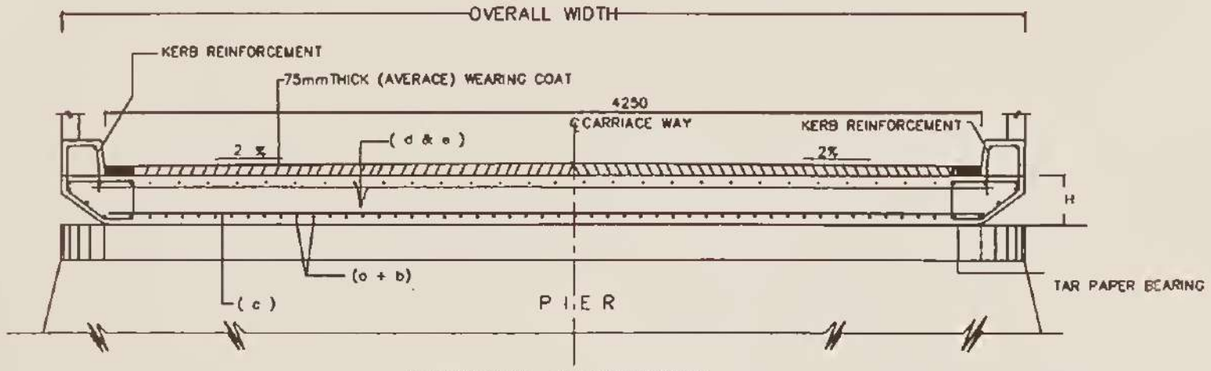
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

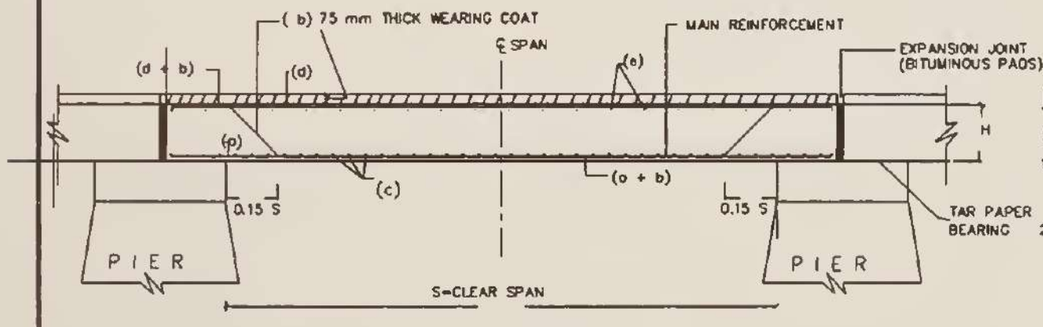
DRG.TITLE.

R.C.C. SLAB 1.5 M. UPTO 6.0 M. SPAN
WIDTH AT ROAD TOP 7.5 M.

PLATE NO.-7.09



CROSS SECTION



LONGITUDINAL SECTION

NOTES :

(A) GENERAL

1. THESE NOTES ARE APPLICABLE FOR THE STANDARD DRAWINGS FOR R.C.C. SOLID SLAB SUPERSTRUCTURE WITHOUT FOOTPATHS.
2. THESE DRAWINGS ARE APPLICABLE ONLY FOR RIGHT ANGLED BRIDGES.

SR. NO.	LANE	CLEAR ROAD WIDTH (m)	OVERALL WIDTH (m)
1	SINGLE	4.25	HIGH LEVEL-5.0 SUBMERSIBLE-4.70

3. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE MENTIONED. ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED. NO DRAWING SHALL BE SCALED.
4. DESIGN CRITERIA :
   - I THE DESIGN IS ACCORDING TO THE FOLLOWING CODES
     - (a) I.R.C.:5-2000
     - (b) I.R.C.:6-2000
     - (c) I.R.C.:21-2000
   - II THE FOLLOWING LOADS HAVE BEEN CONSIDERED IN THE DESIGN:
     - (a) SINGLE LANE - SINGLE TRAIN OF CLASS-A
     - (b) DENSITY OF WEARING COAT IS 2.21/m^3
     - (c) DENSITY OF CONCRETE IS 2.4 1/m^3
   - III THE DESIGNS ARE APPLICABLE FOR 'MODERATE' CONDITION OF EXPOSURE.
5. PUBLIC UTILITY SERVICES eg. WATER SUPPLY AND SEVERAGE PIPES SHALL NOT BE CARRIED OVER THE BRIDGE . IF NECESSARY, SPECIAL PROVISION FOR THE SAME SHALL BE MADE IN THE DESIGN.
6. 25 mm PREMOULDED BITUMINOUS EXPANSION PAD SHALL BE PROVIDED AS EXPANSION JOINT
7. SUPPORT FOR DECK SLAB SHALL PROVIDE A MINIMUM BEARING WIDTH OF
   - i) AT ABUTMENT - 600 mm
   - ii) AT PIER - 375 mm
8. TYPE /POSITION OF RETURN WALLS, RAILINGS GUARDS POSTS, RAMP etc. IN APPROACH PORTION SHALL BE DECIDED BY THE ENGINEER-IN-CHARGE.
9. THERE SHALL BE A CLEAR JOINT BETWEEN PARAPET & KERB ON R.C.C. BOX RETURN/SOLID RETURN AND MAIN BRIDGE & RIDING RETURN.
10. IN CASE OF HIGH LEVEL BRIDGES, WATER SPOUTS OF 150 mm DIA G.I. PIPE SHALL BE PROVIDED AT 3 m c/c.
11. A CAMBER OF 2% SHALL BE PROVIDED IN WEARING COAT FOR BOTH CEMENT CONCRETE AND BITUMINOUS ROADS. THE THICKNESS OF DECK SLAB SHALL BE UNIFORM.
12. FOR THE SUPERSTRUCTURE IN HIGH LEVEL BRIDGE, RAILING SHALL BE OF R.C.C. PARAPETS.
13. TAR PAPER BEARING SHALL BE USED FOR SPANS UPTO 10 m.
14. 0.90 m. THICK FLEXIBLE STONE MAT SHALL BE PROVIDED FOR FULL ROAD WIDTH BEHIND THE RETURN FOR THE LENGTH OF 3.5 m.

(B) MATERIALS SPECIFICATIONS

Concrete :

1. CONCRETE SHALL BE OF DESIGN MIX AND SHALL HAVE MINIMUM 28 DAYS CHARACTERISTIC STRENGTH ON 150 mm CUBES FOR ALL ELEMENTS OF SUPERSTRUCTURE SHALL BE 25 MPa.
2. HIGH STRENGTH ORDINARY PORTLAND CEMENT CONFORMING TO IS:8112 OR ORDINARY PORTLAND CEMENT CONFORMING TO IS: 269 AND 43 GRADE CEMENT CONFORMING TO IS:12269 CAPABLE OF ACHIEVING THE REQUIRED DESIGN CONCRETE STRENGTH SHALL BE USED.

Reinforcement :

CLEAR COVER TO REINFORCEMENT:-
- i) FOR SPANS UP TO & INCLUDING 6m : 25mm AT BOTTOM AND 40mm ON SIDE.
- ii) FOR SPANS 7,8,9,10m : 40mm TO ALL REINFORCEMENT.

ALL REINFORCING BARS SHALL BE HIGH YIELD STRENGTH DEFORMED BARS (GRADE DESIGNATION Fe 415) CONFORMING TO IS:1786.

Water :

WATER TO BE USED IN CONCRETING AND CURING SHALL CONFORM TO CLAUSE 302.4 OF IRC 21-2000.

(C) WORKMANSHIP/DETAILING

1. FOR ENSURING PROPER COVER OF CONCRETE TO REINFORCEMENT BARS , SPECIALLY MADE POLYMER COVER BLOCKS SHALL ONLY BE USED.

2.Construction Joints

- I THE LOCATION AND PROVISION OF CONSTRUCTION JOINTS SHALL BE APPROVED BY ENGINEER-IN-CHARGE. THE CONCRETING OPERATION SHALL BE CARRIED OUT CONTINUOUSLY UPTO THE CONSTRUCTION JOINT.
- II THE CONCRETE SURFACE AT THE JOINT SHALL BE BRUSHED WITH A STIFF BRUSH AFTER CASTING WHILE THE CONCRETE IS STILL FRESH AND IT HAS ONLY SLIGHTLY HARDENED.
- III BEFORE NEW CONCRETE IS POURED , THE SURFACE OF OLD CONCRETE SHALL BE PREPARED AS UNDER:
  - a) FOR HARDENED CONCRETE, THE SURFACE SHALL BE THOROUGHLY CLEANED TO REMOVE DEBRIS AND MADE ROUGH.
  - b) FOR PARTIALLY HARDENED CONCRETE, THE SURFACE SHALL BE TREATED BY WIRE BRUSH FOLLOWED BY AN AIR JET.
  - c) THE OLD SURFACE SHALL BE SOAKED WITH WATER WITHOUT LEAVING PUDDLES IMMEDIATELY BEFORE STARTING CONCRETING TO PREVENT THE ABSORPTION OF WATER FROM NEW CONCRETE.
- IV NEW CONCRETE SHALL BE THOROUGHLY COMPACTED IN THE REGION OF THE JOINT.

3. WELDING OF REINFORCEMENT BARS SHALL NOT BE ORDINARILY PERMITTED PL. REFFER CLAUSE 304.6.6.3 OF I.R.C. 21-2000
4. LAPS IN REINFORCEMENT:
   - I MINIMUM LAP LENGTH OF REINFORCEMENT SHALL BE KEPT AS 50 d WHERE "d" IS THE DIAMETER OF BAR.
   - II NOT MORE THAN 25% OF REINFORCEMENT SHALL BE LAPPED AT ANY ONE LOCATION AND ALL JOINTS SHOULD BE WELL STAGGERED.
5. BENDING OF REINFORCEMENT BARS SHALL BE AS PER IS:2502.
6. SUPPORTING CHAIRS OF 12mm DIAMETER SHALL BE PROVIDED AT SUITABLE INTERVALS AS PER IS:2502.
7. CONCRETE SHALL BE PRODUCED IN A MECHANICAL MIXER OF CAPACITY NOT LESS THAN 200 LITRES HAVING INTEGRAL WEIGH-BATCHING FACILITY AND AUTOMATIC WATER MEASURING AND DISPENSING DEVICE.
8. PROPER COMPACTION OF CONCRETE SHALL BE ENSURED BY USE OF FULL WIDTH SCREED VIBRATORS FOR CONCRETE IN DECK SLAB.
9. PROPERLY BRACED STEEL PLATES SHALL BE USED AS SHUTTERING.
10. SHARP EDGES OF CONCRETE SHALL BE CHAMFERED.

(D) PRECAUTIONS FOR SUBMERSIBLE BRIDGES : (SINGLE LANE BRIDGES SHALL BE PREFERABLY HIGH LEVEL ONLY)

- i) STOPPERS SHALL BE PROVIDED ON D/S SIDE OF ALL PIERS AND ABUTMENTS.
- ii) RAILING SHALL BE PIPE & POST TYPE (REMOVABLE) WITH DISCONTINUOUS KERB.
- iii) WEARING COAT SHALL BE IN R.C.C.

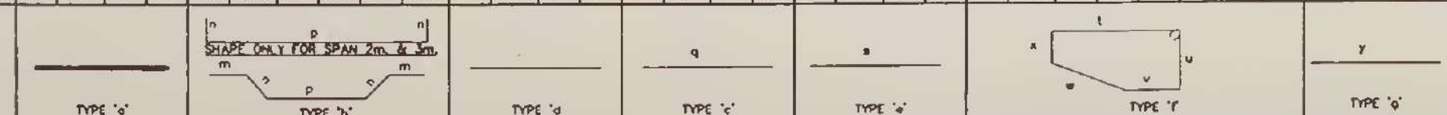
(E) GENERAL SPECIFICATIONS

THE WORK SHALL BE EXECUTED IN ACCORDANCE WITH MORT&H'S SPECIFICATION FOR ROAD AND BRIDGE WORKS (FOURTH REVISION) EXCEPT WHEREVER OTHERWISE MENTIONED.

REINFORCEMENT TABLE FOR SINGLE LANE DECK SLAB(CONC. M 25, STEEL-Fe 415)

CLEAR SPAN (m)	OVERALL DEPTH d (mm)	MAIN SLAB LONGITUDINAL a				b					c				TRANSVERSE d				e				
		DIA. (mm)	SPACING (mm)	NO.OF BARS	l (mm)	DIA. (mm)	SPACING (mm)	NO.OF BARS	m (mm)	n (mm)	p (mm)	DIA. (mm)	SPACING (mm)	NO.OF BARS	r (mm)	DIA. (mm)	SPACING (mm)	NO.OF BARS	q (mm)	DIA. (mm)	SPACING (mm)	NO.OF BARS	s (mm)
2.0	200	16	380	13	2700	16	380	12	-	150	2700	8	300	16	2700	10	290	11	4250	8	300	11	4350
3.0	260	16	260	18	3700	16	260	17	-	210	3700	8	300	16	3700	10	250	18	4250	8	300	14	4350
4.0	330	16	200	23	4700	16	200	22	670	396	2600	8	300	16	4700	10	200	25	4250	8	300	17	4350
5.0	390	20	280	17	5700	20	280	16	760	481	3500	8	300	16	5700	10	170	35	4250	8	300	21	4350
6.0	440	20	240	19	6700	20	240	18	860	552	4200	8	300	18	6700	10	140	49	4250	8	300	24	4350
7.0	500	20	220	21	7670	20	220	20	965	594	4900	10	300	16	7670	10	150	61	4250	10	300	27	4350
8.0	560	20	200	23	8670	20	200	22	1055	679	5600	10	300	18	8670	10	110	80	4250	10	300	30	4300
9.0	620	25	280	17	9670	25	260	16	1145	764	6300	10	300	16	9670	12	140	71	4250	10	300	34	4350
10.0	700	25	240	19	10670	25	240	18	1215	877	7000	10	300	18	10670	12	120	90	4250	10	300	37	4350

CLEAR SPAN (m)	KERBS LONGITUDINAL f				t	u	v	w	x	TRANSVERSE y				QUANTITY STEEL (Nos)	QUANTITY CONCRETE (Cum)
	DIA. (mm)	SPACING (mm)	NO.OF BARS	l (mm)						DIA. (mm)	SPACING (mm)	NO.OF BARS	l (mm)		
2.0	10	300	22	585	150	250	345	70		16	-	14	2700	0.2274	2.3169
3.0	10	300	28	585	210	250	363	70		16	-	14	3700	0.3386	3.853
4.0	10	300	34	585	280	250	396	70		16	-	14	4700	0.497	5.979
5.0	10	300	42	585	340	250	431	70		16	-	14	5700	0.692	8.587
6.0	10	300	48	585	390	250	464	70		16	-	14	6700	0.912	11.931
7.0	10	300	54	585	420	250	485	70		16	-	14	7670	1.188	16.207
8.0	10	300	60	585	480	250	530	70		16	-	14	8670	1.504	21.131
9.0	10	300	68	585	540	250	577	70		16	-	14	9670	1.897	27.154
10.0	10	300	74	585	620	250	644	70		16	-	14	10670	2.311	33.918



RURAL ROADS MANUAL

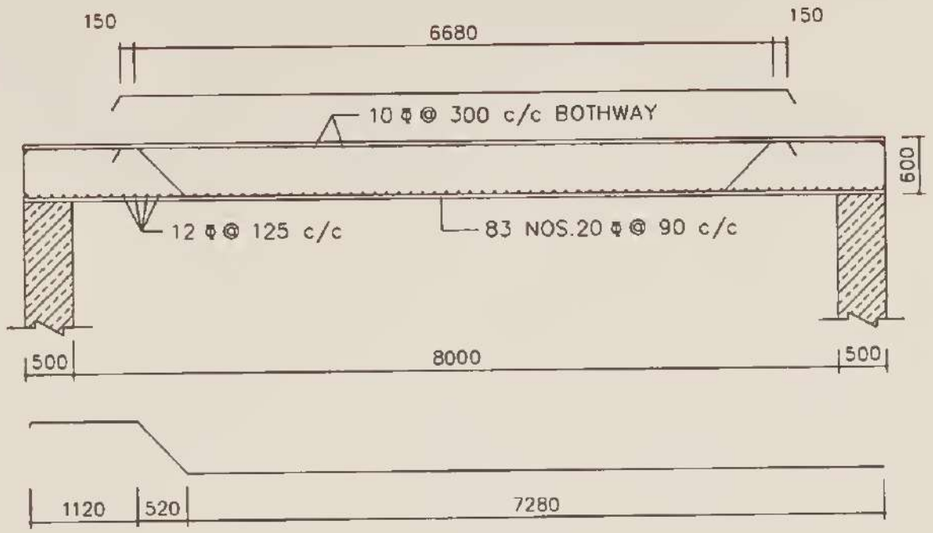
CULVERTS & SMALL BRIDGES

DRG.TITLE.

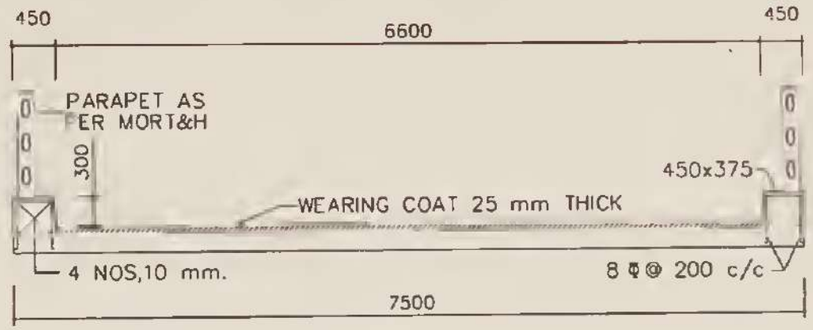
TYPE PLAN FOR DETAILS OF R.C.C. SOLID SLAB SINGLE LANE (WITHOUT FOOTPATH)

(CONCRETE - M25, STEEL - Fe 415)

PLATE NO.-7.10

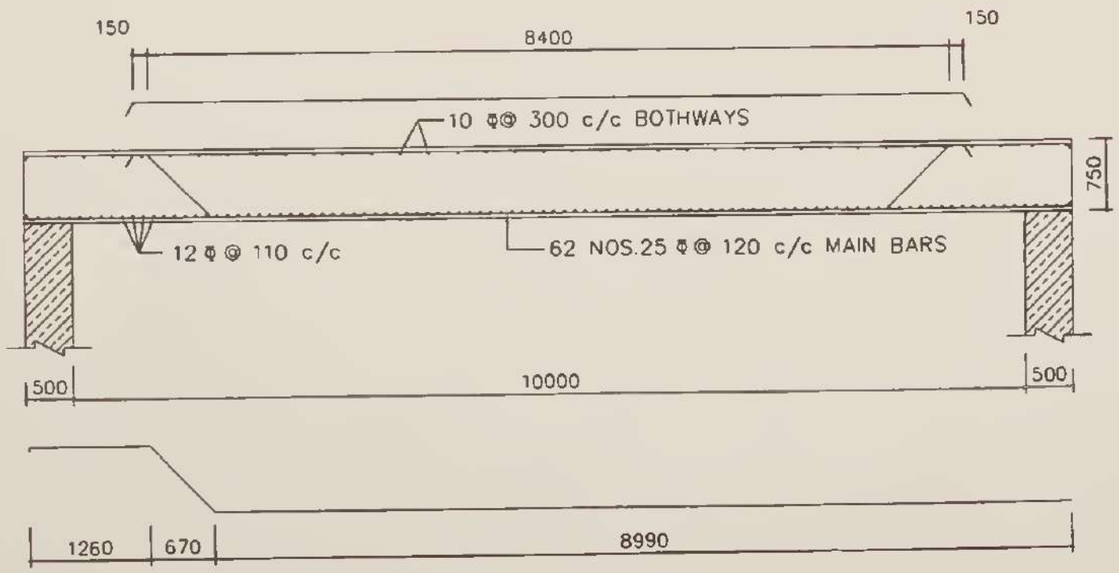


8.0 M. SPAN



CROSS SECTION OF CULVERT

A CAMBER OF 2.5% TO BE PROVIDED IN WEARING COAT



10.0 M. SPAN

NOTES:

1. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
2. SURFACE STEEL AT TOP LONGITUDINAL:-10mm @ 300 C/C LENGTH AS SHOWN IN SKETCH TRANSVERSE 10 mm @ 300 C/C ALL THROUGHOUT. IN LONGITUDINAL DIRECTION PROVIDE STEEL IN THE ZONE WHERE MAIN STEEL IS NOT AVAILABLE PLUS 150mm ON EITHER SIDE.
3. CONCRETE 1:1.5:3
4. STEEL H.Y.S.D. AS PER I.S. 1786.
5. COVER 40mm AT BOTTOM AND 40mm SIDE.

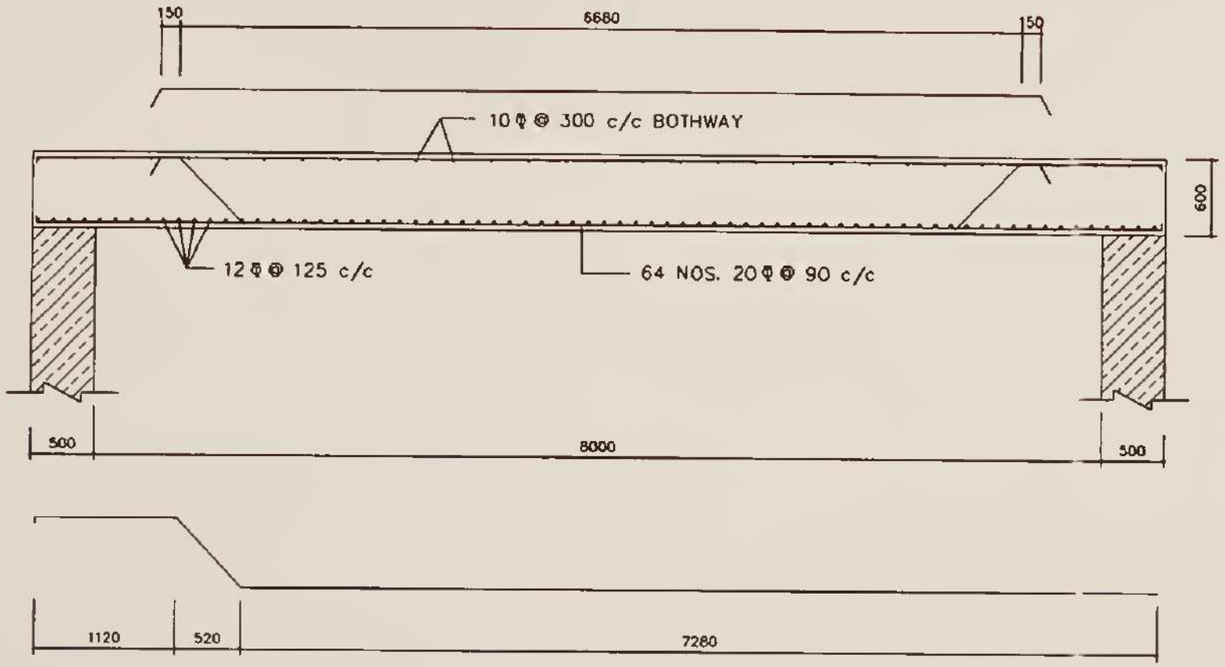
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

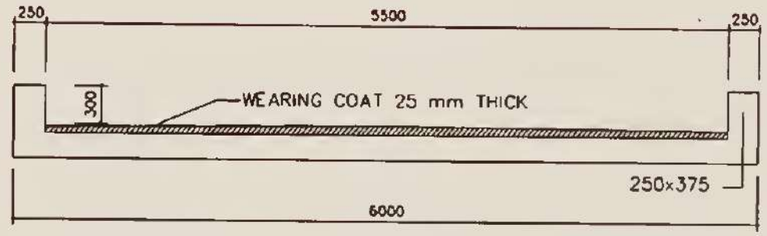
DRG.TITLE.

DETAILS OF R.C.C. SLAB OF 8.0M. & 10.0M. SPAN WIDTH AT ROAD TOP 7.50 M.

PLATE NO.-7.11

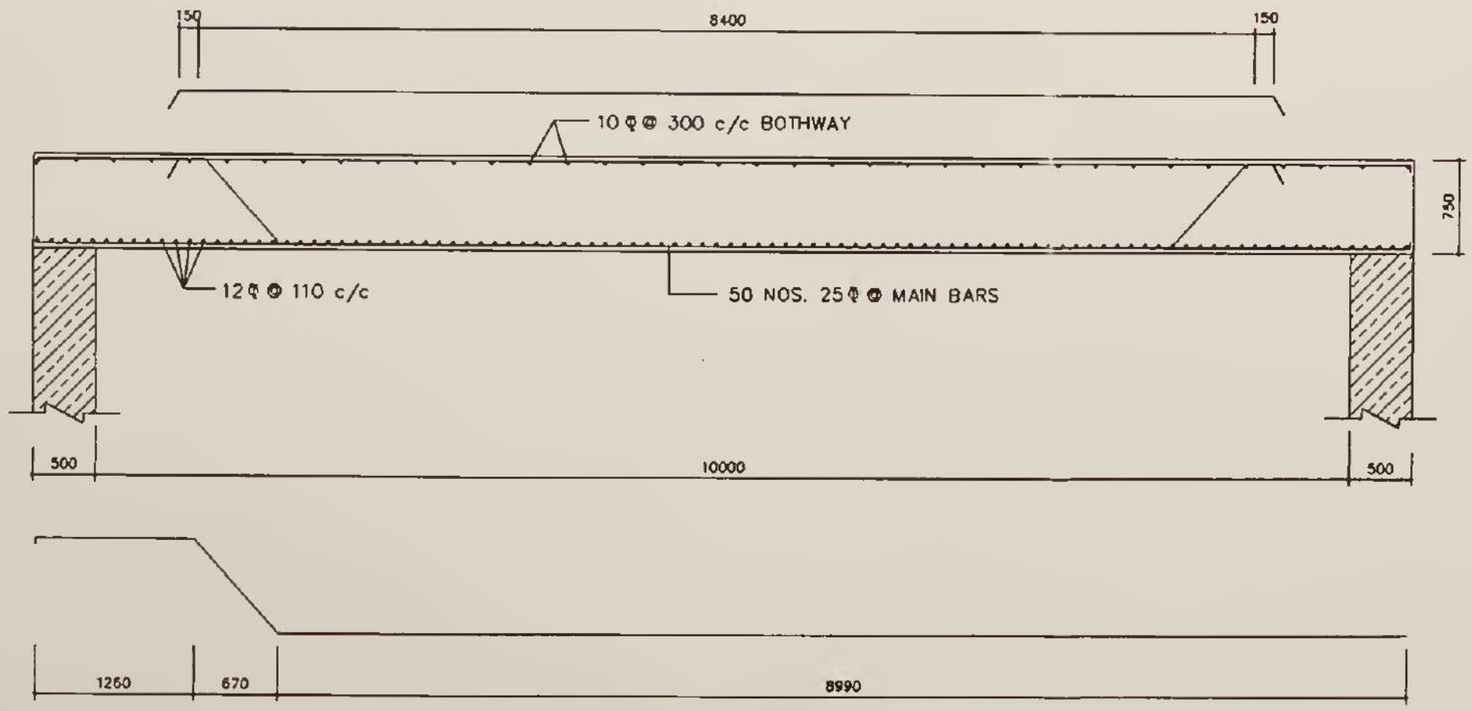


8.0 M. SPAN



CROSS SECTION OF CULVERT

A CAMBER OF 2.5% TO BE PROVIDED IN WEARING COAT



10.0 M. SPAN

NOTES:

1. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
2. SURFACE STEEL AT TOP LONGITUDINAL:-10mm Φ 300 C/C LENGTH AS SHOWN IN SKETCH TRANSVERSE 10 mm Φ 300 C/C ALL THROUGHOUT. IN LONGITUDINAL DIRECTION PROVIDE STEEL IN THE ZONE WHERE MAIN STEEL IS NOT AVAILABLE PLUS 150mm ON EITHER SIDE.
3. CONCRETE 1:1.5:3
4. STEEL H.Y.S.D. AS PER I.S. 1786.
5. COVER 40mm AT BOTTOM AND 40mm SIDE.

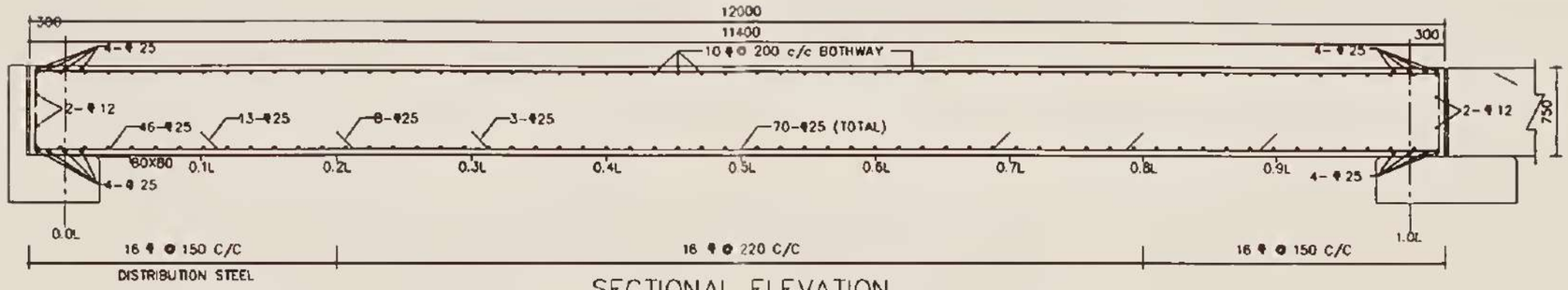
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

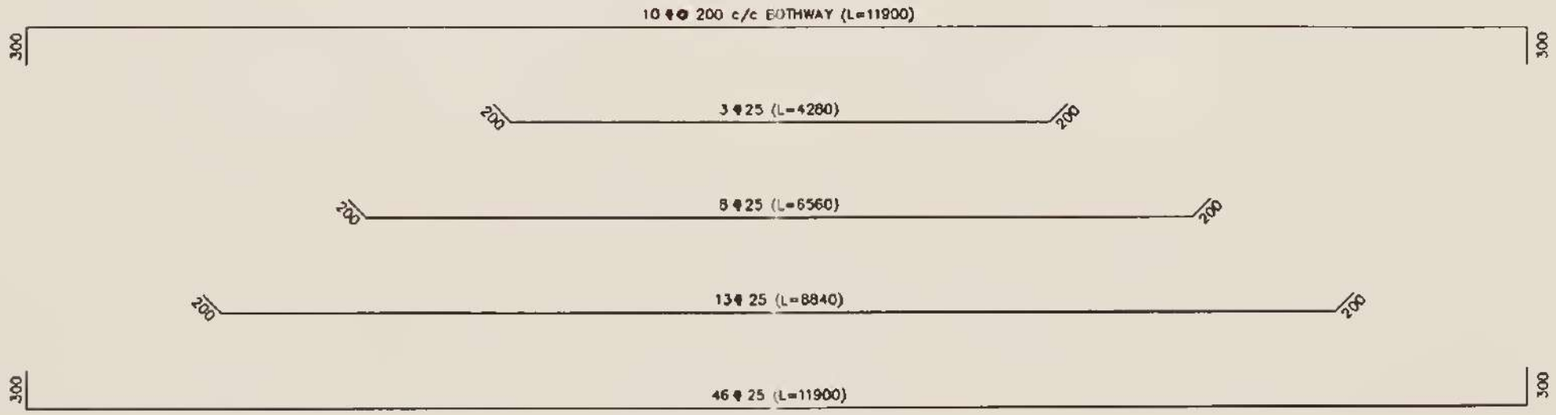
DRG.TITLE.

BRIDGES ON RURAL ROADS
8.0M. & 10.0M. SPAN R.C.C. SLAB
(OVERALL WIDTH 6.0 M.)

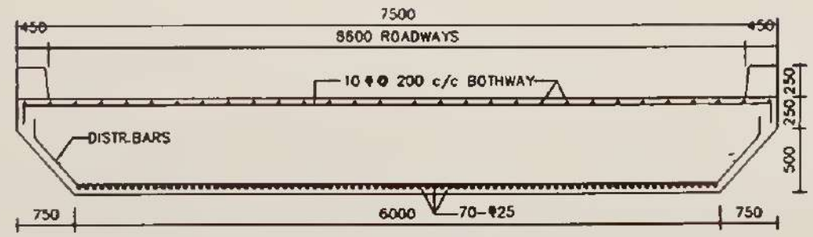
PLATE NO.-7.12



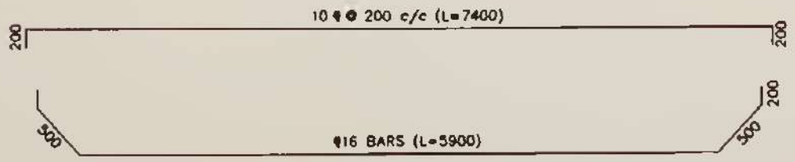
SECTIONAL ELEVATION



SHAPE OF BARS



CROSS SECTION



SHAPE OF BARS

SPECIFICATIONS

1. CONCRETE – 1:1.5:3
2. AGGREGATE – 25mm & DOWN GRADE.
3. STEEL – H.Y.S.D. BARS AS PER I.S.1786.
4. CLEAR COVER – 40mm.
5. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED

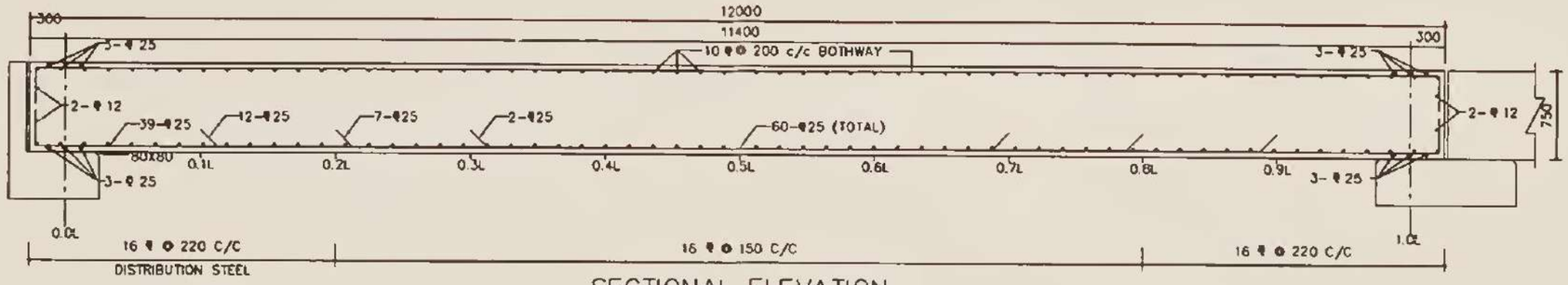
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

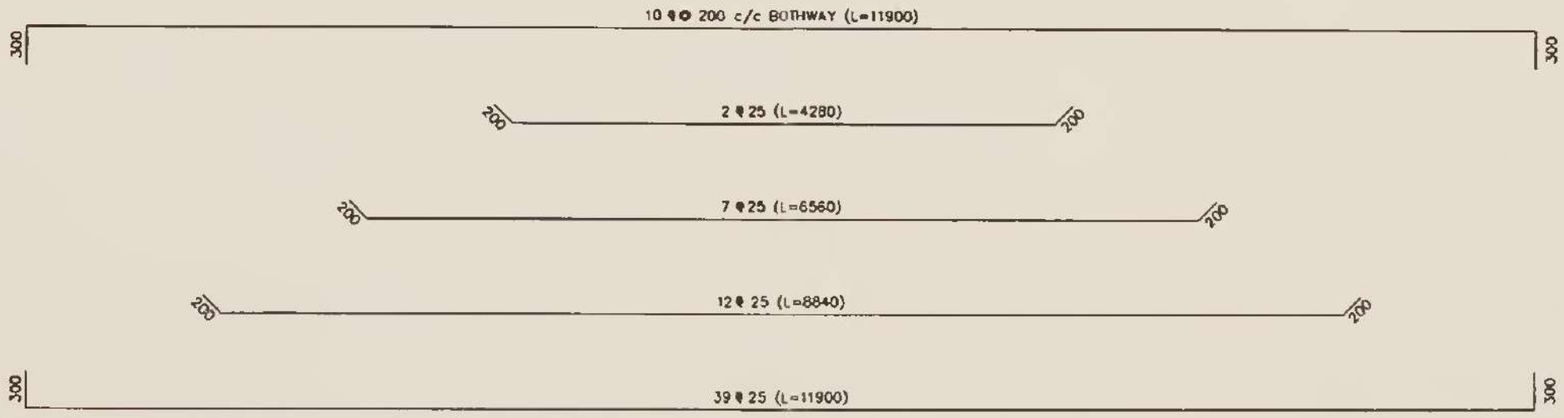
DRG.TITLE.

DETAILS OF DECK SLAB FOR 12.0 M. SPAN. ROAD TOP WIDTH 7.5 M.

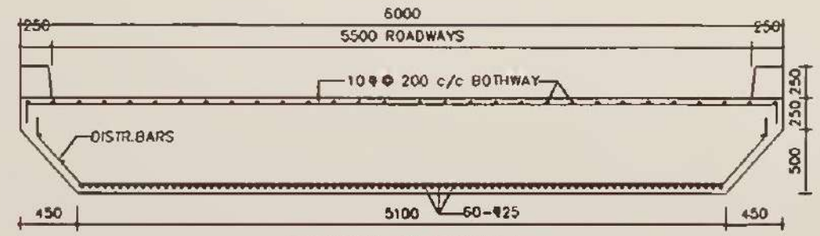
PLATE NO.-7.13



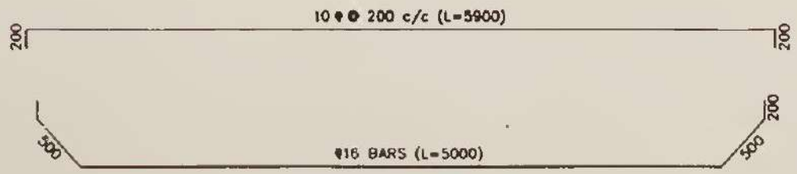
SECTIONAL ELEVATION



SHAPE OF BARS



CROSS SECTION



SHAPE OF BARS

SPECIFICATIONS

1. CONCRETE – 1:1.5:3
2. AGGREGATE – 25mm & DOWN GRADE.
3. STEEL – H.Y.S.D. BARS AS PER I.S.1786.
4. CLEAR COVER – 40mm.
5. WEARING COAT – 20mm THICK PMC+5mm THICK SEAL COAT WITH 2.5% CAMBER
6. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED

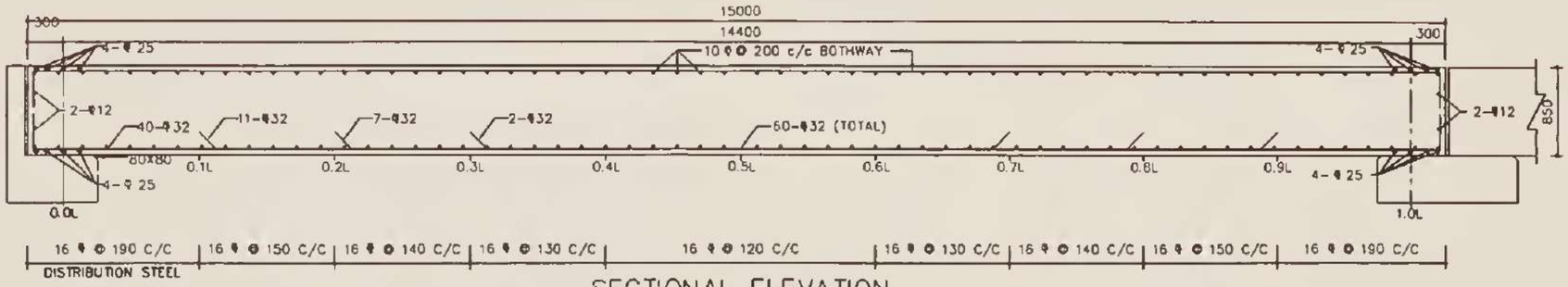
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

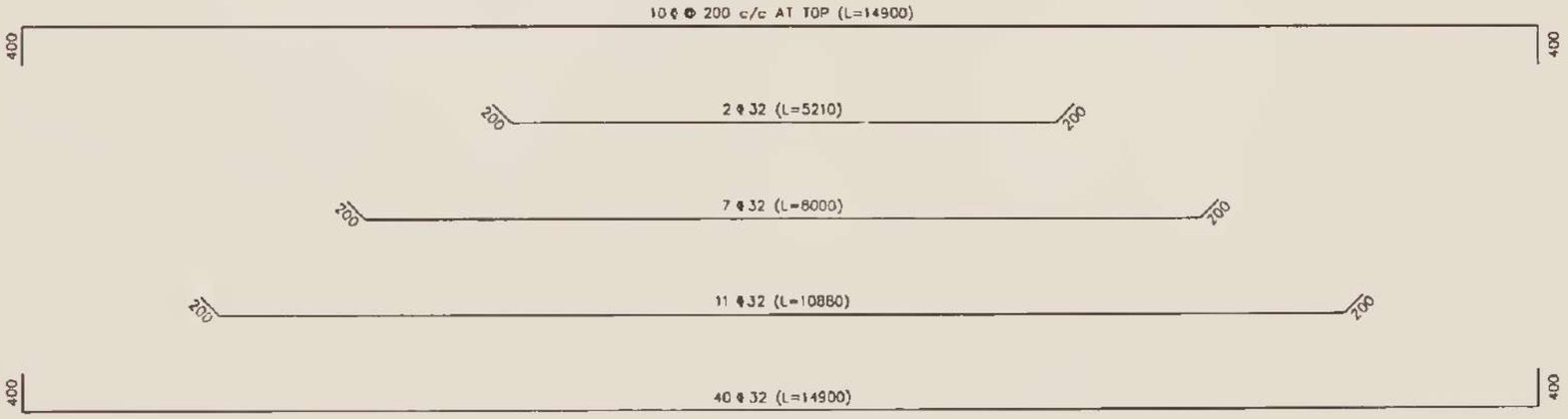
DRG.TITLE.

DETAILS OF DECK SLAB FOR 12.0 M. SPAN (OVERALL WIDTH 6.0 M.)

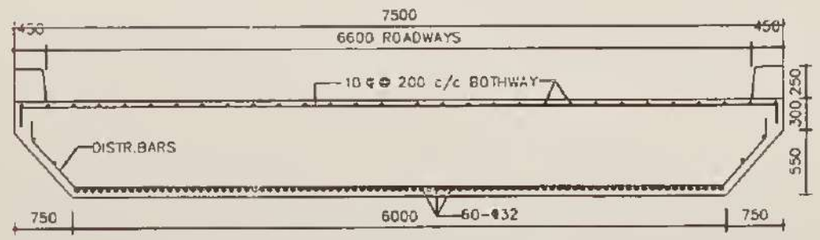
PLATE NO.-7.14



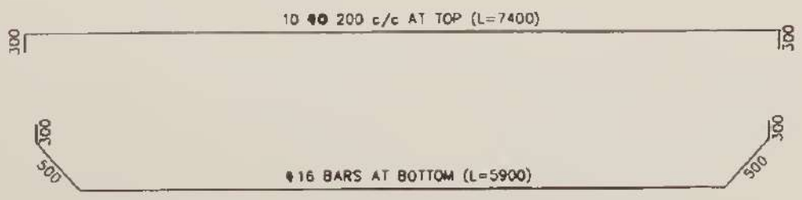
SECTIONAL ELEVATION



SHAPE OF BARS



CROSS SECTION



SHAPE OF BARS

SPECIFICATIONS

1. CONCRETE – 1:1.5:3
2. AGGREGATE – 25mm & DOWN GRADE.
3. STEEL – H.Y.S.D. BARS AS PER I.S.1786.
4. CLEAR COVER – 40mm.
5. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED

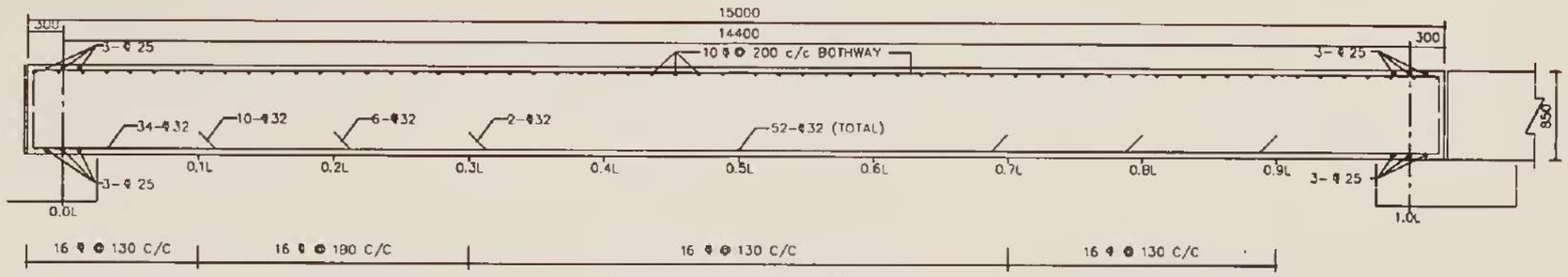
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

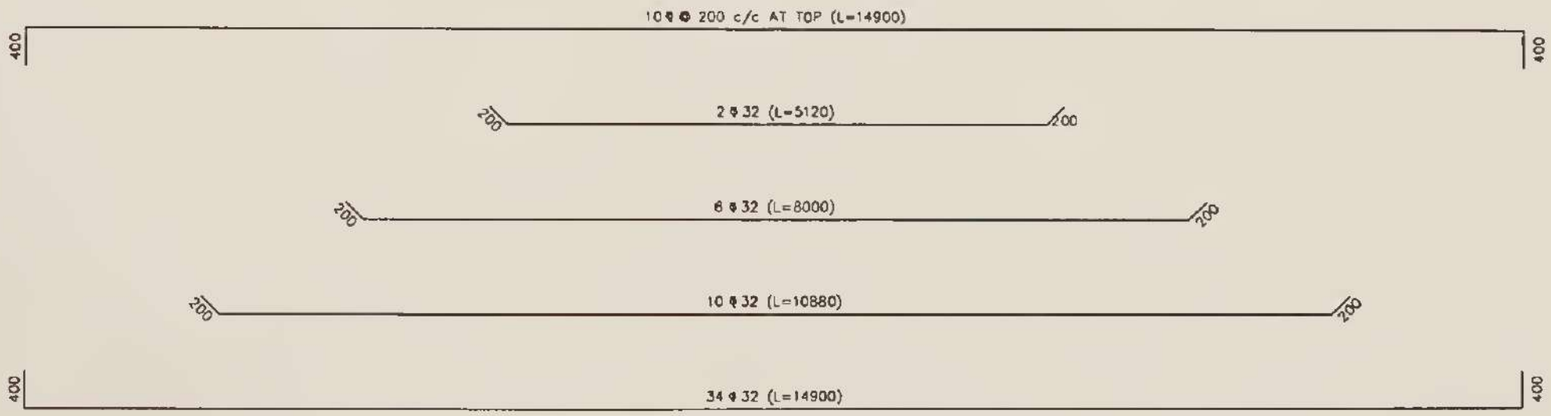
DRG.TITLE.

DETAILS OF DECK SLAB FOR 15.0 M. SPAN, ROAD TOP WIDTH 7.5 M.

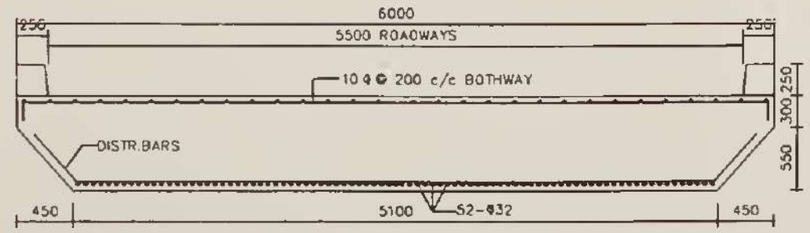
PLATE NO.-7.15



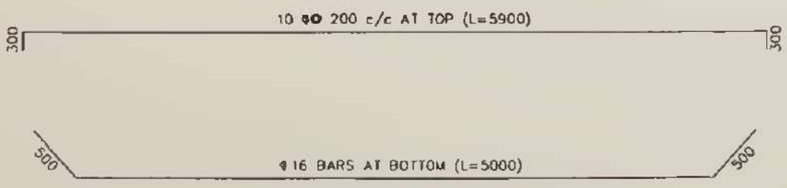
SECTIONAL ELEVATION



SHAPE OF BARS



CROSS SECTION



SHAPE OF BARS

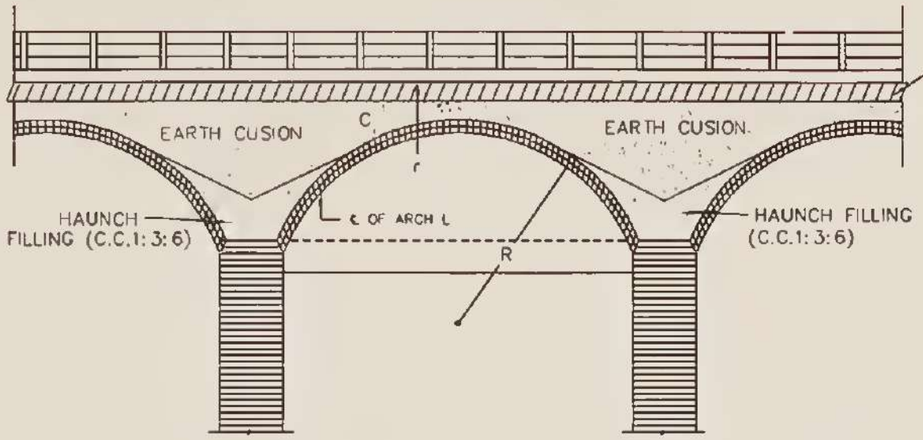
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

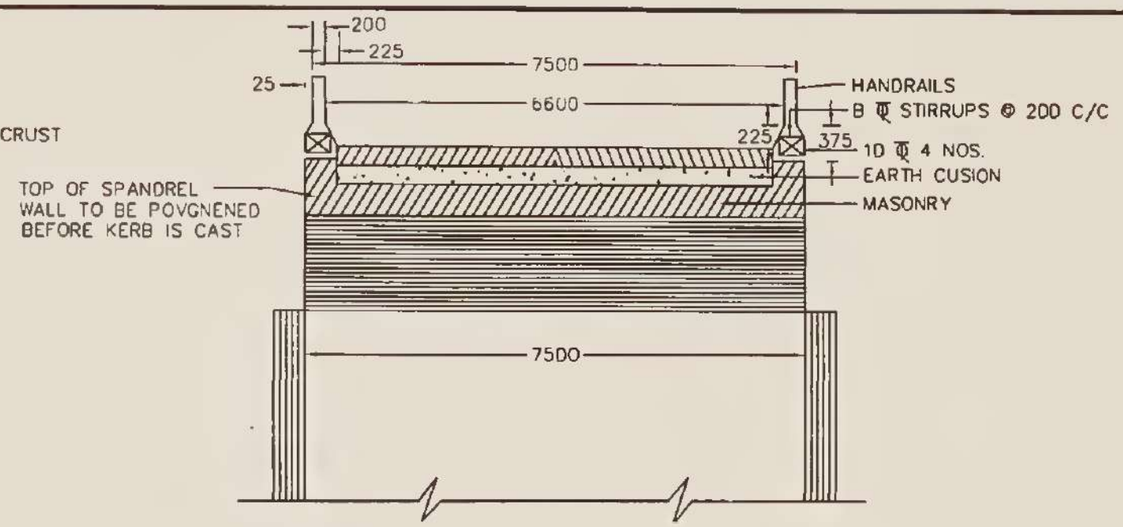
DRG.TITLE.

DETAILS OF DECK SLAB FOR 15.0M. SPAN, (OVERALL WIDTH 6.0M.)

PLATE NO.-7.16



SECTIONAL ELEVATION



CROSS SECTION AT THE CROWN OF ARCH

(SCALE-1:50)

TABLE

EFFECTIVE SPAN (L) METERS	6	9	,12
CLEAR SPAN (S) METERS	5 572	8 512	11 368
RISE (R) MILLIMETERS	1500	2250	3000
RADIOUS OF CENTERLINE(R) MILLIMETERS	3750	5625	7500
CUSION ABOVE CROWN (C) MILLIMETERS	810	760	760
ARCH THICKNESS (T) MILLIMETERS (UNIFORM SECTION FROM ARCH RING OR CROWN)	535	610	790
DEPTH OF HAUNCH FILLING AT PIER AND ABUTMENT	1018	1430	1895

GENERAL NOTES: –

SPECIFICATIONS: – I.R.C STANDARD SPECIFICATION CODE OF PRACTICE OR ROAD BRIDGES SECTION I.II.AND IV.

DESIGN LIVE LOAD: – I.R.C.CLASS A LODING TWO LANES.

MATERIAL: – THE MASONRY OF THE ARCH RING MAY CONSIST OF EITHER CONCRETE BLOCKS (C.C.1:3:6) OR DRESSED STONES OR BRICK IN 1:4 CEMENT MORTAR. THE CRUSHING STRENGTH OF CONCRETE STONE OR BRICK UNITS SHALL NOT BE LESS THAN 105 Kg/cm. WHERE STONE MASONRY IS ADOPTED FOR THE ARCH RING IT SHALL BE EITHER COURSED RUBBLE MASONRY OR ASHLAR MASONRY.

DESIGN STRESSES: – PERMISSIBLE TENSILE STRESS
(MASONRY OF ARCH RING) PERMISSIBLE COMPRESSIVE STRESS — AS SPECIFIED IN I.R.C. BRIDGE CODE SECTION IV (1971).

RAILINGS: – AS PER DETAILS APPROVED.

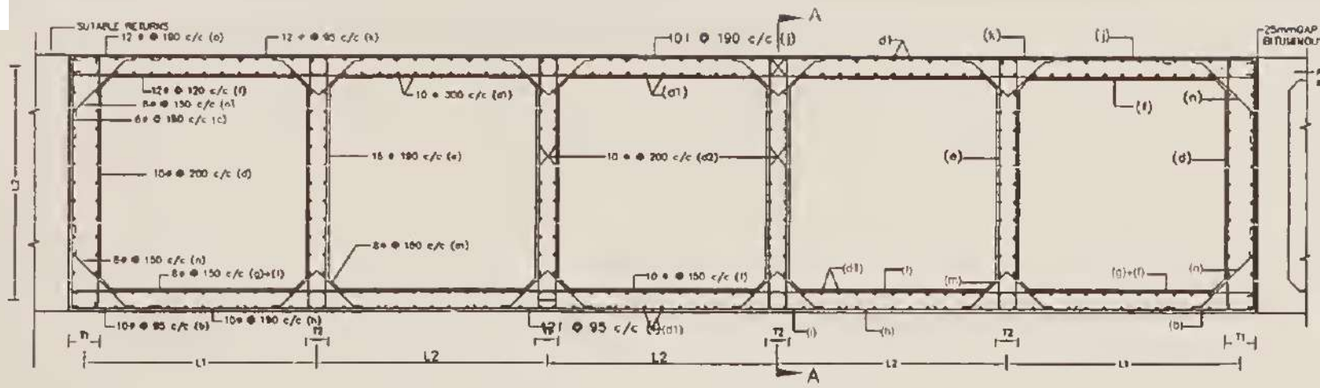
NOTES: –

I) THIS DRAWING IS APPLICABLE TO BRIDGES LOCATED IN NON SEISMIC ZONES ONLY.
II) THE RATE OF RISE TO SPAN OF THE CENTRAL LINE OF ARCH RING SHALL BE 1/4.
III) THIS DRAWING IS APPLICABLE FOR OVERALL ROAD WIDTH OF 7.5M, 6.4M. OR 6.0M FOR HIGH LEVEL BRIDGES AND CAUSEWAY.
IV) FIGURED DIMENSIONS SHALL BE TAKEN INSTEAD OF SCALED DIMENSIONS.
V) ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED

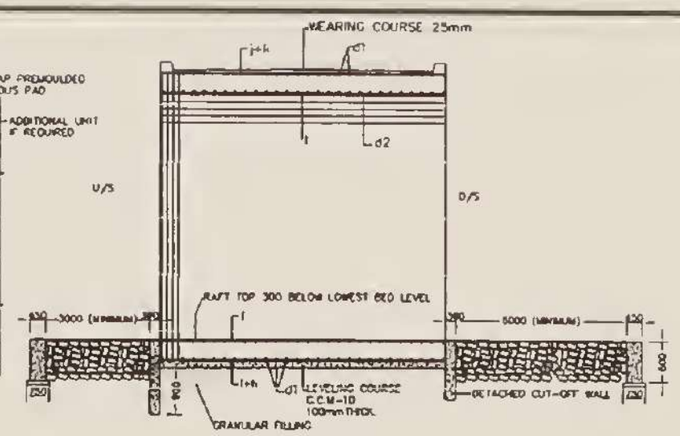
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES

DRG.TITLE.
MASONRY ARCH BRIDGES EFFECTIVE SPANS 6.0 M.,9.0 M. & 12.0 M.

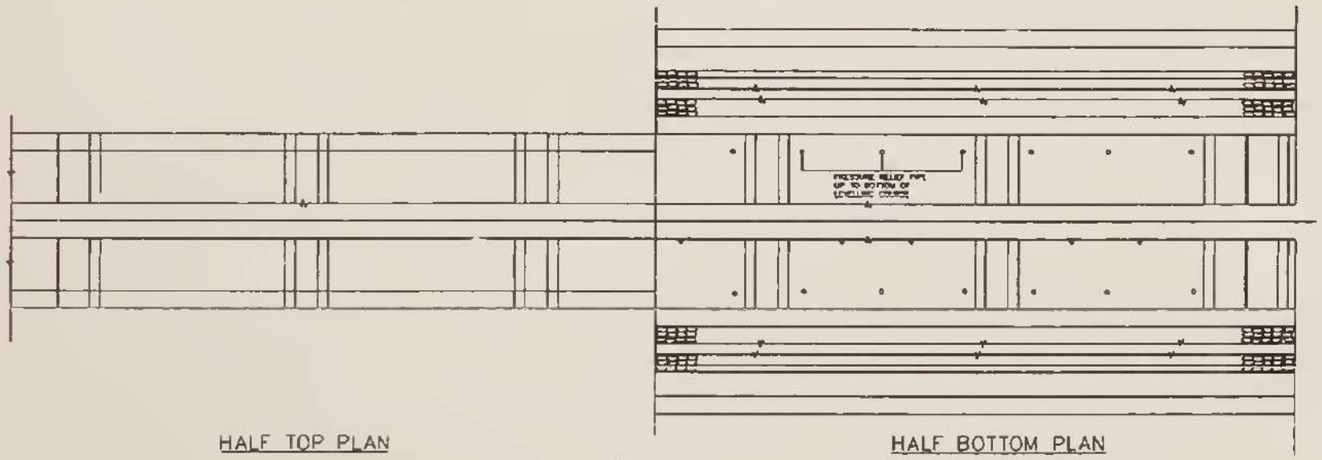
PLATE NO.-7.17



LONGITUDINAL SECTION



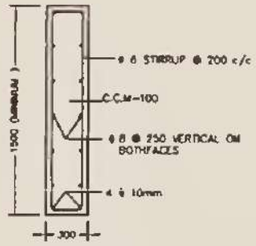
CROSS SECTION AT A-A



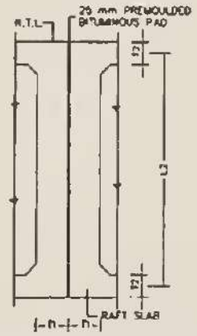
HALF TOP PLAN

HALF BOTTOM PLAN

PLAN



CUT-OFF WALL (MINIMUM DEPTH 1500)



DETAILS OF JOINT AND GAP FOR MORE THAN ONE UNIT

NOTES: -

1) ALL DIMENSIONS ARE IN mm EXCEPT OTHERWISE SPECIFIED.
2) GRADE OF CONCRETE 1:1.5:3
3) GRADE OF STEEL-Fe 415 AS PER I.S:1786.
4) EXPOSURE CONDITION - MODERATE
5) CLIMATIC CONDITION - MODERATE AND SEVERE.
6) SEISMIC EFFECT IS NOT CONSIDERED AS LENGTH LESS THAN 60 M.
7) SUB-GRADE REACTION OF SOIL ASSUMED AS 2800 M.T/Sqm (I.E. SANDY OR SOFT MURUM)
8) CLEAR ROADWAY WIDTH IS 7.5 M. FOR DOUBLE LANE BRIDGE.
9) 70R WHEELED/TRACKED SINGLE LANE OR CLASS A TWO LANE PRODUCTING WORST EFFECT ARE CONSIDERED FOR DESIGN.
10) FILLING BEHIND ABUTMENT SHALL BE AS PER GOVT. OF INDIA CIRCULAR NO. LR-8(3) 68 DATED 17/8/1971 AND ANNEXURE-6 OF I.R.C.-78.
11) ADEQUATE WHEEP HOLES SHALL BE PROVIDED IN ABUTMENT AND RETURN AT SPACING NOT MORE THAN 1000 mm HORIZONTALLY AND VERTICALLY IN STAGGERED MANNER.
12) CUT-OFF WALL ALONG PERIPHERY OF RAFT SHALL BE PROVIDED AS SHOWN IN THE FIGURE. THE CUT-OFF WALLS SHALL NOT BE INTEGREL WITH THE RAFT. THE LONGITUDINAL AND CROSS CUT-OFF WALLS SHALL BE MONOLITHIC.
13) RAFT TOP SHALL BE KEPT 300mmBELOW LOWEST BED RAFT TOP SHALL BE KEPT 300mmBELOW LOWEST BED
14) CLEAR COVER OF 40 mm SHALL BE PROVIDED TO MAIN LEVEL.
15) SUITABLE TYPE OF RETURNS SHALL BE PROVIDED DEPENDING UPON FOUNDING STRATA.
16) PRESSURE RELIEF PIPE OF 100 mm DIA SHALL BE PROVIDED AT 8 NO. PER SPAN FOR TWO LANE BRIDGE AREA 0.5 x 0.5M. BELOW PRESSURE RELIEF PIPE SHALL BE PROVIDED IN THE FORM OF INVERTED FILTER OR PERMEABLE GEOTEXTILE OF SUITABLE GRADE FOUNDATION SOIL.
17) FILLING BEHIND END WALL SHALL NOT BE DONE BEFORE COMPLETION OF BOX.
18) THE MINIMUM DEPTH OF CUT-OFF WALL SHALL BE 1500mm BELOW TOP OF RAFT HOWEVER, IT MAY BE ENSURED THAT THE NORMAL SCOUR LEVEL WILL BE ABOVE THE BOTTOM OF CUT- OFF WALL.
19) CUT-OFF WALLS ARE NOT DESIGNED AS RETAINING WALL HENCE FILLING SHALL BE DONE EVENLY ON BOTH SIDE.
20) IN ORDER TO ENSURE SAFETY OF RAFT FOUNDATION THE WORK OF R.C.C. RAFT FOUNDATION AND PROTECTIVE WORK SHALL BE FINISHED BEFORE FLOODS.
21) APPRON LENGTH SHOWN IN THIS DRAWING ARE MINIMUM ONE SIZE OF STONE/CONE BLOCK DEPENDS UPON VELOCITY OF FLOW BUT IN NO CASE WEIGHT OF EVERY STONE SHALL BE LESS THAN 40 Kg.
22) RAILING/EXPANSION JOINT/WEARING COAT SHALL BE OF APPROVED TYPE.
23) THE DESIGN CALCULATIONS ARE BASED ON THE ASSUMPTION THAT THE ANGLE OF INTERNAL FRICTION OF THE FILL IS 30° AND DENSITY 1.8 TON/M³
24) IF FULL LENGTH BARS ARE NOT AVAILABLE JOINTS HAVE TO BE OVERLAPPED AS PER I.R.C. CLAUSE NO 304.8 OF I.R.C.-21 OVERLAPPING OF BAR SHALL BE SUITABLE STAGGERED.
25) SUPPORT CHAIRS OF SUITABLE DIAMETER BARS SHALL BE PROVIDED TO SUPPORT REINFORCEMENT.
26) THE DESIGN IS ALSO APPLICABLE FOR SUBMERSIBLE BRIDGES. HOWEVER, THE KERB SHALL BE DISCONTINUOUS AND THE RAILING SHALL BE OF REMOVABLE TYPE.
27) THE VENT WAY SHALL BE PROVIDED FOR FULL WIDTH OF THE CHANNEL. IT IS DESIRABLE TO KEY THE SUBMERSIBLE BOX ADEQUATELY INTO THE BANKS TO AVOID OUT FLANKING.
28) THE TYPE DESIGN IS APPLICABLE FOR VARIATION IN PIER HEIGHT BY± 300 mm.

		OPENING 2000X2000 mm			OPENING 3000X3000 mm			OPENING 4000X4000 mm			OPENING 5000X5000 mm		
BAR MARKS	SHAPE OF BARS	BAR DIAMETER	SPACING	LENGTH	BAR DIAMETER	SPACING	LENGTH	BAR DIAMETER	SPACING	LENGTH	BAR DIAMETER	SPACING	LENGTH
a		10 2420 710	140	3840	12 3220 1110	180	5040	12 4820 410	155	7840	16 4820 710	160	8540
b		10 1600 710	95	2310	10 1600 1110	95	2210	16 2200 410	155	4110	16 2200 710	160	4810
c		8 210 710	140	1420	8 1110 1110	180	2220	10 1410 410	310	2820	8 1210 710	160	3420
d		10 2420	200	2420	10 3020	200	3520	10 4420	220	4820	12 5220	260	4620
d1		10 7950	300	795	10 7950	300	795	10 7950	300	795	10 7950	300	795
d2		10 7950	200	795	10 7950	200	795	10 7950	200	795	10 7950	200	795
e		12 1380 162	180	5084	12 3480 212	180	7384	16 4610 262	155	9744	16 ø 10 ø 3720 342	160	12184
f		10 11420	160	11420	10 16920	150	16920	12 22200	155	22200	16 27520	160	27520
f1													
g		8 2450	320	2460	8 3650	150	3650	10 4750	155	4750	8 5650	160	5360
g1													
h		10 11420	140	11420	10 16920	180	16920	10 22200	155	22200	12 27520	160	27520
i		12 1250	140	1250	12 1900	85	1900	16 2450	155	2450	20 3000	160	3000
j		10 11420	140	11420	10 16920	180	16920	10 22200	155	22200	10 27520	160	27520
k		12 1250	140	1250	12 1900	85	1900	16 2450	155	2450	20 3000	160	3000
l		12 11420	130	11420	12 16920	120	16920	16 22200	155	22200	16 27520	160	27520
m		8 200 200	150	824	8 200 200	150	824	8 200 200	150	966	8 200 200	150	966
n		8 200	160	612	8 200	150	812	8 200	160	683	8 200	150	683
		HUNCH 150 x 150			HUNCH 150 x 150			HUNCH 200 x 200			HUNCH 200 x 200		
		T 1 250	T 2 250		T 1 400	T 2 300		T 1 450	T 2 350		T 1 500	T 2 400	
		L 1 2250	L 2 2250		L 1 3350	L 2 3300		L 1 4400	L 2 4350		L 1 5450	L 2 5400	

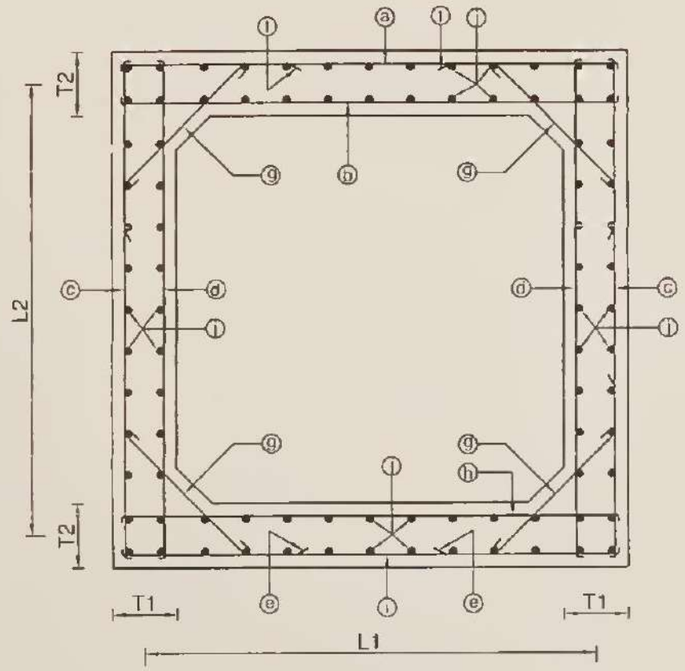
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

DRG. TITLE

CONTINUOUS R.C.C. BOX CELL BRIDGE
CLEAR OPENING 2 x 2m, 3 x 3m,
4 x 4m AND 5 x 5m.

PLATE NO.-7.18



L-SECTION

	OPPENING 2000X2000 m.m. HUNCH 150X150				OPPENING 3000X3000 m.m. HUNCH 150X150				OPPENING 4000X4000 m.m. HUNCH 200X200				OPPENING 5000X5000 m.m. HUNCH 200X200			
BAR MARK	BAR DIA.	SHAPE	SPACING	LENGTH	BAR DIA.	SHAPE	SPACING	LENGTH	BAR DIA.	SHAPE	SPACING	LENGTH	BAR DIA.	SHAPE	SPACING	LENGTH
a	10	2420 (75 75)	140	2570	10	3720 (75 75)	190	3870	10	4820 (75 75)	155	4970	10	5920 (75 75)	160	6070
b	12	75 75 / 2420	130	2570	12	75 75 / 3720	120	3870	16	75 75 / 4820	155	4970	16	75 75 / 5920	160	6070
c	10	710 / 2420	140	3840	12	1110 / 3520	190	5740	12	1410 / 4020	155	7440	16	1710 / 5720	160	9140
d	10	75 / 2420 / 75	200	2570	10	75 / 3520 / 75	200	3670	10	75 / 4620 / 75	200	4770	12	75 / 5720 / 75	200	5870
e	12	710 710	140	1420	10	1110 1110	95	2220	16	1410 1410	155	2820	16	1710 1710	160	3420
f	8	710 / 710	140	1420	8	1110 / 1110	190	2220	10	1410 / 1410	155	2820	10	1710 / 1710	160	3420
g	8	200 / 750 / 200	150	1150	8	200 / 800 / 200	150	1200	8	200 / 850 / 200	150	1250	8	200 / 900 / 200	150	1300
h	10	2420 (75 75)	160	2570	10	3720 (75 75)	150	3870	12	4208 (75 75)	155	4970	16	6920 (75 75)	160	6070
i	10	75 75 / 2420	140	2570	10	75 75 / 3720	190	3870	10	75 75 / 4820	155	4970	12	75 75 / 5920	160	6070
j	10	8320	200	8320	10	8320	200	8320	10	8320	200	8320	10	8320	200	8320
	T1=250 T2=250 L1=2250 L2=2250				T1=400 T2=300 L1=3400 L2=3300				T1=450 T2=350 L1=4450 L2=4350				T1=500 T2=400 L1=5500 L2=5400			

ALL DIMENSIONS ARE IN mm UNTILL & UNLESS STATED

THIS TABLE IS 7.5M. TOP ROAD WIDTH

THIS DRAWING MAY BE COMMON FOR ROAD TOP WIDTH 7.5M.,6.4M.AND6.0M.

STEEL SPACING WILL NOT BE CHANGED NUMBER OF BARS ADJUST ACCORDING TO WIDTH.

STEEL MUST CONFORM TO Fe 415 (I.S:1786)

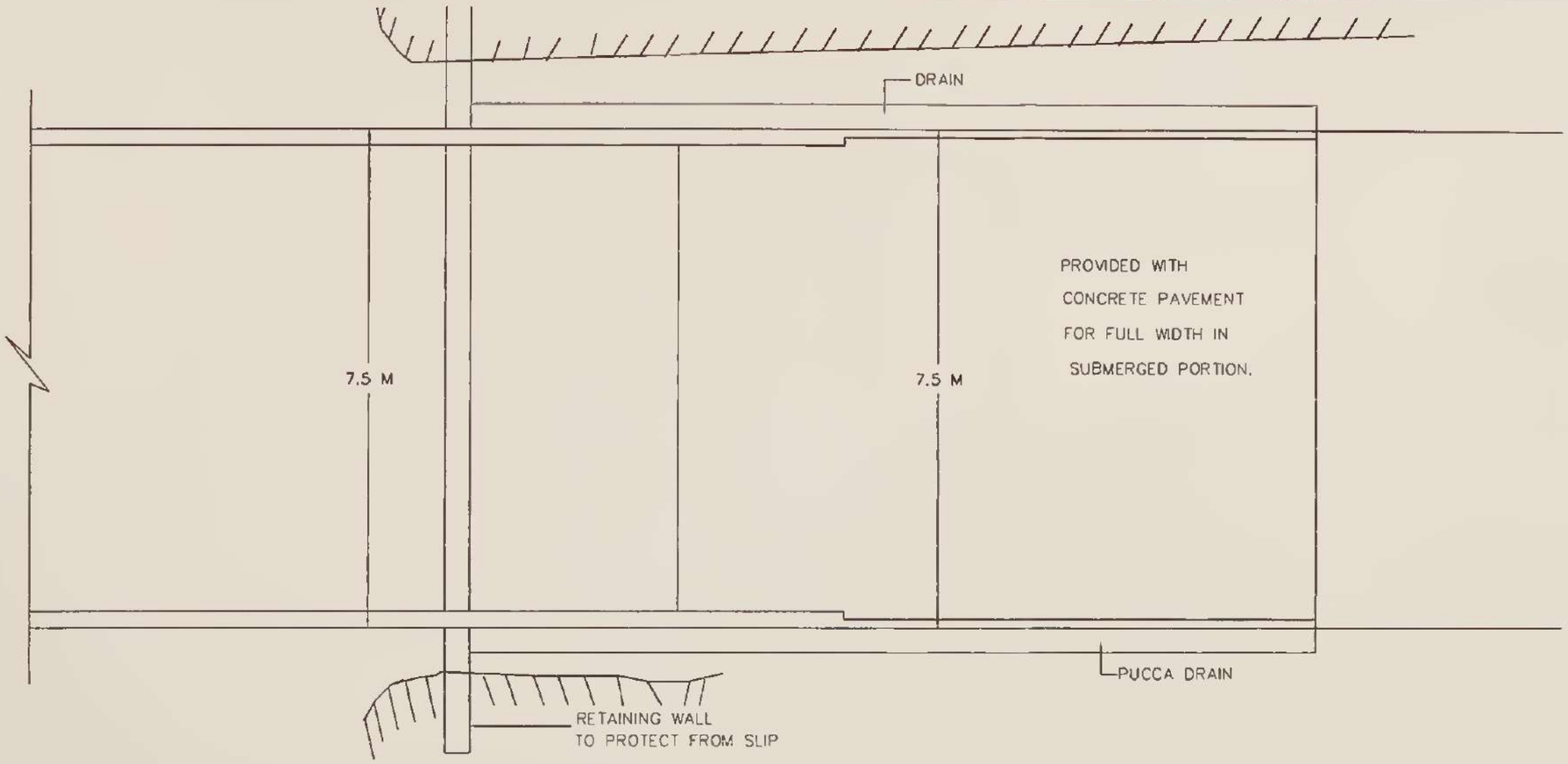
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

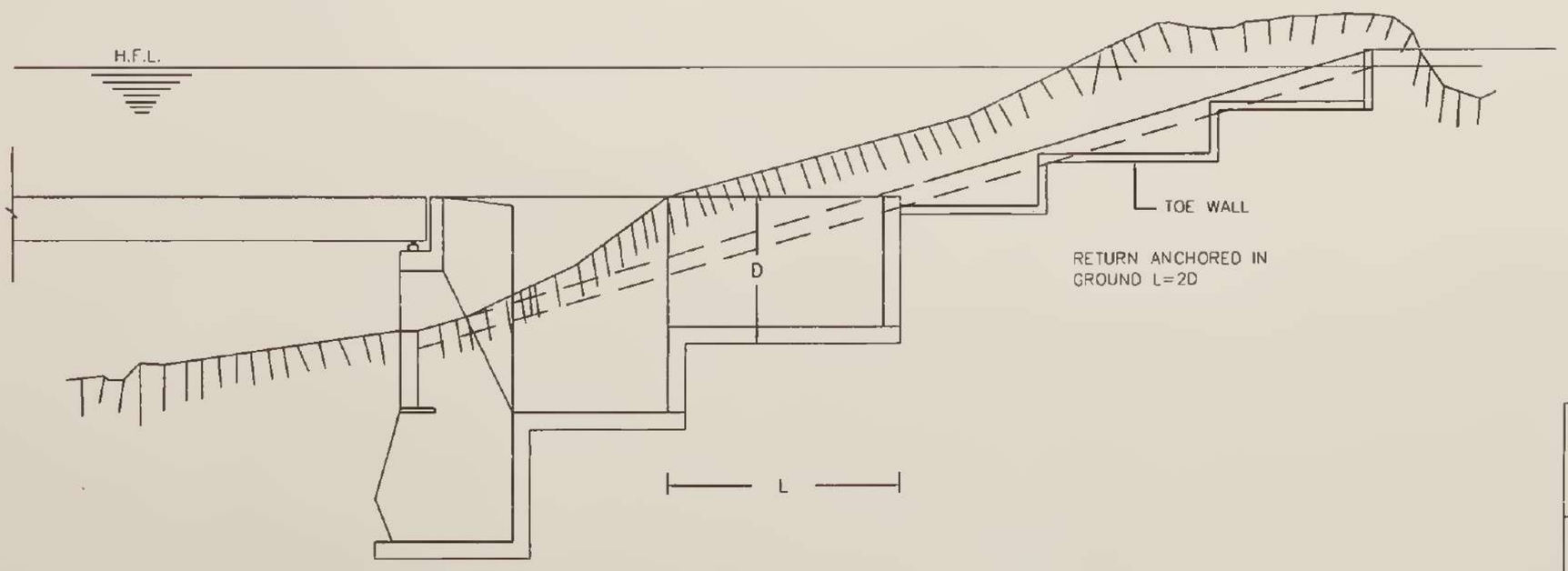
DRG TITLE:

SINGLE R.C.C. BOX CELL BRIDGE
CLEAR OPENING 2 x 2m, 3 x 3m,
4 x 4m AND 5 x 5m.

PLATE NO -7.19



PLAN



LONGITUDINAL SECTION

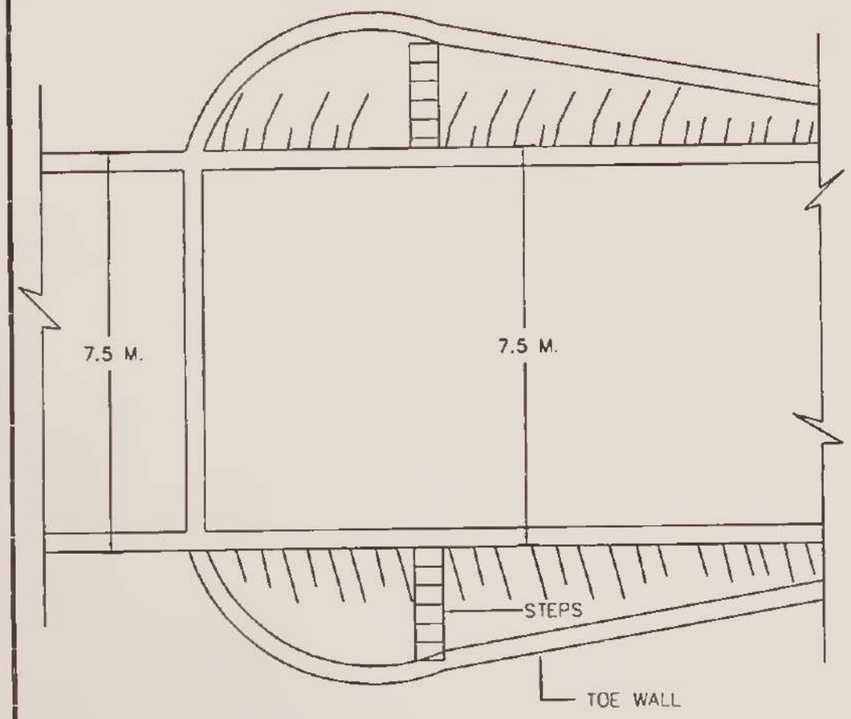
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

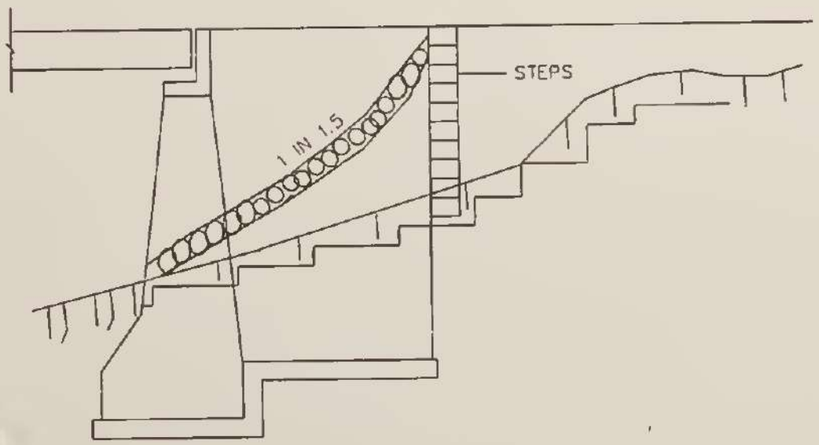
DRG.TITLE.

CULVERTS AND SMALL BRIDGES
PROTECTION WORK OF BRIDGES

PLATE NO.-7.20

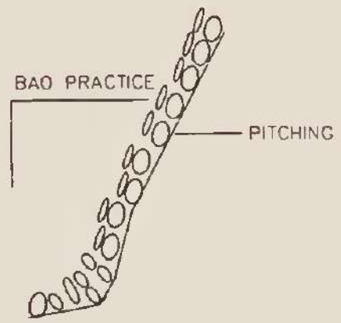


PLAN

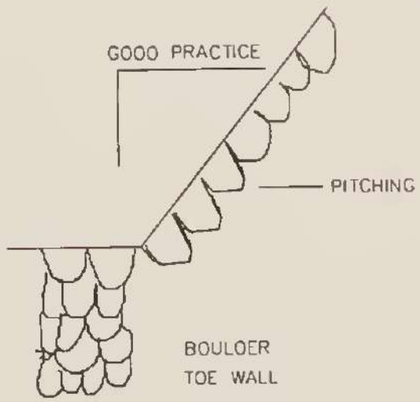


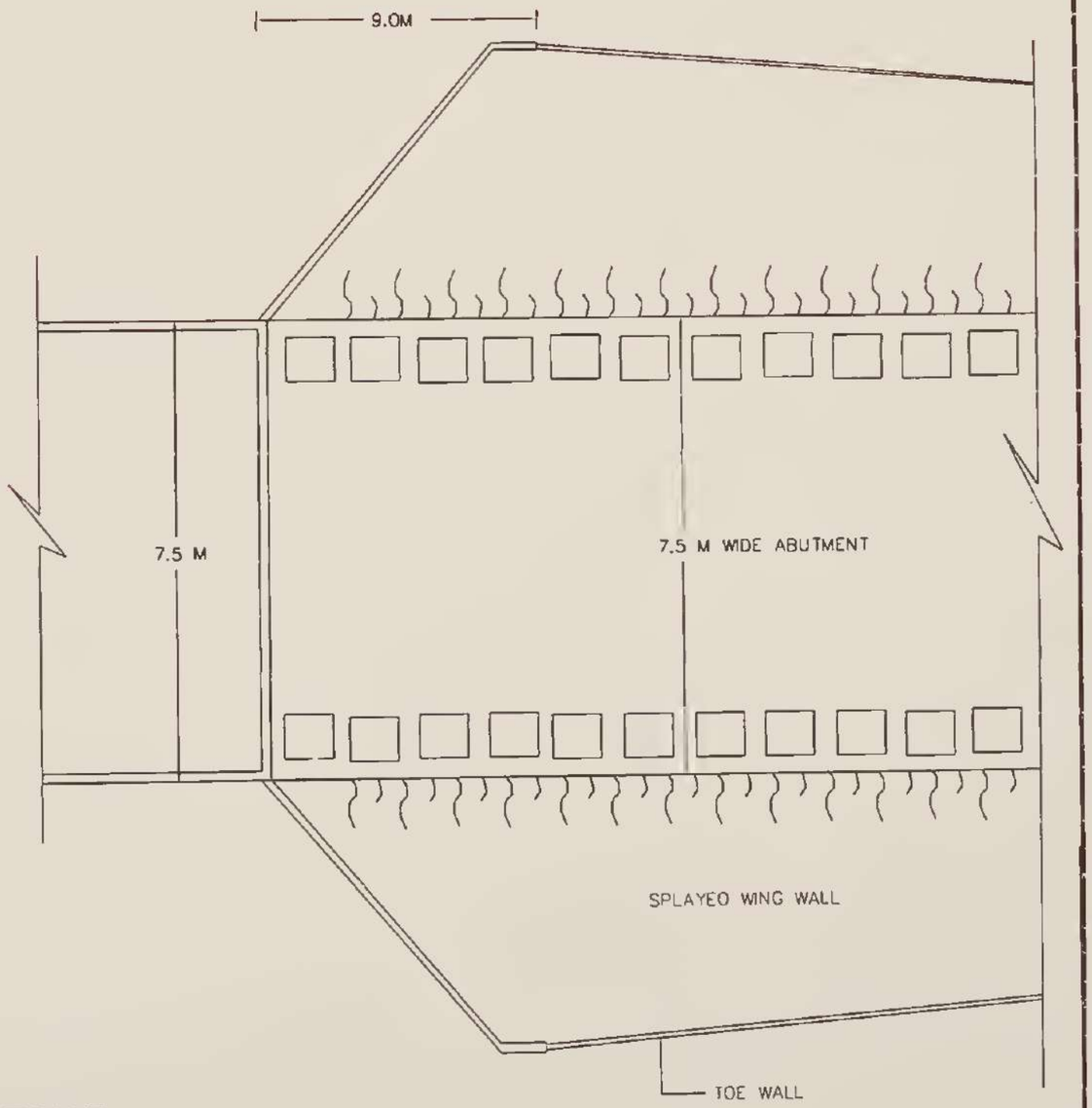
ELEVATION

STRAIGHT & FLAIRED UP RETURNS



BOULOERS OUMP FOR
PITCHING OOES NOT
STANO.





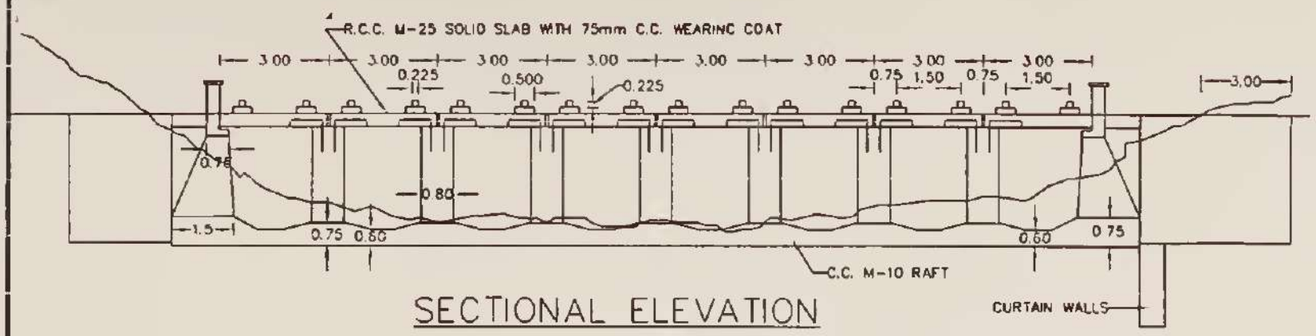
MASONRY STONE

200 X 200 X 250mm
200 x 150 x 400mm
SIZE USED FOR PITCHING
LAID ON 150 mm MOORUM.
TOE WALL IS MUST

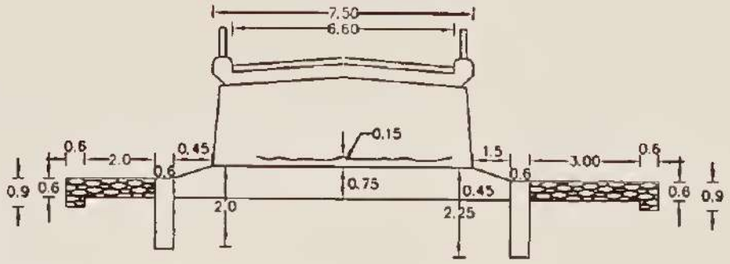
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES

DRG.TITLE.
CULVERTS AND SMALL BRIDGES
PROTECTION AROUND ABUTMENT

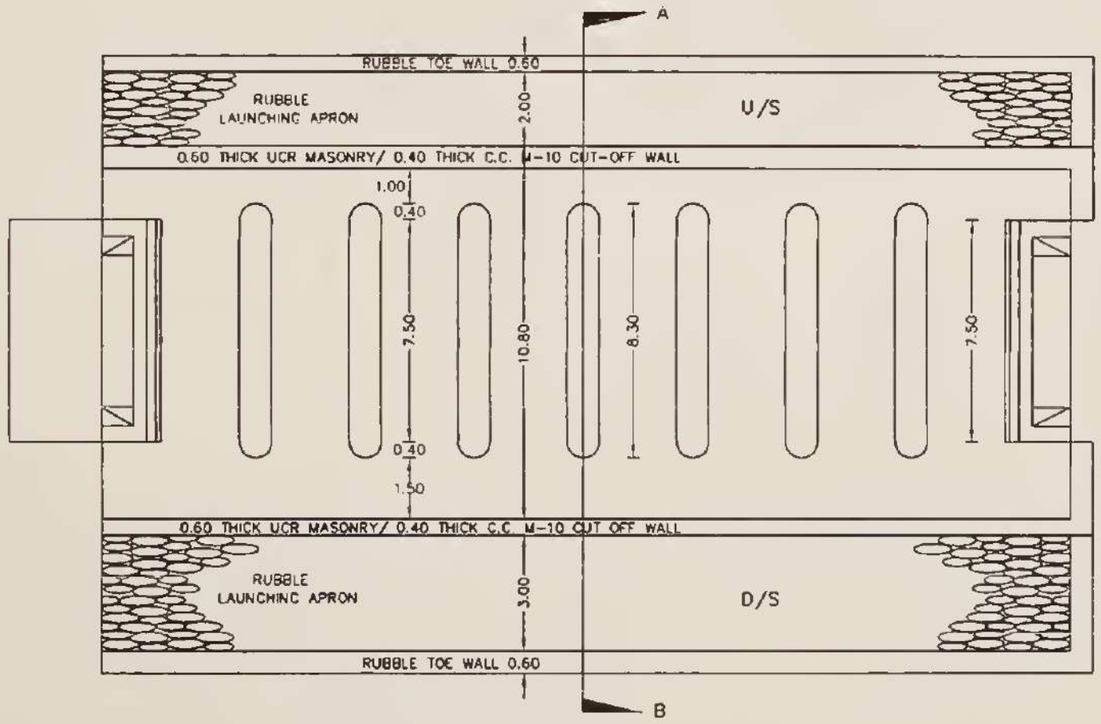
PLATE NO.-7.21



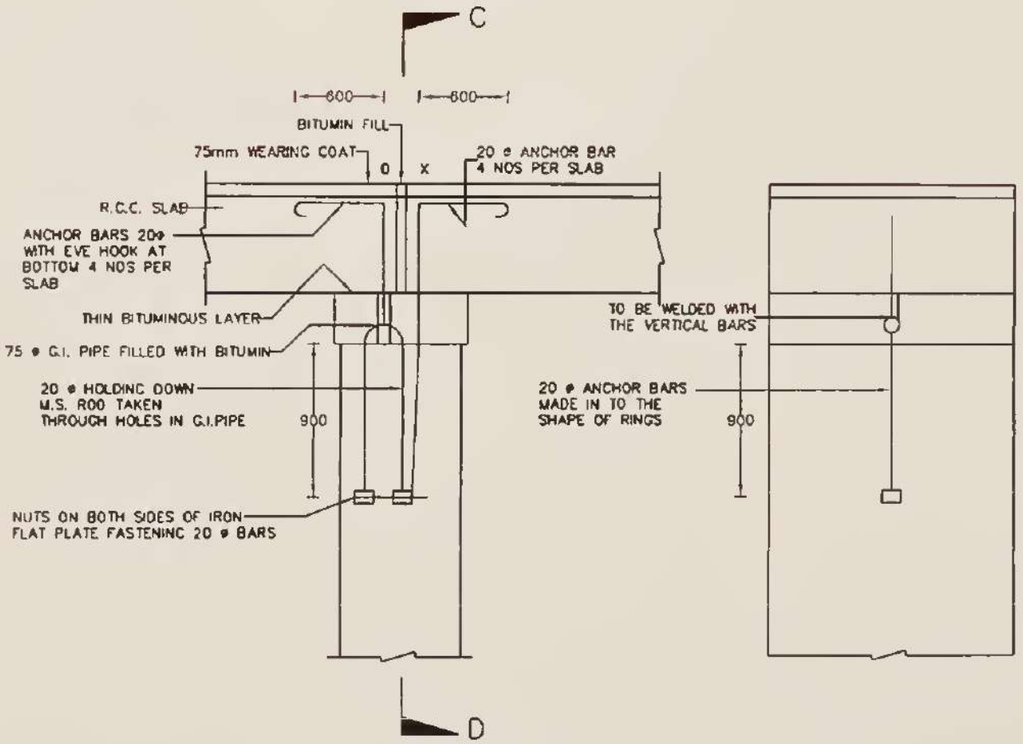
SECTIONAL ELEVATION



SECTION A–B



PLAN



SECTION ELEVATION

SECTION C–D

HIGHER LEVEL CAUSEWAY WITH RAFT FOUNDATION

ANCHOR BAR FOR R.C.C. SLABS OF SUBMERSIBLE BRIDGE

ALL DIMENSIONS IN RC DETAILING ARE IN mm.

NOTES :–

1. ALL DIMENSIONS ARE IN METRES FOR PLAN & ELEVATION OF CAUSEWAY.
2. FDR PIERS ABUTMENTS RAFT RETURNS USE CEMENT CONCRETE M–1D ALTERNATELY C R MASONRY IN C.M. 1:5 MAY BE USED FOR PIER ABUTMENTS AND RETURNS.
3. BACK FILLING BETWEEN RETURNS SHALL BE AS PER SPECIFICATIONS LAID DOWN IN MORT&H SPECIFICATIONS FOR ROADS AND BRIDGE WORKS PARA 2907.
4. HEIGHT OF HIGHER LEVEL CAUSEWAY SHALL BE 2 METRES ONLY.
5. SURFACE REINFORCEMENT OF 8 ø @ 200 C/C ON EXPOSED SURFACE OF M–15 CONCRETE OF PIERS ABUTMENTS RETURNS AND CONCRETE AT ROAD SURFACE OF RETURNS.
6. WIDTH OF C.R. MASONRY PIER– 1M FOR DETAILS OF R.C.C. SLAB SEE DRGS. ATTACHED SEPARATELY.
7. THIS DRAWING IS FOR 7.5 M. WIDTHICK IT CAN BE ADOPTED FOR 6.4M.,6.5M. OVERALL WIDTHS.
8. STEEL MUST CONFORM TO GRADE Fe 415 (I.S:1786)

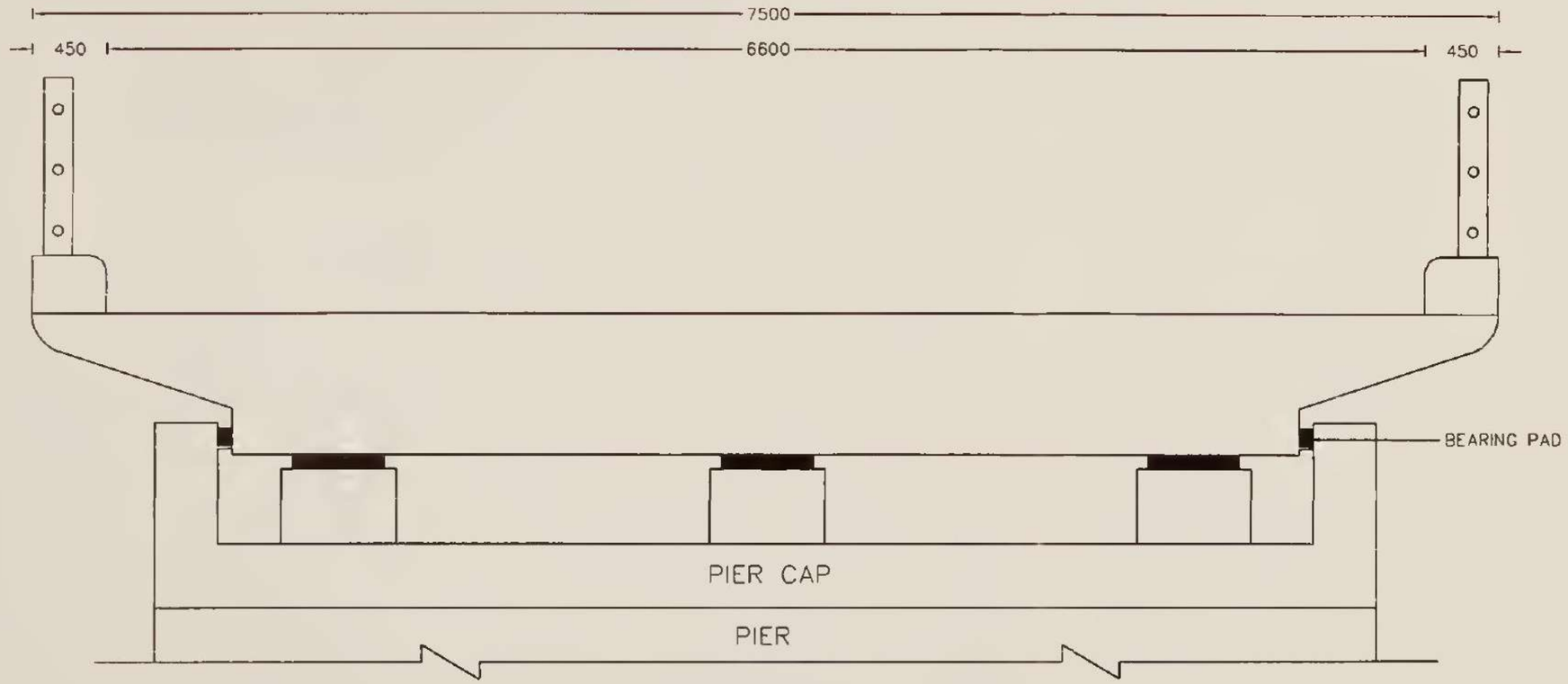
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

DRG.TITLE.

BRIDGES AND CAUSEWAYS
ON SANDY BED

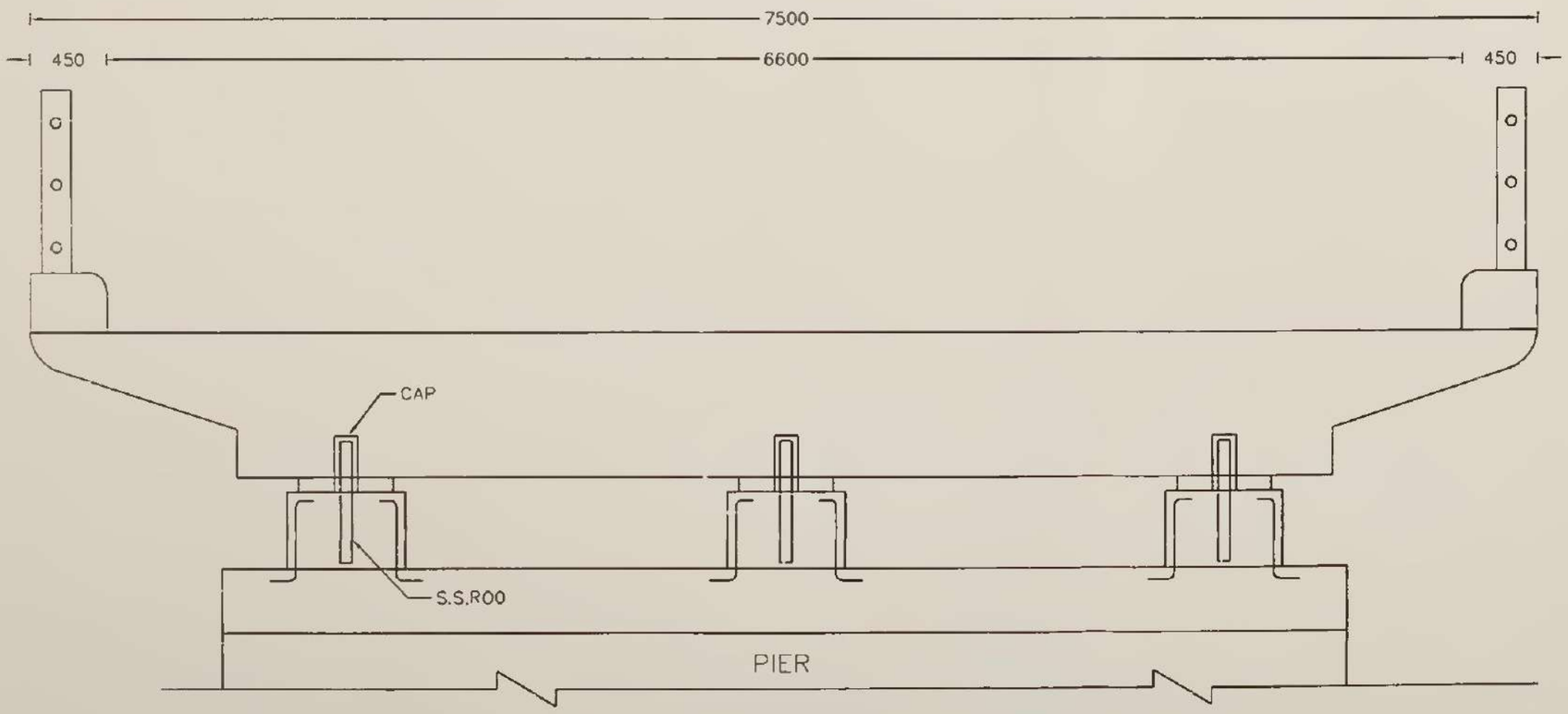
PLATE NO.-7.22



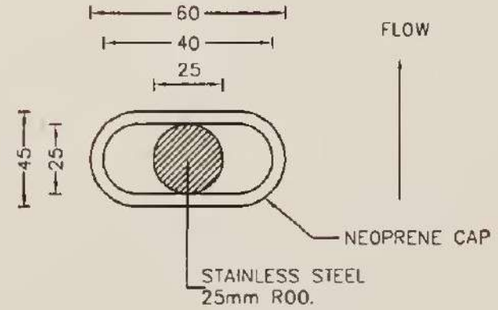
APPLICABLE FOR ROAD TOP WIDTH 7.5 6.4 & 6.0 M.

ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED

ANCHORAGE ARRANGEMENT



ANCHORAGE THROUGH BEARING



PLAN

RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

DRG.TITLE.

ANCHORAGE ARRANGEMENT FOR SUBMERSIBLE BRIDGE

PLATE NO.-7.23

QUANTITIES OF MASONRY & P.C.C. IN ABUTMENT AND RETURN WALL.

HEIGHT OF ABUTMENT & RETURN ABOVE FOOTING (IN MTRS.)	QUANTITY IN ABUTMENT		RETURN			P.C.C. FOOTING		TOTAL QUANTITY OF MASONRY		TOTAL QUANTITY OF P.C.C.	CROSS SECTION AREA OF RETURN		
	MASONRY C.R. IN		MASONRY C.R. IN			ABUTMENT	RETURN	C.M. 1:4	C.M. 1:5		P.C.C. FOOTING	MASONRY IN	
	C.M. 1:4 Cum.	C.M. 1:5 Cum.	LENGTH MTRS.	C.M.1:4 Cum.	C.M.1:5 Cum.	Cum.	Cum.	Cum.	Cum.			C.M. 1:4 Sq.m.	C.M. 1:5 Sq.m.
3.00	27.84	19.94	3.00	22.62	11.86	6.16	4.20	50.46	31.80	10.36	0.385	1.998	1.050
3.50	35.44	25.30	3.00	23.52	16.24	6.46	4.46	58.96	41.54	10.92	0.420	2.219	1.532
4.00	37.82	34.38	3.00	24.22	20.99	6.78	4.80	62.04	55.37	11.58	0.450	2.459	2.129
4.50	40.08	44.14	3.00	27.08	28.25	9.04	5.26	67.16	72.39	14.30	0.485	2.697	2.183
5.00	48.76	62.86	4.00	40.68	51.38	10.30	7.74	89.44	114.24	18.04	0.623	3.380	4.270
6.00	69.42	87.32	4.00	66.56	86.30	10.48	11.12	135.98	173.62	21.60	0.712	4.500	5.980
7.00	74.70	103.04	4.00	83.28	115.36	10.74	13.48	157.98	218.40	24.22	0.800	5.760	7.940
8.00	102.30	138.86	4.00	111.90	158.50	11.90	14.90	214.20	297.36	26.80	0.890	7.200	10.200

QUANTITIES OF P.C.C. CAP & DIRTWALL FOR ABUTMENTS

SPAN IN MTRS.	P.C.C. IN Cu.m.	REINFORCEMENT K.G.
3.50	35.44	25.30
4.00	37.82	34.38
4.50	40.08	44.14
5.00	48.76	62.86
6.00	69.42	87.32
7.00	74.70	103.04
8.00	102.30	138.86

QUANTITIES OF R.C.C. DECK SLAB

CLEAR SPAN 1.50 M. TO 10.00 M.	CONCRETE m^3	STEEL Kg.
1.5	3.31	298
2.00	4.68	478
3.00	8.10	827
4.00	12.76	1273
5.00	18.70	1828
6.00	24.48	2592
7.00	40.50	2684
10.00	61.87	3684
SPANS M.	CONCRETE m^3	STEEL Kg.
12.00	63.00	4683
15.00	89.50	7253
PER METRE QUANTITIES OF KERB & WEARING COAT		
SPAN	CONCRETE m^3	STEEL Kg.
1.50 M TO 15.00 M.	0.83	54
12.00 M. TO 15.00 M.	0.72	44

NOTES :-

1. FOR INTERMEDIATE HEIGHTS IN EACH GROUP SAY BETWEEN 3.00 M. TO 3.50 M. THE QUANTITIES MAY BE WORKED FROM OFFSETS OF THE SECTION. THE QUANTITIES OF FOOTING MAY BE BY PROVIDING OFFSET OF 100mm ON EITHER SIDE OF MASONRY.

2. ONLY TWO LENGTHS OF THE RETURN WALLS ARE CONSIDERED i.e. 3.00 M. & 4.00 M. IN SOME CASES FOR HEIGHTS FROM 5.00 M. TO 8.00 M., THE LENGTH OF RETURN WALL IS LIKELY TO BE MORE THAN 4.00 M. SINCE THE LENGTH OF RETURN WALL IS 1.5 TIMES OF THE HEIGHT FROM BED LEVEL TO ROAD TOP LEVEL OF THE ABUTMENT: THE CROSS SECTIONAL AREA OF THE RETURN WALL ARE MENTIONED, THIS AREA x LENGTH OF RETURNS ON 4 SIDES WILL BE ADDED IN QUANTITIES OF MASONRY, BASE CONCRETE & COPING.

3. INSTEAD OF STONE MASONRY IF IT IS DECIDED TO PROVIDED P.C.C., THAN THE BATTER MAY BE PROVIDE IN PLACE OF STEPS.

4. THE SURFACE REINFORCEMENT IN P.C.C. CAP & DIRT WALL BE 8mm BARS AT 200mm C/C OR 4 Kg/m^2 ON EXPOSED FACES.

5. COPING IN RETURNS
   FOR 3.00 M. LENGTH = 1.61 cum.
   FOR 4.00 M. LENGTH = 2.31 cum.
   THE QUANTITY OF 150mm THICK COPING IS 0.06 cu.m. PER METRE LENGTH
   REINFORCEMENT IN COPING @ 4 Kg/m OF EXPOSED SURFACE AREA.
   FOR 3.00 M. LENGTH = 6.44 Kg.
   FOR 4.00 M. LENGTH = 9.24 Kg.

6. WASTAGE IN STEEL OF DECK SLAB MAY BE WITHIN 3%.

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES

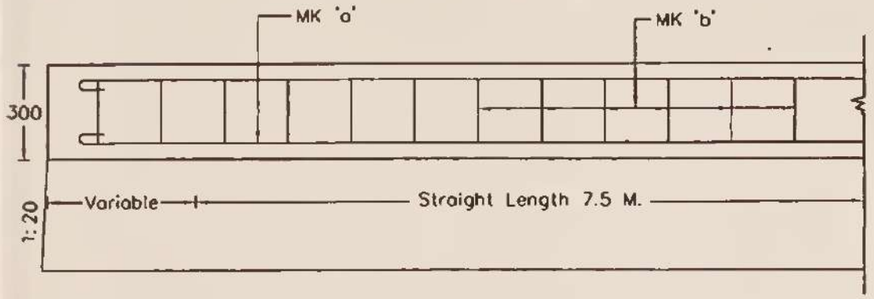
DRG.TITLE.

QUANTITIES OF ABUTMENTS, RETURNS & R.C.C. SLAB

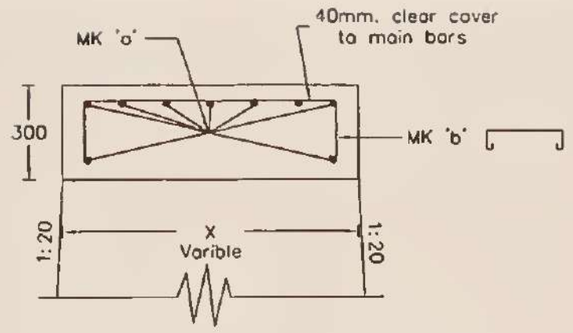
PLATE NO.-7.24

A R.C.C. PIER CAP FOR SOLID SLAB

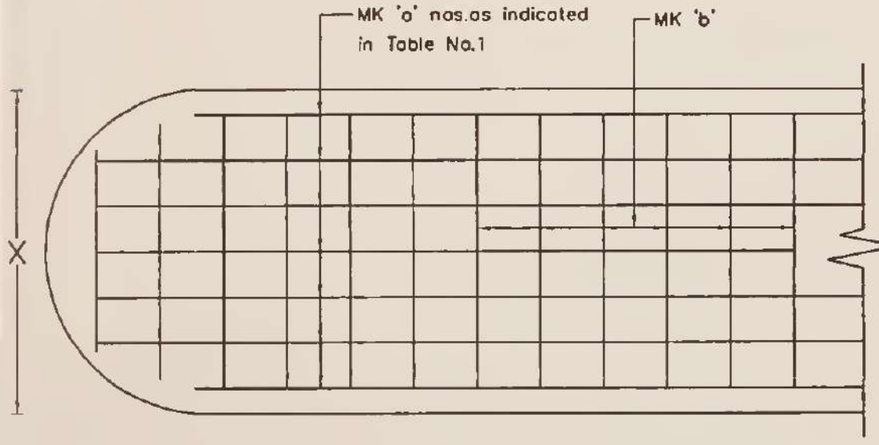
(SPAN MORE THAN 10 M. WHERE BEARINGS ARE PROVIDED)



ELEVATION



SECTION OF PIER CAP



PLAN

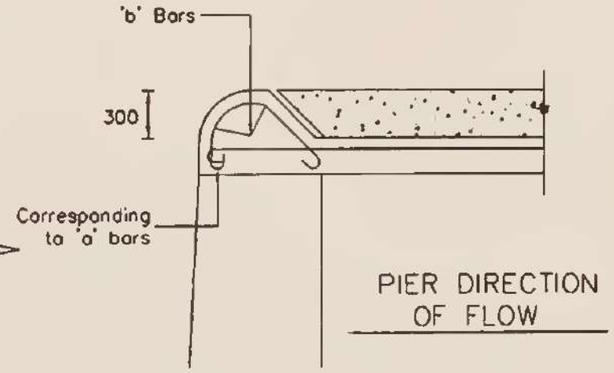


TABLE NO. I

REINFORCEMENT DETAILS FOR PIER CAP (SOLID SLAB)

SR. NO.	X WIDTH C.M.	REINFORCEMENT				QTY. OF H.Y.S.D. BARS Including 5% wastage	
		MK 'a'		MK 'b'		Per Metre Length	Per Cubic Metre
		DIA. mm.	No.	DIA. mm.	Spacing mm.	Kg.	Kg.
1.	75	12	8	12	150	16.7	74
2.	90	12	9	12	150	18	67
3.	105	12	10	12	150	20	74
4.	120	12	11	12	150	22	82

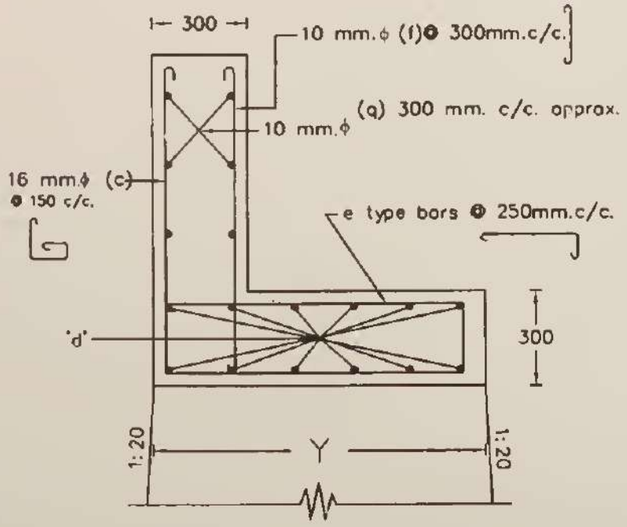
TABLE NO. II

REINFORCEMENT DETAILS FOR ABUTMENT CAP (SOLID SLAB)

SR.NO.	Width C.M. Y	REINFORCEMENT (H.Y.S.D.)						Qty. of H.Y.S.D. Bars	
		MK-'d'		MK-'c'		MK-'e'		Per Metre Length KG	Per Cubic Metre KG
		DIA mm.	No.	DIA mm.	Spacing mm.	DIA mm.	Spacing mm.		
1	90	12	9	12	250	12	250	23	85
		DART WALL STEEL = 75 kG./Cu.M.							

B DETAILS OF ABUTMENT CAP & DIRT WALL FOR SOLID SLAB

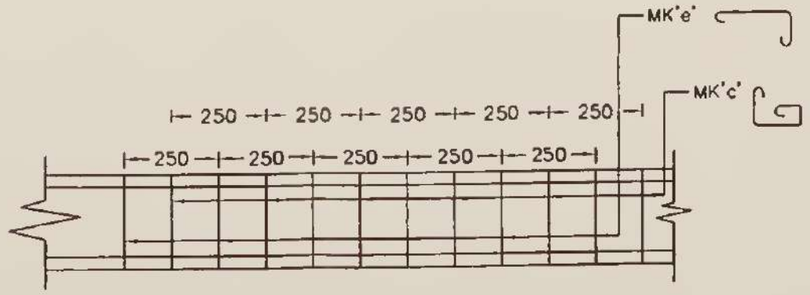
(TO BE PROVIDED FOR SPANS MORE THAN 6 M.)



A DETAILS FOR SUBMERSIBLE SOLID SLAB

SPECIAL NOTE :-

for submersible bridges the cop in the eose water portion may be roised by 0.3 m. ond rounded ot top os shown @ Schedule of bors should be suitobly modified.



PART SIDE ELEVATION OF CAP ONLY

NOTES :-

1. All dimension are in milimetres unless otherwise mentioned.
2. Concrete C.C.M.20 os per specificotions of I.R.C. section III.
3. Steel should conform to Fe 415 (I.S:1786)

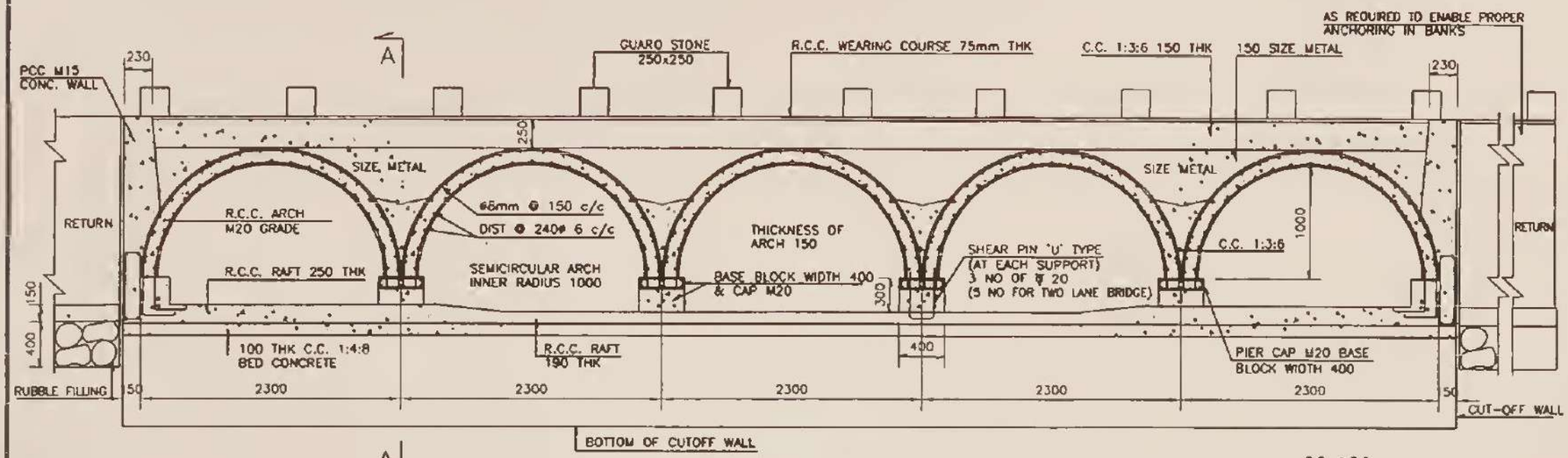
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

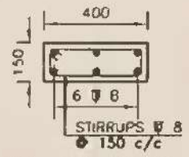
DRG.TITLE.

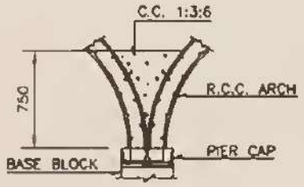
TYPE SECTIONS FOR PIER CAP & ABUTMENT CAPS & DIRT WALL

PLATE NO.-7.25



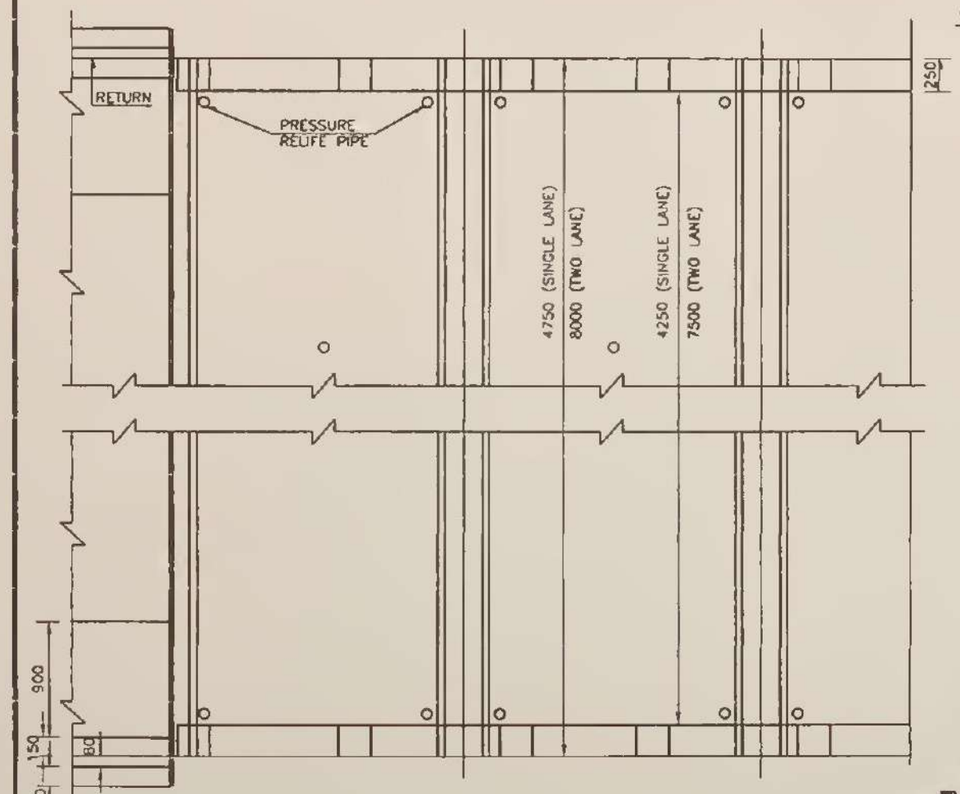
LONGITUDINAL SECTIONAL ELEVATION
1:50





NOTES:

1. ALL DIMENSIONS ARE IN mm EXCEPT OTHERWISE MENTIONED.
2. THE CLEAR ROAD WIDTH IS 7.5m FOR DOUBLE LANE WIDE ARCH BRIDGE & 4.25m FOR SINGLE LANE WIDE ARCH BRIDGE. THE CLEAR ROAD WIDTH SHALL BE MEASURED IN A DIRECTION PERPENDICULAR TO THE DIRECTION OF TRAFFIC.
3. THE ARCH BRIDGE HAVE DESIGNED AS,
   FOR SINGLE LANE WIDE SINGLE LANE OF CLASS 'A'.
   FOR DOUBLE LANE WIDE SINGLE LANE OF IRC CLASS 70R LOADING OR TWO LANES OF CLASS 'A' LOADING.
4. FILLING BEHIND RETURNS SHALL BE AS PER GOVT. OF INDIA CIRCULAR NO. LR-9 (3) C8 DATED 17/8/1971.
5. ADEQUATE WEEP HOLES SHALL BE PROVIDED IN RETURNS AT NOT MORE THAN 2000mms. c/c HORIZONTALLY & 1000mms. c/c VERTICALLY RESULARIY STAGGERED.
6. THERE SHALL BE A CLEAR JOINT BETWEEN PARAPET & KERB ON RETURNS & MAIN BRIDGE.
7. CROSS CUT-OFF WALL AT THE RAFT ENDS SHALL BE PROVIDED.
8. RAFT TOP SHOULD BE KEPT 300mm BELOW LOWEST BED LEVEL.
9. FOR R.C.C. DETAILS OF RAFT REFERS SEPARATE DRAWING NO. ARCH-3
10. R.C.C SEMICIRCULAR ARCH.
    a) CLEAR RADIUS _____ 1000 mm
    b) THICKNESS _____ 150 mm
    c) MIX _____ 1:1;5:3
    d) MAIN STEEL _____ FE-415-8mm @ 150mm c/c
    e) DISTRIBUTION STEEL _____ FE-250-8mm @ 240mm c/c
11. CLEAR COVER OF 40mm SHOULD BE GIVEN FOR MAIN REINFORCEMENT.
12. SUITABLE TYPE OF RETURNS MAY BE PROVIDED DEPENDING UPON THE FOUNDATION STRAIGHT.
13. HEIGHT OF BASE BLOCK INCLUDING CAP CAN BE MAXIMUM UP TO 750mms.
14. STEEL CONFORM TO GRADE Fe 415 (IS:1786)

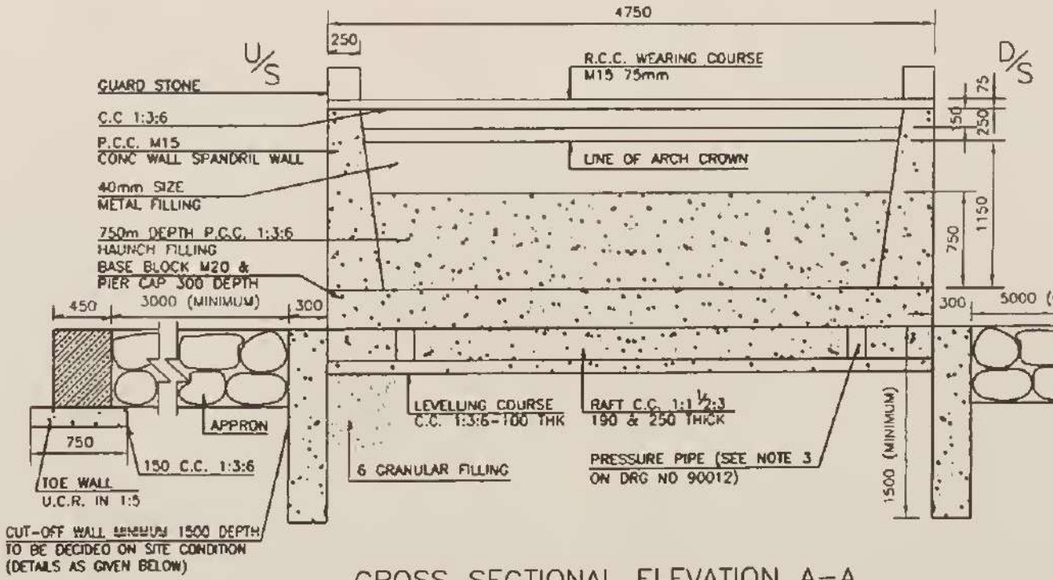


HALF TOP PLAN
1:50

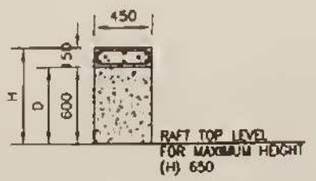
C/S OF PIER CAP

CUT-OFF WALL (MINIMUM DEPTH 1500)
1:50

DETAILS OF ANCHORAGE REINFORCEMENT
1:50



CROSS SECTIONAL ELEVATION A-A
1:50



DETAILS OF BASE BLOCK
1:50

RURAL ROADS MANUAL

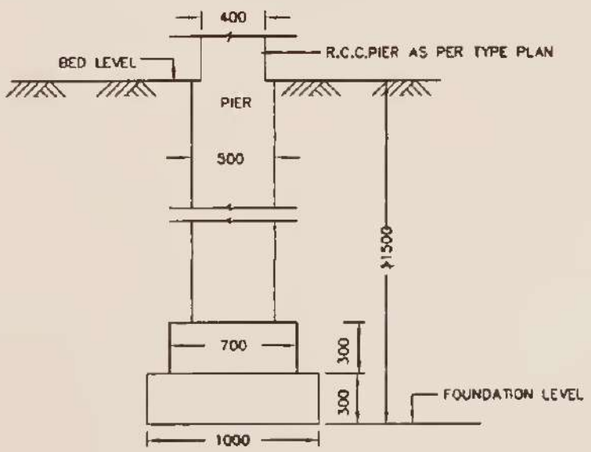
CULVERTS & SMALL BRIDGES

DRG.TITLE.

ARCH TYPE VENTED CAUSWAY (ARCH-1)

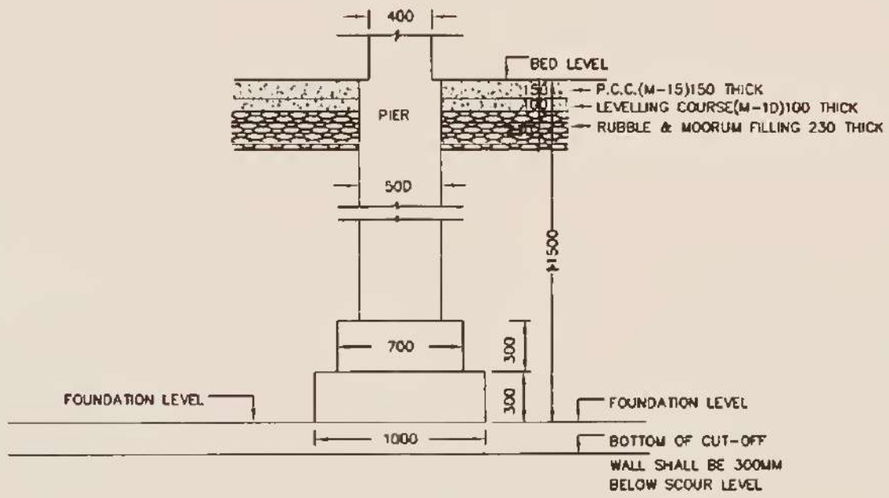
PLATE NO.-7.26.1

(A) SECTIONS FOR NON-ERODIBLE BED

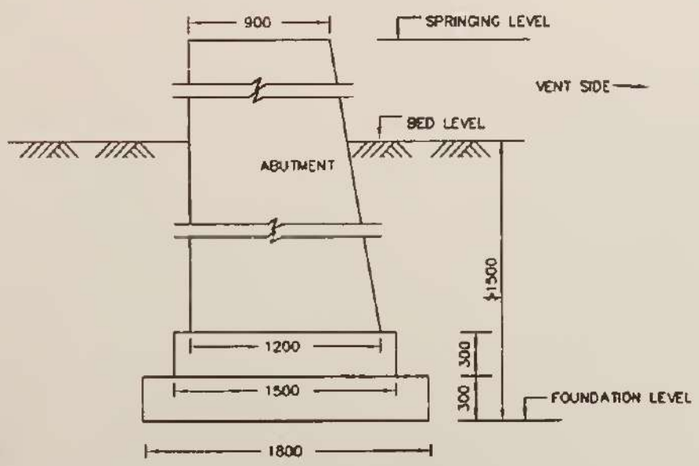


PIER SECTION A-1

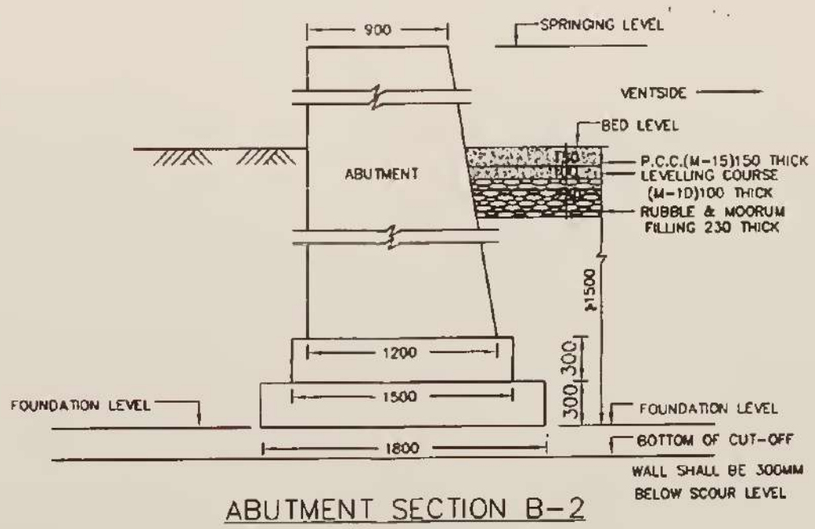
(B) SECTIONS FOR ERODIBLE BED



PIER SECTION B-1



ABUTMENT SECTION A-2



ABUTMENT SECTION B-2

NOTES:-

1. OPEN FOUNDATION DETAILS ARE SHOWN IN CASE OF ERODEBLE AND NON-ERODIBLE BED.
2. MINIMUM SBC AT FOUNDATION LEVEL SHOULD NOT BE LESS THAN 35T/SQ.M.
3. HEIGHT FROM FOUNDATION TO SPRINGING LEVEL SHOULD NOT EXCEED 2.25 METRE.
4. IN CASE OF ERODIBLE BED ADEQUATE BED PROTECTION ON U/S & D/S SHOULD BE PROVIDED & THE VENTS SHOULD BE PAVED BY PROVIDING A LAYER OF 150 MM THICK P.C.C.M-15 OVER A LEVELLING COURSE OF 100 MM THICK C.C. M-10. THIS SHOULD BE LAID OVER A SUBBASE OF 230 MM RUBBLE AND MOORUM FILLING. THE PAVING IN THE VENTS SHOULD BE PROTECTED BY PROVIDING 300x1500 MM P.C.C. M-10 GRADE CUT-OFF WALLS AS SHOWN IN TYPE DRAWING.
5. ALL DIMENSIONS ARE IN MM EXCEPT OTHERWISE MENTIONED.
6. READ THIS DRAWING ALONG WITH DRAWING NO. ARCH-1 AND ARCH-3.
7. IN CASE OF EXCAVATION IN ROCK THE ANNULAR SPACE AROUND THE FOOTING SHALL BE FILLED WITH CONCRETE OF 1:3:6 MIX UP TO TOP OF ROCK.
8. RESTRICTIONS ON USE OF ARCH TYPE VENTED CAUSEWAY.
   - I) OPENING SHOULD BE PROVIDED FOR LENGTH FROM BANK TO BANK.
   - II) ADEQUATELY LONG RETURNS SHALL BE PROVIDED AND KEYED INTO BANK.
   - III) ADEQUACY OF CUT-OFF WALL DEPTH OF 1.5 METRE SHOULD BE CHECKED WITH REFERENCE TO SCOUR CALCULATIONS.
   - IV) ROAD TOP LEVEL ON CAUSEWAY SHOULD BE DESIRABLY MINIMUM 2m BELOW H.F.L. FOR LESSER WATER DEPTH, AFFLUX SHOULD BE CALCULATED AND CHECKED FOR ITS UNDESIRABLE EFFECTS.
   - V) EVERY 5TH PIER SHOULD BE ABUTMENT PIER AND ITS THICKNESS SHALL BE 30cm. MORE.
   - VI) SHOULD BE ADOPTED FOR FAIRLY DISCHARGING SECTION.
   - VII) APRON LENGTHS SHOWN HERE ARE MINIMUM ONE.SIZE OF STONE IN APRON SHOULD BE DECIDED IN REVALATION TO VELOCITY OF FLOW. BUT IN NO CASE WEIGHT OF EVERY STONE SHALL NOT BE LESS THAN 40kg.
   - VIII) SHOULD NOT BE USED WHERE WOODEN LOGS TREES ARE LIKLY BE CARRIED IN FLOOD.
   - IX) APPLICABLE FOR VALUE OF SUBGRADE REACTION OF 5800t/m^3 FOR SANDY STRATA AND 2800t/m^3 FOR B.C.SOIL. RAFT FOUNDATION SHOULD NOT BE USED ON ROCKY STRATA. SHOULD NOT BE USED WHERE MANNINGS MEAN VELOCITY EXCEED 5m/sec.

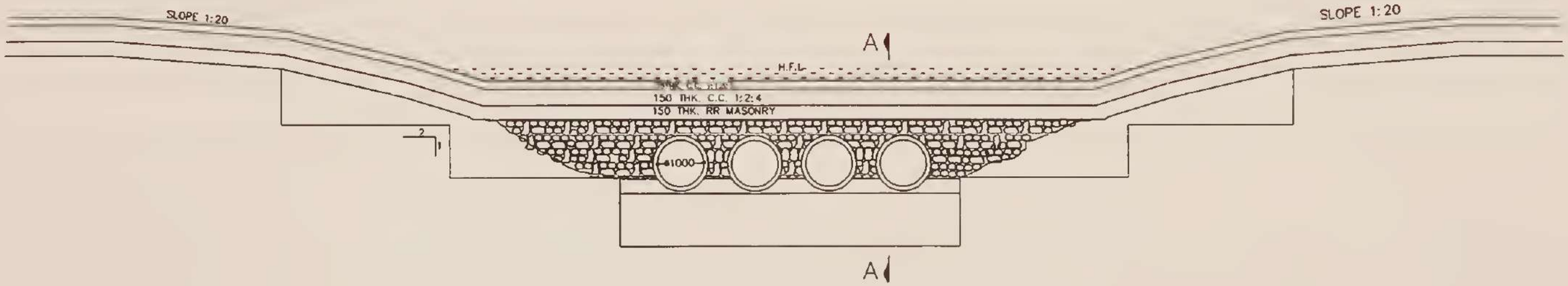
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

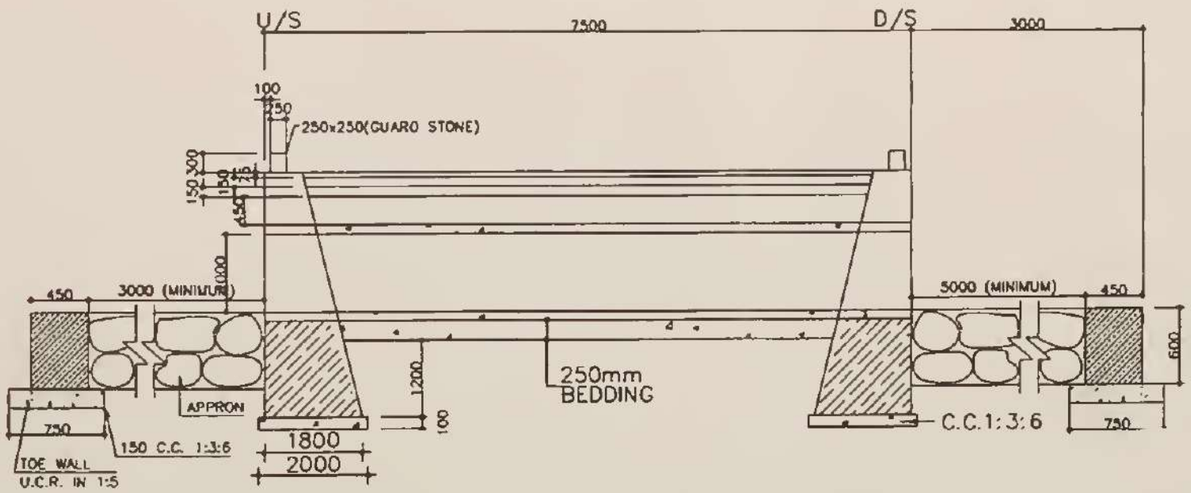
DRG.TITLE.

ARCH TYPE VENTED CAUSEWAY
WITH OPEN FOUNDATION
(ARCH-2)

PLATE NO.-7.26.2



LONGITUDINAL SECTIONAL ELEVATION



CROSS SECTION ELEVATION AT A–A

NOTES: –

1. THE PIPES SHALL BE R.C.C. NP.3 NON PRESSURE PIPES. THE SPECIFICATIONS OF PIPES SHALL BE AS PER I.S.458 OF 1988.
2. MINIMUM CUSHION ABOVE PIPE EXCLUDING ROAD CRUST SHALL BE 0.45M.
3. ALL OIMENSIONS ARE IN M.M.
4. CLEAR DISTANCE BETWEEN PIPES MAY BE ADOPTED 500M.M FOR 1000ø PIPES (UPTO 6 ROWS) & 600M.M. FOR 1200ø PIPES (UPTO 5 ROWS), LENGTH OF HEAD WALL WILL BE : –
5. PARAPETS COULD ALSO BE BUILT WITH BRICK MASONRY IN C.M.1:3 OR CEMENT CONCRETE 1:3:6.

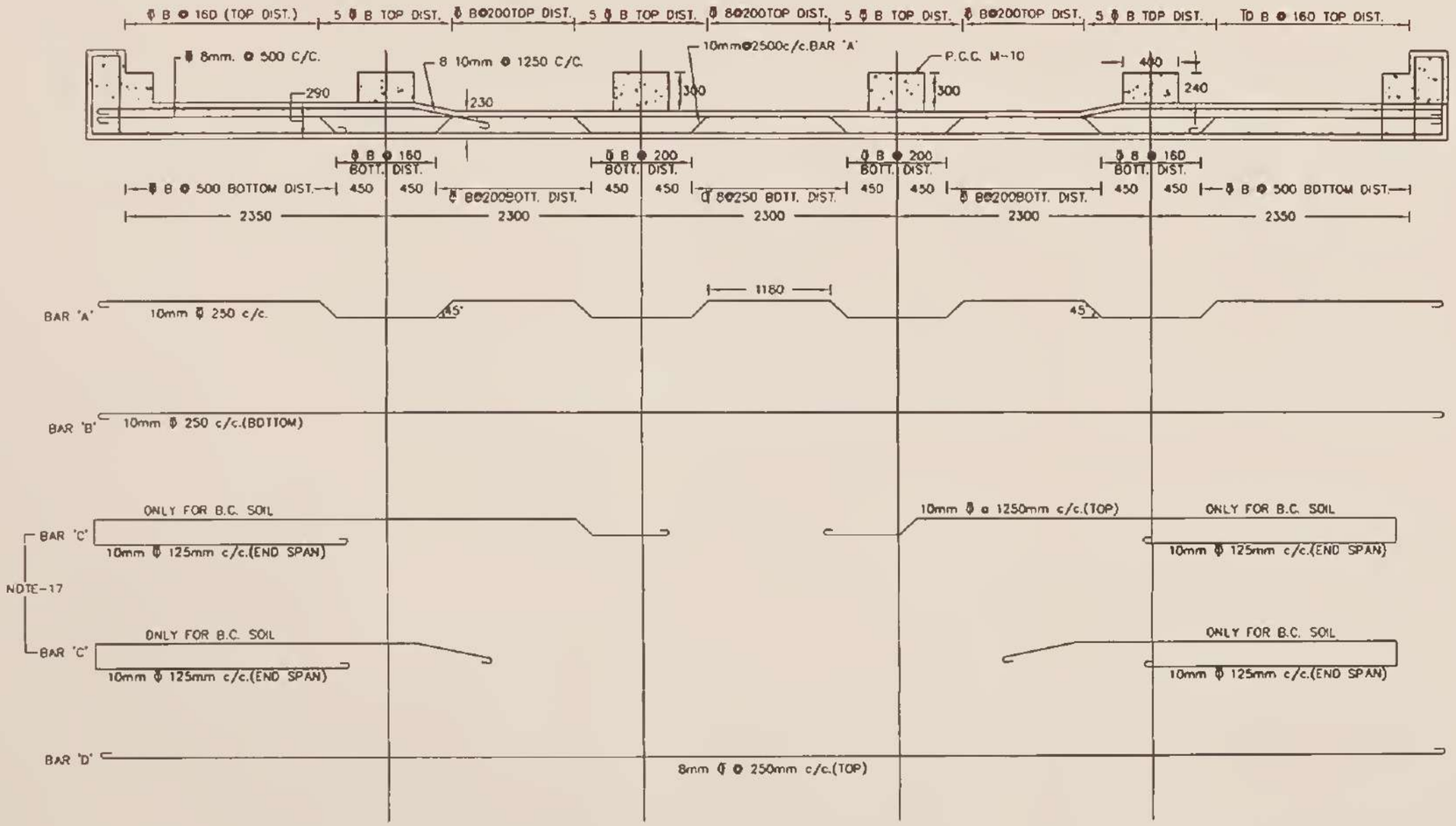
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

DRG.TITLE.

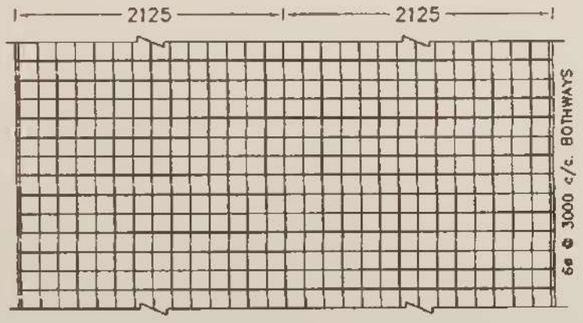
SUBMERSIBLE VENTED PIPE CAUSEWAYS

PLATE NO.-7.26.3



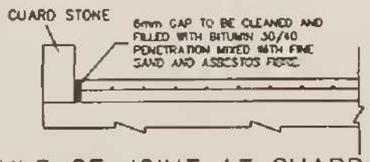
NOTES :-

1. RAFT CAN BE CONSTRUCTED ON COHESIVE & NON-COHESIVE SOIL.
2. THE MINIMUM DEPTH OF CUT-OFF WALL SHALL BE 1.50m. BELOW TOP OF RAFT, HOWEVER IT MAY BE ENSURED THAT THE NORMAL SCOUR LEVEL WILL BE ABOVE THE LEVEL OF BOTTOM OF THE CUTOFF WALL.
3. THE CUT-OFF WALLS ARE NOT DESIGNED AS RETAINING WALL HENCE FILLING SHALL BE DONE EVENLY ON BOTH SIDES.
4. 0.6m. THICK RUBBLE APRONS 3.0m. WIDE ON U/S AND 5.0m. WIDE ON D/S WITH TOP AT THE SAME LEVEL AS THAT OF THE RAFT SHOULD BE PROVIDED.
5. RAFT CONCRETE IS OF GRADE M:20.
6. PERMISSIBLE STRESS IN CONCRETE COMPRESSION BENDING 67 Kg/cm.^{2}
7. PERMISSIBLE TENSILE STRESS 2000 Kg/cm.^{2} IN H.Y.S.D. REINFORCEMENT.
8. CLEAR COVER TO REINFORCEMENT 40mm.
9. THIS DESIGN IS SUITABLE FOR BOTH SANDY SOIL & B.C. SOIL.
10. THICKNESS OF RAFT (A) END SPAN 29cm. INTERMEDIATE SPAN 23cm.
11. THE AREA BETWEEN THE CUT OFF WALLS SHOULD BE EXCAVATED TO A DEPTH OF 1.0m. BELOW BOTTOM OF THE RAFT AND FILLED WITH COARSE SAND WHERE THE BEDS ARE OF CLAY NATURE.
12. THE LEAN CONCRETE 1:3:6 OF 0.10m THCK SHOULD BE LAID BELOW THE RAFT.
13. PRESSURE RELIEF PIPE OF 1000mm.Φ OF 5 NOS PER SPAN SHALL BE PROVIDED IN THE RAFT AND AREA OF 0.5x0.5m. BELOW THEM SHALL BE IN THE FORM OF INVERTED FILTER TO AVOID OOZING OUT OF FOUNDATION SOIL.
14. IN ORDER TO ENSURE THE SAFETY OF THE RAFT FOUNDATION THE WORK OF R.C.C. RAFT AND THE PROTECTIVE WORK (APRONS TOE WALL ETC.) SHALL BE CARRIED OUT SIMULTANEOUSLY. THE PROTECTIVE WORKS SHALL BE COMPLETED BEFORE THE FLOODS SO THAT THE FOUNDATION DOES NOT GET UNDERMINED.
15. ALL STEEL CONFORM TO GRADE Fe 415 (I.S: 1786)
16. FOR GENERAL DRAWING REFER DRG. NO. ARCH-1.
17. EITHER OF BAR MARKED C OR C1 (ANY ONE OUT OF TWO) SHOULD BE USED FOR FOUNDATION STRATA OF B.C. SOIL OR NON B.C. SOIL.
18. DIMENSIONS SHOULD NOT BE SCALED FROM DRAWING, INSTEAD FIGURED DIMENSIONS SHOULD BE TAKEN.
19. THIS DRG. SHALL NOT BE USED FOR LENGTH MORE THAN 45m. WITHOUT PROPER CONSIDERATION.
20. SHEAR PINS AS SHOWN ON OTHER DRG. SHALL BE PROVIDED.
21. ABUTMENT PIER SHALL BE PROVIDED AT ABOUT 15m. INTERVAL AND ITS WIDTH SHALL BE INCREASED BY 30cms.
22. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED



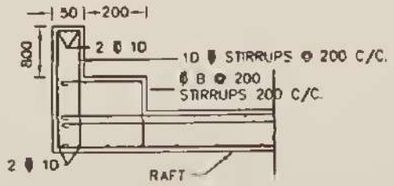
PLAN AT REINFORCEMENT LEVEL R.C.C. WEARING COURSE

(SCALE-1:50)



DETAILS OF JOINT AT GUARD STONE

(SCALE-1:50)



END BASE BLOCK

(SCALE-1:50)

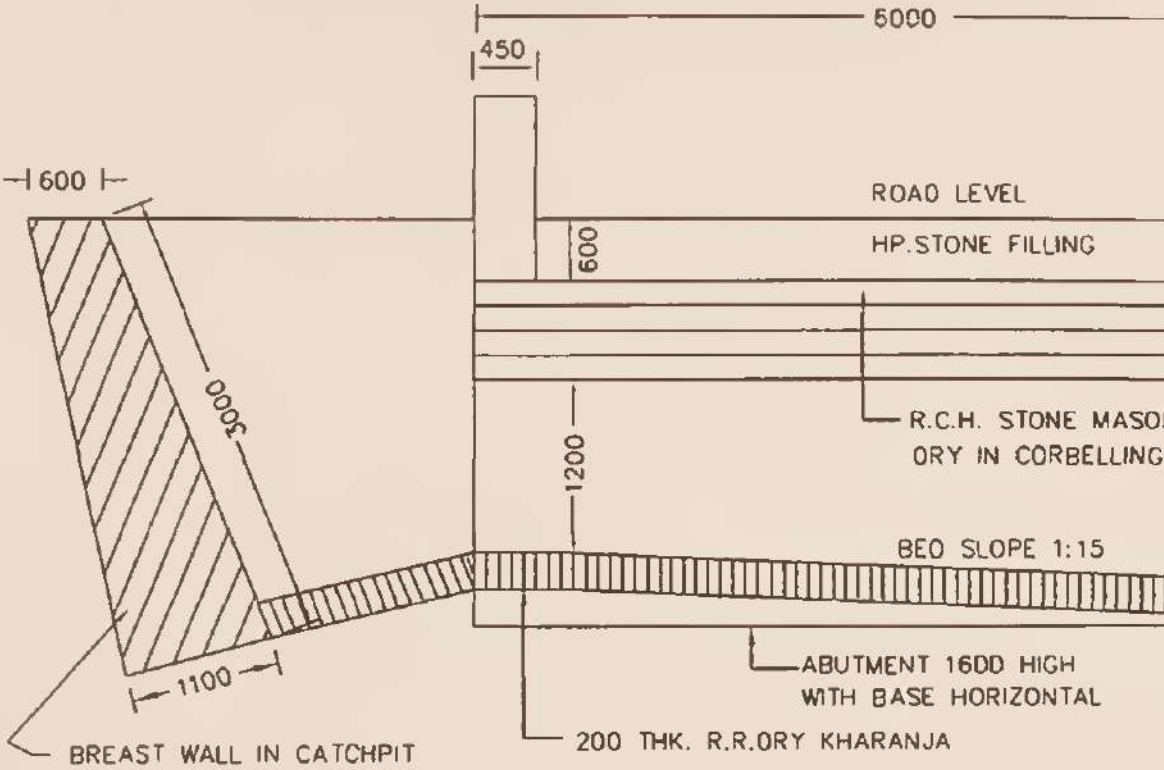
RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

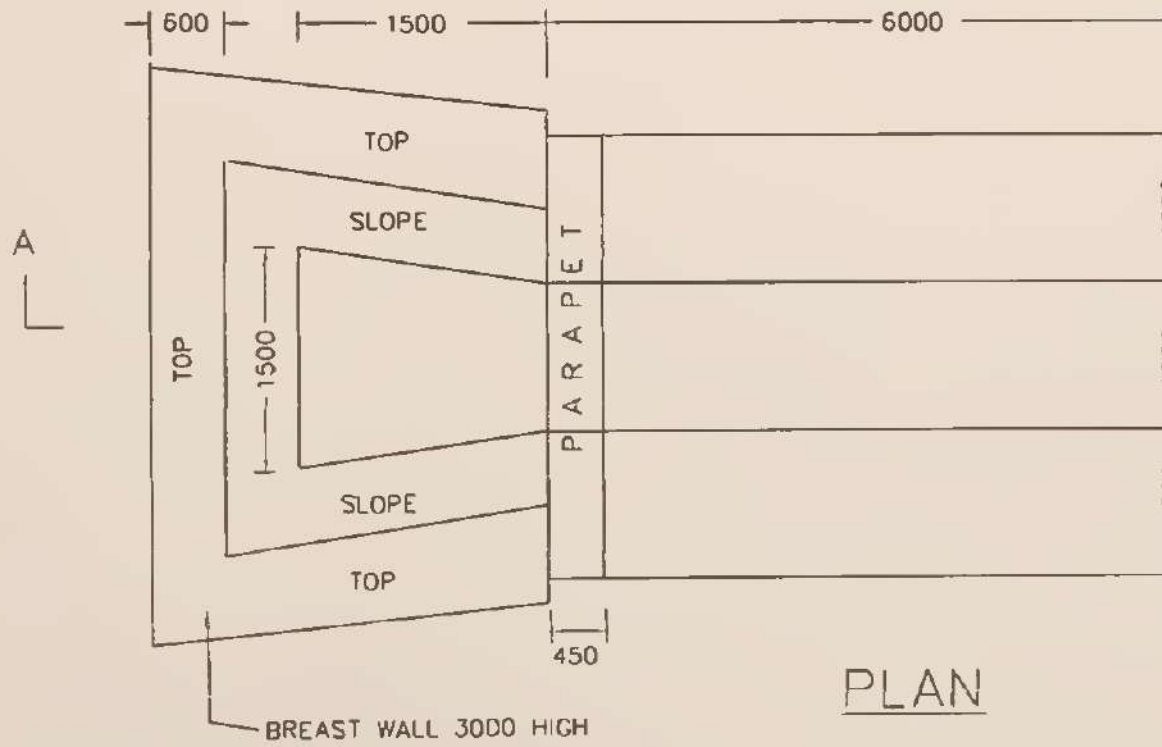
DRG. TITLE.

RAFT FOUNDATION
(ARCH-3)

PLATE NO.-7.26.4



SECTION AT A–A



PLAN

NOTES: –

1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. FOUNDATION OF ABUTMENT SHALL BE HORIZONTAL.
3. LENGTH OF SCUPPER MAY BE INCREASED/DECREASED ACCORDING TO REQUIREMENT AS PER SITE.
4. THE QUANTITIES OF PARAPET ARE NOT INCLUDED IN THE QUANTITIES OF SCUPPER.
5. CORBELLING STONE SHOULD BE CALCULATED & HAMMER DRESSED IN ADVANCE BEFORE FOUNDATION, EXCAVATION PERMITTED, IF GOOD STONE IS NOT AVAILABLE LOCALLY, CARRIAGE OF STONE FROM A SUITABLE QUARRY(UPTO A DISTANCE OF 10 KM.) MAY BE PAID, OTHERWISE SCUPPER BE REPLACED BY HP. OR R.C.C. SLAB CULVERT.

QUANTITIES OF SCUP

1 HILL SIDE CUTTING
OF ROCK/SHALES
2. EXCAVATION IN FO
TYPE OF ROCK/SH
3. R.R. ORY STONE M
THE QUANTITIES O
4. H.P. STONE FILLIN
5. R.C.R. DRY STONE
CORBELLING

Chapter 8

CONSTRUCTION AND SPECIFICATIONS

8.1. Introduction

The performance of roads is directly linked with quality of construction. Road construction techniques have been upgraded recently and use of new and alternate materials have been advocated for all type of roads. It is logical to see that the purpose of road construction is to provide a firm, durable and even surface of the pavement which could stand the stress imparted due to traffic and climatic conditions. The road construction activity starts from earthwork for embankment and completes with high quality surface finish with bituminous or concrete construction. Each component of the road has appropriate construction requirements and specification to be followed. This Chapter deals with details of construction techniques and specifications for various pavement courses involving use of traditional as well as alternate and locally available materials for all-weather rural roads.

8.2. Selection of Materials and Methodology

The typical rural road consists of embankment/subgrade constructed using local soils, sub-base or a blanket layer of moorum, gravel or similar granular material followed by base course and sealing with thin bituminous surface course. Rural roads may also be provided with cement concrete pavement and/or special pavement wherever felt essential. The construction techniques for rural roads could be broadly classified as follows:

(i) Conventional methods
(ii) Mechanised methods
(iii) Intermediate techniques

The details are discussed in the following Sections:

8.2.1. Materials and source : The quality of materials, lead to the borrow areas and climatic conditions are key factors for cost effective construction. Selection of materials shall be strictly as per guidelines given in Chapters 3 and 4 on climatic factors and road materials.

8.2.2. Construction techniques : Conventional construction methods are typically labour based and most of the construction operations are done manually. In case of mechanised method of construction, most of the operations are done with machines like grader, bulldozer, and paver, etc. Vibratory roller may also be used for compaction where these are available. The selection of construction methodology will be based on various considerations. No doubt, a modern mechanised method will lead to larger and faster output and will also help in maintaining the better quality of construction. However, considering the magnitude and scattered nature of these works in remote areas of the country, modern mechanised methods may not be always cost effective in case of rural roads. In manual methods, use of local material and manpower is effectively made. These methods generate the fruitful employment to the local people and also give them satisfaction of participation in their asset building. On account of availability of cheaper and abundant labour, only labour intensive methods have so far been largely used for rural road construction in the country. Hence, complete mechanisation is not considered necessary for rural roads. Almost all road construction activities can be carried out manually except obligatory items like transportation of materials, paving and rolling.

In case of the hilly and remote areas, labour has to be brought from plains due to paucity of local labour. The construction of roads in some areas requires extensive blasting and the roads have to be carved through very steep and vertical rock faces. Thus exclusive dependence on manual labour for work in hilly areas has

associated safety hazards. Due to severe climatic conditions also in most of the hilly areas, the fair weather period available for work is also less. Some of the hilly areas have heavy rainfall or snowfall for major portion of the year. Since the time available for work is limited, mechanisation is a necessity to achieve high productivity during the available short time in some special cases.

8.2.3. Machinery and tools : In India, road construction activities are accomplished in various stages. The tools, appliances and equipment required for different construction activities may also be classified as manual and mechanised method. Most of the tools and appliances used by manual labour for various phases of construction are conventional tools and appliances common to all the activities and phases of construction. Special tools, appliances and equipment are also used for special construction activities like bituminous work and construction of concrete road, etc. Some machines/equipments, like, dozers, compressors, crushers, loader and load carriers are also common to most of the construction activities where mechanised methods are adopted. The list of tools, appliances and equipment required for semi-mechanised method is given in ***Appendix-8.1.*** On major projects, the work of bulky and repetitive nature can be done more economically and efficiently by well-designed machines. Practically every operation in construction of roads can be performed by different types of equipment, but under any given set of conditions only a particular type of machine would be most effective. Thus selection of machine for any particular phase of construction requires detailed study about brand, model and specifications of the various equipment available and their suitability for particular phase of construction. IRC publication "MOST Handbook on Road Construction Machinery", may be referred for further details. The surface evenness and compaction are generally checked with camber board/template, straight edge, depth gauge and density measuring kit. Recently unevenness indicator and nuclear density meters have also been introduced for exercising quality control. A list of plants, equipment commonly required for different phases of mechanised construction is given in ***Appendix-8.2.***

8.3. Embankment and Subgrade

Construction of embankment and preparation of subgrade are part of earthwork. The main activities associated with construction are, soil survey and identification of borrow areas, construction of embankment and subgrade. The details are discussed in the following paragraphs.

8.3.1. Embankment with conventional earth : The height of road embankment depends on the highest flood level (HFL) in area generally 0.6 to 1.0 m height above HFL is to be ensured. The embankment may be constructed by rolling in relatively thin layers. Each layer should be compacted by suitable roller to a desired density before the next layer is placed. Compaction should be carried out at optimum moisture content so as to take advantage of maximum dry density using a specified compacting effort and equipment. The thickness of each compacted layer may vary between 150 to 300 mm depending upon various factors such as soil type, compaction equipment and specifications. Using ordinary 8-10 tonne rollers, compacted thickness shall not exceed 150 mm. IRC:36, IRC:56, IRC:75 may be referred for construction of embankments.

For identification of suitable borrow area, samples may be collected at different depths from the test pits dug open in borrow areas from where the embankment material is to be obtained. The soil for processing should be brought to proper moisture content, so that the needed degree of compaction can be imparted with least effort. Needed amount of water should be quite uniformly dispersed in the entire soil mass. Depending upon the weather conditions and time gap between sprinkling of water and commencement of rolling, an allowance of 3 to 4 per cent for evaporation should be made in the quantity of water to be added during summer when temperature is greater than 35°C, in winter this allowance may be reduced to 1 to 2 per cent. For earthwork construction, the loose thickness of the soil layer should not normally exceed 200 mm when ordinary 8-10 tonne rollers are used.

When the earthwork has reached a stage where the general form of the final shape of the embankment has been obtained, the spreading of earth should be done in straight reaches to a crowned shape, and to appropriately banked profile if the reach is on a curve. The moisture content in the laid soil should be the optimum moisture content subjected to the permitted tolerance. Highly expansive soils such as black cotton soil should be compacted at the specified moisture content, which is usually on the wet side of the optimum moisture content. The tolerance limits of variation from the specified moisture content OMC are normally +1 per cent to -2 per cent for sandy/silty soils and Optimum Moisture Content (OMC) to +2 per cent for clayey/ black cotton soils. Earth to be used should be good soil, free from slumps, roots and leaves of trees, plants and rubbish. The clots should be broken to less than 75 mm size. The equipment for compaction of earthwork should be ordinarily an 8-10 tonne smooth wheeled power roller. However, if such a power roller is not available, the use of lighter rollers of 6 to 8 tonne weight may be permitted. In such cases, the thickness of loose soil layer should be suitably reduced and the number of passes needs to be increased to achieve the desired density.

Densities to be aimed at in the compaction process shall be chosen with due regard to factors such as soil type, height of embankment, drainage conditions, position of individual layers and type of available compaction machinery. Each compacted layer shall be tested in the field for density and compacted fully before the operations for the next layer commence. The minimum field density in case of the embankment shall not be less than 97 per cent Standard Proctor compaction (IS:2720 (Part 7)-1980). The overall profile should be improved with each successive layer so that the subgrade level is approached. The profile of the formation is as per lines and grades.

8.3.2. Embankment using coal ash (Fly Ash, Pond Ash and Bottom Ash) : Coal ash can be used for construction of embankment of rural road projects near thermal power plants. When embankment construction is undertaken using coal ash, the top soil from all areas to be covered by the embankment foundation should be stripped to specified depth not exceeding 150 mm and stored in stockpiles of height not exceeding 2 m, for use in covering the coal ash embankment slopes, cut slopes and other disturbed areas where revegetation is desired. Top soil should not be unnecessarily trafficked either before stripping or when in stockpiles. The various construction steps shall be as given in Chapter 9. The following end product specification as given in Table 8.1 has been suggested for construction of coal ash embankments.

TABLE 8.1. SPECIFICATION FOR COMPACTION OF EMBANKMENT

Description	Limits
Minimum dry density in embankment after compaction as percentage of MDD IS:2720 (Part 7)-1980	97 per cent
Minimum dry density after compaction when used in bridge abutments for embankment as per cent of MDD IS:2720 (Part 7)-1980 (length equal to 1.5 times the height of embankment)	100 per cent

Embankment shall be constructed evenly over their full width and the contractor shall control and direct construction plant and other vehicular traffic uniformly across the width. Damage by the construction equipment or other vehicular traffic shall be made good by the contractor with material having the same characteristics and strength as it had before it was damaged. Embankments shall not be constructed with steeper side slopes or to greater width than those shown in the drawings. Whenever embankment construction is to be taken up against the face of natural slope or sloping earthworks face including embankments, cuttings and excavations steeper than 1:4 (Vertical: Horizontal), such faces shall be benched immediately before placing the subsequent fill. A less permeable capping layer of selected earth should be constructed on the top of coal ash embankment, which would form the subgrade for the road pavement. The thickness of this layer should not be less than 500 mm. IRC:SP:58 may be referred for detailed procedure.

8.3.3. Subgrade with natural earth : The preparation of subgrade includes all operations before the pavement structure could be laid over it and compacted. Thus the preparation of subgrade would include site clearance (if the formation already exists), grading (embankment or cut section) and compaction to desired density at optimum moisture. The subgrade may be situated on embankment or excavation or at the existing ground surface. In all the cases, site should be cleared off and the top soil consisting of grass, roots, rubbish and other organic matter are to be removed. The grading operation is started thereafter so as to bring the vertical profile of the subgrade to designed grade and camber. Bulldozers, tippers and blade graders are useful equipment to speed up this work. Highly clayey and black cotton soil shall not be used directly as a subgrade material. In such case a capping layer of 100 mm thickness shall be provided with material of CBR higher than 10 per cent or geo-textile shall be used as a filter material, if found economical. In case the reach is in cutting and in-situ soil is to be used for subgrade, the method consists in loosening of the soil to appropriate depth to compact to a thickness of 300 mm bringing the moisture to required level and compacting it with a suitable roller to 100 per cent Standard Proctor compaction density. The compaction process should commence at the edges and progress towards the centre except at super-elevated portions where it shall commence from lower edge and progress towards higher edge. When the reach is in fillings, it is necessary to ensure that at least the top 300 mm of the embankment constituting the subgrade of the pavement should be compacted to 100 per cent of Standard Proctor compaction density in at least two layers at optimum moisture content. The subgrade should be finished to the desired profiles; a camber board should be used to check the cross slope.

8.3.4. Subgrade with stabilised earth : When the soil does not fulfil the requirements of normal subgrade soil, a stabilisation technique can be used to modify and improve the same. Stabilisation is of four different types as follows:

(a) Stabilisation with lime and sand
(b) Stabilisation with coal ash
(c) Stabilisation with soft aggregates
(d) Stabilisation with gravel/moorum
(e) Stabilisation with cement

The salient features of construction of the above stabilisation techniques are given below:

(a) Stabilisation with lime and sand : The specification involves mixing of clay with sand so that the resulting mixture will have a certain controlled plasticity and certain minimum percentage of sand content. It is intended mainly for clayey type of soils. Depending upon the natural moisture of the borrow pit soil, the borrow areas may be pre-wetted for facilitating excavation. The clay shall be excavated and clods shall be broken with wooden mallets or by 4-6 passes of a tractor-towed disc harrows, so that, by and large there are no clods larger than 10-12 mm. The soil shall be spread in place to the required loose thickness. The requisite quantity of lime (2 per cent) and sand transported from local sources is then added. To bring the moisture content to the optimum value, the required quantity of water is added. The wet soil is then mixed thoroughly and laid on the compacted subgrade to proper profile to a width greater than the pavement width by 150 mm on either side. The loose thickness of the soil layer shall not exceed 200 mm. Depth blocks should be used for the control of the required layer thickness. Soil shall be compacted with 8-10 tonne roller to achieve 100 per cent Standard Proctor compaction density (IRC:49, IRC:51).

(b) Stabilisation with coal ash : The clayey subgrade can be stabilised using coal ash, e.g., fly ash, pond ash and bottom ash as per details given in Chapter 9 and IRC:SP:58 and IRC:88.

(c) Stabilisation of soil with soft aggregates : This specification involve use of locally available soft aggregates such as brick bats, kankar and laterite in soil mass for stabilisation. The soft aggregate to be added to the soil shall be of size less than 30 mm with most of it coarser than 6 mm. The soft aggregates to be added shall have aggregate impact value not more than 50 per cent. The soil and aggregates should be mixed together in the ratio 70:30 by volume. The construction shall be carried out in a manner similar to stabilised soil technique stated in Section 8.3.4 (part a). Soil and soft aggregates shall be spread in the above said proportion and then the resulting material is mixed, watered and laid to proper camber. On spread soil-aggregate mix, stone aggregates of 25 mm size should be spread to single layer thickness uniformly at the rate of 0.20 to 0.23 cum/10 sqm. The layer of stabilised soil alongwith the super-imposed layer of grafting stone should be rolled. The rolling is done in two to three stages. Relatively light rolling is done on the first day. The same evening hungry spots are made up with the stabilised soil mix and water should be sprinkled on the surface as may be necessary. Rolling shall be resumed the following day (IRC:28, IRC:63).

(d) Stabilisation with gravel/moorum : The material to be used shall be graded and shall contain a fair proportion of all the particle sizes together with sufficient fines to provide proper cohesion. The maximum aggregate size should generally not exceed one-third the thickness of compacted stabilised layer. The construction shall be carried out in the same manner as for the stabilised soil construction stated in Section 8.3.4 (part a). Care shall be taken that the layer is thoroughly compacted and laid to proper profiles.

(e) Stabilisation with cement : The cement for cement stabilisation shall comply with the requirements of IS:269, 455 or 1489. The mix design shall be done on the basis of 7 days unconfined compressive strength (UCS) and/or durability test under 12 cycles of wet-dry conditions. The laboratory strength values shall be at least 1.5 times the minimum field UCS value stipulated in the contract. The construction procedure as regard spreading and mixing the stabiliser except that cement or combination of lime and cement as the case may be, shall be used as the stabilising material. The care shall be taken to see that the compaction of cement stabilised material is completed within two hours of its mixing or such a shorter period as may be found necessary in dry weather (IRC:50).

8.3.5. Surface drains : The fast disposal of runoff on the road surface is achieved by surface drainage. Surface drains shall be excavated to the specified lines, grades, levels and dimensions based on the type of the drain as mentioned in Chapter 6. The excavated material shall be removed from the area adjoining the drains and if found suitable, utlised in embankments or subgrade construction. All unsuitable materials shall be disposed of as directed. The excavated bed and sides of the drains shall be dressed to bring this in close conformity with the specified dimensions, levels and slopes as mentioned in Chapter 6. If required, the drains shall be lined with suitable material.

8.4. Sub-Base (Granular)

Sub-base is an intermediate layer between subgrade and granular base course. The function of this layer is as a drainage layer for the pavement to avoid excessive wetting and weakening of subgrade. Various materials and techniques are used for construction of sub-base course. Various types of construction for sub-base, which are appropriate for rural road, are detailed here.

8.4.1. Granular sub-base (GSB) : The grading for coarse graded GSB for construction of sub-base course shall be as given in Table 8.2 after conducting the wet sieve analysis.

TABLE 8.2. GRADING FOR COARSE GRADED GRANULAR SUB-BASE MATERIALS (WET SIEVE ANALYSIS)

IS Sieve Designation	Per cent by weight passing the IS sieve		
	Grading I	Grading II	Grading III
75 mm	100	-	-
53 mm	-	100	-
26.5 mm	55-75	50-80	100
4.75 mm	10-30	15-35	22-45
75 μ	<10	<10	<10

Note: The material passing 425 micron sieve for all the three grading when tested according to IS:2720 (Part 5) shall be having liquid limit and plasticity index not more than 25 and 6 respectively. The material with CBR >15 per cent shall be accepted for construction of GSB course. (MoRT&H Specifications for Road and Bridge Works).

Immediately prior to the laying of sub-base, subgrade shall be prepared with the help of a motor grader of adequate capacity. The granular material for sub-base shall be preferably natural. Mixing of ingredients to make granular sub-base may be undertaken under strict quality control. Manual methods shall be permitted only where the width of laying is not adequate for mechanical operations or in small sized jobs. Moisture content of loose material shall be checked in accordance with IS:2720 (Part 2). After water has been added (at +1 per cent to -2 per cent of OMC as per IS:2720 (Part 8)-1983), the material shall be processed by mechanical or other approved means like disc harrows, rotavators until the layer is uniformly wet. Immediately thereafter, rolling shall start. The thickness of single compacted layer shall not exceed 100 mm.

Rolling shall commence at the lower edge and proceed towards the upper edge longitudinally for portions having unidirectional cross fall and super elevation. It shall commence at the edges and progress towards the centre for portions having cross fall on both sides. Each pass of the roller shall uniformly overlap not less than one-third of the track made in the preceding pass. Rolling shall be continued till the density achieved is at least 98 per cent of the IS heavy compaction density for the material as per IS:2720 (Part 8)-1983. The surface of any layer of material on completion of compaction shall be well closed, free from movement under compaction equipment and from compaction plane, ridges, cracks or loose material.

8.4.2. Coarse sand sub-base : The coarse to medium sand sub-base gives comparatively more effective drainage to pavement, where the embankment is clayey or black cotton soil. Sand layer shall be provided as a part of sub-base over the compacted subgrade layer where annual rainfall is more than 1000 mm. The sand layer shall normally be in 100 to 150 mm compacted thickness (necessary arrangements shall be made for local confinement of sand). The coarse to medium sand for construction of a drainage layer shall conform to grading given in Table 8.3.

TABLE 8.3. GRADING OF COARSE TO MEDIUM SAND FOR SUB-BASE

IS Sieve	Per cent Passing
11.2 mm	100
5.6 mm	80-100
2.36 mm	70-90
180 micron	< 5

The sand conforming to the grading as given in Table 8.3 shall be spread uniformly and evenly upon the prepared subgrade in required quantities from stockpiles along the side of the road or directly from tippers. Immediately following the spreading of the sand, watering shall be done and rolling shall be started with vibratory roller of approved type at optimum moisture conditions decided before construction or through saturation/vibration.

8.4.3. Gravel roads : The gravel of appropriate quality can be used for construction of surface course (gravel road) of rural roads. The material to be used shall be graded and shall contain a fair proportion of all the particle sizes together with sufficient fines to provide proper cohesion as per technical grading limits given in Section 8.3. The maximum aggregate size should generally not exceed one third the thickness of compacted layer. The construction shall otherwise be carried out in the same manner as for the mechanically stabilised soil construction. Care shall be taken that the layer is thoroughly compacted and laid to proper profiles at optimum moisture content. The compaction shall be at least 98 per cent of the IS heavy compaction density.

8.4.4. Use of low cost alternate materials : The use of local and waste materials is always economical in construction sector. Sometimes locally available construction materials are not suitable in their natural form and thus needs further treatment. Some of these materials for sub-base and base course construction are:

(a) Lime stabilised sub-base
(b) Coal ash
(c) Slags
(d) Municipal wastes
(e) Marble waste

The construction details of sub-base and base courses using these materials are as given below:

(a) Lime stabilised sub-base : The specifications for lime stabilised soil construction shall apply essentially to stabilisation of clay including black cotton soils. As mentioned earlier, the borrow areas may be previously watered for easy excavation. For lime stabilisation, the soil before addition of stabiliser shall be pulverised using agricultural equipments like disc harrows and rotavators to the extent that it passes the requirements set out in Table 8.4 when tested. In case of black cotton soil, the borrow areas shall be previously watered and the clods, which are generally in the size of 100-150 mm should be pulverised with agricultural equipment. The pulverised soil-moorum/black cotton soil shall be spread on the prepared receiving surface, and slaked lime spread over it in the required quantity. The laid material shall be cut and mixed 2-3 times manually so that a homogenous soil-lime mix is formed. Lime-soil stabilisation shall not be done when the air temperature is less than 10°C.

TABLE 8.4. SOIL PULVERISATION REQUIREMENTS FOR LIME STABILISATION

IS Sieve Designation, mm	Per cent by Weight Passing the IS Sieve
26.5	100
5.6	80

Addition of lime: Lime may be mixed with the prepared material either in slurry form or dry state as approved by the Engineer. The tops of windrowed material may be flattened or slightly trenched to receive the lime. The distance to which lime may be spread upon the prepared material ahead of the mixing operation shall be determined by the Engineer. The moisture content at compaction shall neither be less than optimum moisture content corresponding to IS:2720 (Part 8)-1983, nor more than 2 per cent above it. The staking of lime for lime stabilised sub-base shall be done properly. Manual mixing of lime should be discharged. It can be undertaken in special cases, if the equipment is not available. The soil from borrow areas shall be first freed of all vegetation and the deleterious materials and placed on the prepared subgrade. The soil shall then be pulverised by means of crowbars, pick axes or other means. Water in requisite quantities may be sprinkled on the soil for pulverisation. On the pulverised soil, the blending material in requisite quantities shall be spread uniformly and mixed thoroughly by working with spades or other similar implements till the whole mass is uniform. After adjusting the moisture content within the limits mentioned, the material shall be levelled upto the required thickness so that it is ready to be rolled.

Rolling: Immediately after spreading, grading and levelling of the mixed material and compaction shall be carried out with approved equipment preceded by a few passes of lighter rollers if necessary. Rolling shall commence at edges and progress towards the centre, except at super elevated portions where it shall commence at the lower edge and progress toward higher edge. During rolling, the surface shall be checked for grade and camber and any irregularities corrected by loosening the material and renoving/adding fresh material. Compaction shall continue until the density achieved is at least 98 per cent of the IS heavy compaction density for the material determined in accordance with IS:2720 (Part 8)-1983. Care shall be taken to see that the compaction of lime stabilised material is completed within three hours of its mixing. The final surface shall be well closed, free from movement under compaction planes, ridges, cracks or loose material. All loose or segregated or otherwise defective areas shall be made good to the full thickness of the layer and re-compacted.

Curing: The sub-base shall be cured for moist curing with water for a minimum period of 7 days after which subsequent pavement courses shall be laid to prevent the surface from drying out and becoming friable.

(b) Use of coal ash : Sub-base course can be constructed using pond ash or bottom ash replacing conventionally used moorum or granular materials. Lime fly ash bound macadam using lime stabilised filler (mixture of lime, fly ash and sand or moorum) will inhibit softening in presence of water leading to longer life and better serviceability of the roads. The details of all such construction using coal ash are given in Chapter 9.

(c) Use of slags : Slags from various metallurgical industries can also be used for construction of sub-base of rural roads. The details are given in Chapter 9.

(d) Use of municipal wastes :

The granulated processed municipal waste can also be used for construction of sub-base course. The details are given in Chapter 9.

(e) Use of marble waste : The marble slurry dust is a waste of marble cutting industry and it can be utilized in stabilization of granular soil and sand using lime and other chemical additives. The details are given in Chapter 9.

8.5. Base Course (Granular)

The following specifications are recommended for construction of granular base course:

(a) Water Bound Macadam
(b) Crusher Run Macadam
(c) Use of Alternate Materials

8.5.1. Water bound macadam (WBM)

(a) Grading :

WBM may be used as sub-base as well as base course and also surface course of rural roads. In each case, it shall be constructed in conformity with line, grades and cross-section shown on the drawings of the tender document. The existing surface of the subgrade, sub-base or base to receive WBM course, shall be prepared to the required grade and camber and cleaned of all dust. Any ruts or soft yielding places that have appeared due to improper drainage of surface under traffic or season shall be corrected and rolled. The grading of aggregates shall conform to requirements given in the Tables 8.5 and 8.6. The quantity of binding materials, where it is to be used will depend on the type of screenings. Generally, the quantity required for 75 mm compacted thickness of water bound macadam will be 0.06-0.09 cum/10 sqm. The quantity shall be in the range of 0.08-0.1 cum/10 sqm for 100 mm compacted thickness. Necessary arrangements shall be made for the

lateral confinement of aggregates. There may be construction of side shoulders in advance to a thickness corresponding to the compacted layer of the WBM course. After shoulders are ready, inside edges may be trimmed vertical and included area cleaned of all spilled material thereby setting the stage for spread of coarse aggregates. Table 8.7 gives the quantities of materials (loose) required for 10 sqm for sub-base/base course with compacted thickness of 100 or 75 mm.

TABLE 8.5. GRADING REQUIREMENTS OF COARSE AGGREGATES FOR WBM

Grading No.	Size Range (mm)	IS Sieve Designation (mm)	Per cent by weight passing
1	90 to 45	125 90 63 45 22.4	100 90-100 25-60 0-15 0-5
2	63 to 45	90 63 53 45 22.4	100 90-100 25-75 0-15 0.5
3	53 to 22.4	63 53 45 22.4 11.2	100 95-100 65-90 0-10 0-5

TABLE 8.6. GRADING REQUIREMENTS FOR SCREENINGS FOR WBM

Grading No.	Size Range, mm (mm)	IS Sieve Designation (mm)	Per cent by weight passing
A	13.2	13.2 11.2 5.6 0.180	100 95-100 15-35 0-10
B	11.2	11.2 5.6 0.180	100 90-100 15-35

TABLE 8.7. QUANTITIES REQUIRED FOR 75 mm AND 100 mm COMPACTED WBM COURSE

Grading No.	Size Range, (mm)	Compacted Thickness, (mm)	Loose Quantity of Coarse Aggregate, cum	Screenings			
				Stone Screening		Crushable Type, such as, Moorum or Gravel, cum	
				Size, mm	Quantity, cum		
1	90 to 45	100	1.21 to 1.43	Type A 13.2	0.27 to 0.30	Not uniform	0.30 to 0.32
2	63 to 45	75	0.91 to 1.07	Type A 13.2	0.12 to 0.15	Not uniform	0.22 to 0.24
				Type B 11.2	0.20 to 0.22	-do-	0.22 to 0.24
3	53 to 22.4	75	0.91 to 1.07	Type B 11.2	0.18 to 0.21	Not uniform	0.22 to 0.24

The compacted thickness for a layer with grading 1 shall be 100 mm while with grading 2 and 3 shall be 75 mm. Grading 2 and 3 shall be preferably used for construction of Water Bound Macadam for rural roads.

(b) Spreading and rolling of coarse aggregates : The coarse aggregates shall be spread uniformly and evenly upon the prepared base in required quantities from stockpiles along the side of the road or directly from vehicle.

In no case shall these be dumped in heaps directly on the area where neither these are to be laid nor shall their hauling over a partly completed base be permitted. The aggregates shall be spread to proper profile by using templates placed across the road about 6 m apart. Where possible approved mechanical devices shall be used to spread the aggregates uniformly so as to minimise the need for their manipulation by hand. The WBM course shall normally be constructed in layers of not more than 75 mm compacted thickness. However, for aggregates of grading No.1 the compacted thickness shall be 100 mm. No segregation of large or fine particles shall be allowed. The coarse aggregates, as spread shall be of uniform gradation with no pockets of fine material. Immediately following the spreading of the coarse aggregates rolling shall be started with 3 wheeled power roller of 8-10 tonne capacity or tandem or vibratory roller of approved type.

The type of roller to be used shall be approved by the Engineer-in-Charge based on trial run. Except on superelevated portions where the rolling shall proceed from inner to the outer edge, rolling shall begin from the edges gradually progressing towards the centre. First the edges shall be compacted with roller running forward and backward. The roller shall then move inwards parallel to the centre line of the road, in successive passes uniformly overlapping preceding tracks by at least one half of the width. Rolling shall be discontinued when the aggregates are partially compacted with sufficient void space in them to permit application of screenings. However, where screenings are not to be applied as in the case of crushed aggregates like brick metal, laterite and kankar, compaction shall be continued until the aggregates are thoroughly keyed. During rolling slight sprinkling of water may be done, if necessary. Rolling shall not be done when the sub-grade is soft or yielding or when it causes a wave like motion in the sub-grade or sub-base course. The rolled surface shall be checked transversely and longitudinally with templates and any irregularities corrected by loosening the surface by adding or removing necessary amount of aggregates and re-rolling until the entire surface conforms to the desired camber and grade. In no case shall the use of screenings be permitted to make up depressions.

(c) Application of screenings : After coarse aggregates have been rolled, screenings shall be applied gradually over the surface to fill the interstices. Dry rolling shall be done when the screenings are being spread so that the jarring effect of roller causes them to settle into the voids of the coarse aggregates. The screenings shall not be dumped in piles but applied uniformly in successive thin layers either by spreading motion of hand shovels, mechanical spreaders or directly from trucks. Trucks plying over the base course to spread screenings shall be equipped with pneumatic tyres and so operated as not to disturb the coarse aggregates. The screenings shall be applied at a slow rate in three or more applications as necessary. Rolling or brooming shall accompany this. In no case shall the screenings be applied so fast and thick as to form cakes or ridges on the surface making the filling of voids difficult or preventing the direct bearing of roller on the coarse aggregates. After the application of screenings, the surface shall be copiously sprinkled with water, swept and rolled. Hand brooms shall be used to sweep the wet screenings into voids and to distribute them evenly. The sprinkling, sweeping and rolling operations shall be continued and additional screenings applied where necessary until the coarse aggregates are well bounded and firmly set. Grout of screenings and water formed ahead of the wheels of rollers shall be taken out so that the base or sub-grade does not get damaged due to addition of excessive quantities of water during the construction.

(d) Application of binding material : After the application of screenings, binding material (PI≈4-6) that is required to be used shall be applied at a uniform rate in two or more successive thin layers. After each

application of binding material, the surface shall be sprinkled with water and the resulting slurry swept in with brooms so as to fill the voids properly. After final compaction, the road shall be allowed to cure overnight. Next morning, hungry spots shall be filled with screenings or binding material lightly sprinkled with water, if necessary it may be also rolled. No traffic shall be allowed till the macadam sets. In the case of WBM base course to be provided with bituminous surfacing, the latter shall be laid only after the WBM course is completely dry and primed before allowing any traffic on it.

8.5.2. Crusher run macadam (CRM) : The work shall consist of furnishing, placing and compacting crushed stone aggregate sub-base and base courses constructed in accordance with the requirements set forth in this specification and in conformity with the lines, grades, thicknesses and cross-sections shown on the plan or as directed by the Engineer-in-Charge. The grading shall conform to the grading and quality requirements shown in Table 8.8.

TABLE 8.8. AGGREGATE GRADING REQUIREMENTS FOR CRUSHER RUN MACADAM

Sieve Size, mm	Per cent Passing by Weight	
	53 mm max. size	37.5 mm max. size
63	100	-
45	87-100	100
22.4	50-85	90-100
5.6	25-45	35-55
0.710	10-25	10-30
0.90	2-9	2-9

The aggregate shall be uniformly deposited on the approved subgrade by means of the hauling vehicle with or without spreading devices. Aggregates will be distributed over the surface to the depth specified on the plans or as directed by the Engineer-in-Charge. After the base course material has been deposited, it shall be thoroughly mixed to full depth of layer by alternately blading the entire layer to the centre and back to the edges of the road. It shall then be spread and finished to the required cross-section by means of a motor grader. Water shall be applied prior to and during all blading and processing operations to moisten the material sufficiently to prevent segregation of the fine and coarse particles. Water shall be applied in sufficient quantity during construction to assist in compaction. Compaction shall commence immediately after the spreading operation. If the thickness of single compacted layer does not exceed 100 mm, a smooth wheel roller of 8-10 tonne weight may be used. For a compacted single layer upto 200 mm, the compaction shall be done with the help of vibratory roller of minimum of 8-10 tonne or equivalent capacity. The speed of the roller shall not exceed 5 km/h. Each layer of material shall be compacted to not less than 98 per cent of the IS heavy compaction density as per IS:2720 (Part 8)-1983.

8.5.3. Use of special material : The details are given in Chapter 9.

8.6. Shoulder

Shoulder gives adequate side support to the pavement and also drains off surface water from the carriageway to the road side drain.

8.6.1. Construction of shoulders : The construction shall be done in layers each matching the thickness of adjoining layer. Only after a layer of WBM, shoulder shall be laid and compacted. Next corresponding layers in pavement shall be taken up after the completion of first layer of WBM and shoulder. This procedure shall be followed upto the surface course. In the case of bituminous courses, work on shoulder shall start only

after the pavement course has been laid and compacted. The compaction requirement of earthen shoulder shall be 100 per cent of Standard Proctor compaction density as per IS:2720 (Part 7)-1980.

During all stages of shoulder construction, the required cross fall shall be maintained to drain off surface water. Regardless of the method of laying all shoulder construction material shall be placed on the shoulder. Any spilled material dragged on to the pavement surface shall be immediately removed without damage to the pavement.

8.7. Bituminous Constructions

Rural roads are expected to have very low traffic, and therefore, any all-weather surfacing will provide the needed connectivity. But, where there is reasonable volume of motorised traffic, thin bituminous surfacing will be desirable. This section deals with construction of all different bituminous construction required for flexible pavement. The basic objective of providing thin bituminous surfacing on rural roads is to seal granular surface cost effectively and to reduce maintenance efforts.

8.7.1. Prime coat on granular surfaces : Prime coat is a spray application of low viscosity liquid bituminous material on top of the top most granular layer of the base course. Prime coat performs following important functions.

- Coats and bonds loose mineral particles of granular surface
- Water proofs the surface of the base by plugging capillary or interconnected voids
- Provides adhesion or bond between the granular base and bituminous layers

The primer shall be a slow setting bitumen emulsion complying with IS:8887-1995, or medium curing cut-back as per IS:217-1983. The use of medium curing cut-back shall be restricted to sub zero temperature conditions only. The procedure for preparation of cut-back for primer is given in ***Appendix-8.3***. The requirement of viscosity and quantity of liquid bituminous materials to be used for priming shall be as given in Table 8.9.

TABLE 8.9. REQUIREMENT OF VISCOSITY AND QUANTITY OF LIQUID BITUMINOUS MATERIALS FOR PRIMING

Porosity	Type of Surface	Viscosity at 60°C Saybolt Furol (Seconds)	Quantity per 10 sqm (kg)
Low	WBM	14-28	6-9
Medium	Stabilised base	33-66	9-12
High	Gravel base	117-234	12-15

The primer can be applied using one of the following equipments as decided by Engineer-in-Charge:

- Self propelled distributor
- Towed bitumen pressure sprayer
- Hand sprayer (for small works)

Prior to applying the primer, the surface shall be carefully swept or brushed clean of dust and loose particles. The desirable range of temperature of cutback as primer for grades, viz., MC-30, MC-70, MC-250 shall be 30 to 55°C, 50 to 80°C and 75 to 100°C respectively. Emulsion as primer can be sprayed at 20-60°C. A primed surface shall be allowed to cure for atleast 24 hours before application of next bituminous layer. Emulsion for priming always requires dilution with water in 1:1 ratio (water: emulsion). A very thin layer of clean sand may be applied to the surface of the primer to prevent the primer picking up under wheels of paver or trucks delivering material for construction of bituminous layer.

8.7.2. Tack coat application : Tack coat is a very light application of liquid bituminous material on a bituminous layer when a new layer is to be laid over it. It is used to create a bond between a new bituminous layer to be placed on the existing bituminous or a primed granular layer. The following types of liquid bituminous

materials can be used for tack coat applications:

- Rapid or medium or slow setting type emulsion (IS:8887-1995)
- RC-70 or MC-70 grade cutback bitumen (IS:217-1988)
- Hot bitumen

The existing surface shall be made slightly damp in case of tack coat using emulsion and dry if bitumen or cutback bitumen is used. Hot bitumen or cut back bitumen may be used in special case, where it is felt necessary for climatic reasons. The tack coat may be sprayed by one of the following equipments:

- Self propelled pressure distributor
- Towed bitumen sprayer
- Pressure hand sprayers
- Perforated cans for small areas

The surface to be tack coated must be clean, free of loose material and dust. In case emulsion is used for tack coat, the bituminous layer is placed after complete breaking of emulsion as indicated by change in colour from brown to black. The recommended quantities of liquid bituminous material for tack coat are as given in Table 8.10.

TABLE 8.10. RECOMMENDED QUANTITIES OF LIQUID BITUMINOUS MATERIAL FOR TACK COAT

Types of Surface	Quantity per 10 sqm
Granular (Primed)	3.0 kg
Bituminous Surface	2.5 kg

If, the existing surface is a freshly laid bituminous layer, a tack coat is not mandatory and it may not be required at all.

8.7.3. Modified penetration macadam (MPM) : A thin premix carpet (20-25 mm) laid directly on granular surface gets deteriorated fast if the traffic is reasonably high. Thicker treatments, like, DBM and BM are costly and for level of traffic on rural road does not justify the same. Therefore, it is essential to have transition/intermediate layer. One can, therefore, consider the use of penetration macadam, modified penetration macadam, built-up spray grout etc. for such special cases. Built-up spray grout involves use of mechanically crushed metal. However, the requirement of crushed metal is reduced in the case of penetration macadam and modified penetration macadam, as hand broken metal by local unskilled rural labour can be used and is also cost effective. In such a situation, it is desirable to replace the top layer of WBM by one layer of MPM. The specifications of MPM are given in ***Appendix-8.4***.

8.7.4. Bituminous macadam : Construction of bituminous macadam may be required in specific locations, only for strengthening purpose where traffic is very heavy and laying of bituminous base course is essential. Bituminous macadam is generally laid in compacted thickness of 50 mm to 100 mm on previously prepared base, and aggregate for such layer shall conform to grading given in Table 8.11.

The Grading-I shall be used for 75-100 mm compacted thickness while Grading-II shall be used for 50-75 mm compacted thickness. The aggregate shall consist of hard crushed rock, crushed gravel, any other material and of uniform quality conforming to the specifications given in Chapter 4. The bitumen shall be of paving grade conforming to IS:73-1992 and grade shall be 80/100 or 60/70 depending upon climatic conditions (Chapter 4). The 80/100 grade shall be used for cold climate areas or where difference between minimum and maximum temperature is more than 20°C, otherwise 60/70 grade bitumen shall be used. The aggregate of different sizes shall be proportioned and blended to produce a uniform mixture complying with requirements of grading given in Table 8.11. The range of temperature for different construction operations shall be as per Table 8.12.

TABLE 8.11. GRADINGS OF AGGREGATE FOR BITUMINOUS MACADAM

IS Sieve	Per cent Passing	
	Grading I	Grading II
45.0 mm	100	—
37.5 mm	90-100	—
26.5 mm	75-100	100
19.0 mm	—	90-100
13.2 mm	35-61	56-88
4.75 mm	13-22	16-36
2.36 mm	4-19	4-19
300 μ	2-10	2-10
75 μ	0-8	0-8

TABLE 8.12. RANGE OF TEMPERATURE FOR DIFFERENT CONSTRUCTION OPERATIONS

Bitumen Grade	Mixing Temperature (°C)		Temperature of Mixed Material (°C)	Laying Temperature (°C)	Rolling Temperature (°C)
	Bitumen	Aggregate			
S-65	150-165	150-170	165 max.	125 min.	100 min.
S-90	140-160	140-165	155 max.	115 min.	90 min.

The binder content shall be in between 3.1 to 3.5 per cent depending upon the type of aggregate. The method for preparation of mixture, spreading and rolling shall be as described in ***Appendix-8.5***. The layer of bituminous macadam shall be covered with wearing coat or subsequent layer within 48 hours. If there is any delay, surface may be covered by sand seal. The surface finish and other requirements of completed construction shall comply to quality control as detailed in Chapter 10.

8.7.5. Construction of bituminous surfacings : The following specifications can be used for surface course of rural roads:

- Surface dressing
- Open graded premix carpet with seal coat
- Closely graded premix carpet or mix-seal surface

The details of their construction procedures are given in following Sub-Sections.

8.7.5.1. Surface dressing : The construction of surface dressing may be undertaken in one coat or two coats. It is an age-old technique of surfacing roads, which is continually modernised in recent years. In practical terms, it involves successive spraying and spreading of binder and aggregate respectively. The merits of this type of construction which mainly seals granular surface are:

- Binder ensures water proofing of the base layer as well as fixation of aggregates and prevents further oxidation of old surface
- Aggregates serve to ensure contact between the traffic and pavement and provides skid resistant surface

The construction may be conveniently accomplished in various manner e.g. manually or through synchronous spreading. The quality and speed of work can be achieved by way of synchronised surface dressing. The machine is truck mounted with bituminous sprayer and chip spreader. The spreading of bitumen is synchronised with respect to application of chips as per design requirement. The binder shall be a liquid bituminous material, e.g., paving bitumen conforming to IS:73-1992, modified bitumen (IRC:53) or a rapid setting bitumen emulsion (IS:8887-1995), as decided by the Engineer-in-Charge.

The aggregates shall be in conformity with specifications given in the Chapter 4.

In case water absorption of aggregates exceeds 1 per cent, chips precoated with 1 per cent bitumen may be used. The quantities of aggregates and binders per 10 sqm shall be as given in Table 8.13 .

TABLE 8.13. QUANTITIES OF AGGREGATE AND BINDERS PER 10 sqm

Types of Construction	Normal Size of Chipping (mm)	Specification of Aggregate (mm)	Quantity of Aggregate (cum/10 sqm)	Quantity kg/ 10 sqm	
				Bitumen	Emulsion
First coat	19	19.0-13.2	0.10	10	11
Second coat	13	13.2-9.5	0.08	9	18

The aggregate shall conform to grading given in Table 8.14. In case of single coat surface dressing, grading of second coat will be adopted. The rate of spread of binder and aggregate can be calculated by an engineering approach to design surface dressing based upon determination of average least dimension (ALD) of aggregate. The concept of ALD has been developed including four factors of traffic, condition of existing surface, climate and type of chipping. The factors for these four characteristics are given in Table 8.15. The sum of these factors shall be used for calculation of design binder content and chipping application rate. Determination of design binder content and chipping application rate as shown in Figs.8.1 and 8.2 or by the procedure given in "Manual for Construction and Supervision of Bituminous Works" of MoRT&H.

TABLE 8.14. GRADING OF CHIPS FOR SURFACE DRESSING

Sieve Size	Per cent Passing	
	First Coat (19 mm)	Second Coat (13 mm)
26.5 mm	100	-
19.0 mm	85-100	100
13.2 mm	0-40	85-100
9.5 mm	0-7	0-40
6.3 mm	-	0-7
2.36 mm	0-2	0-2
75 μ	0-1	0-1

TABLE 8.15. FACTORS FOR DESIGN OF SURFACE DRESSING

Traffic Level		Types of Chipping		Existing Surface		Climate	
CVPD	Factor	Description	Factor	Description	Factor	Description	Fac-tor
0-100	+3	Round	+2	Untreated	+6	Wet & Cold	+2
100-500	+1	Dusty	+2	Primed	+6	Wet & Hot	+1
		Cubical	0	Lean	0	Temperate	0
		Flaky	-2	Average	-1	Dry & Hot	-1
		Precoated	-2	Rich	-3	Very Dry, Hot	-2

The spraying temperature for different types of binders is given in Table 8.16.

TABLE 8.16. SPRAYING TEMPERATURE FOR DIFFERENT TYPES OF BINDER

Binder	Whirling Spray Jets		Slot Jets	
	Min. °C	Max. °C	Min. °C	Max. °C
Penetration grade bitumen (S-90)	170	190	165	175
Modified bitumen	180	200	175	185
Emulsion (RS)	25	50	25	50

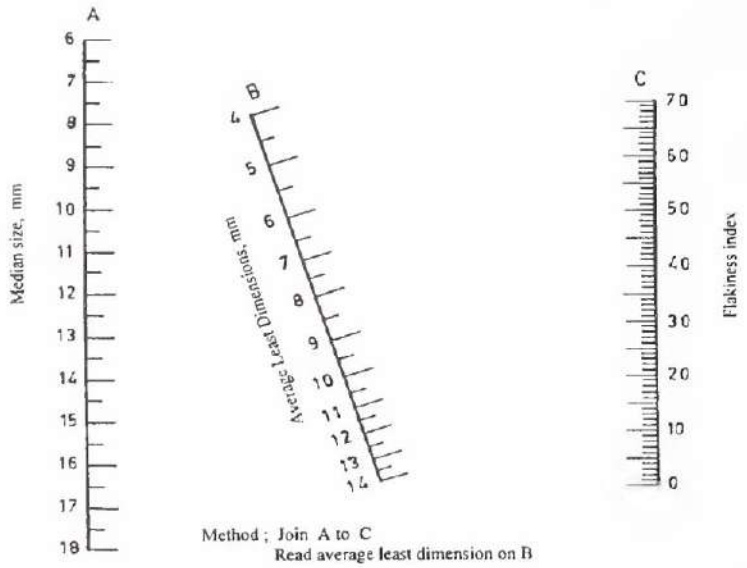


Fig. 8.1. Determination of Average Least Dimension of Aggregate

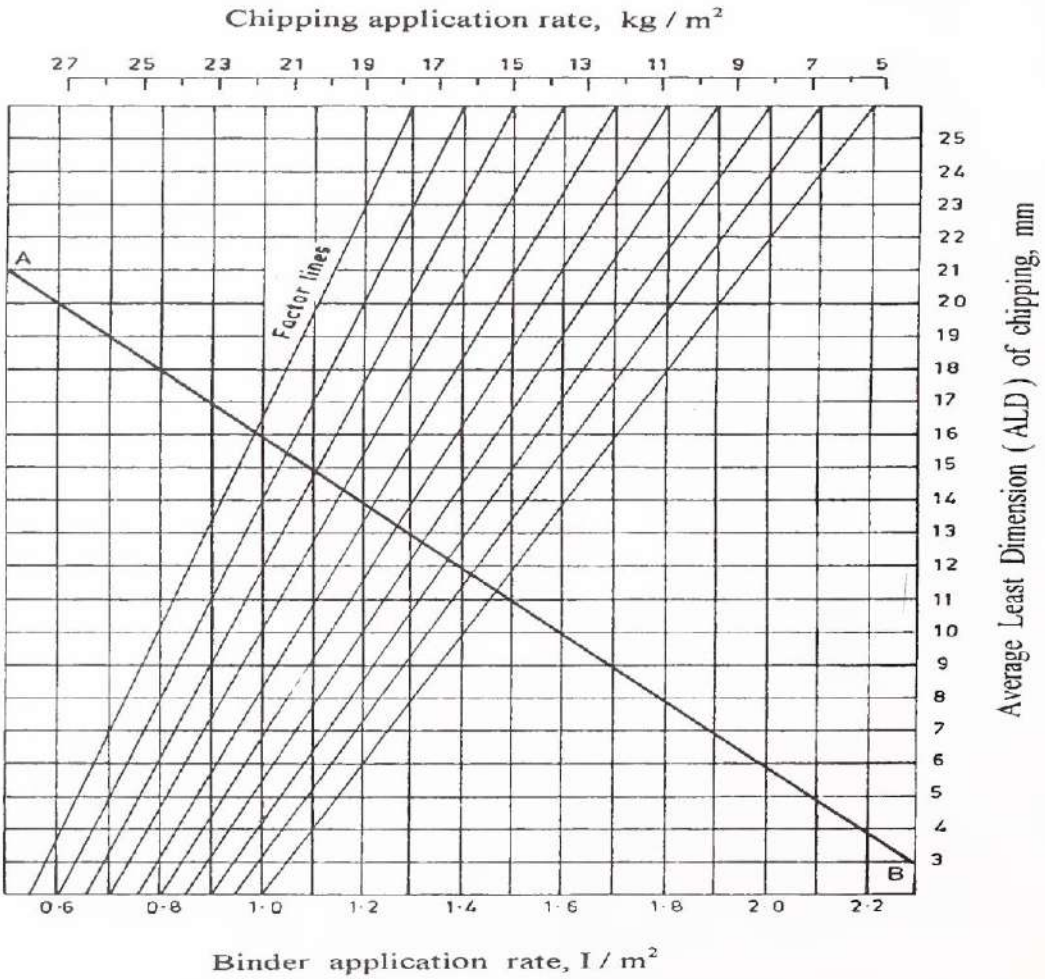


Fig. 8.2. Determination of Design Binder Content and Chipping Applicatioon Rate-Jackson Method

The surface shall be cleaned of dust or loose material either by using a mechanical broom or compressed air or as specified in the contract or as decided by Engineer-in-Charge. Equipment used for construction of surface dressing has a major impact on the quality of finished surface and subsequent performance. Binder (paving bitumen or modified bitumen) shall be heated to desired temperature and sprayed on dry surface in a uniform manner with the help of self propelled mechanical sprayer or any other suitable equipment decided by the Engineer. The equipment and general procedure shall be in accordance to "Manual for Construction and Supervision of Bituminous Works" of MoRT&H (2001). Immediately after application of binder, stone chipping in dry and clean state shall be spread uniformly on the surface by means of a self propelled or towed mechanical grit spreader to cover the surface completely. Spreading of binder and aggregate can also be accomplished by synchronised equipment in one step. Immediately after application of cover aggregate, entire surface shall be rolled with 8-10 tonne smooth wheeled steel roller or 8-10 tonne static weight vibratory roller or any other approved equipment. Rolling shall continue until all aggregate particles are finally embedded in binder and present a uniform closed surface. The second coat of surface dressing if required shall be undertaken after the surface is exposed to traffic for about 15-20 days. A trial patch shall be laid to find out the quantity of bitumen depending upon the condition of existing surface. However, surface shall be duly cleaned before application of second coat. Some of the special precautions are necessary during construction of surface dressing as surface dressing always matures in summer. It should not be done under the effects of low temperature and water. The sweeping of loose aggregate particles after rolling help in prevention of loss of aggregate due to traffic movement. Traffic shall not be permitted to run on any newly surface dressed until following day. In special circumstances, traffic may be allowed at the speed of 10-15 km/hour until following day. An example for calculation of design of surface dressing is given in ***Appendix-8.6***.

8.7.5.2. Open graded premix carpet with seal coat : The open graded premix carpet construction involves use of mixed bituminous material laid in compacted thickness of 20 mm followed by a seal coat. The aggregate quality for premix carpet shall conform to requirements as given in Chapter 4. In case water absorption exceeds 1 per cent, the polished stone value as measured by the test in BIS:812 Part II shall be less than 55. The binder shall be paving bitumen conforming to IS:73-1992 or emulsion conforming to IS:8887-1995 specifications or modified bitumen conforming to IRC:SP:53. The quantity of materials needed for 10 sqm road surfaces for 20 mm compacted thickness of open graded premix carpet are given in Table 8.17.

TABLE 8.17. MATERIAL REQUIREMENTS FOR OPEN GRADED PREMIX CARPET

Aggregate		Bitumen, kg per 10 sqm	Emulsion, kg per 10 sqm
Size, mm	Quantity, cum per 10 sqm		
22.4-11.2	0.18		
13.2-5.6	0.09	14.6	20-23

Any hot mix plant or spot mixer of appropriate capacity and type shall be used for preparation of mixed material. The temperature of ingredients and mix shall be as given in Table 8.18.

TABLE 8.18. TEMPERATURE OF INGREDIENTS AND MIX

Grade of Bitumen	Temperature °C			
	Bitumen at mixing	Aggregate at mixing	Mix delivered at site	Mix at the time of rolling
S-35	165-170	170-175	135-155	> 100
S-65	155-165	160-170	130-150	> 95
S-90	150-160	155-165	125-145	> 90

The construction operations, like, mixing, spreading and rolling shall be same as described in ***Appendix-8.5***. In case of construction of open graded premix carpet using bitumen emulsion premixing of cationic emulsion shall be carried out in a suitable mixing device such as cold mix plant as per IS:5435 (Revised) or concrete mixer. The other details regarding mixing, spreading and rolling are given in ***Appendix-8.5***. The surface shall be sealed with suitable seal coat.

Seal Coat : These types of construction are undertaken for sealing open graded premix carpet surface or a pervious surface of bituminous macadam. The binder shall be S-90 grade conforming to IS:73-1992. The grading and quantities of binder shall be as given in Table 8.19.

TABLE 8.19. REQUIREMENTS OF MATERIALS FOR SEAL COAT

Type	Aggregate		Bitumen		Emulsion	
	Specification Size, mm	Quantity, cum	Specification	Quantity, kg/10 sqm	Specification	Quantity, kg/10 sqm
A	11.2-2.36	0.09	S-65	9.8	RS	15.0
B	2.36-0.18	0.06	S-90	6.8	SS	10.0

The type A seal coat shall be used for high rainfall areas (over 1500 mm) and type B seal coat for other climatic conditions.

8.7.5.3. Closely graded premix surfacing or mixed seal surfacing : This type of construction involve laying of closely graded premixed material in 20 mm compacted thickness on a previously prepared surface. The aggregate shall consist of angular clean hard and durable material of uniform quality as specified in Chapter 4 conforming to gradings given in Table 8.20.

TABLE 8.20. AGGREGATE GRADATION FOR CLOSELY GRADED PREMIX SURFACING

IS Sieve (mm)	Per cent Passing
13.2	100
11.2	88-100
5.6	31-52
2.8	5-25
0.09	0-5

The total quantity of aggregate shall be 0.27 cum per 10 sqm area. The quantity of bitumen shall be 19 kg/10 sqm. If emulsion is used as binder the quantity shall be 28-30 kg/10 sqm. The other conditions will be identical as specified in Section 8.7.5.2 and details are given in ***Appendices-8.5 and 8.7***.

8.8. Semi-Rigid Pavement Construction

Semi rigid pavements are those having wearing course materials of modulus of elasticity less than pavement quality concrete and greater than bituminous material. For example, dry lean cement concrete, cement fly ash bound macadam, lime fly ash concrete, lime fly ash bound macadam, etc. are some of the semi rigid materials. These are also used for making Cement Treated Base (CTB). Semi rigid materials have wide range of compressive strength 40-150 km/sqcm. In case of rural roads, the wearing course shall be thin bituminous surface over a semi-rigid base. Before starting the construction of these roads samples of soil, earth filling from borrows pits, aggregate, etc. shall be collected. Engineering properties of the same shall be determined as per IRC/Bureau of Indian Standard Codes (IRC:SP:49, IRC:15, IRC:SP:11, IS:516-1959 and IS:1199-1959). To get uniform quality of pavement works and their proper mix design, there is a need for the selection of

suitable standard materials and equipment :

(i) The existing loose soil/subgrade upto adequate depth (depending upon levelling) shall be cut or spread to a camber (2 per cent) and compacted with road roller 8 to 10 tonne capacity, at optimum moisture content. The maximum dry density (compacted) in this case shall be as per Section 8.3.3.

(ii) Before, spreading any semi-rigid material or WBM over the subgrade the existing subgrade layer shall be kept wet with water for 48 hours before compacting with static road roller of 8-10 tonne capacity.

(iii) Over the compacted subgrade, water bound macadam (macadam thickness 150 mm, WBM Grade II) shall be laid in two layers and compacted separately. A layer of Dry Lean Concrete (DLC) 1:4:8 (cement: sand: coarse aggregate) shall be laid over compacted moist Water Bound Macadam (WBM) uniformly and then compacted to a thickness of 100-150 mm. DLC shall be provided either over the compacted subgrade or over the compacted WBM in case of very weak soil (CBR 2 per cent or less) (Black cotton soil or its equivalent) or in snow bound regions and heavy rainfall areas (rainfall more than 1000 mm).

(iv) Dry lean cement concrete with or without fly ash is laid over the compacted and properly cambered sub-base. Dry Lean Concrete shall be cured with water for minimum fourteen days. Light traffic may be allowed after 28 days of laying of pavement. For higher traffic, a bituminous layer or roller compacted concrete layer may be provided. This will have adequate abrasion resistance and structurally adequate surface.

(v) Any ruts or soft yielding places that appear, due to improper drainage condition, traffic or from any other cause, DLC shall be corrected and rolled, before laying wearing surface.

(vi) The coarse aggregates shall not be dumped in heaps directly on the subgrade/WBM within the area over which DLC is to be spread. The DLC shall be spread uniformly and evenly upon the prepared subgrade/WBM in required quantities before compaction starts.

(vii) There should not be any variation of level greater than 10 mm when 3 meter long straight edge is laid parallel to centre line of dry lean cement concrete.

(viii) DLC of 10-15 cm thickness (compacted) may be laid in one layer. The layer shall be tested for thickness using wooden blocks.

(ix) DLC surface shall be covered with 20 mm thick premix carpet with seal coat or closely graded premix carpet or 20 mm thick mixed seal surface.

8.9. Concrete Pavements

8.9.1. Rigid pavement using pavement quality concrete (PQC) : Rigid pavement can be constructed as per the designed based on IRC:58, construction procedure as mentioned in IRC:15 "Construction of Concrete Roads" and Clause 602 of MoRT&H Specifications for Road and Bridge Works.

8.9.2. Materials requirements : The constituents of rigid pavements are cement, water sand and coarse aggregate. These materials shall be in conforming and in accordance with relevant standard methods of testing prescribed by the Bureau of Indian Standards and IRC:15 "Standard Specification & Code of Practice for Construction of Concrete Roads". The materials and their specifications for base, sub-base, and subgrade preparation shall be as per IRC :SP:49 "Guidelines for the Use of Dry Lean Concrete as Sub-base for Rigid Pavement" and IRC:19 "Standard Specification & Code of Practice for Water Bound Macadam". IRC:109 "Guidelines for Wet Mix Macadam" and IRC:60 "Tentative Guidelines for the Use of Lime Fly Ash Concrete as Pavement Base or Sub-base" and other materials as mentioned in Chapter 4 may also be used as base or sub-base course for rigid pavement construction.

8.9.3. Concrete mix design : After selecting the material and their availability, the cement concrete mix shall be designed as per IRC:44 "Tentative Guidelines for Cement Concrete Mix Design for Pavements" or IS:10262-1982 for minimum flexural strength of 40 kg/sqcm in the field assuming good degree of quality control in the field. As per MoRT&H "Specifications for Road and Bridge Works", the cement content in the pavement quality concrete (PQC) shall not be less than 350 kg/cum and not more than 425 kg/cum. The approximate mix proportions (by weight) generally used is 1:1.5:3.0 [cement: sand (fine aggregate) : coarse aggregate] with water/cement ratio 0.38. The exact mix proportion shall be taken only after testing the materials

in a recognized laboratory, the supplied cement, aggregate and water to be used at site. If fly ash or any other specified material is to be added as replacement of cement or sand, as per IS:456-2000 "Code of Practice for Plain and Reinforced Concrete", the mix proportion accordingly may be changed.

Cement concrete cubes and beams (6 No. each) shall be cast daily to check 7 and 28 days strength as per IRC:SP:11. The maximum size of coarse aggregate may be upto 20 mm. The aggregate normally used has water absorption not more than 3 per cent and silt content (size less than 75 micron) shall not exceed 3 per cent in case of natural aggregate. The flexural strength of concrete obtained in the field shall not be less than 40 kg/ sqcm. The workability of the concrete at the time of placing shall preferably be 10 mm slump.

8.9.4. Equipment : Tools, equipments and appliances for concrete pavement construction shall be as per IRC:43 and IRC:SP:49. Edging tool shall be used for making the sharp edges of the joints in the slabs. Proper care shall be taken while maki n edges. Needle and screed vibrator shall be used for compaction of concrete. Excessive compaction of the concrete is to be avoided. It has to be checked that no extra water or bleeding shall occur on the top surface of concrete. Excessive water at the top will make the top surface very weak and there will be more abrasion as compared to adequately concrete surface. Edges of concrete shall be atleast 1 meter away from a tree there, if any.

(a) Preparation of subgrade : This shall be as per procedure mentioned for bituminous construction. For details IRC:15 "Standard Specification and Code of Practice for Construction of Concrete Roads" may be referred. We may provide a drainage layer/crack absorbing layer using granular material in addition to the base course layer in case of very weak subgrade (CBR lass tan or equal to 2 per cent). The thickness of subgrade shall be 150-300 mm. The drainage layer shall consist of well drained material placed on the subgrade, or even on the existing flexible pavement as a crack arresting layer as well as drainage layer. This may be made up of natural coarse sand, moorum, gravel, open graded crushed stone, GSB or its equivalent. The thickness of drainage layer shall be 150 mm (compacted). The drainage layer shall be at proper gradient and camber (1 in 80 in the transverse direction).

(b) Preparation of base course : Any of the specified material as mentioned below may be used as base course for construction of concrete pavement. The following three types of specifications are used for construction:

(i) **Water Bound Macadam (WBM):** It shall be laid as per the procedure given in Section 8.5.1

(ii) **Wet Mix Macadam (WMM):** It shall be laid as per the procedure laid down in IRC :109.

(iii) **Dry Lean Cement Concrete with or without fly ash:** It shall be laid as per the procedure laid down in IRC:SP:49. The base course consists of dry lean cement concrete minimum grade M10) placed above subgrade or drainage layer. The base layer may be of 100-150 mm thickness, compacted with road roller 8-10 tonne capacity, at 7 to 8 per cent water by weight of concrete, so that the concrete could take the weight of roller and could be compacted with roller conveniently. The mix proportion of dry lean concrete (DLC) of grade minimum M10, shall be, 1:4:8 (1 cement: 4 sand : 8 coarse aggregate). It shall be laid uniformly and then compacted (Compacted Thickness of DLC = 100-150 mm) as per IRC:SP:49. The cement content in the DLC shall not be less than 150 kg/cum. If fly ash is available within 50 km radius, it may be used as replacement of sand by 50 per cent by weight. Any ruts or soft yielding places that appear due to improper drainage condition traffic or from any other cause on DLC, shall be corrected and rolled until firm, before the Pavement Quality Concrete (PQC) is placed thereon for better compaction of PQC.

(c) PQC wearing course : Wearing course shall be laid as per the procedure as mentioned in IRC:15. In brief the procedure is given here as:

(i) Fixing of formwork (shuttering) shall be over the base course. It shall be set to true level and securely fixed in position to prevent any subsequent disturbance during compaction.

(ii) Manufacture and placement of concrete unless otherwise permitted, the constituents shall be weighed in a batching plant. Where volume batching is permitted, every effort should be made to minimise variation in batching. Mixing of concrete

shall be done in a power driven mixer of approved type that will ensure a uniform distribution of materials.

(iii) Concrete shall be placed on the prepared base between formwork in such a manner as to avoid segregation and uneven compaction. Concrete shall be deposited within 20 minutes and compacted within 60 minutes in summer and 75 minutes in winter. Concreting shall not be done when the atmospheric temperature is below 5°C and above 40°C .

(iv) Concrete shall be compacted fully using vibrating screed and internal vibrator. Water in the fresh concrete should not be in excess of the stipulated quantity, otherwise concrete is likely to crack within very short period after drying. After compacting and finishing with screed, a float and then a broomer is used to finally finish the top surface with required texture to avoid skidding. Any depressions or high spots showing departures from the true surface shall be immediately rectified. High spots shall be cut down and refinished. Depressions shall be enlarged to about 80-100 mm and refilled with the same fresh concrete, compacted and finished. All the above operation shall be completed within 75 minutes in winter or 60 minutes in summer from the time of adding water into the mix.

(v) If concrete slab shall be laid in two layers, the second layer shall be placed within 30 minutes of compaction of the lower layer.

(vi) Over the compacted DLC, a layer of Pavement Quality Concrete (PQC) of thickness 150-240 mm shall be laid as per the design with proper shoulder on both sides of the 3.75 m wide lane. The flexural strength of concrete shall not be less than 40 kg per sqcm. Accordingly the minimum compressive strength of concrete may be approx. 350 kg/sqcm. The actual relation between compressive and flexural strength of concrete shall be established for calculating the actual flexural strength of concrete. There should not be any variation more than 12 mm when 3 meter long straight edge is laid parallel to centre line of the dry lean cement concrete base course and 10 mm for PQC.

(vii) The layers shall be tested for thickness with wooden block.

(viii) The coarse aggregate shall not be dumped in heaps directly on the subgrade/DLC within the area over which PQC is to be spread.

(ix) Adequate compaction of concrete by suitable vibratory (first by needle vibrator specially at edges and then by screed vibrators) equipments is necessary. Every 1 per cent void remaining in the concrete means a loss of strength of the order of 4-5 per cent.

(x) The strength of concrete shall be ascertained either from cube or beams specimens. For this purpose; during the progress of work, cube and beam samples shall be cast for testing at 7 and 28 days as per IS:516-1959 and IS:1199-1959. Adequate quality control should be exercised at all stages of construction by suitable trained staff as per guidelines given in IRC:15 "Standard Specification and Code of Practice for Construction of Concrete Roads" and "Handbook of Quality Control for Construction of Roads and Runways" (IRC:SP:11) and also as per Hill Road Manual (IRC:SP:48).

(xi) Contraction and expansion joints shall be provided as per the Guidelines mentioned in IRC:15 or IRC:58. All materials required for the joints, viz. tie bars at longitudinal joints, dowel bars at expansion joints, expansion joint filler boards and joint sealing compounds shall be checked for specification requirements as per IS:1834 and IRC:57.

(xii) Curing shall commence soon after the finished pavement surface can take the weight of the wet burlap, cotton or jute mats normally employed for initial curing, without leaving any marks thereon (IRC:SP:11). The mats shall extend beyond the pavement edges at least by 0.5 m and be constantly wetted. Initial curing shall be for 24 hours or till the concrete is hard enough to permit labour operations without damages. Upto 24 hours no water other than mixing water, should be added to the surface of concrete except just wet burlaps. Final curing, after removal of the mats, etc. shall be carried out by wet ponding earth, ponding of water or other means specified. Where water is scarce or pavement is on a steep gradient, impervious membrane curing shall be adopted as per specified standard of MoRT&H. Pavement can be opened to traffic after 28 days of curing of concrete slabs.

8.9.5. Special requirements

(i) The angle between any two joints should be right angle or obtuse and joints (contraction, longitudinal, expansion) shall match with the other joints to avoid sympathetic cracks in the adjoining slabs.

(ii) The contraction joints shall be provided by cutting the concrete slab with diamond blade cutter of width 6-8 mm and depth 60 mm after 48-72 hours of casting the slabs. The contraction joints spacing shall be at 4.5 m c/c filled with hot bituminous sealing compound (upto one third of the thickness of PQC) to be provided up to say 60 mm in height (width 6 to 8 mm), as per IRC:15. The expansion joint shall be provided as per IRC:15 as a butt joint with dowel bars of dia 30 mm at a spacing of 400 mm centre to centre properly fixed in a steel cage. Expansion joints are provided when thickness of PQC is more than 150 mm. The width of the expansion joint shall be 20 mm. Premoulded joint filler board of width 20 mm and height 110-200 mm Over the board hot sealing compound may be filled.

(iii) If dry fly ash of lime reactivity greater than 40 kg/sqcm is available within reasonable lead (say 50 km), the same may be used as replacement of cement by 10-20 per cent as performance improver in Pavement Quality Concrete (PQC) or 50 per cent of sand can also be replaced by fly ash in Dry Lean Cement Concrete (DLC) to have better durability, less heat of hydration and better finishing provided 28 days strength of PQC or DLC is not reduced.

(iv) Unless special precautions are taken, concreting shall not be done when atmospheric temperature in shade is above 40°C or below 5°C (IRC:61).

(v) The tools and equipments should be according to IRC:43.

8.9.6. Roller compacted concrete pavement

(i) For construction of roller compacted concrete pavement as a rigid pavement, formwork as per IRC:43 is preferably required over WBM/semi-rigid pavement to properly confine the concrete for adequate compaction by smooth wheel roller (preferably vibratory roller).

(ii) For the construction of roller compacted concrete pavement, roller compacted concrete (RCC) can be either laid on compacted base course of WBM or dry lean concrete or any equivalent base course as per IRC:SP:49.

(iii) Over the compacted DLC, a layer of roller compacted concrete (RCC) of thickness 22 cm shall be laid when maximum axle load on the rural roads is of 10.2 tonne. The flexural strength of concrete shall not be less than 40 kg per sqcm. Accordingly the minimum compressive strength of concrete may be approximately 350 kg/sqcm. The concrete shall be preferably cured for 28 days from casting. The size of slabs is 5 m x 3.75 m with contraction joint at 5 m interval using hot sealing compound. The joint may be provided with cut up to h/3 to h/4 in depth (width 6 to 8 mm) where h is the thickness of RCC.

(iv) All fine and coarse aggregate, cement and water, if weigh batched (double bucket, swing type weigh batchers are now easily and economically available in the market which are generally being used for larger projects) gives greater uniformity in the quality of concrete. Ready mixed concrete, if available, may also be used. Due to non-availability of weigh batcher, volume batching may also be allowed for the construction of rural roads, but with very good quality control.

(v) Adequate compaction of zero slump concrete by suitable equipments is necessary. Every 1 per cent void remaining in the concrete means a loss of strength of the order of 4 to 5 per cent.

(vi) Surface water can be drained off to side drains by providing proper camber in the base course of 2 per cent from centre line towards the transverse direction.

(vii) Longitudinal slope is essential to drain water along side drains. A minimum gradient specified in Chapter 2 are provided in longitudinal direction.

(viii) All form works, finishing operation and curing shall be as per relevant standard specifications (IRC:43 and IRC:15).

(ix) The K value on WBM is between 10-14 kg/cucm, which is also greater than the minimum K-value (taken as 5.54 kg/cucm). Therefore RCC may be laid directly over WBM or DLC or both combined in case of heavy loads or extremely weak subgrade.

8.10. Construction of Special Pavements

8.10.1. Concrete block pavement (CBP)/interlocked concrete block pavement (ICBP) : This type of construction can be undertaken for road portion passing through village. The provision of drainage at the surface, sub-surface and sub-soil levels and preparation of the subgrade for Concrete Block Pavement (CBP)/ Interlocked Concrete Block Pavement (ICBP) is the same as for normal road construction. The compacted subgrade shall provide a stable working platform for subsequent construction and shall be graded and trimmed as per requirements. A good drainage layer shall be provided over the compacted subgrade. Base course shall have minimum 100 mm compacted thickness. The surface evenness of the base course shall be within 10 mm of the design profile. Bedding sand shall not be used as filler to correct base course profile. The base course shall be extended on both sides of the pavement, at least just beyond the positions of the edge restraints. Edge restraints shall be installed before preparation of bedding sand, and shall present a straight, vertical face to the

blocks. After the construction of base course and installation of edge restraints, a typical construction sequence to be adopted in construction of block pavement for maximum productivity is illustrated in Fig. 8.3. Bedding sand shall be unloaded in small piles and regularly placed over the base course. Bedding sand shall preferably have moisture content of about 6 per cent, which will facilitate its spreading and compaction. Bedding sand shall be screeded in a uniform layer over the base course. The screed can be guided to level by tensioned string line set above the base course. At the time of screeding, the thickness of sand must allow for the amount by which it will be subsequently compacted.

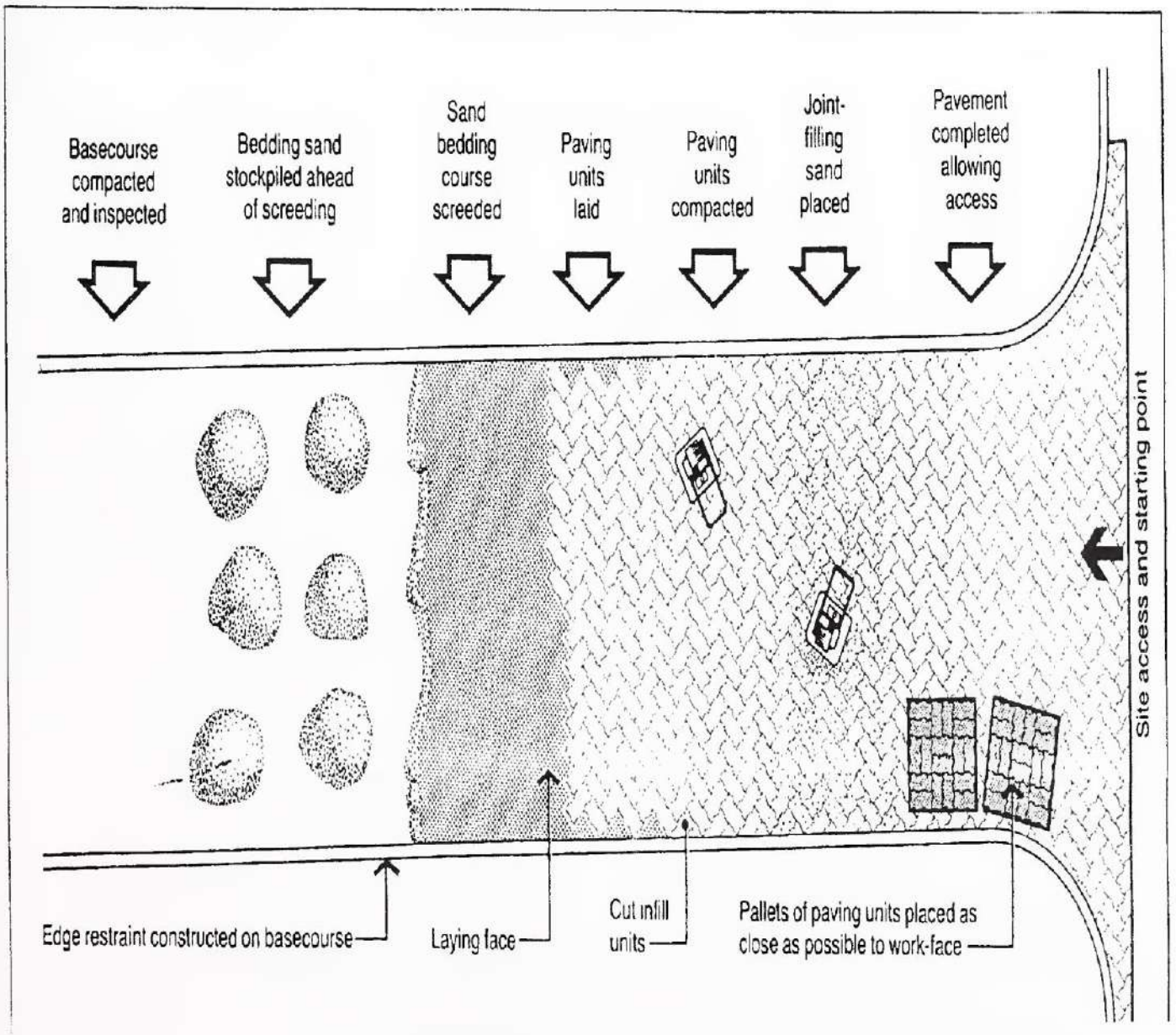


Fig. 8.3. Sequence of Construction Operation

The sand shall be distributed evenly with a small surcharge maintained in front of the screed. Screeding shall not proceed beyond about 1 m ahead of the planned end of block paving for the day. Sand shall be compacted with a manual, fabricated plate compactor and the level shall be readjusted using the screed. The surface profile of the screeded bedding sand shall match that required for the completed pavement.

The pattern in which blocks are to be paved shall be decided from the three main choices available, namely herringbone, basketweave and stretcher patterns. A typical plan view of paving patterns is shown in Fig. 8.4. By and large, these patterns are the same as adopted for brick paving, and shall be familiar to local workers. For paving in trafficked areas, herringbone pattern shall be adopted for ensuring better performance. Paving shall commence and progress from one starting line only. Wherever possible, paving shall commence adjacent to or against edge restraint.

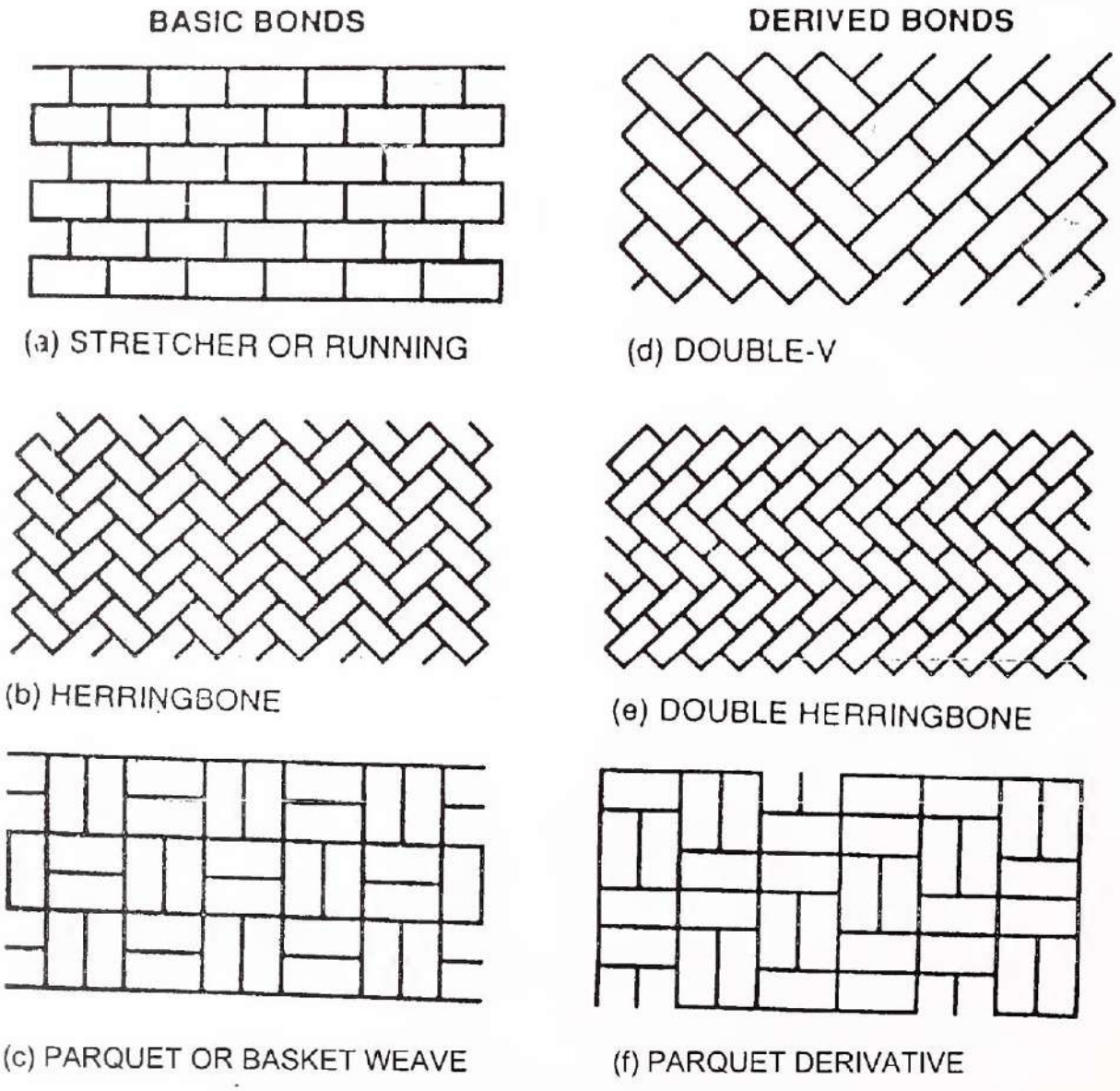


Fig. 8.4. Common Laying Patterns

Blocks shall be placed at the correct angle to the start line to achieve the final orientation of the laying pattern. For curved or unfavourably oriented edge restraint, a string line shall be established to permit fast, easy laying such that it is never necessary to force a block between blocks already paved. Maintenance of control over alignment, laying pattern and joint width can be assisted by the use of chalked string lines set at about 5 m intervals. Nominal joint width of 2 to 4 mm shall be maintained by holding the paving unit lightly against the face of the adjacent block and allowing it to slide into position. Cutting paving units for filling the paving gaps occurring against edge restraints etc. shall be deferred until sufficient work has progressed to allow reasonably continuous operation. When space does not permit the use of cut pieces of blocks, the use of premixed or dry packed concrete is recommended.

After a section has been paved, compaction with vibrating plate compactor is effected by the following sequence of operations:

- Vibrate the blocks with three passes of a standard vibrating plate compactor.
- Spread a thin layer of fine sand on top of the paved blocks and sweep it into the joints, using suitable brooms.
- Vibrate the sand into the joints by making three passes of the compactor.
- Sweep off the excess sand on top.

A standard vibrating plate compactor has a weight of 0.9 kN, a plate area of 0.3 sqm and is capable of applying a centrifugal force of 15 kN. Use of heavy-duty compactor is desirable for heavily trafficked pavements. A typical heavy-duty plate compactor weighs between 3 to 6 kN, has a plate area of about 0.5 to 0.6 sqm and is capable of applying a centrifugal force in the range of 20 to 30 kN. In the absence of a heavy compactor, the number of passes by the light compactor may be suitably increased.

8.10.2. Construction of stone-sett pavement : Regularly cut stone-sett pavements (typical size: 150x150x300 mm) are laid in herringbone or stretcher bond pattern with the rows running either across or at 45^0 to the axis of the road. Regularly cut stones help in maintaining narrow joint spacing. With good quality stones joint widths of 10 mm or less can be achieved. For irregularly cut stones, the flat surface of the stones should be tolerated. While paving irregularly cut stones, joint widths upto 20 mm may be tolerated. While paving irregularly cut stones the flat surface of the stones should be facing the top. Properly graded coarse bedding sand should be used. The stones can also be set on a thick layer (50 mm) of hot sand bitumen mix. The compacted thickness of bedding sand should be 40 mm. The stones are compacted into the bedding sand using suitable compacting devices. The joint gaps are filled with fine sand, stone dust, or sand-cement mortar. Joints can also be sealed with hot bitumen. In case of application of mortar, moist curing for minimum one week has to be ensured for obtaining maintenance free pavement. Joint sealing can also be done with limestone dust mixed with 30 to 40 per cent bitumen. In case the stone-sett pavement is meant for trafficked areas, suitable precautions in regard to selection of base course should be taken, so that damage due to water ingress is minimised. The technique is best suitable for areas with low and slow-moving traffic, where good quality stones are locally available and craftsmen with knowledge of stone paving are available.

8.10.3. Construction of brick-on-edge pavement : Brick-on-edge pavement is similar to stone-sett pavement and is constructed over a thin layer of bedding sand. The compressive strength of bricks used for paving should not be less than 7 MPa. Brick laying is suitable for very low traffic areas, for paving on shoulders of pavements, local market areas, locations with difficult drainage, etc. For better performance, two layers can be used. Both layers should be paved in herringbone pattern with the flat sides of the bricks placed in the vertical direction (brick on edge). The bricks are embedded by light compaction. The joint gaps are filled with sand or hot bitumen.

8.11. Equipment Required for Different Operations (Intermediate Technology)

Rural road construction and maintenance has been labour intensive in our Country. So much so that most of the time even a road roller has not been used for compaction on rural road works. It has to be recognised that providing employment opportunities in rural areas is an important aspect of overall rural development. At the same time compromising the engineering requirements would not be in the larger interest of the country, if the objective of rural road development programme is restricted to only providing employment opportunities. It is, therefore imperative to adopt an intermediate type of technology for rural road works. There has to be a good combination between the purely manual methods and total mechanisation. The intermediate technologies for various tasks/operations in rural road development works are outlined in Table 8.21. However, effort should be to use only the appropriate conventional equipments for each task.

TABLE 8.21. INTERMEDIATE TECHNOLOGY FOR RURAL ROADS

Sl. No.	Task	Intermediate Technology
(i)	Excavation	
	(a) Soft soils	Manual method
	(b) Hard soil	Tractor-towed mould broad plough/rotavator
	(c) Soft soil/Stony soils	Manual aids, like, pickaxes, spades, etc.
(ii)	Loading, hauling and unloading	
	(a) 0-100	Wheel borrows and pack animals
	(b) 100-1000 m	Pack animals, animal carts and tractor trolleys
	(c) Over 1000 m	Tractor trolleys/trucks
(iii)	Watering	Tractor towed/animal drawn water tanker. If lead involved is less than 75 m head loads
(iv)	Spreading of soil or aggregate	Head load if stacked outside the carriageway, Shovels spades if collected on the carriageway.
(v)	Mixing of soil aggregate/stabiliser water	Tractor towed such as Disc harrow and rotavator Where available, otherwise manual methods.
(vi)	Production of aggregates	Preferably manual methods and only in case of Smaller metal size crushers.
(vii)	Loading, hauling, unloading of aggregate	Same as under task (ii) above.
(viii)	Compaction	
	Embankment	10-12 Tonne power roller, if not available lighter rollers Tractor-towed/animal drawn.
	Sub-base course other than WBM and Surfacing	8-10 tonne power roller/tractor-towed roller.

Tools, Appliances and Equipments Required for Manual Methods

A. Road Alignment – Reconnaissance Survey and Trace Cut, Layout

(i) Abbey level/quick setting level
(ii) Ghat tracer
(iii) Prismatic Compass and Theodolite, where required
(iv) Dumpy level with staff
(v) Altimeter
(vi) Measuring chain with arrows/tape
(vii) Ranging rods, flags, pegs and nails
(viii) Sharp knife
(ix) Pick axes, crow bars, shovels and spades
(x) Felling axes sledges and Dahs
(xi) Rope and mason's thread

B. Formation Cutting/Embankment/Jungle Clearance

(i) Hand saws, felling axes and dahs
(ii) Anchor bars and rope
(iii) Flags and measuring tape

C. Excavation/Embankment

(i) Pick axes, crow bars, shovels and spades
(ii) Cane baskets and wheel barrows
(iii) Sledges and chisels
(iv) Rammers and compactors
(v) Flags and rope
(vi) Water cans, empty drums for storage of water and hose pipe
(vii) Sheep foot roller with prime mover
(viii) Template, straight edge 3 metres long and Engineer's sprit level
(ix) Mason's thread and other tools as required for surface dressing or making camber.

D. Blasting Tools

(i) Auger/Crow bar
Jumping bar - Made of steel for drilling holes in rocks
(ii) Stemming rod - Made of wood to charge and steam the holes for blasting
(iii) Scraper - Made of brass to clean the holes
(iv) Pricker - Made of brass, aluminium or wood to prick the cartridge prior to inserting detonator or detonating fuses.
(v) Crimper - Made of non-ferrous, non-sparking material for rimping the detonator to fuse.

E. Protective and Drainage Work

Layout and construction

(i) Measuring boxes, water measures and sieves
(ii) Spades and shovels
(iii) Mortar pans, cane baskets and wheelbarrows
(iv) Iron rammers and wooden tampers
(v) Dressing hammers and chisels
(vi) Mason's tools including trowel, float, spirit level, straight edge and thread etc.

(vii) GI buckets – 6 to 12 litres
(viii) Empty drum or GI storage tank 2000 litres capacity
(ix) GI sheet for mixing mortar/concrete
(x) Vibrator and concrete mixer
(xi) Tools for making scaffolding

Curing

(i) Hessain cloth and polythene sheets
(ii) Buckets, cans and hose pipe
(iii) Empty drums or water storage tanks 2000 litres capacity

F. Pavement Work

Picking or removing old pavement

(i) Pick axes, crow bars, hammers and chisels

Laying out

(i) Pegs, nails, rope, measuring tape, chalk and angle iron
(ii) Wooden strips of required dimensions for edge support

Cleaning the surface

(i) Wire brushes
(ii) Coir brushes
(iii) Brooms and old gunny bags

Handing and spreading materials

(i) Baskets lines with gunny cloth and wheel barrows
(ii) Bucket GI – 6 to 12 litres capacity
(iii) Empty drums or GI storage tank-200 litres capacity
(iv) Heating trays, wheel barrows
(v) Hammer and cutter for opening bitumen drums
(vi) 15 to 30 litres capacity containers for measuring aggregate
(vii) Shovels and spades
(viii) Rakers with small and long handle
(ix) Spring balance 10 and 25 kg
(x) Bitumen boiler
(xi) Chain pulley arrangement for lifting drums
(xii) Tractor or other arrangement to pull the bitumen boiler (Road Roller may also be able to do this)

Checking profile and quality control

(i) Thermometer dial type range 0°-250°C
(ii) Thermometer, mercury in glass-range 00-250°C
(iii) Straight edge-metres
(iv) Camber board/template
(v) Depth gauge

Special tools for pavement surfacing

(i) Manually operated sprayers
(ii) Road rollers -3 wheeled smooth, tandem, vibratory and pneumatic as per specification of component layers of pavement

Appendix-8.2

Plant and Equipment Required for Different Phases of Mechanised Construction

A. Formation Cut/Embankment

Jungle clearance

(i) Crawler tractor with bulldozer attachment
(ii) Power saw
(iii) Tractor mounted winch
(iv) Rooters

Formation cutting, excavation/embankment

(i) Scraper, tractor/motorised or towed
(ii) Crawler tractor with bulldozer/angel dozer/ripper and wheel dozer
(iii) Excavator with shovel/drag-line attachment
(iv) Pay loader-(Front end loader)
(v) Disc harrow
(vi) Rotary tillers
(vii) Water lorries
(viii) Water pump
(ix) Motor grader
(x) Compactor-Sheep foot with prime mover, Vibratory roller and smooth wheel roller (8/10 tonne capacity)

Blasting

(i) Air compressor
(ii) Wagon drill
(iii) Jack hammer with accessories
(iv) Exploder with shot firing cable
(v) Ohm-meter
(vi) Winch for suspending scaffolding

B. Protective and Drainage Works

(i) Excavator
(ii) Back hoe ripper with prime mover/tractor
(iii) Concrete mixer
(iv) Tripod pulley block/crane
(v) Truck mounted mixers
(vi) Vibrators Internal and screed type
(vii) Fork lift
(viii) Water lorries
(ix) Bar bending machine
(x) Water pump
(xi) Load Carriers (Dumper/Tipper & Trucks)

A. Flexible Pavement – (Pavement with Bituminous Surfacing)

Crushing of aggregate

(i) Stone crusher
(ii) Granulators
(iii) Air compressor
(iv) Jack hammer with accessories
(v) Blasting accessories
(vi) Tractor with dozer attachment, wheel dozer

(vii) Pay loader (front end loader)
(viii) Load carriers (Dumper/Tipper & Trucks)
(ix) Generator

Laying base/sub-base course

(i) Motor/Grader
(ii) Water bowser with water sprinkling system
(iii) Disc harrow/rotary tillers
(iv) Paver finisher
(v) Compactor – 3 wheeled smooth 8/10 tonne capacity roller
(vi) Mixer for wet-mix macadam
(vii) Plate compactor for compacting narrow widths
(viii) Load carriers (Dumpers/Tippers)

B. Bitumen Work

Bituminous spraying and mixing equipment

(i) Mechanical Broom
(ii) Bitumen pressure distributor
(iii) Gritter (Grit spreader)
(iv) Hot mix or cold mixing plant of appropriate capacity with all accessories as laid down in IRC:72 and IRC:43 (for cement concrete roads)
(v) Dumper/Tippers and Trucks

Spreading and laying bituminous courses

(i) Paver finisher

C. Rolling Equipment and Pavement Marking Equipment

(i) Three wheeled roller, 8-10 tonne
(ii) Tandem roller
(iii) Vibratory roller
(iv) Pneumatic tyre roller
(v) Pavement marker

D. Tools for Checking Surface Evenness and Compaction

(i) Profilometer
(ii) Density meter

E. Tools for Checking Surface Evenness and Density/Compaction

(i) Profilometer
(ii) Density meter

F. Rigid Pavement-Cement Concrete Roads

(i) Motor grader
(ii) Compactor - 8/10 tonne steel wheeled roller, vibratory roller, tandem roller
(iii) Water lorry with water sprinkling arrangement
(iv) Hydraulic hammer
(v) Hydraulic concrete cutter for cutting/dressing the concrete pavement neatly etc.
(vi) Screed vibrator
(vii) Mixer

G. Preparation of Concrete Mix and Laying

(i) Concrete weigh batching plant of suitable capacity
(ii) Trucks/dumpers/tippers

(iii) Mixer mounted on truck (transit mixer)
(iv) Water bowser/water lorry
(v) Cement silo
(vi) Concrete laying appliances
(vii) Joint sealing machine
(viii) Joint cutting machine
(ix) Forklift for shifting at work site
(x) Water pump
(xi) Concrete vibrators-internal type and screed type

H. Tools and Appliances for Safety during Construction

(i) Road barriers
(ii) Diversion and Caution boards
(iii) Red flags
(iv) Field tent and accessories
(v) Gum boots, gloves and Goggles
(vi) First aid box

Appendix 8.3

Procedure for Field Preparation of Cut-Back Bitumen

Paving bitumen 80/100 is heated at 100°C to 110°C in a bitumen boiler. The required quantity of distillate of specified type is taken in an empty drum. Hot bitumen from the boiler is added to the drum. After closing the lid of the drum containing distillate and hot bitumen, it is rolled on the ground to and fro till a uniform blend is obtained. The blend so prepared is transferred to a storage tank. Sufficient quantity of cut-back bitumen has to be prepared before undertaking the road construction work. It may be ensured that the drum containing distillate is kept at a safe distance from bitumen boiler equipment. Naptha, kerosene oil, heavy distillate and diesel oil shall be used for preparation of rapid curing, medium curing, slow curing and primer type cut-back bitumen respectively.

Specifications for Modified Penetration Macadam (MPM)

1. Scope

These guidelines comprises providing and laying 50/75 mm thick Modified Penetration Macadam (MPM).

2. Description

The work consists of supply of materials and labour required for providing and laying MPM surface for compacted thickness of 50 or 75 mm. This item includes preparing the existing road surface to receive the MPM course, i.e., cleaning of the existing WBM surface spreading of 40 mm size metal layer in required thickness, with compaction with power roller, heating and spraying bitumen with sprayer, spreading key aggregates (12 mm chips) and final compaction with power roller, etc. Complete and finishing in accordance with the requirement in close conformity with grades lines, cross-sections and thickness as per approved drawings, etc.

3. Materials

3.1. Aggregates : The aggregate for providing MPM surface shall comply with MoRT&H Specifications and shall normally comply with the following regarding size and quantity of aggregates and grade and quantities of bitumen:

Description	Rate of application for 10 sqm area			
	75 mm		50 mm	
	On asphalt Surface, cum	On WBM Surface, cum	On asphalt Surface, cum	On WBM Surface, cum
(a) 40 mm size hand broken metal	0.9	0.9	0.6	0.6
(b) 12 mm size chips	0.18	0.18	0.18	0.18

Note: Hand broken metal is preferred. However up to 30 per cent of total quantity of 40 mm size metal, 40 mm crusher broken, metal can be used.

3.2. Bitumen : The bitumen shall be paving grade of S-35 to S-65 (30/40 to 60/70) as per IS:73-1992 specifications. The rate of application 75 mm and 50 mm MPM to be constructed over existing bituminous or WBM surface is given in the table below:

Description	Rate of application for 10 sqm area (kg)			
	75 mm		50 mm	
	Bituminous surface	WBM surface	Bituminous surface	WBM surface
(a) Bitumen for grouting	20	20	17.5	17.5
(b) Tack coat for existing bituminous surface	5	-	5	

4. Preparing the Base

4.1. Any pothole in the existing bituminous road surface and broken edges shall be repaired in advance and the surface shall be brought to correct level and camber with additional metal and bitumen as required. Before starting the work, the surface shall be swept clean of the entire dirt, mud cakes, animal droppings and other loose foreign material.

4.2. If so required by the Engineer, the Contractor shall keep the side width and nearby diversion watered to prevent dust from blowing over the surface to be bituminised.

Existing water bound macadam surface shall be picked and surface loosened for a depth of 2.5 cm and the picked surface shall be brought approximately to the correct camber and section. Edge line shall be correctly marked by dog bellying the surface to form a continuous vee notch.

There shall always be sufficient length of prepared surface ahead of the bituminous surfacing operations as directed by the Engineer to keep these operations continuous.

5. Tack coat on Bitumen Surface

Applying tack coat for existing bituminous surface only at the rate of 50 kg/100 sqm

6. Preparation of Existing WBM Surface

Preparation of existing WBM surface for receiving MPM which is quite similar to the Bituminous Bound Macadam as per MoRT&H.

7. Spreading and Compaction

7.1. 40 mm size metal shall be spread evenly at the specified rate of 9 cum or 6 cum per 100 sqm of area so as to form a layer (for 75 mm and 50 mm MPM respectively) over the width of road with correct camber/super elevation as required. Any foreign matter, organic matter, dust, grass etc. shall be removed immediately. The sections shall be checked with camber board and straight edge batten etc. Any irregularities shall be made good by adding aggregates in case of depressions and removing aggregates from high spots checked with camber board and straight edge batten etc.

7.2. The surface of 40 mm metal layer after bringing it to necessary grades and sections shall be rolled with the use of 8 to 10 tonnes power roller. Rolling shall commence from the edges and progress towards centre longitudinally except on super elevated portion, it shall progress from the lower to upper edge parallel to the centre line of pavement. When the roller has passed over the whole area any high spots or depressions, which become apparent, shall be corrected by removing or adding aggregates.

7.3. Rolling shall then be continued till the entire surface has been rolled to desired compaction such that there is no crushing of aggregates and all roller marks have been eliminated. Each pass of roller shall uniformly overlap not less than one third of the track made in the preceding pass.

8. Application of Bitumen

Bitumen of paving grade S-35 or S-65 supplied for the work shall be heated to temperature of 177°C to 191°C in a bitumen boiler and temperature shall be maintained at the time of actual application. The hot bitumen shall be applied through a pressure sprayer on road surface uniformly at the rate of 200 kg/100 sqm or 175 kg/100 sqm as the case may be. The road surface shall be divided into suitable rectangles marked by chalk so as to ensure correct rate of application of the bitumen.

9. Key Aggregates

On completion of bitumen application, 12 mm size key aggregate shall be spread immediately at a uniform rate of 1.8 cum or 1.2 cum per 100 sqm. Brooms shall be used to ensure even distribution of key aggregate.

10. Final Compaction

Immediately after spraying of bitumen and spreading of key aggregates, the surface shall be rolled with

a power roller to obtain full compaction and to force the blindage of key aggregates into the interstices of the coarse aggregate. The rolling shall continue till the asphalt surface hardens and key aggregates stop moving under power roller.

11. Surface Finish and Quality Control

The surface finish shall conform to the requirements of Clause 902 of Specifications for Road and Bridge Works of MoRT&H and as detailed in Chapter 10.

12. Items to Include

(i) Diversions unless separately provided in the tender.
(ii) Preparing the road surface.
(iii) Applying tack coat on existing B.T. or Picking the existing W.B.M. surface.
(iv) Supplying spreading and compaction of 40 mm size aggregates.
(v) Supplying, heating and spraying bitumen.
(vi) Supplying, spreading and compaction of 12 mm size chips.
(vii) All labour, materials, including bitumen and aggregates use of tools, plants and equipment for completing the item satisfactory.

Sl No.	Test	Frequency
1.	Quality of binder	Two samples per lot to be subjected to all or some test as directed by the Engineer.
2.	Aggregate Impact Value	One test per 200 cum of aggregate
3.	Flakiness Index and Elongation Index	One test per 200 cum of aggregate
4.	Stripping value	Initially one set of three representative specimens for each source of supply subsequently when warranted by changes in the quality of aggregate.
5.	Water absorption of Aggregates	Initially one set of three representative specimens for each source of supply subsequently when warranted by changes in the quality of aggregates.
6.	Aggregate grading	One test per 100 cum of aggregates.
7.	Temperature of binder at application	At regular close intervals.
8.	Rate of spread of binder	One test per 500 sqm of area.

Appendix 8.5

Mixing, Transportation and Laying of Hot Mixed Bituminous Materials

Hot mixed bituminous materials shall be made with following methods and precautions:

(i) Premixed bituminous materials which includes bituminous macadam, open graded premix carpet and closely graded premix carpet shall be prepared in a hot mix plant of adequate capacity capable of yielding a mix of uniform quality with respect to grading and binder content. The difference in temperature of bitumen and aggregate shall not exceed 14°C. The temperature of binder shall not exceed 175°C in any case.

(ii) A batch type or continuous type or a spot mixer may be used for preparation of mix as decided by Engineer-in-Charge. If a continuous mixing plants to be used for mixing, contractor must demonstrated by laboratory analysis that cold feed combined grading is within permissible grading limits and binder content is in compliance to job mix formula. The maximum permitted variations in binder content of mix is 0.3 per cent.

(iii) The surface shall be cleaned of all loose and extraneous matter by a mechanical broom or any other means like high-pressure air jet etc. Laying of bituminous mixture shall not be carried out when air temperature is below 10°C or the wind blowing exceeding 40 km/hr.

(iv) Excluding the areas, where mechanical paver can not access, bituminous material shall be spread, levelled and tamped by self propelled paver finisher. The rate of delivery of material to the paver shall be regulated to enable paver to run continuously without any break in paving process. The hand paving of premixed material shall be permitted in following circumstances.

- Small laying area
- Patch work and paving of footpaths
- Locations where it is impractical for a paver to operate

(v) Compaction shall be completed before the temperature falls below the minimum specified rolling temperature, i.e., 100°C. The initial and breakdown rolling shall be done with 8-10 tonne dead weight smooth wheeled rollers followed by intermediate rolling with the same roller or a vibratory roller. The final rolling shall be done with a light roller smooth wheeled tandem roller. The roller shall first compact materials adjacent to joints then lower to upper side of layer, over lapping on successive passes by at least one third of the width of the rear roll. In case of rolling in super elevated and uni-directional camber, the rolling shall progress from lower to upper edge after the edge has been rolled.

(vi) The minimum thickness of material laid in each paver pass shall be maintained in accordance with minimum value given in the specifications. When laying of wearing course approaches an expansion joint, machine laying shall be stopped 300 mm before start of the joint. The pavement area upto joint and beyond it shall be hand paved.

(vii) During the period of construction, arrangements for traffic shall be made in accordance with provisions of Clause 112 of the MoRT&H of the Specifications for Road and Bridge Works.

Design of Surface Dressing (Typical Example)

(i) Properties of ingredients

- Properties of aggregates are as follows:
  - (a) Flakiness Index - 30 per cent
  - (b) Medium size - Passing 50 per cent through 9.5 mm sieve
- Characteristics of site
  - (a) Traffic 150 CVPD
  - (b) Type of chipping Flaky
  - (c) Existing surface Average
  - (d) Climate Temperate

(ii) Calculations of Average Least Dimension

- Read Average Least Dimension (ALD) from Fig. 8.1, considering medium size of aggregate which is 9.5 mm where Flakiness Index is 30 per cent in the present case.
- Join 9.5 mm from line (Line A, Fig. 8.1) with 30 per cent of Flakiness Index (Line C, Fig. 8.1), the value of ALD is estimated 6.5 from line B (Fig. 8.1).
- The sum of factors for site are calculated as under.

(a)	Item	Description	Factor
(b)	Traffic	150 CVPD	+1
(c)	Type of Chipping	Flaky	-2
(d)	Existing Surface	Average	-1
(e)	Climate	Temperate	0
(f)	Sum of Factors		-2

- The design binder and chipping application rate are determined by summing the four factors and entering the value in the Fig. 8.2. The intersection point of ALD and the factor line (of -2) gives the design rate of spread of binder (bottom scale) which comes to be 0.82 litre/sqm.
- The intersection point of the ALD and the l ine AB (Fig. 8.2) gives the application rate for the chipping, which comes to be 9 kg/sqm (top scale)

Appendix 8.7

Mixing, Transportation and Laying of Cold Mixed Bituminous Materials

Cold mixed bituminous materials shall be made with following methods and precautions:

(i) Premixing of cold mixed bituminous material can be undertaken in concrete mix plants as per IS:5435 (Part-I). The mixing plant may be either batch or drum mix plant. On batch plant, the pug mill mixing chamber should be vented to allow for steam to escape. The discharge end of the bitumen emulsion circulating pipe should be kept below the surface of emulsion in storage tank to prevent foaming. The temperature of emulsion should be above 30°C and will never reach above 100°C. The manual mixing may be undertaken in case of small works in rare cases.

If a concrete mixer is used, 0.135 cum of aggregate per batch conforming to specifications shall be used. First coarse aggregate shall be placed into mixer followed by required quality of cationic bitumen emulsion, then fine aggregate and remaining quantity of emulsion. After material has been mixed thoroughly, it will be transported to the laying site in tippers. The cold premixed material shall be spread within 10 minutes of applying tack coat and levelling and raking shall be completed within 20 minutes. The mix shall be spread to desired thickness, grade and camber.

(ii) The rolling shall start immediately after laying cold mixed material using smooth wheeled tandem roller of 8-10 tonne as listed in ***Appendix-8.2***. Vibratory rolling of open graded cold mix is not recommended because fracture of aggregate and bitumen bond may occur. A light blotter of coarse sand may be applied to permit rolling with a pneumatic tired roller. The blotting prevents pickup and damage of surface by traffic.

The other precautions under cold mix construction are as under:

- If rain occurs before the mix is cured, traffic should be kept off.
- Water content should not be more than designed.
- Over mixing should be avoided to prevent pre-mature breaking of emulsion. The reasonable mixing time is one to two minutes.
- Sealing of open graded surface should be done after a reasonable gap.

Chapter 9

USE OF WASTE MATERIALS

9.1. Introduction

Conventionally road pavements are constructed using aggregates and binder. The usual binder adopted in road works is bitumen. Aggregates form major portion of the total volume of pavement structure and is the primary mineral material used in road construction. Large volumes of aggregates are consumed by the road building programme and similar quantities are used in maintenance works. It is estimated that construction of one cubic metre of Water Bound Macadam (WBM) involves use of about 1.2 to 1.4 cubic metre of aggregates, and laying of bituminous pavements involve even higher quantities. The extraction of aggregates from natural outcrop of rocks results into loss of forest lands, noise, dust, blasting vibrations, pollution hazards, etc. Such environmental impacts are causing concern in many parts of the country. Unplanned exploitation of natural rock mass may sometimes lead to landslides of weak and steep hill slopes.

In addition to aggregates and binder, enormous quantities of soil is also required for construction of road embankments and approaches of bridges. Loss of precious topsoil in this process renders agricultural lands infertile. R&D studies and successful field demonstration projects have proved that waste materials like fly ash, iron and steel industry slags, municipal waste, rice husk ash, marble slurry dust, recycled concrete, etc. can be used for construction of roads. While using such materials, the construction procedure would be broadly similar to construction of roads using conventional materials

9.2. Fly Ash for Road Construction

Due to industrialisation and rapid economic growth, demand for electricity has risen tremendously. To meet this demand a number of coal based thermal power plants have been set up in the country. At present, thermal power plants produce about 95 million tonnes of fly ash per annum. When pulverised coal is burnt in the furnace of the power stations, about 80 per cent of the ash produced is very fine in nature. This part gets carried along with flue gases and is collected by using either electro-static precipitator or cyclone precipitator. The ash collected from such precipitators is called fly ash. The remaining ash sinters and falls down at the bottom of the furnace. This is known as bottom ash. Fly ash may be disposed in dry form (in ash mounds) where as the bottom ash is disposed through water slurry in a pond. When fly ash and bottom ash are mixed and disposed in the form of water slurry to ash ponds, it is called pond ash. For the purpose of these guidelines the term 'fly ash' generally denotes any type of coal ash unless specifically mentioned.

Fly ash is causing environmental pollution, creating health hazards and requires large areas of precious land for disposal. Due to increasing concern for environmental protection and growing awareness of the ill effects of pollution, disposal of ash generated at thermal power plants has become an urgent and challenging task.

The properties of fly ash depend upon type of coal, pulverisation and combustion techniques, collection and disposal systems, etc. Ash collected from the same ash pond may exhibit different physical and engineering properties depending on the point of collection, depth, etc. Obviously ash from two different thermal power plants can be expected to have different properties. These factors can be easily taken care during characterisation, design and quality control operations. Fly ash possesses several desirable characteristics such as lightweight, ease of compaction, faster rate of consolidation, better drainage, etc. In comparison to soil, spreading and compaction of fly ash can be started much earlier after a rainfall. For construction of embankments over weak subsoil fly ash could be a preferred material. The present manual has been formulated to help executing agencies

to take up rural road works using fly ash. List of thermal power stations is placed in ***Appendix-9.1*** and map showing location of thermal power plants is given at Fig. 9.1. Further, it may be noted that the Government of India in a Gazette Notification dated 14.9.1999, has instructed all the thermal power stations to make ash available for such purposes, free of cost for a period of ten years from the date of notification.

9.3. Design and Construction of Fly Ash Embankments

9.3.1. Design considerations : The design of fly ash embankments is similar to design ot soil embankments. Fly ash embankments of height upto 3 m can be constructed adopting a side slope of 1:1.5 (V:H). A flatter slope of 1:2 may be adopted at places where weak subsoil conditions exist or the embankment is constructed in flood prone areas. Regardless of the height of the embankment, fly ash embankments should always be constructed with soil cover. For construction of embankments of height more than 3 m, the design process for embankments involves the following steps:

- Site investigations
- Characterisation of materials
- Detailed design

In case of high embankment construction, the site investigations are carried out as per IRC:75. The design of embankment is an iterative process. It involves developing conceptual plans, which satisfy site needs, design requirements pertaining to slope stability, bearing capacity, settlement and drainage. The conceptual designs are based on the engineering properties of fly ash and specific site conditions. The design includes analysis for establishing structural features of the embankment at the selected site. Special emphasis is required with respect to provision of earth cover for fly ash embankments. The thickness of earth cover on the side slope would be typically in the range of 1 to 3 m which is governed by the height of the embankment and the side slope. For embankment upto 3 m height, in general, the earth cover thickness of about 1 m (measured horizontally) would be sufficient. The cover thickness may be increased for high embankments and embankments to be constructed in flood prone areas. The side cover should be regarded as a part of embankment for design analysis.

The embankment would, therefore, be designed as a composite structure with fly ash in the core and earth cover on the sides. The software for stability analysis of high embankments available with the Indian Roads Congress, approved by Ministry of Road Transport & Highways (MoRT&H), Government of India, can be used for design of fly ash embankments.

It is recommended that the factor of safety for embankments constructed using fly ash should not be less than 1.25 under normal serviceability conditions and should not be less than 1.0 when checked for worst combination under seismic and saturated conditions.

Intermediate soil layers are often provided in the fly ash, embankment of height more than 3 m, for ease of construction, to facilitate compaction and to provide adequate confinement. Such layers also minimise liquefaction potential. The compacted thickness of intermediate soil layer should not exceed 200 mm. One or more intermediate layers can be provided depending upon the design requirements. The vertical distance between such layers may vary from 1.5 to 3 m. The top 0.5 m of embankment should be constructed using selected earth to form the subgrade for the road pavement. Typical cross-sections of fly ash embankment with and without intermediate soil layers are shown in Figs. 9.2 and 9.3 respectively.

9.3.2. Materials for construction : The physical and engineering properties of the materials to be used in construction, fly ash and soil should be characterised to assess suitability of material and to obtain design parameters.

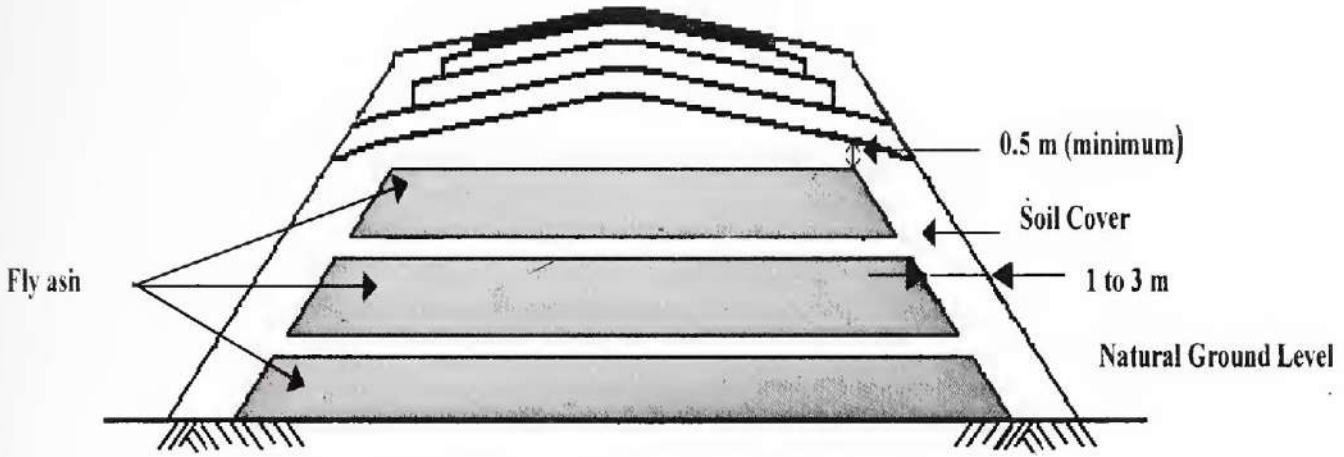


Fig. 9.2. Typical Cross-Section of Embankment with Alternate Layers of Fly Ash and Soil

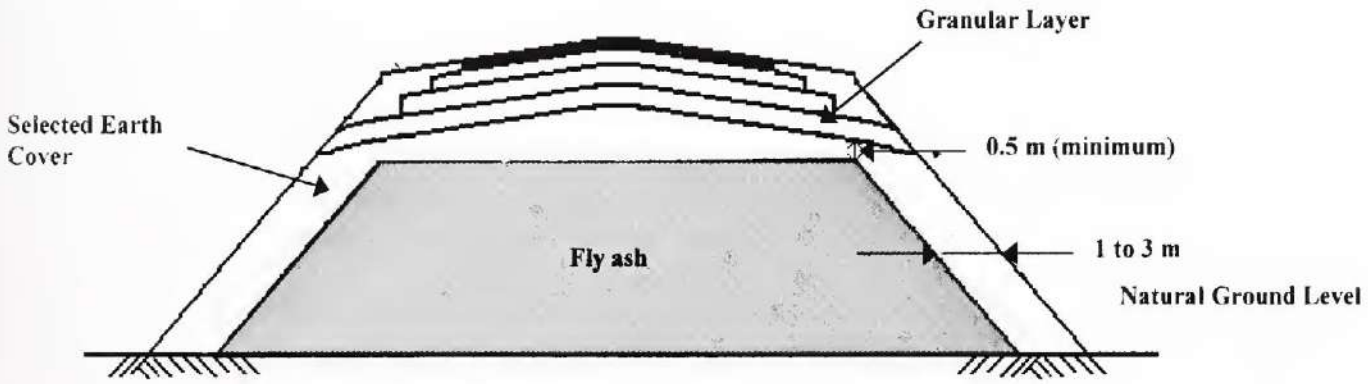


Fig. 9.3. Typical Cross-Section of Embankment with Core of Fly Ash

9.3.2.1. Fly ash : The following information on the fly ash should be made available for engineer's approval before commencement of compaction:

(i) Particle size analysis of the material as per wet sieve analysis [IS:2720 (Part 4)-1985]

(ii) The maximum dry density (MDD) and optimum moisture content (OMC) as per modified proctor test, and the graph of density plotted against moisture content [IS:2720 (Part 8)-1983)]

Once the Engineer has approved the above information, it shall form the basis for compaction. The density of fly ash is in general considerably lower than density of soils. So, unlike soils, fly ash with low MDD value should not be rejected for using it as a fill material.

To determine engineering properties of fly ash, tests should be carried out in accordance with the procedures laid down in IS:2720 (Method of Tests for Soils-relevant parts).

- Shear strength parameters, for evaluation of the stability of proposed slopes and the bearing capacity of foundations located on the fill.
- Compressibility characteristics, for predicting the magnitude and duration of the fill settlement.
- Permeability and capillary characteristics to assess seepage and to design drainage systems.

The design analysis of an engineered fill or embankment requires the shear strength of fill material to be determined. This is accomplished in the laboratory by conducting triaxial shear or direct shear test. Shear strength is affected by the density and moisture content of the specimen. To determine shear strength parameters 'c and φ', laboratory shear strength tests should be conducted on samples compacted to densities equivalent to those expected to be attained in the field. Fly ash gets consolidated at a faster rate and primary consolidation is completed very quickly. So it has low compressibility and shows negligible post construction settlements. Liquefaction generally occurs when fly ash is deposited under loose saturated condition during construction. There is very little possibility of liquefaction to occur, when fly ash is used in embankment construction, as the material is compacted to maximum dry density at optimum moisture content, i.e., under partially saturated condition. In regions of moderate to high seismic activity, analysis of embankment stability should consider liquefaction potential of the ash fill. To avoid the possibility of any liquefaction to occur, the following precautions may be taken:

- Proper compaction of the fill material as per specifications
- Lowering of high water table by providing suitable drains or capillary cutoff layer.
- By sandwiching ash between intermediate horizontal soil layers

Typical values for different geotechnical properties of fly ash acceptable for embankment construction are given in Table 9.1.

TABLE 9.1. TYPICAL GEOTECHNICAL PROPERTIES OF FLY ASH

Parameter	Normal Range
Specific Gravity	1.90 – 2.55
Plasticity	Non-Plastic
Maximum Dry Density (g/cc)	0.9 – 1.60
Optimum Moisture Content (per cent)	38.0 – 18.0
Cohesion (kN/m^2)	Negligible
Angle of Internal Friction (φ)	30^0 - 40^0
Coefficient of Consolidation C_v (cm^2/s)	1.7×10^{-5} - 2.0×10^{-3}
Compression Index C_c	0.05 – 0.40
Permeability (cm/s)	8×10^{-6} - 7×10^{-4}
Particle Size Distribution (per cent of materials)	
Clay size fraction (Less than 0.002 mm)	1 – 10
Silt size fraction (0.075 to 0.002 mm)	8 – 85
Sand size fraction (4.75 to 0.075 mm)	7 – 90
Gravel size fraction (80 to 4.75 mm)	0 – 10
Coefficient of Uniformity	3 – 11

The chemical characteristics of fly ash, which need to be evaluated, are pozzolanic property, leachability and self-hardening characteristics. The pozzolanic property of fly ash would be of importance if stabilisers like lime are used. Self-hardening property of bituminous coal ashes is insignificant. Fly ash to be used as fill material should not have soluble sulphate (expressed as SO_3) content exceeding 1.9 g per litre when tested according to BS:1377-1975 Test 10 but using a 2:1 water-soil ratio. Otherwise it shall not be deposited within 500 mm (or other distance prescribed by the engineer) of concrete, cement bound materials and other cementitious material or metallic surface forming part of permanent works. Generally Indian fly ashes are found to be safer on this parameter.

The primary environmental concern regarding use of fly ash for embankments would be contamination of ground and surface water due to heavy metal leaching. But it may be noted that most fly ashes are relatively inert. Moreover, coal used in Indian thermal power plants have high ash content. As a result, enrichment of heavy metals is lower compared to fly ash produced by thermal power plants abroad. Studies have shown that even though constituents in fly ash particle may dissolve initially but retention by weathered fly ash residues reduces the possibility of their migration into ground water.

The leaching problem can be minimised by controlling the amount of water, which infiltrates into fly ash embankment. Normally percolation of water into the fly ash core will be minimum when sides and top are protected using good earth. Further by providing impervious wearing course to the pavement constructed over the embankment seepage can be minimised. Side slopes should be properly benched and protected using soil cover with vegetation or soil cover with stone pitching. Monitoring of fly ash embankments has indicated that relatively little water tends to percolate through the complete embankment. Even in such a case, the alkaline nature of the fly ash-water solution restricts heavy metal leaching.

9.3.2.2. Earth cover : The fly ash embankments should be covered on the sides and top by soil to prevent erosion of fly ash. Good earth suitable for embankment construction can be adopted as cover material for fly ash embankments. Gravel may be used to construct granular cut-off at the bottom. The soil used for cover should have maximum dry density more than 1.52 g/cc when height of embankment is upto 3 m and in areas not subjected to extensive flooding, otherwise the maximum dry density of cover soil should not be less than 1.60 g/cc when tested according to IS:2720 (Part 8)-1983. Subgrade/earthen shoulder material should have minimum compacted dry density of 1.75 g/cc when tested according to IS:2720 (Part 8)-1983. Plasticity index of cover soil should be between 5 to 9 per cent when tested according to IS:2720 (Part 5)-1985. Chemical analysis or determination of deleterious constituents would be necessary in salt-infested areas or when presence of salts is suspected in the borrow material. Expansive soils should not be used for construction of cover, unless it is properly stabilised using lime.

9.3.3. Construction of fly ash embankments

9.3.3.1. Clearing and grubbing : This work consists of cutting, removing and disposal of trees, bushes, shrubs, roots, grass, rubbish, etc., from the alignment and within the area of road land which will accommodate road embankment, drains, and such other areas as specified on the drawings. During clearing and grubbing, the contractor shall take adequate precautions against soil erosion, water pollution, etc. All trees, stumps, etc. falling within fill area should be cut to at least 500 mm below ground level and pits shall be filled with suitable material and compacted thoroughly so as to make the surface at these points conform to the surrounding area.

9.3.3.2. Stripping and storing of top soil : When constructing embankment using fly ash, the top soil from all areas to be covered by the embankment foundation should be stripped to specified depth not exceeding 150 mm and stored in stock piles of height not exceeding 2 m, for use in covering the fly ash embankment slopes, cut slopes and other disturbed areas where re-vegetation is desired. Topsoil should not be unnecessarily trafficked either before stripping or when in stockpiles. Also, these stockpiles shall not be surcharged or otherwise loaded and multiple handling should be kept to minimum.

9.3.3.3. Setting out : After the site has been cleared, the limits of embankment should be set out true to lines, curves, slopes, grades and sections as shown on the drawings of the project. The limits of the embankment should be marked by fixing batter pegs on both sides at regular intervals as guides before commencing the construction. The embankment should be built sufficiently wider than the design dimensions so that surplus material may be trimmed, ensuring that the remaining material is of the desired density and in position specified, and conforms to the specified slopes. Bench marks and other stakes should be maintained as long as they are required for the work in the opinion of the engineer.

9.3.3.4. Compacting the ground supporting embankment : Where necessary, the original ground should be levelled, scarified, mixed with water and then compacted by rolling so as to achieve minimum 97 per cent of MDD determined as per IS:2720 (Part 7) for the foundation soil. At locations where water table is high and the soil has potential for rapid and relatively great migration of moisture by capillarity, a granular layer or

impervious membrane (geomembrane) shall be laid so that moisture is not able to rise to the subgrade level. Sand blanket of adequate thickness over full width of embankment can be adopted as an effective capillary cut off. Medium grained sand can be used for this purpose. This will provide a working platform for the construction of fly ash fill and function as capillary cut-off. Drainage blanket can be nominally compacted with or without vibration. Bottom ash can also be used for construction of drainage blanket. Its grain size distribution is generally compatible with the grain size distribution of medium grained sand.

9.3.3.5. Handling fly ash : Fly ash being a very fine material gets air borne easily and causes dust nuisance if not properly handled. Dust at a construction site may be a safety hazard. It may also lead to environmental pollution, public resentment and damage to internal combustion engine of the construction equipment besides being a health hazard to workers. To avoid this, fly ash from hoppers or silos must be conditioned with water at power plant to prevent dusting enroute. Fly ash is typically delivered to the site in covered dump truck to minimise loss of moisture and dusting. On the other hand, pond ash generally contains enough moisture to prevent dusting, and may even contain excess moisture to create road spillage during transport. In such cases, periodic inspections and lifting of ash from relatively dry areas of the pond would be needed.

Fly ash may require on site temporary stockpiling if the rate at which the ash is supplied to the project site is more than the contractor's demand for an efficient rate of placement. Such cases should be avoided to the extent possible, and in case stockpiling at site is inevitable, adequate precautions should be taken to prevent dusting by spraying water on stockpiles at regular intervals. Otherwise, the surface of the fly ash stockpile may be covered with tarpaulins or a thin layer of soil or other granular material not subject to dusting. Traffic movements may be restricted to those areas which are kept moist, to prevent dispersing ash into air by tyres of passing vehicles.

9.3.3.6. Spreading and compaction : The side soil cover, of required width shall be provided along with the core and mechanically compacted as the embankment progresses upwards. The addition of side cover subsequent to the construction of the core is prohibited. The fill material should preferably be spread by mechanical means. Manual spreading may be permitted by the Engineer-in-Charge if the quantum of work is less. The most efficient lift thickness is a function of roller weight and vibratory energy. Smaller vibratory rollers with dead weights of 10 to 15 kN perform well on loose layer thickness of the order of 100-150 mm. Medium weight vibratory rollers with dead weights in the range 60-100 kN, provide satisfactory compaction for loose layer thickness of about 250 mm. When vibratory roller of dead weight 80-100 kN are used, loose layer thickness upto 400 mm can be adopted if site trials show satisfactory compaction. When compaction is carried out using only static roller of 80-100 kN weight, loose layer thickness shall not exceed 200 mm. The cover soil and fly ash should be laid simultaneously before compaction, to ensure confinement of fly ash. Clods in cover soil shall be broken to have a maximum size of 50 mm.

Moisture content of the fill material shall be checked at the site of placement prior to commencement of compaction. Moisture content of fly ash laid for compaction shall normally vary from OMC (determined as per IS:2720-1983 (Part 8) to OMC $\pm$ 2 per cent. The moisture content limits can be varied by the Engineer-in-Charge, depending on the weather conditions, provided specified compaction is achieved as revealed through actual site trials. It may be noted that grain shape and particle size of fly ash make the upper layers difficult to compact. At moisture contents higher than the appropriate range, fly ash may liquefy and would be difficult to handle and compact. Moisture content of cover soil shall be maintained at its OMC. Where water is required to be added to the fill material, it shall be sprinkled from a water tanker fitted with a sprinkler capable of applying water uniformly without any flooding. The water shall be mixed thoroughly by blading, discing or harrowing

or by manual means until uniform moisture content is obtained throughout the depth of the layer. If the material delivered to the construction site is too wet, it shall be dried by aeration and exposure to sun, till the moisture content is acceptable for compaction.

Fly ash can be compacted using vibratory or static rollers. Regardless of the equipment used, fly ash must be compacted as early as possible after spreading. The contractor shall demonstrate the efficacy of the equipment he intends to use by carrying out compaction trials. The use of test strips to develop compaction method specifications (optimum compaction procedure to satisfy density requirements) for the construction of the embankment is advisable.

Each layer of fly ash shall be thoroughly compacted to the specified density. When vibratory roller is adopted for compaction, two passes without vibration followed by 5 to 8 passes with vibration would be sufficient to compact each layer. The recommended mass per metre width of roller is 2300-2900 kg/m and frequency range 1800-2200 rpm. The construction of fly ash core and earth cover on the sides should proceed simultaneously. Each compacted layer shall be finished parallel to the final cross-section of the embankment. The end product specifications as given in Table 9.2, are suggested for construction of fly ash embankments.

TABLE 9.2. SPECIFICATIONS FOR COMPACTION

Minimum dry density after compaction as percentage of MDD IS:2720 (Part 7)-1980.	97 per cent
Minimum dry density after compaction when used in bridge abutments for embankment length equal to 1.5 times the height of the embankment	100 per cent

Subsequent layers shall be placed only after the finished layer has been tested for its density requirements. The contractor shall maintain record of all such tests. When density measurements reveal any soft areas in the embankment, further compaction shall be carried out as directed by the engineer. In case the specified degree of compaction is not achieved, the material in the soft areas shall be removed and replaced by approved material, moisture content brought to permissible limits and recompacted to the required density. Embankment shall be evenly constructed over full width and the contractor shall control and direct construction plant and other vehicular traffic uniformly across the width. Damage by the construction plant or other vehicular traffic shall be rectified by the contractor with material having the same characteristics and strength as before the damage. Embankments shall be constructed with side slopes conforming to the drawings. Whenever embankment construction is to be taken up against the face of natural slope or sloping earthwork faces including embankments, cuttings, and excavations, which are steeper than 1:4 (Vertical:Horizontal), such faces shall be benched immediately before placing the subsequent fill. A less permeable capping layer of selected earth should be constructed on the top of fly ash embankment, which would form the subgrade for the road pavement. The thickness of this layer would normally be kept equal to 500 mm.

9.3.3.7. Finishing operations : Finishing operations shall include the work of shaping and dressing the shoulders/verges/roads beds and side slopes to conform to the alignment, levels, cross-sections and dimensions shown on the drawing or as directed by the engineer subject to the tolerance. Both upper and lower ends of side slopes shall be rounded off to improve appearance and to merge the embankment with the adjacent terrain. In case turfing is proposed, topsoil should be provided so that after seeding, a dense cover can develop. The depth of topsoil should be sufficient to sustain plant growth, the usual thickness being 75 to 100 mm. In order to provide satisfactory bond, slopes shall be roughened and moistened slightly before the application of topsoil. Embankments in flood prone areas should be protected by stone pitching.

9.3.4. Quality control : Quality of compacted material shall be controlled through periodic checks on the compaction process or the end product, singly or in combination as directed. The end product must conform to the specifications.

9.3.4.1. Control test on borrow material : If fly ash from more than one source is being used at the project site, monitoring must be done to identify the ash type being placed. The tests required to be conducted on fly ash to be used as borrow material for embankment are indicated below. The frequency of testing indicated refers to the minimum number of tests to be conducted. The rate of testing must be stepped up as found necessary, depending on the compaction methods employed at the project.

- **Standard Proctor Compaction Test:** At the rate of 2 tests per every 3000 m^3 of ash, as per IS:2720 (Part 7)-1980.
- **Moisture Content:** One test for every 250 m^3 of ash, as per IS:2720 (Part 2)-1973.

The samples collected for testing moisture content should be representative of the material being placed. Because fly ash may air dry relatively rapidly, samples should not be taken from the surface of the lift, but should represent the overall moisture content.

9.3.4.2. Analysis and acceptance of density results : Field density of compacted ash should be checked as per IS:2720 (Part 28)-1974 or IS:2720 (Part 29)-1972 or by using a nuclear density gauge. Regardless of the test procedure used, a sufficient number of tests must be conducted for the results to be representative. The criteria for acceptance of results shall be same as detailed in Chapter 10.

9.4. Lime Fly Stabilised Soil

A mixture of fly ash and soil, when stabilised using lime is called as 'Lime Fly Ash Stabilised Soil'. This material can be used for constructing sub-base or base course of rural roads. The use of stabilised fly ash sub-base/base course would be particularly attractive in locations where fly ash is easily available and supplies of aggregates are unavailable or expensive. It is possible to construct lime fly ash stabilised layer without admixing soil for sub-base layer. This would increase the utilisation of fly ash and also prevent usage of topsoil.

9.4.1. Materials

9.4.1.1. Fly ash : Fly ash may be either from anthracitic coal or lignitic coal. Fly ash to be used in lime fly ash stabilisation shall conform to the requirements given in Tables 9.3 and 9.4.

TABLE 9.3. CHEMICAL REQUIREMENTS FOR FLY ASH AS A POZZOLANA

Sl. No.	Characteristics	Requirements for Fly Ash		Method of Test
		Anthracitic Fly ash	Lignitic Fly ash	
1.	$SiO_2 + Al_2O_3 + Fe_2O_3$ in per cent by mass, Min	70	50	IS:1727
2.	SiO_2 in per cent by mass, Min	35	25	IS:1727
3.	MgO in per cent by mass, Max	5.0	5.0	IS:1727
4.	SO_3 in per cent by mass, Max	2.75	3.5	IS:1727
5.	Available alkalies as Na_2O in per cent by mass, Max	1.5	1.5	IS:4032
6.	Total chlorides in per cent by mass, Max	0.05	0.05	IS:1727
7.	Loss on ignition in per cent by mass, Max	5.0	5.0	IS:1727

TABLE 9.4. PHYSICAL REQUIREMENTS FOR FLY ASH AS A POZZOLANA

Sl. No.	Characteristics	Requirements
1.	Fineness-specific surface in m^2/kg by Blaine's permeability test , Min.	250
2.	Particles retained on 45 micron IS sieve, Max.	40
3.	Lime reactivity in N/mm^2, Min.	3.5
4.	Soundness by autoclave test- expansion of specimen in per cent, Max.	0.8
5.	Soundness by Lechatelier method-expansion in mm, Max.	10

Typically, the supply of fly ash for a given construction project is determined almost solely by the proximity of the plant to the construction site. Within a power plant, however, fly ash to be used for stabilisation should preferably be obtained directly from hopper or silo where it is still relatively fresh and dry. It would be preferable to supply fly ash in bags. In case bagging is not possible, fly ash should be conditioned with water at power plants to prevent dusting during transportation. The conditioned ash when stockpiled at site should be sprinkled with water at regular intervals and covered with tarpaulins or stored in a covered place. If the fly ash had been stockpiled for some period before use and had got partially or wholly set, it should be pulverised so that minimum 98 per cent of it passes 600 micron sieve and minimum 30 per cent passes 75 micron sieve. Fly ash may sometimes be obtained from multiple sources and often fly ash from a single source itself exhibits variable properties. This requires that fly ash samples from all sources should be tested.

Ashes obtained from lagoons or ponds (pond ash) and bottom ash have reduced reactivity. Pond ash or bottom ash, which do not meet the requirements as per Tables 9.3 and 9.4, can also be used for stabilisation with lime. However in such cases a suitable percentage (usually varying from 15 to 25 per cent) of clayey soil should be mixed with pond ash or bottom ash so that, clay particles react with lime to produce cementitious compounds.

9.4.1.2. Lime : The lime to be used for lime fly ash soil stabilisation should be quick lime, which has been pre-slaked at site, it should be used within 7 days. Slaked lime supplied in airtight bags should not be stored for more than 3 months. Only hydrated high calcium and mono hydrated dolomite limes in powdered form are used in lime fly ash soil stabilisation. Most of the commercially available hydrated limes are suitable for lime fly ash soil stabilisation. In addition, some by-product limes can also be used. Each source of lime should be evaluated before approval. Generally, the lime used should have a purity (available lime content) of not less than 70 per cent when tested according to IS:1514-1990. High calcium content varieties of lime give higher strengths even when used in small quantities. In exceptional circumstances, if lime with minimum 70 per cent purity is not available, the difference may be accounted for by providing proportionately higher quantity of lime. Since lime deteriorates with storage the purity must be checked at site before use and the required quantity of lime be added should be regulated accordingly. Lime when stored should be kept in airtight bags to prevent its carbonation and deterioration from any other cause. Besides the primary reaction between lime and fly ash, lime may also react chemically with the fines in the mixture resulting in base exchange, flocculation and aggregation of particles. The magnitude of this reaction depends on degree of fineness of clay component and mineralogical characteristics.

9.4.2. Soil : Granular soils, free from high concentrations of organic matter or deleterious salts and sandy soils with fine silts, are better suited for lime stabilisation. Normally, soils with plasticity index between 4 and 20 are suitable. This technique may also be applied to soils with plasticity index value more than 20, provided strength tests on lime fly ash soil mixes, show favourable results. The ideal proportion of particles smaller than 425-micron sieve size would be between 15 and 25 per cent by dry weight of the soil-lime-fly ash mixture.

9.4.3. Water : Water used for mixing and curing should be clean and free from injurious salts, organic substances and other deleterious matter. Potable water is generally considered satisfactory. The permissible limits for solids in water should be as given in Chapter 4.

9.4.4. Mix proportion : The mix proportions of fly ash and lime should meet the following requirements:

- Provide adequate strength and durability
- Be easily placed and compacted
- Be economical

To increase utilisation of fly ash, adequate attention should be paid to stabilise fly ash using lime alone and avoiding soil admixture. The mix shall be designed to make optimal use of fly ash. Amount of lime less than 2 per cent (by weight of lime + fly ash + soil) is not generally amenable to proper mixing and hence not recommended. Lime fly ash mixes develop strength at a slow rate. After deciding lime and fly ash content for trial mix, moisture density relationship should be determined in accordance with IS:2720 (Part 7)-1983. The unconfined compressive strength testing is done on samples compacted at maximum dry density and optimum moisture content. The mix proportion should be designed to obtain minimum unconfined compressive strength of 1.5 MPa after 28 days moist curing in a humidity chamber, for samples with a length to diameter ratio of 2:1. Curing may be carried out in the temperature range 30 to 38°C. The specimens should be compacted at optimum moisture content to maximum dry density for the soil-fly ash lime mix determined as per Standard Proctor Compaction IS:2720 (Part 7)-1983. In high rainfall areas, the mix should be designed for a minimum unconfined compressive strength of 0.75 MPa after 28 days moist curing in a humid chamber and 4 days soaking in water.

The design mix should not only indicate the proportions of fly ash and stabilisers, but also mention quantity of water in the mix and a specified compacted density that is required to satisfy specified strength. When fly ash from more than one source is adopted, less reactive fly ash sample should be selected for design trial mixes. If the design is economically unacceptable or if it exceeds double the compressive strength of the weak mix, considerations must be given to eliminate the source of fly ash requiring highest stabiliser content.

9.4.3. Construction Operations

9.4.3.1. Preparation of subgrade : The subgrade over which the lime fly ash soil layer is to be laid should be shaped to the desired crown and checked for line, grade and cross-section. All irregularities beyond the permitted tolerance should be corrected. The road bed shall be prepared by light sprinkling with water to prevent absorption of moisture from the base course and rolled with 80-100 kN static weight smooth wheeled roller. Soft and yielding spots, ruts etc. if present should be rectified and backfilled with suitable material and rolled until firm.

9.4.3.2. Weather limitations : Lime fly ash soil stabilisation should not be done when air temperature in the shade is less than 10°C.

9.4.3.3. Mixing and laying : Lime and fly ash should preferably be mixed by weigh batching. Volume batching should be adopted only when unavoidable. Thorough mixing of fly ash and other materials is extremely important to obtain a blend that provides a uniform strength and durability for the pavement. Since soil stabilisation is generally done in-situ, mix-in-place techniques are more economical than central mixing. In mix-in-place methods, the spreading and mixing are typically sequenced operations where the lime fly ash mix is uniformly distributed over the surface and then blended. The mix-in-place method requires distribution of fly ash and lime evenly over the work area, subsequent addition of moisture and mixing with a travelling mixing plant. Manual mixing and laying can also be adopted in case Engineer-in-Charge permits the same. Soil should be free from all vegetation and other deleterious matter and pulverised to conform the requirement as given in Table 9.5.

TABLE 9.5. SOIL PULVERISATION REQUIREMENTS FOR LIME-FLY ASH STABILISATION

Sieve Size	Per cent by Weight of Soil Passing IS Sieve
26.5 mm	100
5.6 mm	80

Soil shall then be spread uniformly on the prepared roadbed. The thickness of uncompacted layer required is about 25-35 per cent more than the specified thickness determined through field trials. Lime and fly ash shall be spread ahead of mixing, taking care to prevent dusting. Tractor towed rotavator developed at CRRI or any other similar equipment can be used for mixing. Mechanical method of mixing is found to be more convenient for achieving consistency than manual mixing. Mixing should be continued with successive passes until the required depth and uniformity of mixing has been obtained.

This moisture content (OMC+2 per cent) is specified to compensate for the loss of moisture during spreading operations. moisture content of the construction mix. If it is necessary to adjust the moisture content of the mix, water is added uniformly and in a controlled using a sprayer. Where manual mixing is adopted, soil free from organic matter is scarified or brought from the identified borrow areas and pulverised using crow bars, pickaxes, etc., to meet the specifications given in Table 9.5. Water in requisite quantities may be sprinkled on soil to aid pulverisation. On the pulverised soil, lime and fly ash shall be spread uniformly and mixed thoroughly by working with spades or other implements to get a uniform mix. After adjusting the moisture content to be within the limits specified, the mixed material shall be spread upto required thickness.

The thickness of individual compacted layer should not be less than 0.1 m or more than 0.2 m. Thickness greater than 0.2 m shall be constructed in multiple layers. Before laying the second layer, compacted first layer shall be roughened to ensure proper bond between the layers. The width of lime fly ash base/sub-base should extend 0.3 m more than the width of the top layer on it.

9.4.3.4. Rolling : Immediately after spreading, grading and levelling of the mixed material, compaction should be carried out with 80-100 kN static weight smooth wheel rollers or other roller approved by engineer. Rolling shall begin at edges and progress towards centre in straight road portion. Compaction shall continue until the density achieved is at least 100 per cent of the maximum dry density of the material, as per Standard Proctor Compaction IS:2720 (Part 7)-1980. The suitability of a particular compaction equipment and number of passes required may be verified on a test strip. Ideally not more than 60 minutes should elapse between the start of moist mixing and start of compaction process. Care should be taken to see that compaction is completed within three hours of mixing or such shorter period as may be necessary during dry weather.

9.4.3.5. Curing : Curing period, temperature and moisture maintained during the process of curing are important factors for the development of strength. Either of the following two curing methods may be adopted.

Bituminous curing : A rapid curing seal coat such as a cut back or emulsion may be applied at the rate of 0.7 to 1.4 l/m^2 in case of scarcity of water for moistening. The sealant or curing material should be applied within 30 minutes of the completion of finishing operations and after the surface of the stabilised course has been broomed free of all loose and foreign material and sufficient water has been applied to wet the surface. Additional layers such as base or wearing course can be constructed soon thereafter.

Moist curing : Curing of the compacted layer can also be done by spreading moist straw or sand and sprinkling water periodically. Curing shall be carried out for a minimum period of 7 days after which subsequent pavement layers shall be laid to prevent the surface from drying out. No traffic shall be allowed to ply during the curing period, unless permitted by the engineer. Curing by ponding of water is not permitted to avoid leaching of lime.

9.4.3.6. Construction joint : At the end of day's work, a transverse construction joint for full depth should be made by chamfering at an angle of 30°.

9.4.4. Quality control : For satisfactory performance of lime fly ash soil stabilised layer, strict quality control measures are essential. It is prudent to conduct periodic testing during construction to confirm

that the properties of fly ash being used are within the range of values anticipated during the design. For each consignment of lime and fly ash, testing should be done to check purity. In case of lime, available lime (calcium oxide) content should be determined according to IS:1727-1967, which should not be less than 70 per cent. Quality control tests and their minimum desirable frequency are as given in Table 9.6. Strict control should be exercised during the mix-in-place operations, with frequent checks on mixing efficiency. This can be done by trenching through the in-place material and inspecting the colour of the mixture. Unmixed streaks or layers indicate poor mixing, and the material in that area should be remixed until uniformity of colour is achieved. The camber, grade and thickness should be checked as outlined in Chapter 10.

TABLE 9.6. QUALITY CONTROL TESTS FOR LIME FLY ASH SOIL STABILISATION

Test	Test Method	Minimum Desired Frequency
Quality of lime	IS:1514-1990	Once initially for approval of the source of supply and later for each consignment of the material subject to minimum of one test per 5 tonne of lime
Quality of fly ash	IS:3812 -1981	Once initially for approval of the source of supply and later for each consignment of the material subject to minimum of one test per 10,000 kg of fly ash
Degree of pulverisation	IS:2720 (Part 4)-1985	Periodically as considered necessary
Moisture content	IS:2720 (Part 2)-1973	One test per 250 sqm
Density of compacted layer	IS:2720 (Part 28)-1974 IS:2720 (Part 29)-1972	One test per 500 sqm
Deleterious constituents	IS:2720 (Part 22)-1972 IS:2720 (Part 27)-1977	As required

9.5. Lime Fly Ash Bound Macadam (LFBM)

In conventional Water Bound Macadam (WBM) non-plastic or low-plasticity materials with screenings are used as filler for stone metal. When WBM is used in the upper layers of the road pavement or thin bituminous surface dressing or premix carpet is adopted as wearing course, it permits penetration of water into WBM. The filler being a material having very little binding property, WBM gets markedly softened upon being wetted. As a result, potholes are formed in the pavement under traffic, which are enlarged subsequently. On the other hand, filler made of a mixture of lime, fly ash and moorum in suitable proportions improves the performance as it has cementitious properties and does not soften in presence of water. Load bearing capacity of lime fly ash bound macadam (LFBM) will be superior to that of conventional WBM. WBM constructed with lime-fly ash–moorum as filler would have longer life and better serviceability in the areas of heavy rainfall (annual rains fall greater than 1000 mm).

9.5.1. Materials

9.5.1.1. Coarse aggregates : Coarse aggregates shall be either crushed or broken stone, naturally occurring aggregates such as kankar or laterite of good quality. Kankar shall be tough, having a blue almost opalescent fracture. It shall not contain any clay in the cavities. Laterite shall be hard, compact, heavy and of dark colour. The coarse aggregates shall conform to strength requirements as given in Chapter 4. The aggregates should be free from deleterious organic or chemical substances that may interfere with the chemical reaction. Coarse aggregates shall conform to one of the grading given in Chapter 4.

9.5.1.2. Filler : The filler used shall be a mixture of fly ash, lime and moorum. Instead of moorum, sand or soil may also be used. Soil/moorum used as filler shall have plasticity index between 4 to 6. The fly ash should be collected dry from hopper or silos and conform to requirements of the Section 9.4.1.1. Lime to be

used should conform to the requirements of the Section 9.4.1.2. The typical proportion of dry lime, fly ash and moorum or sand or soil can be 1:2:9 (by weight).

9.5.1.3. Screenings : The grading of screenings shall be within the limits given in Table 4.10, Chapter 4.

9.5.2. Construction procedure

9.5.2.1. Preparation of foundation for laying LFBM : Requirements of Section 9.4.3.1 shall apply when LFBM course is being laid on soil subgrade. When LFBM is to be laid on an existing unsurfaced road, the surface shall be scarified and reshaped to the required grade and camber as necessary. Weak places shall be strengthened, corrugations removed and depressions/potholes filled with suitable materials before spreading the coarse aggregates for LFBM. In case of black topped roads, the existing black top shall be removed, before laying LFBM. In all cases, the foundation shall be kept well drained during the construction operations.

9.5.2.2. Weather limitations : Requirements of Section 9.4.3.2 shall apply.

9.5.2.3. Provision of lateral confinement to aggregates : Before starting with LFBM construction, necessary arrangements shall be made for the lateral confinement of aggregates. One method is to construct side shoulders in advance to a thickness corresponding to the compacted thickness of the LFBM course. After shoulders are ready, their inside edges may be trimmed vertical and the included area cleaned of all spilled material, thereby, setting the stage for spreading of coarse aggregates. In the second method, side supporters are to be provided during construction operations to confine the LFBM.

9.5.2.4. Spreading coarse aggregates : The coarse aggregates shall be spread uniformly and evenly upon the prepared base in the required quantities from stockpiles or along the side of the road or directly from the vehicle. In no case these shall be dumped in heaps directly on the area where LFBM is to be laid. They shall be spread to proper profile by using templates placed across the road about 6 m apart. No segregation of large and fine particles shall be allowed. The coarse aggregates, as spread, shall be of specified gradation with no pockets of fine materials. The coarse aggregate shall not be normally spread in lengths exceeding the three days average work.

9.5.2.5. Rolling : After laying the coarse aggregates, they shall be compacted to full width by rolling with either smooth wheeled static roller of 80 to 100 kN capacity or an equivalent vibratory roller. The rolling shall begin from the edge so that edge portion is firmly compacted. The roller shall then progress gradually from edges to the centre, parallel to the centre line of the road and overlapping uniformly each preceding rear wheel track by one half width and shall continue until the entire area of the course has been rolled by the rear wheel. Rolling shall continue until the road metal is thoroughly keyed and creeping of the stone metal ahead of the roller is no longer visible. Slight sprinkling of water may be done, if required. On superelevated portions of the road, rolling shall begin from the lower edge and progress gradually towards the upper edge of the pavement. Rolling shall not be done when subgrade is soft to yielding or when it causes a wavy motion in the base course or subgrade. If irregularities, which exceed 12 mm (when tested using a 3 m straight edge), develop during rolling, the surface shall be loosened and aggregates added or removed as required, before rolling again to achieve a uniform surface conforming to the desired cross-section and grade. The surface shall also be checked transversely by template for camber, and irregularities, if any, are corrected in the manner described above. In no case, the use of screenings shall be permitted to make up depressions.

9.5.2.6. Application of screening material : After the coarse aggregates have been compacted, screening material shall be applied gradually over the surface. The screenings shall be applied at a slow and uniform rate so as to ensure filling of all voids. This shall be accompanied by dry rolling and brooming. After

the screenings have been applied, the surface shall be copiously sprinkled with water, swept and rolled.

9.5.2.7. Application of filler material : After coarse aggregates have been rolled, filler shall be applied gradually over the surface to fill the interstices. The filler material has to be prepared by proper blending of the dry constituent materials, namely lime, fly ash and sand or moorum or soil in suitable proportions just before use. The required amount of filler material is spread uniformly over the stone metal surface. Enough quantity of water is then added while rolling so that the slurry penetrates into voids taking care that the water used is not as profuse as in normal WBM.

9.5.2.8. Setting and drying : After final compaction of the layer, the LFBM layer shall be allowed to cure for 7 days (moist). Hungry spots shall be filled with screenings or binding material, lightly sprinkled with water if necessary, and rolled. Only light motor vehicles should be allowed during the curing period. In case the LFBM course is to be provided with bituminous surfacing, the latter course shall be laid only after LFBM course is completely dried after curing and before allowing any traffic.

9.5.2.9. Plying of construction traffic : In general construction traffic may ply over completed portion of LFBM course provided vehicles move over its full width avoiding any rutting or uneven compaction. However, the Engineer-in-Charge shall have full authority to stop the passage of traffic when in his opinion this is leading to excessive damage.

9.5.3. Quality control : The surface evenness of completed LFBM course in longitudinal and transverse directions, measured with a 3 m straight edge shall be within the tolerance indicated below:

9.5.3.1. Grading I

- Maximum permissible undulations in longitudinal profile-15 mm.
- Maximum number of undulations exceeding 12 mm permitted in any 300 m stretch-30.
- Maximum permissible variation from specified profile under a camber template-12 mm.

9.5.3.2. Grading II and III

- Maximum permissible undulations in longitudinal profile-12 mm.
- Maximum number of undulations exceeding 10 mm permitted in any 300 m stretch – 30.
- Maximum permissible variation from specified profile under a camber template – 8 mm.

The longitudinal profile shall be checked at the middle of each traffic lane along a line parallel to the centre line of the road. The transverse profile shall be checked with a series of three camber boards at intervals of 10 m. Quality control tests on materials shall be carried out according to Table 9.7.

TABLE 9.7. QUALITY CONTROL TESTS FOR LIME FLY ASH BOUND MACADAM

Sl. No.	Test	Test Method	Minimum Desired Frequency
1.	Quality of lime	IS:1514-1990	Once initially for approval of the source of supply and later for each consignment of the material subject to minimum of one test per 5 tonne of lime.
2.	Quality of fly ash	IS:3812-1981	Once initially for selection of the source of supply and later for each lot of 10,000 kg
3.	Los Angeles Abrasion value on aggregates/ Aggregate Impact Value test	IS:2386 (Part 4)-1963	One test per 250 cum.
4.	Grading of aggregates and screening	IS:2386 (Part 1)-1963	Two tests per 250 cum.

9.6. Lime Fly Ash Concrete

Lime fly ash concrete is resistant to softening under water action and can serve as a good working platform on soft foundations. Hence, a lesser thickness of this material can replace water bound macadam layer. It is particularly suitable for heavy rainfall regions, black cotton soil areas and places where good quality aggregates are not easily available. The stiff lime fly ash concrete layers distribute the load over large areas of subgrade, by slab action, reducing the low vertical stresses transmitted to the subgrade.

9.6.1. Materials

9.6.1.1. Lime : Lime to be used, storage and handling shall comply with Section 9.4.1.2.

9.6.1.2. Fly ash : Fly ash to be used, supply and storage shall conform to section 9.4.1.1. The moisture content of conditioned fly ash should be determined and accounted for while preparing the lime fly ash concrete mix.

9.6.1.3. Aggregates : The aggregate may be either stone, gravel, slag or brickbats, crushed or uncrushed, or any combination thereof. Coarse aggregates may be either conforming to IS:383-1970 (natural stone aggregates) or broken bricks conforming to IS:3068-1986. The maximum size of aggregate normally used is 40 mm. Chances of segregation increases, if maximum size of aggregate exceeds 20 mm. A wide range of aggregate gradation is permitted. Coarse and fine aggregates should be combined in such a way that it should meet any one of the gradation limits given in Table 9.8, and aggregates should be selected in such a way that, the lime fly ash concrete should give a minimum compressive strength of 4.0 MPa at 28 days in the field. In addition to the fine aggregates, supplementary fly ash may be used as a mineral filler to provide desired fines content. The portion of the aggregate material passing 425 microns shall have a liquid limit less than 25 and plasticity index less than 6. Aggregates are typically stored in piles according to gradation and the area must be free draining and also free from deleterious matter.

TABLE 9.8. AGGREGATE GRADATION FOR LIME-FLY ASH CONCRETE

Sieve Designations	Percentage by Weight Passing		
	Grading A	Grading B	Grading C
45 mm	100	100	100
26.5 mm	55-85	70-95	100
19 mm	50-80	55-85	70-100
4.75 mm	40-60	40-60	40-65
425 micron	10-30	10-30	15-30
75 micron	5-15	5-15	5-15

9.6.1.4. Water : Water used for lime fly ash concrete works should conform Section 9.4.1.4.

9.6.2. Proportioning of lime fly ash concrete : To act as a semi-rigid pavement layer, lime fly ash concrete should be designed with zero slump, as compaction in the field is done by rollers. The mix proportions are designed by trial and error method. As a rough guide, to achieve 28 days compressive strength of 4.0 to 6.0 MPa, the approximate total aggregate/binder (lime+fly ash) ratio would be between 2.5 and 3.5 (by weight) with about 10-11 per cent of water content by weight of dry material when crushed stone is used as coarse aggregate. Generally, the lime fly ash content of a mixture ranges from 10 to 30 per cent, with lime to fly ash ratios being 1:2 to 1:4. Particulars for a few lime fly ash concrete mixes designed with fly ash of lime reactivity

4.0-5.0 MPa, lime of 60 per cent purity, good quality crushed stones (20 mm nominal size) and medium coarse sand are presented in Table 9.9. While selecting the trial mix, allowance should be made for type of aggregate, quality of fly ash, maximum size of aggregate, etc. For ensuring 28 days field strength of 4.0–6.0 MPa, laboratory mix should be designed at least 1.25 times the required field strength.

TABLE 9.9. EXPECTED STRENGTH OF LIME-FLY ASH CONCRETE MIXES

Sl. No.	Mix Proportions (by weight) Lime:Fly ash:Sand:Coarse Aggregate	Water Content (per cent by Dry Weight of Mix)	28 days Strength in MPa	
			Compressive	Flexural
1.	1 : 2.0 : 2.5 : 5.25	10.0	6.9	1.48
2.	1 : 2.0 : 2.25: 6.75	10.8	7.2	1.16
3.	1 : 2.0 : 2.7 : 6.3	11.0	7.5	1.48
4.	1 : 1.5 : 3.3 : 7.5	9.7	6.0	0.80
5.	1 : 1.5 : 2.7 : 8.3	7.0	6.9	1.16
6.	1 : 1.5 : 2.25 : 5.25	9.7	7.5	1.48

9.6.3. Construction

9.6.3.1. Preparation of subgrade : Requirements of Section 9.4.3.1 shall apply.

9.6.3.2. Weather limitations : Requirements of Section 9.4.3.2 shall apply.

9.6.3.3. Batching and mixing of materials : Thorough mixing is extremely important so that a blend that provides uniform strength and durability is obtained. Mixing is usually done with batch type concrete mixers or pug mill mixers. A permanent mixing plant may be set-up at a suitable location or smaller capacity units can also be brought on site. Accurately controlled amounts of fly ash and other ingredients are fed into the mixing chamber where they are mixed until uniform composition is obtained. The batch should be calibrated by weight and volume batching may be permitted only in exceptional cases. Proportioning of constituent materials should be as specified on the basis of designated mix, making due allowance for free moisture absorption in aggregate and moisture present in lime and fly ash. It has been found that moist fly ash facilitates easier mixing to obtain desired compaction. The mixer should not be overloaded and adequate mixing time (1-2 minutes) should be given to ensure uniform mixing. The volume of the material in the mixer shall not be more than 60 per cent of the space inside the mixer.

9.6.3.4. Transportation and placement of lime fly ash concrete : The lime fly ash concrete should be transported and placed on the prepared subgrade so that the compacted layer would have the required thickness, slope and camber. In case central mixing is adopted, the mix is hauled to the construction site in covered trucks to minimise evaporation losses. Spreading should result in a uniform, uncompacted layer, which will achieve the compacted thickness required as per specifications. The thickness of uncompacted layer required is about 20-25 per cent more than the specified thickness. The actual thickness of uncompacted layer required may be determined through field trials. Transportation and placement should be done in such a way, so as to avoid segregation. Any portion of the batch that becomes segregated during placing, should be thoroughly mixed with fresh concrete before spreading. The layer of lime fly ash concrete should be laid to specified grade and camber before commencing rolling operations. Spreading should progress in such a way, so that not more than 30 minutes elapse between adjacent passes. A construction joint should be formed along the edge of the previous pass if more than 30 minutes elapse between adjacent passes.

9.6.3.5. Compaction : When sufficient length of lime fly ash concrete has been laid to permit rolling, compaction should be started. Compaction in the field should be done by means of 80-100 kN smooth wheeled roller, when crushed stone aggregate are used and 60-80 kN roller when soft aggregates like brick-bats, cinder

are used. Alternatively, vibratory roller of equivalent capacity can also be used. Rolling should start from the outer edge of the pavement and continue towards the middle except at superelevated portions where it should begin at lower edge of the pavement and progress towards the higher. Adequate number of passes should be given to ensure full compaction. While using heavy vibratory roller, care should be taken not to overstress the surface. Generally four to eight passes are necessary to achieve the desired compaction. The grade and camber of surface should be checked during compaction and all irregularities should be corrected by removing or adding fresh materials. Ideally, not more than 60 minutes should elapse between the start of moist mixing (on site or off site) and start of compaction. Compaction should be completed within specified period, which shall not exceed 4 hours after mixing. When lime fly ash concrete is to be laid in two layers, the second layer should be laid within 2-3 hours after compaction of the lower layer.

9.6.3.6. Joints : No joint need to be provided except construction joint at the end of day's work and each successive length taken up for rolling. Construction joints should be formed by chamfering the edge of already laid concrete at an angle of about 30° and subsequently laying the fresh concrete thereon.

9.6.3.7. Curing : After laying and compaction of the total thickness of lime fly ash concrete has been completed, it should be cured for the first 48 hours by covering it with wet gunny bags or Hessian, subsequently by spreading wet sand or watering frequently in moderate quantities. Curing should not be done by ponding as that would lead to leaching of lime. Curing should be carried out for at least 7 days and preferably 14 days depending on seasonal and other considerations. No traffic should be allowed on the lime fly ash concrete layer before top courses are placed thereon.

9.6.3.8. Rectification of surface irregularities : The finished surface should be checked for line, level, camber, grade and surface finish as per Chapter 10 and irregularities should be corrected.

9.6.4. Quality control : Relevant quality control tests and their minimum desirable frequency are given in Table 9.10.

TABLE 9.10. QUALITY CONTROL TESTS FOR LIME FLY ASH CONCRETE

Sl. No.	Test	Test Method	Minimum Desirable Frequency
1.	Quality of lime	IS:1514-1990	Once initially for approval of the source of supply and later for each consignment of material subject to minimum of one test per 5,000 kg
2.	Quality of Fly ash	IS:3812-1981	Once initially for selection of the source of supply and later for each lot of 10,000 kg
3.	Los Angeles Abrasion value on aggregates/ Aggregate Impact Value test	IS:2386-1963 (Part 4)	One test per 250 cum
4.	Aggregate Gradation	IS:2386-1963 (Part 1)	Two tests per 250 cum
5.	Aggregate and Fly ash Moisture Content	IS:2386-1963 (Part 3)	As required

9.7. Roller Compacted Fly Ash Concrete Pavement

Roller compacted fly ash concrete (RCFC) is a zero-slump Portland cement concrete which is compacted using a road roller. Fly ash is an additive for roller compacted concrete, and it is strongly recommended that fly ash should be used as an ingredient in all works involving RCFC.

9.7.1. Materials : The contractor shall indicate to the engineer the source of all materials to be used in RCFC work with relevant test data. Approval of the Engineer for the same shall be obtained sufficiently in advance and sufficient quantity of materials should be stockpiled before commencement of the work. Uniformity of the materials over the duration of the project is critical to the performance of RCFC pavement.

9.7.1.1. Cement : Cement conforming to IS:269-1989 or IS:8112-1989 can be used. Portland pozzolana cement should not be used for making RCFC when fly ash is used as an ingredient.

9.7.1.2. Aggregates : Coarse and fine aggregate for RCFC shall conform to Chapter 4.

9.7.1.3. Fly ash : Fly ash to be used for RCFC work may be either from anthracitic coal or lignite. Fly ash to be used for RCFC work shall conform to the requirements given in Tables 9.3 and 9.11.

TABLE 9.11. PHYSICAL REQUIREMENTS FOR FLY ASH AS CONCRETE ADMIXTURE

Sl. No.	Characteristic	Requirements
1.	Fineness-specific surface in m^2/kg by Blaine's permeability test, Min	320
2.	Particles retained on 45 micron IS sieve, Max	34
3.	Lime reactivity in N/mm^2, Min	4.5
4.	Soundness by autoclave test-expansion of specimen in per cent, Max	0.8
5.	Soundness by Lechatelier method-expansion in mm, Max	10

Fly ash should be obtained directly from hopper or silo where it is still relatively fresh and dry. Fly ash may be obtained in bulk or in bags. In case bagging is not possible, fly ash must be conditioned with water at the power plant. The conditioned ash when stockpiled at site should be sprinkled with water at regular intervals and covered with tarpaulins during its storage. Ash obtained from lagoons or ponds (pond ash) and bottom ash have reduced reactivity, and should not be used for RCFC work.

9.7.1.4. Water : Water used for mixing and curing of roller compacted concrete shall be clean and free from injurious amounts of oils, salts, acid, etc. It shall meet the requirements as per IS:456-2000. Potable water is generally considered to be acceptable for RCFC work. The permissible limits for solids in water should be as per Chapter 4.

9.7.2. Mix design for roller compacted fly ash concrete : The mix design shall be based on flexural strength. Flexural strength achieved for roller compacted fly ash concrete (RCFC) usually exceeds those for conventional concrete with similar cement contents. Flexural strengths up to 4.5 MPa can be achieved. Initial rate of strength gain of RCFC may be slower when compared to the same mix of plain cement concrete without fly ash. Consequently, designs based on more than 28 days strengths would be appropriate depending on the available lead time prior to opening to traffic. While designing the mix in the laboratory, correlation between flexural and compressive strengths of concrete shall be established on the basis of tests on samples for use at a later date to verify the in-situ flexural strength of RCFC through testing on cores. Considering the variations in the field, the laboratory mix should be designed for at least 1.25 times the required 28 days field strength as per IRC:44.

Proportions in an RCFC mix generally comprise 81-84 per cent aggregates, 12-14 per cent cementitious binder and 4-6 per cent water by weight. The maximum aggregate to cement ratio of the mix should be 15:1. The minimum cement content in RCFC shall not be less than 150 kg/m^3 of concrete. When RCFC is used in the wearing course, minimum cement content should be 250 kg/m^3 of concrete. Due to low water content of RCFC, amount of fines required is more than normal concrete. This helps to reduce segregation. The fines are

typically supplied by fly ash. An additional benefit is gained from the pozzolanic property of fly ash, which contributes to strength of RCFC. Generally, the fly ash content in RCFC pavements has been upto 35 per of total cementitious ingredients, with typical contents being about 25-30 per cent. When 43 grade cement is used the percentage of fly ash replacement can be increased, after investigating the strength properties in the laboratory.

The concrete used in RCFC work would be usually having zero slump. Modified Proctor compaction test can be used for determining the optimum moisture content for compaction. This test would also indicate maximum achievable density of the mixture, against which field densities can be compared. The right amount of water for the RCFC pavement work shall be decided for ensuring full compaction. Excess water will cause the concrete to heave in front of the roller wheels resulting in uneven compacted surface while too little water will lead to inadequate compaction, low in-situ strength and an open textured surface. The optimum water content, as determined in laboratory trials shall be adjusted during construction at field by trial rolling a small stretch. The variations in water content in the mix shall be $\pm$ 1 per cent from the specified value.

9.7.3. Construction : The laying programme of roller compacted concrete shall match with the laying of base/sub-base course. In case base course of dry lean fly ash concrete is to be laid as per specifications, RCFC shall be over laid after 10 days but within 30 days of laying dry lean fly ash concrete sub-base/base.

9.7.3.1. Preparation of subgrade/sub-base : The subgrade or sub-base over which RCFC is to be laid shall conform to grades and cross-sections as per drawings and uniformly compacted to the designed strength as per stipulations in the contract. The checking and rectification of the underlying layer should be done at least 2 days before laying RCFC. The subgrade shall not be softened by rain water, shall be devoid of surface trenches and soft spots. Soft spots if any shall be filled and compacted to maximum dry density. To prevent absorption of water from RCFC, the underlying layer should either be covered with water proof paper/plastic sheets or sprinkled with water 2-3 hours before laying the RCFC layer. It would be preferable to provide compacted granular sub-base course of 100-150 mm, below RCFC layer rather than laying RCFC directly over subgrade.

9.7.3.2. Batching and mixing : The batching plant shall be capable of proportioning the materials by weight. Each type of material shall be weighed. Volume batching may be permitted only when unavoidable. Due allowances for moisture present in aggregates and fly ash should be made. The accuracy of weighing shall be within $\pm$ 2 per cent by weight in case of aggregates and $\pm$ 1 per cent by weight in case of binder and water. Production of RCFC may be carried out using mobile continuous mixing plants, which are called pug mills. Other types of power driven mixers may be permitted subject to demonstration of its satisfactory performance during field trials. Due to relatively low amount of cement and water, thorough mixing is critical to obtain the full strength of the material. The mixer should not be over loaded and adequate mixing time (minimum 1.5 minutes) should be allowed to ensure proper mixing.

9.7.3.3. Transportation : The plant mix concrete, discharged from the mixer, shall be immediately transported directly to the point where it is to be laid. Haulage of RCFC from the production plant can be carried out using tipping trucks or manually if quantities are less. During its transit, concrete shall be protected by covering it with tarpaulin on the top surface. Segregation of concrete should be controlled. RCFC should be placed as soon as possible after mixing. Travel time between the mixing plant and the paver should be limited to 15 minutes. In case the distance of laying is more than 10 to 12 km from the plant, concrete would get compacted in the tipper beds resulting in difficulties in unloading. Provision of form vibrators, locally attached to the tipper hoppers, would help in unloading concrete under such conditions.

9.7.3.4. Placing : Concrete shall be placed uniformly over the sub-base stretch avoiding segregation. RCFC can be laid using a paver having vibrating screed. Manual laying may also be resorted to subject to the approval by Engineer-in-Charge.

9.7.3.5. Compaction : Compaction shall be carried out immediately after the material is laid and levelled over sub-base. Smooth wheeled vibratory rollers of minimum 80 to 100 kN static weight are considered to be suitable for compacting zero slump concrete. Initially 2 or 3 passes are made without vibration, followed by about 6 to 8 passes of roller in vibrating mode. Final rolling should be performed with a smooth wheeled static roller. During the period when roller is changing direction or when roller is about to stop, vibration should be switched off. Roller speeds should be limited to 2.5 kmph.

The minimum dry density of RCFC pavement shall be 97 per cent of that achieved during trial length construction/laboratory testing. Edge region i.e., upto 0.5 m from the edge cannot be compacted to the same degree as the general area. At edge regions, compaction shall be done adequately to achieve at least 95 per cent of the density achieved during field trials. If necessary, vibrating plate compactor or manually driven rollers can be used to compact edges. Another solution would be the provision of a suitable wide shoulder extension. Use of kerb stones results in the best edge compaction.

The need to obtain good compaction and also a high standard of surface finish dictates that a limit needs to be imposed on the maximum thickness of RCFC pavement layer. In order to achieve full compaction, the maximum thickness of compacted layer should not be generally more than 150 mm. The engineer may, however, permit placing of RCFC pavement layers upto 200 mm thickness (compacted) if satisfactory compaction is achieved as shown through field trials. The minimum compacted thickness of RCFC pavement should not be less than 100 mm in a single lift. Thickness of more than 150 mm are usually constructed in multiple layers. In order to provide monolithic bond, the next layer should be placed within minimum working period from the time the previous layer was mixed. If this cannot be achieved, then retarding agents (0.5 to 1 per cent by weight of binder depending on ambient temperature) should be used in the preceding run. Alternatively second layer may be treated as partially bonded overlay. However, this would result in higher pavement thickness requirement. For rectifying unevenness in the green stage, concrete of same cement content with aggregate size of 10 mm and below shall be spread and compacted. It is necessary to check the rolled surface for unevenness as per Chapter 10. Surface irregularities should be checked with 3 m straight edge and shall be corrected with the fresh concrete and rolled.

9.7.3.6. Curing : Due to low moisture content of RCFC, it is especially important that surface be kept moist after placement and curing commenced as soon as practicable. Wet curing methods like spraying of water or spreading wet Hessian would be advisable. Water curing moderates the temperature of the pavement and it is better for both durability of the surface and increased pavement strength. The total curing period should extend for at least seven days. If high fly ash contents are used, this period needs to be extended to at least 14 days unless a seal coat or overlay is applied within this period. It is recommended to avoid use of curing compounds. Opening to traffic should be after 28 days of curing.

9.7.3.7. Joints : Sawn contraction joints can be provided in RCFC. These joints are to be sawn 24 hours after compacting concrete. The saw cut should be between one quarter to one third of the pavement depth to provide a suitable plane of weakness to induce a crack beneath (tolerance $\pm$ 5 mm). Typical spacing of joints would be between 6 to 8 m, depending on the thickness of the pavement. Generally the maximum joint spacing should be at an interval of 40 times the thickness of the pavement. The joints should be sealed with joint sealing compound. Instead of providing sawn contraction joints, contraction joint inducer (wooden or

plastic strips of triangular section) can be placed at predetermined intervals above sub-base/base before concreting. Expansion joints are not provided in RCFC pavement. Usually if over 90 minutes have passed between placement of two adjacent lanes, the joint is treated as a construction joint. The existing edge should be cut back to a fresh vertical face and dampened prior to placement of the adjacent material. A reasonable paving pattern that results in the shortest total length of construction joints should be adopted.

9.7.4. Quality control : Quality control tests for RCFC and their minimum desirable frequency are as given in Table 9.12.

TABLE 9.12. QUALITY CONTROL TESTS FOR RCFC CONSTRUCTION

Sl. No.	Test	Test Method	Minimum Desirable Frequency
1.	Quality of cement	As per relevant IS Code	Once initially for approval of the source of supply and later for each consignment before using (batch not used for 2 months should be retested)
2.	Quality of fly ash	IS:3812-1981	Once initially for selection of the source of supply and later for each lot of 10,000 kg
3.	Los Angeles Abrasion value/Aggregate Impact Value	IS:2386 (Part 4)-1963	One test per 250 cum
4.	Aggregate gradation	IS:2386 (Part 1)-1963	Two tests per 250 cum
5.	Aggregate and Fly ash Moisture Content	IS:2386 (Part 3)-1963	As required
6.	Strength of concrete cubes (two specimens for each age of 7 and 28 days)	IS:516-1959	One test for 50 cu.m. of concrete
7.	Workability test on green concrete	IS:1199-1959	Regularly

9.8. Dry Lean Fly Ash Concrete for Base Course

Dry lean fly ash concrete (DLFC) is similar to dry lean concrete in composition and properties. The essential difference is with regard to use of fly ash.

9.8.1. Materials for DLFC

9.8.1.1. Cement : Cement should conform to the requirement given in Chapter 4.

9.8.1.2. Fly ash : Fly ash to be used for DLFC work should conform to Section 9.7.1.3. However, unlike roller compacted concrete, where fly ash is used to replace a part of cement, in case of DLFC fly ash is used to replace part of fine aggregates. Pond ash and bottom ash which do not satisfy Section 9.7.1.3 can also be used provided laboratory strength tests satisfy the design strength requirements.

9.8.1.3. Aggregates : Requirements given in Chapter 4 shall apply.

9.8.1.4. Water : Water used for mixing and curing of DLFC shall conform to the requirements of the Section 9.7.1.4.

9.8.2. Proportioning of dry lean fly ash concrete : Requirements of Chapter 4 shall apply. In addition, it may be noted that optimal strength is obtained by replacing about 50 per cent of sand (by weight) in conventional dry lean concrete mix by equal absolute volume of fly ash. However, exact ratio of using sand and fly ash should be determined based on their specific gravity as shown in Table 9.13. The ratio of total

aggregate (including fly ash) to cement will be in the range of 12-18. Considerably lower strength would result when aggregates such as broken bricks or cinders are used. To facilitate selection of suitable proportions of the trial mix, particulars for a few DLFC mixes, designed using medium coarse sand, good quality crushed coarse aggregates of 20 mm maximum size and fly ash are given in the Table 9.13.

TABLE 9.13. TYPICAL MIX PROPORTIONS AND STRENGTH CHARACTERISTICS OF DLFC

Sl. No.	Mix Proportion (by wt)	Water Cement Ratio	Slump in mm	28 day Compressive Strength (MPa)
1.	1 : 2 : 2n : 8	1.32	12	15.8
2.	1 : 2.5 : 2.5n* : 10	1.90	12	13.0

* 'n' is the ratio of specific gravity of fly ash and sand (Sp. Gravity of fly ash/Sp. Gravity of sand)

9.8.3. Construction operations

9.8.3.1. Preparation of subgrade/sub-base : Procedure given in Section 9.7.3.1 shall be followed.

9.8.3.2. Batching and mixing of materials : The materials for making dry lean fly ash concrete mix should be batched by weight using approved weigh-batching equipment. The batching plant shall be capable of proportioning the material by weight, each type of material being weighed separately. The cement from the bulk stock shall be weighed separately from the aggregates. Volume batching may be permitted only when unavoidable. Water may be measured by volume, using calibrated containers. Proportioning of the construction materials should be on the basis of designed mix proportions, making due allowance for moisture present in fly ash and aggregates. The weighing balances shall be calibrated by weighing the aggregates, cement, water and fly ash physically either by weighing with large weighing machine or using a weigh bridge. The accuracy of weighing scales of the batching plant shall be within $\pm$ 2 per cent by weight in case of aggregates and fly ash and $\pm$ 1 per cent by weight in case of cement and water. Batching and mixing shall be carried out preferably in a central batching and mixing plant having necessary automatic controls to ensure accurate proportioning and mixing. Other types of mixers shall be permitted subject to demonstration of their satisfactory performance during the trial length construction. The mixer should not be overloaded and adequate mixing time should be allowed to ensure uniform mixing.

9.8.3.3. Transportation and placement : DLFC after mixing shall be discharged immediately from the mixer, transported directly to the point where it is to be laid and placed on the sub-base to achieve required depth, slope and camber of the compacted layer. The thickness of loose layer to be laid may be determined through field trials. During transportation, DLFC shall be protected from the weather by covering the top surface of concrete with tarpaulins. The lead of the batching plant to the paving site shall be such that travel time required will be less than 15 minutes. DLFC should preferably be laid/placed using a paver. The paving machine shall have high amplitude tamping bars to give good initial compaction to DLFC. Transportation and placement should be done in a way to avoid segregation. Any portion of the batch, which becomes segregated during placing, should be thoroughly mixed with fresh concrete before the process of spreading. The laying of DLFC may be done either in full width or lane by lane. In case quantum of DLFC work taken up is less, the engineer may permit transportation/laying of DLFC using manual methods.

9.8.3.4. Compaction : When sufficient length of DLFC pavement has been laid to permit rolling, compaction should be commenced. Rolling should start from the outer edges of the pavement and continue towards the centre except at super elevated portions where it should begin at the lower edge and continue towards the higher. Double drum smooth-wheeled vibratory rollers of minimum 80-100 kN static weight are considered to be suitable for rolling DLFC. In case any other roller is proposed, the same shall be got approved

by the engineer, after demonstrating its performance. The number of passes required to obtain maximum compaction depends on the thickness of the layer, weight and type of the roller and compactability of the mix. Initially, 2 or 3 passes are made without vibration, followed by about 6 to 8 passes of roller in vibrating mode. Final rolling should be performed with a smooth wheeled static roller. In case soft aggregates, like, brick aggregates or cinder are used for making DLFC, a lighter roller of capacity 60-80 kN static weight should be used. Edge compaction procedure, lift thickness and weather condition limitations shall be as per Section 9.7.3.5. The final surface shall be inspected immediately after compaction while the mix is still plastic and the grade and camber of the surface should be checked. All irregularities, loose, segregated or defective areas should be corrected by removing or adding fresh material of same quality using concrete with aggregates of size 10 mm and below.

9.8.3.5. Joints : No joints need be provided except construction joints. At construction joints, unless vertical forms are used, the edge of the compacted material shall be cut back to a vertical face where the thickness of the properly compacted material has been obtained.

9.8.3.6. Curing : Curing shall commence a soon as DLFC is compacted. For first 48 hours curing should be done by covering it with wet gunny bags or Hessian and for subsequent period of not less than 12 days by spreading wet sand or watering frequently in moderate quantities. No traffic should be allowed on this layer before top courses have been laid.

9.8.3.7. Preventing reflection cracking : DLFC being a semi-rigid material, may develop transverse cracks because of thermal effects/drying shrinkage. These cracks are likely to get reflected on to the wearing surface if a thin bituminous wearing course is laid. To prevent reflection cracking, when DLFC is used in composite construction, it is recommended that an intermediate layer of bituminous macadam should be incorporated before providing the asphaltic wearing course. This intermediate layer would absorb the movements at cracks in the semi-rigid layer, and prevents their reflection on to the surface. In case of rigid pavement, where DLFC is used as base course, the cement concrete wearing course can be laid directly thereon without provision of any intermediate layer, since due to greater rigidity of the concrete layer, cracks from the semi-rigid base do not get reflected.

9.8.4. Quality control : Quality control tests and their minimum desirable frequency should be as given in Table 9.14

TABLE 9.14. QUALITY CONTROL TESTS FOR DLFC CONSTRUCTION

Sl. No.	Test	Test Method	Minimum Desirable Frequency
1.	Quality of cement	As per relevant IS Code	Once initially for approval of the source of supply and later for each consignment before using (batch not used for 2 months to be retested)
2.	Quality of fly ash	IS:3812-1981	Once initially for selection of the source of supply and later for each lot of 10,000 kg
3.	Los Angeles Abrasion Value/ Aggregate Impact Value	IS:2386-1963 (Part 4)	One test per 250 cum
4.	Aggregate Gradation	IS:2386-1963 (Part 1)	Two tests per 250 cum
5.	Aggregate and Fly Ash Moisture Content	IS:2386-1963 (Part 3)	As required
6.	Strength of concrete cubes (two specimens for each age of 7 and 28 days)	IS:516-1959	One test for 50 cum of concrete
7.	Workability test on green concrete	IS:1199-1959	Regularly

9.9. Cement Stabilised Fly Ash

This work shall consist of laying and compacting a sub-base/base course of fly ash treated with cement on prepared subgrade/sub-base, in accordance with requirements of this specifications. This technique can be adopted for improvement of poor subgrades also.

9.9.1. Materials

9.9.1.1. Fly ash : Fly ash to be used for cement-fly ash stabilisation shall conform to Section 9.4.1.1. Pond ash or bottom ash which do not meet the requirements of Section 9.4.1.1 can also be used for cement stabilisation work. However, in all cases the cement stabilised fly ash/bottom ash/pond ash mix should develop adequate strength as given in Section 9.9.2.

9.9.1.2. Cement : Requirements of Section 9.7.1.1 shall apply.

9.9.1.3. Water : Requirements of Section 9.7.1.4 shall apply.

9.9.2. Mix proportion : The objective of the mix design procedures is to provide a pavement material having the required proportions of fly ash and cement to meet the following requirements:

- Provide adequate strength and durability
- Be easily placed and compacted
- Be economical

Amount of cement, less than 2 per cent, is not generally amenable to proper mixing and hence not recommended. After deciding cement and fly ash content for trial mix, moisture density relationship has to be determined in accordance with IS:2720 (Part 8)-1983. The unconfined compressive strength test is done on samples compacted at maximum dry density and optimum moisture content. The mix proportion should be designed to obtain minimum unconfined compressive strength of 17.5 kg/cm^2 after 7 days moist curing in a humidity chamber, for samples with a length to diameter ratio of 2:1. Curing may be carried out in the temperature range 30 to 38°C. The design mix should not only indicate the proportions of fly ash and cement, but also mention quantity of water in the mix and a specified compacted density that is required to satisfy specified strength.

9.9.3. Construction operations

9.9.3.1. Preparation of subgrade : Requirements of Section 9.4.3.1. shall apply.

9.9.3.2. Weather limitations : Requirements of Section 9.4.3.2 shall apply.

9.9.3.3. Mixing and laying : Requirements of Section 9.4.3.3 shall apply.

9.9.3.4. Rolling : Requirements of Section 9.4.3.4 shall apply except that care shall be taken to complete the rolling operations within two hours of mixing or such shorter period as may be found necessary in dry weather.

9.9.3.5. Curing : The stabilised layer shall be cured for 7 days. Curing shall be done either by using wet sand or wet Hessian or soaked jute bags. Subsequent pavement course shall be laid soon after the curing period to prevent the surface from drying out and becoming friable. No traffic shall be allowed over the finished cement stabilised layer.

9.9.3.6. Construction joint : No joints except construction joints shall be provided. At the end of day's work, a transverse joint for full depth may be made by chamfering at an angle of 30°.

9.9.4. Quality control : For satisfactory performance of cement fly ash soil stabilised road, strict quality control measures are essential. It is prudent to conduct periodic testing during construction to confirm that the properties of fly ash being used are with in the range of values anticipated during the design. For each consignment of cement and fly ash, testing should be done to check quality. Quality control tests and their minimum desirable frequency are as given in Table 9.15. Strict control should be exercised during the mix-in-place operations, with frequent checks on mixing efficiency. This can be done by trenching through the in-place material and inspecting the colour of the mixture. Unmixed streaks or layers indicate poor mixing, and the material in that area should be remixed until uniformity of colour is achieved.

TABLE 9.15. QUALITY CONTROL TESTS FOR CEMENT FLY ASH STABILISATION

Test	Test Method	Minimum Desired Frequency
Quality of cement	As per relevant IS specifications	Once initially for approval of the source of supply and later for each consignment of the material
Quality of fly ash	IS:3812-1981	Once initially for selection of the source of supply and later for each lot of 10,000 kg
Degree of pulverisation	IS:2720 (Part 4)-1985	Periodically as considered necessary
Moisture content	IS:2720 (Part 2)-1973	One test per 250 sqm
Density of compacted layer	IS:2720 (Part 28 or 29)-1974	One test per 500 sqm
Deleterious constituents	IS:2720 (Part 27)-1977	As required

9.10. Other Uses of Fly Ash in Road Pavement

Bottom ash or coarse type of fly ash can be used in place of granular sub-base material provided they have CBR more than 15 per cent. However, such bottom ash/pond ash layer should be adequately confined and well compacted to achieve minimum 98 per cent of modified proctor density. Bottom ash or coarse type of pond ash can be used for construction of drainage layer, provided they possess permeability more than 10^{-4} cm/s. Fly ash conforming to Section 9.7.1.3 can be used to replace upto 25-30 per cent of cement while making paving blocks.

9.11. Iron and Steel Slags

Steel making is a strategic part for the economy of any developing nation, like, India. As a result, a large number of steel plants have been set up in the country and they are producing several million tonnes of iron and steel. However, the generation of iron and steel is always associated with the production of waste materials, like, blast furnace slag, steel slag, granulated blast furnace slag, etc. Normally, generation of one tonne of steel results in generation of one tonne of solid waste.

Slag can be used as pavement material in a variety of forms. It can be used as a base or sub base material either bound or unbound. Brief details of different types of slags are given in subsequent sections.

9.11.1. Blast furnace slag : Blast furnace slag is the non-metallic by-product derived from producing iron in a blast furnace. This slag mainly consists of silicates and alumino-silicates of calcium. Different kinds of blast furnace slags are produced based on mode of cooling. When air cooling is adopted, slag formed is similar to coarse aggregates and is called air-cooled blast furnace slag, which can be used for road construction after testing its strength and soundness properties.

9.11.2. Granulated blast furnace slag (GBFS) : When the molten slag is cooled rapidly by means of high pressure water jets and excess of water is maintained, crystals are not formed and instead it solidifies as a glassy mass in form of coarse sand, like, material. This material is known as granulated blast furnace slag since it takes the form of granules. It has marked pozzolanic property when ground to fine powder. Experimental work has been carried out at CRRI to use GBFS as a hydraulic binder in gravel slag and all slag mixes. The studies indicated that granulated slag, in association with a catalyst, sets to form a mix having high strength which can be used in subbase or base layer of a pavement.

9.11.3. Steel slag : Steel slag is formed when lime flux reacts with iron ore, scrap metal or other material in a steel furnace. Steel slag consists of fused mixtures of oxides and silicates, mainly calcium, iron, unslaked lime and magnesium. It is distinguished from blast furnace slag by low SiO_2 content and high amounts of iron and calcium oxides. When steel slag is fresh, it contains significant amount of free lime which suggests that the material could be lacking in stability in the presence of water owing to the hydration of calcium oxide. However, research has proved that if the steel slag is left for weathering in stockpiles for sufficient period of time, free lime would slake and the slag would become usable for road construction works.

R&D work has been carried out in CRRI to explore the feasibility of utilising these steel plant by-products in place of conventional road building materials and subsequently to develop specifications/guidelines for using these materials in different road layers. Some of the typical test results conducted on slag materials are shown in the Table 9.16.

In addition to above, soundness tests on steel slag and blast furnace slags were also carried out and both of these materials were found suitable. Subsequently, these materials were independently tested as mixes. A large number of combination were tried to develop suitable mixes of blast furnace slag, steel slag and granulated slag in combination with fly ash. The results indicated that steel plant wastes have a good potential for use as road pavement material in subbase and base courses of a road pavement. In order to evaluate and assess the performance of steel plant wastes as a road pavement material, test tracks of about 2 to 3 km were constructed at Vishakapatnam and Rourkela. The performance of the test sections were monitored for a period of 3 years and their performance was found satisfactory.

TABLE 9.16. PHYSICAL CHARACTERISTICS OF BLAST FURNACE SLAG AND STEEL SLAG

Physical properties	Test method	Blast Furnace Slag	Steel Slag	Granite Material (commonly used in country)
Aggregate impact value (per cent)	IS:2386 (Part 4)-1963	18-24	8-11	15
Aggregate crushing value (per cent)	IS:2386 (Part 4)-1963	24-26	15-18	20
Los Angeles Abrasion value (per cent)	IS:2386 (Part 4)-1963	28-32	9-10	27
Water absorption (per cent)	IS:2386 (Part 3)-1963	1.5-2.5	1-1.4	0.6
Specific gravity (kg/m^3)	IS:2386 (Part 3)-1963	2650	3220	2800

9.11.4. Use of iron and steel slags in road works : Air-cooled blast furnace slag and weathered steel slag can be used in place of stone aggregates to construct WBM layers and for mechanical stabilisation. Granulated blast furnace slag, which is a pozzolanic material, can be stabilised using lime and used for construction of stabilised layers and lime-GBFS concrete base/sub-base. Addition of a small quantity of gypsum enhances strength. GBFS can also be used in place of granular sub-base provided it meets CBR requirements.

9.12. Lime-Rice Husk Ash Concrete

Rice husk is available as a waste material from rice mills where paddy is processed to obtain rice. Rice cultivation is carried out almost throughout India and rice husk is mostly burnt as a fuel. The ash obtained is thrown back to paddy fields. This ash is chemically similar to fly ash and possesses good binding characteristics in conjunction with lime and moisture. It is a pozzolanic binder. CRRI has carried out extensive laboratory work to investigate the binder properties of lime-rice husk ash mixes and has recommended its use for lime rice husk ash concrete (Lime-RHA-concrete). The Lime-RHA-Concrete may be used as a sub-base/base course

material in the mix proportions 1:2:9 (Lime:RHA: Sand +Coarse aggregate). If a little percentage (2 to 6 per cent) of gypsum is added the strength properties are greatly enhanced. The RHA is available freely at site in rural India and no haulage cost is involved.

9.13. Recyled Concrete Aggregate

Our country has a network of concrete roads built many decades ago and due to increase in traffic and axle loads, the pavements have badly cracked. The rehabilitation and maintenance is costly and time consuming. In certain areas where high quality natural aggregates are scarce, recycled concrete aggregates offer an excellent and economic opportunity. Studies on the use of recycled aggregate (properly graded and having strength greater than the concrete in which it is to be used) in cement concrete and in water bound macadam stone metals show that recycled aggregates with suitable modifications can be used again as a road pavement material in base/sub-base and wearing coarse of road pavement in place of natural aggregate for low volume roads.

9.14. Other Waste Materials

Many other waste materials like processed municipal wastes, quarry waste, marble slurry dust, other metallic slags are available in many parts of the country. Laboratory and field studies conducted on some of these materials have indicated that such materials can be utilised for construction of lower layers of pavement and/or embankment. However, before embarking use of such materials, detailed characterisation and design of mix through a reputed laboratory would be needed.

10.4. Specifications and Codes of Practice

The specifications and codes of practice laid down by Indian Roads Congress, Ministry of Road Transport and Highways, and Bureau of Indian Standards are required to be followed in construction of roads. The list of all relevant standards and codes of practice is given at ***Appendix-10.1.***

10.5. Laboratory and Equipments

The list of needed equipments for quality control tests at district level laboratory as well as field laboratory of the contractor is given at ***Appendix-10.2***. The field laboratory may have equipments for selected tests provided other equipments are available in district laboratory or any other laboratory nearby. The name of other such laboratory to be used shall be indicated by contractor in advance.

10.6. Earth Work and Granular Layer

The materials supplied and the works carried out by the contractor shall conform to the specifications prescribed in the preceding Chapters. For ensuring the requisite quality of construction, the materials and works shall be subjected to quality control tests, as described hereinafter. The testing frequencies indicated are the desirable minimum and the Engineer-in-Charge shall recommend for additional tests whenever felt necessary, to ensure compliance with the appropriate specifications. Some of the important test on soil, aggregate and bituminous materials are described in ***Appendices-10.3, 10.4 and 10.5*** respectively. For details, relevant code of practice may be referred as per list given at ***Appendix-10.1***.

10.6.1. Borrow material : Grid the borrow area for earthwork at 50 m centre to centre (or closer, if the variability is high) to full depth of proposed working area. The tests on representative samples shall be carried out as indicated in Table 10.1.

TABLE 10.1. FREQUENCY OF TEST FOR BORROW MATERIAL

Test No.	Description	Test Method	Frequency
EW-1	Sand content	IS: 2720 (Part-4)	One tests per 4000 cum of soil
EW-2	Plasticity index	IS: 2720 (Part-5)	One tests per 4000 cum of soil
EW-3	Natural moisture content	IS: 2720 (Part-2)	One test for every 500 cum of soil
EW-4	Compaction test	IS: 2720 (Part-7)	One test per 4000 cum of soil
EW-5	CBR test on materials to be used in the subgrade	IS: 2720 (Part-16)	One CBR test for every 5000 cum of soil

10.6.2. Earthwork and compaction control : The frequency of testing for earthwork at construction site shall be as indicated in Table 10.2.

TABLE 10.2. FREQUENCY OF TEST FOR EARTH WORK

Test No.	Description	Test Method	Frequency
EW-6	Moisture content prior to compaction	IS:2720 (Part-2)	One test for every 250 m^3 of soil subject to minimum of 4 test/day
EW-7	Thickness of layer		Regularly
EW-8	Degree of the compaction	IS:2720 (Part-28)	One set of the test per 2000 m^2 area comprising 5-6 measurement

The test locations for compaction control shall be chosen only through random sampling techniques. The guidelines are indicated in Fig. 10.2. Acceptance shall be based on mean value of a set of density determinations. If considerable variations are observed between individual density results, the minimum number of tests in one set of measurement shall be increased to 10. The acceptance criteria shall be subjected to the condition that the mean density (MD) is not less than the specified density plus X.

$$\text{Where, } X = \left(1.65 - \frac{1.65}{(\text{No of samples})^{0.5}}\right) \text{ x (standard deviation)}$$

The minimum value of mean field density shall be 97 per cent of Standard Proctor density in case of embankment and 100 per cent of Standard Proctor density for subgrade layer.

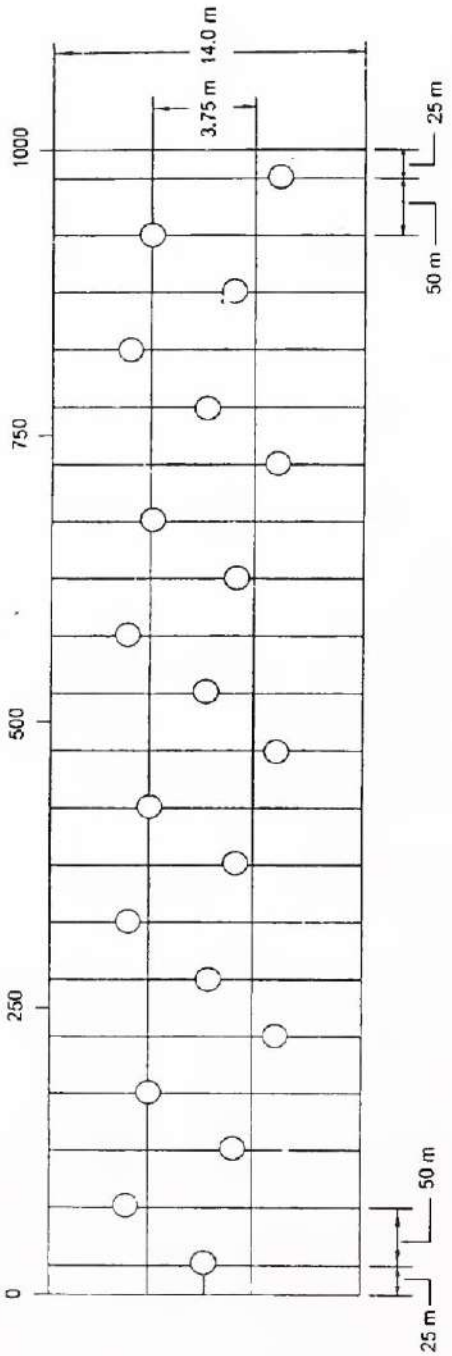


Fig. 10.2. Location of Density Test Points for Earth Work

10.6.3. Granular sub-base and bases : The tests and their frequencies for the different types of base and sub-base shall be as given in Tables 10.3 to 10.5. The evaluation of density results and acceptance criteria for compaction control shall be on lines similar to those set out in Section 10.6.2. However, the compaction density to be complied to for sub-base shall be as per MoRT&H guidelines, i.e., 98 per cent. Further, it must fulfil the statistical criteria given for subgrade compaction. The guidelines for location of test points are given in Fig. 10.3.

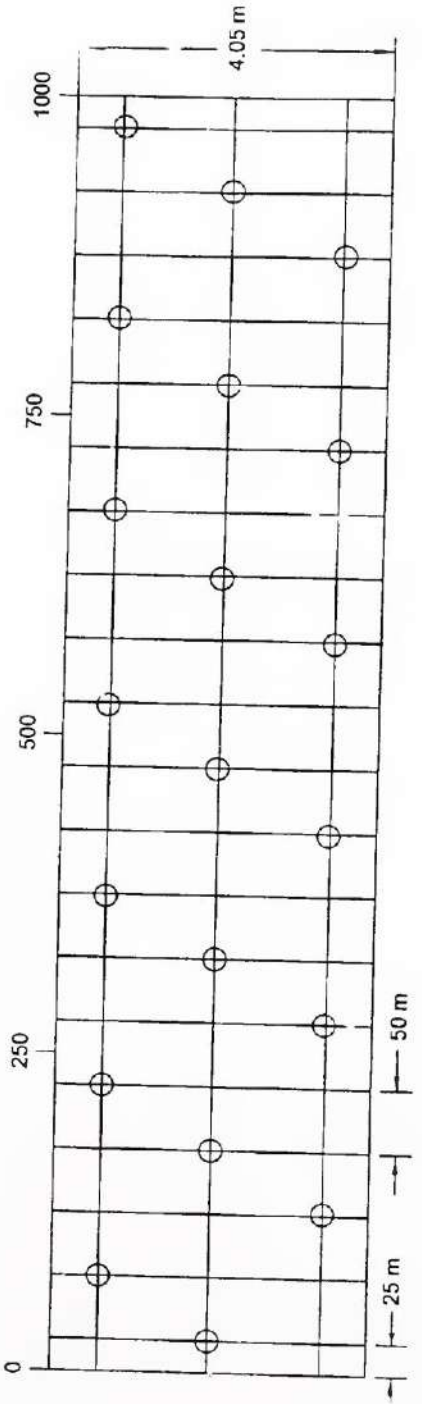


Fig. 10.3. Location of Density Test Points for Sub-Base

TABLE 10.3. FREQUENCY OF TEST FOR GRANULAR AND STABILISED (MECHANICAL) SUB-BASE AND GRAVEL ROADS

Test No.	Test	Test Method	Frequency
SB - 1	Gradation	IS:2720 (Part-4)	Two tests per 500 cum or per day
SB - 2	Atterberg limits	IS:2720 (Part-5)	Two tests per 500 cum or per day
SB - 3	Moisture content prior to compaction	IS:2720 (Part-2)	Two tests per 500 cum or per day
SB - 4	Density of compacted layer	IS:2720 (Part-28)	One set of test per 2000 sqm
SB - 5	Thickness	—	Regularly

TABLE 10.4. FREQUENCY OF TEST FOR STABILISED (LIME/CEMENT/LIME-GBFS/LIME-FLY ASH) SUB-BASE

Test No.	Test	Test Method	Frequency
SB - 6	Purity of lime/cement	IS:1514/IS:269 /455/IS:1489	1 tests per 5000 kg. or/lot
SB - 7	Degree of pulverisation	—	Regularly
SB - 8/9	CBR or unconfined compressive strength test on a set of 3 specimens	IS:2720 (Part-16) IS:4332 (Part-5)	1 tests per 100 cum of mix
SB - 3	Moisture content prior to compaction	IS:2720 (Part-2)	2 tests per 500 cum or per day
SB - 4	Density of compacted layer	IS:2720 (Part-28)	1 set of test per 2000 sqm
SB - 5	Thickness		Regularly

TABLE 10.5. FREQUENCY OF TEST FOR WATER BOUND MACADAM (SUB-BASE, BASE COURSE AND SURFACE COURSE)

Test No.	Test	Test Method	Frequency
GB - 1	Aggregate impact value	IS:2386 (Part-4)	1 tests per 250 cum or source
GB - 2	Grading of aggregate and screening	IS:2386 (Part-1)	2 tests per 250 cum or per day
GB - 3	Flakiness index and elongation index	IS:2386 (Part-1)	1 tests per 250 cum or per day
GB - 4	Atterberg limits of binding material	IS:2720 (Part-5)	1 tests per 50 cum or per day
GB - 5	Water absorption	IS:2386 (Part-3)	1 test per source
GB - 6	Thickness	—	Regularly

In case of use of special materials, like, lime flyash, cement, lime-GBFS (granulated blast furnace slag) and stabilised sand to be used in sub-base and base course construction, the type and frequency of tests shall be same as for conventional materials. Gravel and WBM also may be accepted as wearing coarse for unsurfaced roads. In such cases, the quality control methods and frequency of test will be as indicated here.

10.7. Bituminous Courses

Bituminous materials can be used for construction of prime coat, tack coat, modified penetration macadam, bituminous macadam, open graded premix carpet with seal coat, and closely graded premix carpet (mix seal surfacing, etc.). The modified penetration macadam and bituminous macadam shall be used only at special locations where traffic is heavy and requirement of strengthening by bituminous course is essential.

10.7.1. Prime coat and tack coat : The applications of prime coat and tack coat over granular course is essential before providing a bituminous surfacing. The quality control tests and their minimum frequency for prime coat and tack coat applications shall be as given in Table 10.6.

TABLE 10.6. FREQUENCY OF TEST FOR PRIME COAT AND TACK COAT

Test No.	Test	Test Method	Frequency
BL - 1	Quality of binder	IS:73/217/8887	1 test per lot or per 10 tonne
BL - 2	Temperature of binder	*Appendix-10.6*	Regularly
BL - 3	Rate of spread of binder	*Appendix-10.7*	2 tests per day or per 1000 sqm

10.7.2. Bituminous macadam and modified penetration macadam : The construction of bituminous macadam and modified penetration macadam can be undertaken in special cases where it is felt essential as a design requirement. The tests and minimum frequencies for these bituminous works pertaining to base course construction shall be as given in Tables 10.7 and 10.8.

TABLE 10.7. FREQUENCY OF TEST FOR BITUMINOUS MACADAM

Test No.	Test	Test Method	Frequency
BL - 1	Quality of binder	IS:73/217/8887	1 test per lot or per 10 tonne
BL - 2	Temperature of binder	*Appendix-10.6*	Regularly
BL - 4	Aggregate impact value	IS:2386 (Part 4)	1 test per 250 cum/source
BL - 5	Flakiness index	IS:2386 (Part 1)	1 test per 250 cum
BL - 6	Stripping of aggregate	IS:6241 – 1971	1 test per source
BL - 7	Water absorption	IS:2386 (Part 3)	1 test per source
BL - 8	Grading of aggregates	IS:1286 (Part 1)	1 test per 100 cum
BL - 9	Binder content	*Appendix-10.8*	2 test per day
BL - 10	Thickness	—	Regularly
BL - 11	Density of compacted layer	*Appendix-10.9*	1 test per 1000 sqm area or per day

TABLE 10.8. FREQUENCY OF TEST FOR MODIFIED PENETRATION MACADAM

Test No.	Test	Test Method	Frequency
BL - 1	Quality of binder	IS:73/217/8887	1 test per lot or 10 tonne
BL - 2	Temperature of binder	*Appendix-10.6*	Regularly
BL - 4	Aggregate impact value	IS:2386 (Part 4)	1 test per 250 cum per source
BL - 5	Flakiness index	IS:2386 (Part 1)	1 test per 250cum per source
BL - 6	Stripping of aggregate	IS:6241-1971	1 test per source
BL - 7	Water absorption	IS:2386 (Part 3)	1 test per source
BL - 3	Rate of spread of binder	*Appendix-10.7*	1 test per 1000 sqm
BL - 12	Rate of spread of aggregate	*Appendix-10.10*	1 test per 1000 sqm

10.7.3. Bituminous surface course : The following bituminous surface courses are generally recommended for rural roads construction:

- Surface dressing
- Open graded premix carpet with seal coat
- Closely graded premix carpet or mix seal surfacing

The various tests and their minimum frequencies for different types of bituminous works for surface course are given in Tables 10.9 and 10.10.

TABLE 10.9. FREQUENCY OF TEST FOR SURFACE DRESSING

Test No.	Test	Test Method	Frequency
BL - 1	Quality of binder	IS:73/217/8887	1 test per lot or 10 tonne
BL - 2	Temperature of binder	*Appendix-10.6*	Regularly
BL - 4	Aggregate impact value	IS:2386 (Part 4)	1 test per 250 cum per source
BL - 5	Flakiness index	IS:2386 (Part 1)	1 test per 250 cum per day
BL - 6	Stripping of aggregate	IS:6241-1971	1 test per source
BL - 7	Water absorption	IS:2386 (Part 3)	1 test per source
BL - 3	Rate of spread of binder	*Appendix-10.7*	1 test per 1000 sqm
BL - 12	Rate of spread of aggregate	*Appendix-10.10*	1 test per 1000 sqm

TABLE 10.10. FREQUENCY OF TEST FOR OPEN GRADED PREMIX SURFACING OR CLOSELY GRADED PREMIX SURFACING OR MIX SEAL SURFACING

Test No.	Test	Test Method	Frequency
BL - 1	Quality of binder	IS : 73/217/8887	1 test per lot or 10 tonne
BL - 4	Aggregate impact value	IS : 2386 (Part 4)	1 test per 250 cum per source
BL - 5	Flakiness index	IS : 2386 (Part 1)	1 test per 250 cum per day
BL - 6	Stripping of aggregate	IS : 6341- 1971	1 test per source
BL - 7	Water absorption	IS : 2386 (Part 3)	1 test per source
BL - 8	Grading of aggregates	IS : 2386 (Part 1)	1 test per 50 cum per day
BL - 13	Soundness (magnesium and sodium sulphate)	IS : 2386 (Part 5)	1 test per source
BL - 2	Temperature of binder at application	*Appendix-10.6*	Regularly
BL - 14	Binder content	*Appendix-10.8*	2 test per 500 cum or per day
BL - 10	Thickness		Regularly

10.8. Semi-Rigid and Rigid Pavement

The general guidelines for quality control in construction of these types of pavements are as under:

(i) IRC:SP:11 "Handbook of Quality Control for Construction of Roads and Runways" shall be referred for the quality control of semi-rigid, rigid pavement and roller compacted concrete pavements.

(ii) 43 Grade Ordinary Portland Cement as per IS:8112-1989 is generally used. However, the details about the type of cement and concrete required under different climatic conditions is given in Chapter 4. If the sulphates in soil is more than 0.5 per cent, the cement shall conform to IS:6909.

(iii) The potable or drinking water may be used for mixing and curing of concrete. The concrete pavement (semi-rigid and rigid pavement made with cement and other binding materials) should be water cured for a minimum period of 14 days, and preferably for 28 days after 24 hours of casting. The curing may be done either by ponding water or sprinkling water. If fly ash/granulated slag is used as binder, the curing period may be extended for two more days, to get better results. The temperature of slabs during curing may be preferably, 27±2°C. Construction of such pavement involving concrete shall be carried out when the ambient temperature is between 5 to 40°C. When temperature of air is less than 5°C, the constituents of concrete mainly water and aggregates are required to be heated. When the temperature of air is more than 40°C, the constituents may be cooled down accordingly. The water used shall conform to IS:456-2000.

(iv) The crushed aggregate of maximum size of 25 mm and greater than 4.75 mm and sand (size less than 4.75 mm) may be used for construction of both semi-rigid and RCC pavements, and it shall conform to IS:383-1970 "Specification for Coarse and Fine Aggregates from Natural Sources". The water absorption in the aggregates shall not be more than 2 per cent (IRC:SP:49).

(v) Guidelines for cement concrete mix design for both semi-rigid and rigid pavement/RCCP shall be as per IRC:44 "Tentative Guidelines for Cement Concrete Mix Design for Pavements". The minimum flexural strength of concrete for RCCP shall be 40 kg/sq.cm in the field assuming good degree of quality control in the field. The minimum compressive strength of concrete for DLC shall be 100 kg/sq.cm at 7 days. The approximate mix proportions by weight shall be as 1:1.4:2.75 (Cement:Sand:Coarse aggregate) with water/cement ratio 0.38 for cement concrete pavement. Slump of 0 to 5 mm may be used for DLC or RCCP and slump of 15-20 mm may be kept for pavement quality concrete. The mix design for DLC shall be such that the maximum aggregate:cement ratio shall be 16:1.

(vi) Tools, equipments and appliances for rigid/semi-rigid pavement construction shall be as per IRC:43 and IRC:SP:49". Edging tool shall be used for making the sharp edges of the joints in the slabs. Proper care shall be taken while making edges. Excessive compaction of the concrete shall be avoided. This can be checked by the fact that no extra water or bleeding shall occur on the top surface of concrete. Excessive water at the top will make the top surface very weak. Edges of concrete pavement shall also be about 1 meter away from a tree, if any.

(vii) To provide adequate drainage, the base course and sub-base courses shall be provided with adequate camber (2 per cent). Longitudinal slope may be considered as 1 in 500. The slope shoulder may be provided as given in Chapter 2. Shoulder may be of compacted earth, brick soling or any other suitable material.

(viii) Cement (physical and chemical test), fine aggregate (gradation, deleterious constituents, moisture content test), coarse aggregate (crushing value/Los Angeles abrasion value, soundness, alkali aggregate reaction test), fly ash (physical and chemical test) and water (physical and chemical test) shall be tested once for each source of supply and occasionally when called for. In case of water when it will require long and/or improper storage of water, it will be tested more frequently.

(ix) Six number of cement concrete cubes shall be cast daily to check 7 and 28 days strength as per IRC:SP:11. The minimum compressive strength of any individual cube for DLC shall not be less than 7.5 MPa. The aggregate shall have water absorption not more than 2 per cent and silt content (size less than 75 micron) shall not exceed 3 per cent in case of natural aggregate. The average flexural strength of concrete obtained in the field shall not be less than 40 kg/sqcm for PQC or RCC and the flexure strength of any individual beam shall not be less than 35 kg/sqcm.

(x) Adequate quality control should be exercised at all stages of construction by suitably trained staff as per guidelines given in IRC:15 "Standard Specification and Code of Practice for Construction of Concrete Roads", IRC:SP:11" Handbook of Quality Control for Construction of Roads and Runways", and IRC SP:49, "Guidelines for the Use of Dry Lean Concrete as Sub-Base for Rigid Pavement".

(xi) The difference between the highest and the lowest value of flexural strength at 28 days shall not be more than 15 per cent of the average flexural strength of PQC/RCC.

(xii) Mould for test beam shall be 10x10x50 cm and for cubes 15x15x15 cm conforming to IS:516-1959.

(xiii) The angle between any two joints of DLC should be right angle or obtuse, and joints shall be staggered (by 20 cm to 40 cm as per IRC:SP:49) with each other (Contraction, Construction) with the overlaying concrete.

(xiv) The minimum K-value (modulus of subgrade reaction) of subgrade\sub-base shall be 5.54 kg/cm^3 (minimum CBR 10 per cent) The K-value of DLC of 10 cm thickness, is generally between 10-20 kg/cm^3 which is greater than the minimum K-value (taken as 5.54 kg/cm^3). If dry fly ash of lime reactivity greater than 40 kg/sqcm is available within reasonable lead, the same may be used as replacement of cement by 10-25 per cent as performance improver in PQC/RCCP. 50 per cent of sand can also be replaced by fly ash in Dry Lean Cement Concrete (DLC) to have better durability, less heat of hydration and better finishing, provided 28 days strength is not reduced. The type of cement to be used for construction is given in Chapter 6.

(xv) The compaction of concrete shall be completed critically within 120 minutes if temperature is less than 25°C and not more than 90 minutes when the temperature is between 25 and 40°C. The concrete temperature shall not exceed 40°C.

(xvi) The permissible maximum variation in thickness of layers shall be 10 mm.

(xvii) The other required tests for quality control and their frequency are given in Table 10.11.

TABLE 10.11. FREQUENCY OF TEST FOR CONCRETE ROAD CONSTRUCTION

Test No.	Test	Test Method	Frequency
RP-1	Quality of cement (a) Consistency (b) Compressive strength (c) Initial and final setting time (d) Fineness of cement (e) Soundness of cement	IS:269/455/1189/8112/12269	1 test per source
RP-2	Strength of concrete (a) Comprehensive strength (b) Flexural strength	IS:516-1959	3 test per 150 m^3 for each 7 days and 28 days strength
RP-3	Thickness	Wooden Blocks	Regularly at grid points
RP-4	Purity of water	IS:456-2000	1 test per source
RP-5	Workability sample test	IS:1199-1959	3 test per day
RP-6	Gradation of coarse and fine aggregate	IS:2386 (Part-1)	1 test per day
RP-7	Aggregate impact value	IS:2386 (Part –3)	1 test per source
RP-8	Soundness	IS:2386 (Part –5)	1 test per source

Note : The dry density of roller compacted concrete shall be determined from three density holes for each day.

10.9. Special Pavements

10.9.1. Quality control of concrete blocks for CBP/ICBP : M 30 or higher grade concrete shall be used in production of blocks required for paving of trafficked road. When M 30 grade concrete is used, the 28 days compressive strength of 15 cm cubes shall be 300 kg/cm^2. M 25 grade concrete may also be used when the blocks are to be used for paving in non-trafficked areas like footpaths. Relationship between 28 days compressive strength of 15 cm cubes and blocks produced in Block Making Machine (BMM)/hydraulic press shall be established, so that the block strength can be related to concrete strength. For quality control of blocks, from each lot of 200 blocks, 3 blocks shall be selected at random for water absorption and 28 days compressive strength tests. The block may be first tested for water absorption and the test results recorded as per Format SP-1. The same blocks shall then be tested for apparent compressive strength, and the test results recorded as per Format SP-2. The corrected compressive strength of blocks shall be calculated by applying the appropriate correction factor to the compressive strength value so obtained as indicated in Table 10.12.

Water absorption of blocks shall be below 8 per cent. Mean compressive strength shall be equal to or higher than the design strength. Upto 10 per cent variation of individual values from mean value may be allowed. Blocks rejected for paving in traffic areas can be used for non-traffic areas, if otherwise found suitable.

TABLE 10.12. CORRECTION FACTORS FOR DETERMINATION OF COMPRESSIVE STRENGTHS OF CONCRETE BLOCKS

Block Thickness (mm)	Correction Factor	
	Non-Chamfered Block	Chamfered Block
60	1.00	1.06
80	1.12	1.18

10.9.2. Quality control of stone-sett/brick-on-edge pavement : The quarry stones shall be of more or less uniform size. When skilled craftsmen are available, the stones shall be properly dressed to obtain uniform size. After construction of base course, the area to be paved shall be bounded by installation of edge restraints for which the stones themselves can be used. A portion of the edge restraints shall be embedded in the base course for effective confinement of the pavement. Surface profile shall be corrected to the extent possible.

Good quality burnt clay bricks shall be used in brick-on-edge pavement. The bricks themselves can be used as edge restraints, which shall be partially embedded in the base course. Bricks produced with a high content of lime in the clay will enhance the service life of brick pavement. Proper surface profile shall be maintained during construction.

10.9.3. Quality control for new materials : New materials, like, geotextiles and modified binders can also be used in specific cases. The quality control tests as required for use of these materials shall be as given in Clause 903.4.1 of MoRT&H Specifications.

10.10. Alignment, Level and Surface Regularity

All road works carried out shall conform to the lines, grades, cross-sections and dimensions shown on the drawings or as directed by the Engineer, subject to the permitted tolerances described in the respective Sections. Tests, viz., ALS-1, ALS-2, ALS-3 and ALS-4 are required to be conducted for control of alignment level, and surface regularity.

10.10.1. Horizontal alignments (ALS-1) : Horizontal alignments shall be reckoned with respect to the centre line of the roadway as shown on the drawings. The edges of the roadway as constructed shall be corrected within a tolerance of 20 mm therefrom. The corresponding tolerance for edges of the roadway and lower layers of pavement shall be 30 mm. For hill roads, the tolerances shall be as specified by the Engineer-in-Charge.

10.10.2. Surface levels of pavement courses (ALS-2) : The levels of the subgrade and different pavement courses as constructed, shall not vary from those calculated with reference to the longitudinal and cross profile of the road shown on the drawings or as directed by the Engineer-in-Charge. The tolerances normally accepted are mentioned in Table 10.13. For checking compliance with the above requirement for subgrade, sub-base and base courses, measurements of the surface levels shall be taken on a suitable grid. Maximum two measurement shall be permitted to exceed the tolerance as above, including one measurement being not in excess of 5 mm above the permitted tolerance. For checking the compliance with the above requirement for bituminous wearing courses and concrete pavements, measurements of the surface levels shall be taken on a suitable grid of points spaced at 6.25 m along the length and at 0.5 m from the edges of the pavement.

TABLE 10.13. TOLERANCES IN SURFACE LEVELS (ALS-2)

Sl. No.	Description	Limits
1.	Subgrade	±25 mm
2.	Subbase	± 20 mm
3.	Base Course (i) Machine laid (ii) Manually laid	 ±10 mm ±15 mm
4.	Wearing course for flexible pavement (i) Machine laid (ii) Manually laid	 ± 6 mm ± 10 mm
5.	Wearing course (roller compacted concrete pavement/rigid pavement)	± 10 mm

10.10.3. Surface regularity of pavement courses (ALS-3) : The longitudinal profile shall be checked by 3 meter long straight edge/moving straight edge as desired by the Engineer at the centre line of the roadway or as specified in IRC:SP:11 or MoRT&H Specifications. The maximum permitted number of surface irregularities shall be as per guideline given in Table 10.14. The procedure for checking surface regularity is given in ***Appendix-10.11***.

TABLE 10.14. MAXIMUM PERMITTED NUMBER OF SURFACE IRREGULARITIES (ALS-3)

Irregularity	Number of Irregularity of Size			
	4 mm		7 mm	
Length for Measurement (m)	300	75	300	75
Number of Irregularities	50	25	6	3

The maximum allowable difference between the road surface and underside of a 3 m straight edge when placed parallel with, or at right angles to the centre line of the road at points decided by the Engineer shall be as given in Table 10.15.

TABLE 10.15. MAXIMUM ALLOWABLE TOLERANCE IN ROAD CONSTRUCTION (ALS-4)

Description	Limits
Pavement surface (bituminous and cement concrete)	4 mm
Bituminous base courses	8 mm
Granular sub-base/base courses	10 mm
Sub-base under concrete pavements	15 mm

Where the surface regularity of subgrade and the various pavement courses fall outside the specified tolerances, the contractor shall be liable to rectify these in the manner described in Section 902.5 of MoRT&H "Specifications for Road and Bridge Works"

10.11. Record of Quality Control Data

Quality control tests shall be conducted as per the sequence given in Fig. 10.1 for different layers of pavement. The data shall be recorded in the forms given in ***Appendix-10.12.***

Appendix 10.2

Equipment Requirements at Site and Central Laboratory

[A] Apparatus for Material Testing

Sl. No.	Particulars of Items	Quantity
1.	Riffle Box	1 No.
2.	Sieve Set	2 set
3.	Sieve Shaker (for 450 mm & 200 mm sieves)	1 No.
4.	Atterberg Limits (liquid and plastic limit) Apparatus	1 No.
5.	Specific Gravity Apparatus	1 Set
6.	Auto Compaction Test (Light and Heavy Compaction)	1 Set
7.	Speedy Moisture Meter (With chemical)	1 Set
8.	Compression Machine 200 kN	1 No.
9.	CBR Testing Machine with Proving Ring	1 Set
10.	CBR Mould, Tripod Stand with Dial Gauge, Perforated Plate, etc.	12 Set
11.	Moisture Tins	12 No.
12.	Spatula	4 Set
13.	Aggregate Impact Value Machine with Accessory, as per IS:2386-IV	1 set
14.	Flakiness Gauge as per IS:2386- 1	2 Set
15.	Los Angeles (Abrasion Value) Apparatus as per IS:2386-IV	1 No.
16.	3 m Straight Edge with Wedge	1 No.
17.	Water Bath (Thermostatically Controlled upto 60°C)	1 set
18.	Penetration Machine with Accessory	1 Set
19.	Softening Point Apparatus with Accessory	1 Set
20.	Extraction Machine with 6 Mould, Rammer, Base, etc.	1 Set
21.	Viscosity (Saybolt Furol) with Accessories	1 No.
22.	Ductility Machine with Accessory	1 No.
23.	Sand Replacement Cylinder with Accessories	2 No.
24.	Core Cutter with Collar and Hand Rammer	2 No.

[B] Other Accessories, Reagents and Glassware

Sl. No.	Particulars of Items	Quantity
1.	Auger, Pick Axe, Spade, Crow Bar, etc. (Digging Tools)	2 No. Each
2.	Glass Ware, Filter Paper, Beaker, Cylinder, etc.	6 No. Each
3.	Trychloroethylene	10 litres
4.	Oven Thermostatically Controlled (upto 200°C, Sensitivity 1°C)	1 No.
5.	Electronic Balance 5 kg cap. Accuracy 0.5 gm	1 No.
6.	Electronic Balance 500 gm cap. Accuracy 0.1gm	1 No.
7.	Electronic Balance 200 gm cap. Accuracy .01gm	1 No.
8.	Thermometer (0°C to 50°C, 110°C, 250°C, 300°C)	6 Each
9.	Proving ring 50 kN	2 No.
10.	Proving ring 100 kN	1 No.
11.	First Aid Box	1 Box
12.	Tray Enameled (Big. Medium, Small, Rectangular and Circular)	6 Each
13.	GI Tank 0.75 m x 0.75 m x 0.3 m	1 No.
14.	Hot Plate	1 No.
15.	Stop Watch	2 No.

[C] Sieve Set of Galvanised Iron (GI) Frame

Sieve Size	Dia of Sieve	Quantity
Lid	450 mm	1 No.
Pan	450 mm	1 No.
125.0 mm	450 mm	1 No.
90.0 mm	450 mm	1 No.
75.0 mm	450 mm	1 No.
63.0 mm	450 mm	1 No.
53.0 mm	450 mm	1 No.
45.0 mm	450 mm	1 No.
37.5 mm	450 mm	1 No.
26.5 mm	450 mm	1 No.
22.4 mm	450 mm	1 No.
19.0 mm	450 mm	1 No.
13.2 mm	450 mm	1 No.
11.2 mm	450 mm	1 No.
9.5 mm	450 mm	1 No.
6.7 mm	450 mm	1 No.
5.6 mm	450 mm	1 No.
4.75 mm	450 mm	1 No.

[D] Sieve Set of Brass Frame

Sieve Size	Dia of Sieve	Quantity
Lid	200 mm	2 No.
Pan	200 mm	2 No.
4.75 mm	200 mm	2 No.
2.36 mm	200 mm	2 No.
2.00 mm	200 mm	2 No.
1.70 mm	200 mm	1 No.
1.40 mm	200 mm	1 No.
1.18 mm	200 mm	2 No.
1.00 mm	200 mm	2 No.
850 µ	200 mm	1 No.
710 µ	200 mm	2 No.
600 µ	200 mm	2 No.
425 µ	200 mm	2 No.
300 µ	200 mm	2 No.
250 µ	200 mm	1 No.
180 µ	200 mm	2 No.
150 µ	200 mm	2 No.
90 µ	200 mm	2 No.
75 µ	200 mm	2 No.

Appendix 10.3

Laboratory Testing for Properties of Soil (IS:2720)

Soil is one of the principal materials of construction for embankments and stabilised soil base and su-bbase courses. Some important tests on soil as an engineering material are as under :

1. Plasticity Index (IS:2720–Part 5)

(i) **Liquid Limit (LL)**

The test is carried out in a standard Casagrande Liquid Limit Device in which a cup containing a grooved specimen is made to fall on a rubber Plate. The number of blows to close the groove to a length of about 12.5 mm is determined for different moisture content. The moisture content corresponding to 25 blows is determined from a plot between number of blows and moisture content.

A simpler alternative method to determine the liquid limit is the Uppal's penetrometer. In this method, the liquid limit is the moisture content corresponding to 25 mm penetration of a standard cone in the soil paste which is computed when the penetration ranges between 20 mm to 28 mm.

(ii) **Plastic Limit (PL)**

The moisture content at which a soil water mix when rolled into a thread on a glass plate starts crumbling at 3 mm dia gives the plastic limit of the soil.

(iii) **Plasticity Index (PI)**

The numerical difference between liquid limit and plastic limit is the plasticity index. Thus, it is determined from the liquid limit and plastic limit values of soil. A rough estimate of this can also be made using Uppal's Syringe. A soil paste is made by adding water to soil such that water is above the plastic limit of soil. This paste is put into the syringes and pushed out through the holes in the cap. Depending upon the texture of the thread, the PI can be estimated.

2. Sieve Analysis (IS:2720-Part 4)

The particle size distribution is by far the simplest way of broadly classifying a soil in terms of its being granular, medium grained and fine grained. The sieve analysis consists simply in taking weighed quantity of the sample, soaking it in water overnight and washing out the finer fraction through 75 micron IS Sieve. The fraction retained is dried and then passed through a series of sieves. However, for the rural road works, a set of 7 sieves is recommended. To be able to broadly evaluate the particle size distribution of a soil even three sieves namely 2.36 mm, 425 micron and 75 micron may suffice. While a mechanical shaker is generally used in well equipped laboratories, manual shaking of sieves is considered sufficient if carried out for a period not less than three minutes. In case of dry cohesionless soil such as sand, dry sieve analysis may be carried out.

3. Proctor Compaction (IS:2720-Part 7)

This test is conducted to determine the achievable density in field and the optimum moisture required for compaction. It is conducted in a proctor mould (IS:2720 Part-7 1980) apparatus. The soil sample is compacted in three layers giving 25 blows on each side by a standard rammer at five different moisture contents. From the plot between moisture content and dry density, the optimum moisture content and maximum dry density are determined. In case of heavy compaction method (IS:2720 Part-8 1983), soil sample is compacted in five layers (depending on the size of the mould) giving 56 blows using a IS heavy rammer.

4. CBR (IS:2720-Part 16)

It is extensively used for the design of flexible pavements in India. The test is carried out on a sample compacted at optimum moisture content to maximum dry density and soaked for 4 days. In case of stabilised specimen, the specimen is cured for 7 days in wet sand and then subjected to the 4 days soaking. The CBR of the specimen is computed from the load needed for 2.5 mm/5.0 mm penetration of a standard plunger determined from the graph between penetration and load. If required the zero correction is applied for penetration while computing the load for 2.5 mm/5.0 mm penetration.

Appendix 10.4

Laboratory Testing for Properties of Road Aggregates (IS:2386)

The performance of pavement depend to a great extent on the correct choice of quality and quantity of aggregates as they form the major constituent of road construction materials. Since the aggregates have to bear the brunt of traffic, strength or resistance to degradation of aggregates as well as structural stability offered by mechanical interlock of aggregate particles in a layer form are important factors. IS:2386-1963 (Parts I to VIII) gives the methods of tests for aggregates for road construction.

Great care is necessary in taking out samples of aggregates for testing unless the samples are true representative, the results of various tests may not reflect accurately their characteristics. For sampling of coarse aggregates, fine aggregates and filler, use of a flat shovel is preferable when working on a flat surface to ensure that a representative proportion of fines is picked up. The aggregates should be surface dry. Suitable form of sample divider is the riffle box. In case, a sample divider is not available, the representative sample may be obtained by quartering. For more details on sampling, IS:2386-1963 (Part I) may be referred to.

Some of the important tests on aggregates for road construction are given in the following paragraphs:

(i) **Sieve Analysis :** The test procedure is described in IS:2386-1963 (Part I). The required quantity of sample of aggregates is sieved manually or mechanically on a standard set of sieves depending upon the maximum size of aggregates and the percentage retained on each sieve is determined. The test results are expressed as per cent by weight passing each sieve. Sieve analysis test gives the particle size distribution in a sample of aggregate.

(ii) **Shape of Aggregates :** Aggregates have three different shapes, viz. cubical, flaky and elongated. While cubical aggregates are good for development of mechanical interlock between aggregate particles and consequently for achieving structural stability in a bituminous mix, flaky and elongated aggregates are considered to be undesirable due to their greater susceptibility to fracture and larger surface area per unit volume requiring higher quantity of bitumen for coating. The presence of some quantity of flaky and elongated particles in an aggregate mass is inevitable, as these are bound to be produced in the aggregate crushing operation. But appropriate standards have been prepared to limit the quantity of such particles in an aggregate mass depending upon a particular use of such aggregates. The weight of flaky (or elongated) particles expressed as per cent of total sample of aggregates and weight of long particles as a per cent of non-flaky material is known as flakiness and elongation index respectively.

A flaky particle is one whose least dimension (thickness) is less than 0.6 times its mean dimension. The test is not applicable to aggregates of sizes smaller than 6.3 mm.

An elongated particle is one whose greatest dimension (length) is greater than 1.8 times its mean dimension. The test procedure is given in IS:2386-1963 (Part 1). The elongation test is not applicable to aggregates of sizes smaller than 6.3 mm.

(iii) **Specific Gravity :** Specific gravity is the ratio of the mass of a given absolute volume of aggregates to the mass of an equal volume of water at a specified temperature. The test procedure is given in IS:2386-1963 (Part 3). The specific gravity value of aggregates is required in computation of voids in bituminous mix design. For coarse aggregates, the wire basket method is used for determination of specific gravity, while for fine aggregates, the pyknometer method is used. For filler materials, specific gravity bottle is used.

(iv) **Water Absorption :** Water absorption is the difference in weight of aggregates between 24 hours water-saturated surface-dry condition and oven-dry condition expressed as percentage of the latter. The test procedure is given in IS:2386-1963 (Part 4). Water absorption is high for porous aggregates. It is necessary to provide extra binder in a bituminous premix at the rate of 0.5 per cent for every 1 per cent water absorption in excess of 2 per cent.

(v) **Aggregates Impact Value :** Number of tests are used to evaluate strength characteristics of aggregates. A simple test, which is also correlated with other tests, is the Aggregate Impact Test. The test procedure is given in IS:2386-1963 (Part 4). The aggregate impact value gives a measure of resistance of aggregates degradation due to impact, which differs from characteristics value of resistance to crushing under slow compressive load. In the aggregate impact test, 12.5 to 10 mm size clean dry aggregates of specified volume are subjected to 15 blows of a 13.5 to 14.0 kg hammer falling from a height of 380 ± 5 mm. The weight of the sample of aggregates passing 2.36 mm sieve after the test expressed as percentage of the original weight is the aggregate impact value. The lower the aggregate impact value, the higher is its strength.

(vi) **Soundness :** This test indicates the susceptibility of aggregates to disintegration under the action of water containing sodium and magnesium sulphates. The test procedure is described in IS:2386-1963 (Part 5). Washed and dried aggregates of specified sizes are immersed in saturated solution of sodium sulphate/magnesium sulphate for 16 to 18 hours. The sample is then removed and dried to constant weight. This forms one cycle. The test is repeated for 5 cycles. After 5 cycles, the sample is washed, dried in an oven and re-sieved on those very sieves which were used before the test. The material retained on each sieve is recorded. The cumulative difference between the amounts of material retained on each of the sieves before and after the test is the loss due to disintegration and is expressed as percentage of total initial weight of the sample. The permissible value for loss in sodium sulphate and magnesium sulphate after 5 cycles are 12 per cent and 18 per cent respectively. If the loss is more, then the aggregates are likely to disintegrate by water containing such salts.

(vii) **Stripping Value :** Stripping is the displacement of bitumen film from a coated road aggregate particle in the presence of water. The details of test procedure are given in IS:6241-1971. In this test, 20 to 12.5 mm size aggregates are coated with 5 per cent bitumen under specified conditions and immersed in distilled water at 40°C for 24 hours. The average per cent area of aggregate surface stripped is assessed visually, while the aggregates are under water. The amount of stripped area expressed as per cent, is the stripping value.

Appendix 10.5

Testing of Bituminous Materials

IS:73-1992 specify the requirements of penetration grade bituminous binders. All the tests are detailed in IS:1201, IS:1220, IS:10512 and IS:9381. IS:8887-1995 has specified requirement of cationic bitumen emulsions. A few important tests and their significance are briefly described below:

(A) Tests on Bitumens

(i) **Specific Gravity :** Details of test are given in IS:1202-1978. It is defined as the ratio of the mass of a given volume of the bitumen to the mass of an equal volume of water at 27°C. It is used to compute the volume of bitumen and determination of voids in compacted bitumen mixture in Marshall method of mix design. It is determined by pyknometer.

(ii) **Water Content Test :** This test is specified in IS:1211-1978. Water content is determined using Dean and Stark method. It is desired that bitumen should contain minimum water content. The maximum limit is 0.2 per cent as per IS:73-1992. Water Content more than the specified limit causes frothing during heating.

(iii) **Flash and Fire Point by Cleveland Open Cup :** This test is specified in IS:1209-1978. It is defined as the lowest temperature in °C at which the vapour from heated bitumen catches fire momentarily in the form of flash. The fire point is the lowest temperature in °C at which the vapour of bitumen ignite on application of flame at least for 5 second. The heating rate is 5°C/minute. This test is indicative of fire hazard, if a bitumen is heated beyond flash point. The fire point is usually 5-10°C higher than flash point. The minimum limit of flash point is 220°C.

(iv) **Softening Point Test (Ring and Ball) :** Details of apparatus and procedure are given in IS:1205-1978. Softening point, is a temperature measured in °C, at which a bituminous binder attains a particular degree of softness under specified test conditions. Distilled water is used as bath medium for bitumens with softening point value below 80°C and glycerol for value beyond 80°C. The temperature of bath is raised at 5^{0}C/minute from 5°C in case of water and from 35°C in case of glycerol. The temperature, at which, a standard steel ball (3.5 g) placed over bitumen touches a base plate 25 mm below the ring is recorded as softening point. It signifies the temperature at which bitumen passes from semi-solid state to liquid state and indicate the atmospheric temperature at which the bitumen is likely to bleed. Hence, softening point of a bitumen should be 5-10°C higher than the maximum atmospheric temperature.

(v) **Penetration Test :** This test is specified in IS:1203-1978. It is conducted to measure consistency and identify the grade of bitumen. It is defined as vertical distance traversed by a standard needle in 0.1mm unit under a known load (100g), at a fixed temperature (25°C), for a known time (5 second). The distance in 0.1mm units is known as penetration. Therefore, the greater the penetration of needle, the softer the bitumen. For each test three measurements are needed at 10 mm apart on bitumen surface.

Repeatability :	if penetration is less than 50, 1 unit If penetration is more than 50, 3 per cent of mean
Reproducibility :	if penetration is more than 50, 4 units If penetration is more than 50, 8 per cent of the mean

(vi) **Ductility Test :** Standard test procedure is described in IS:1208-1978. Ductility is measured in cm and is defined as the distance in cm to which a briquette bitumen specimen will elongate before breaking when it is pulled apart at 5 cm/min. rate at 27°C. The corss-section at minimum width of specimen is 10 mm x 10 mm. Sample is to be prepared in standard mould and to be placed at 27°C for minimum 90 minutes. It signified the property by virtue of which a bitumen can exist in a thin film without breaking.

(vii) **Viscosity Test :** Viscosity of bitumen plays a vital role for different operations of bituminous road construction. The suggested viscosity values are given below :

Operation	Viscosity, cST
Pumping	600-800
Spraying	50-200
Mixing	150-300
Laboratory mixing	150-190
Laboratory compaction	250-310
Rolling	1000-10,000

From the viscosity temperature relationship, the appropriate temperature for various operation of bituminous road construction can be determined. It is a standard test specified in IS:1206-1978. Viscosity is defined as resistance to flow due to internal friction of bitumen. In Industrial units, it is measured by time in second taken by specified volume of bitumen/cutback bitumen/emulsion to flow from 10 mm/4 mm orifice cup of standard tar viscometer or saybolt-furol viscometer. There are several cup viscometers available which differs mainly in the size of opening through which bitumen is drained. Absolute viscosity = flow time x density x K. The value of K for 4 mm cup (STV), 10 mm cup (STV), and saybolt-furol viscometer are 0.0132, 0.400 and 0.00218 respectively. The test results may be expressed as : kinematic viscosity = flow time x K. It can measure viscosity between 320-5600 cSt. Kinematic viscosity is expressed in Stocks, which can be obtained by dividing absolute viscosity by density. It is measured by recording time in seconds required for fixed quantity of material to flow through a glass capillary viscometer at a given temperature. The product of time flow and calibration factor gives the kinematic viscosity.

(viii) **Loss on Heat Test :** This test is specified in IS:1212-1978. It is defined as the per cent loss in weight (exclusive of water content) of volatiles, when a sample of bitumen (50 g) is heated at a standard temperature (163°C) under specified test conditions. Sample is prepared in a penetration cup (55 mm dia and 35 mm depth) and placed in an oven for 5¼ hours on a rotating shelf (5-6 revolutions per minute). Penetration test is also conducted on the sample before and after heating. This test signified the resistance of a bitumen to hardening during construction. The loss in weight and per cent retained penetration values are reported.

$$\text{per cent loss in weight} = \left\{ \frac{\text{Wt. of bitumen before heating - Wt. of bitumen after heating}}{\text{Wt. of bitumen before heating}} \right\} \times 100$$

$$\text{Retained Penetration, per cent} = \frac{\text{Penetration after heating}}{\text{Penetration, before heating}} \times 100$$

(ix) **Solubility in Trichloroethylene (TCE) :** Details of test are given in IS:1216-1978. It is a measure of the purity of bitumen (1-2 g) in the solvent and separating the insolubles by filtering over asbestos mat in gooch crucible. The limit for solubility of bitumen in TCE is minimum 99 per cent.

(x) **Stripping Test :** Stripping (IS: 6241-1971) is the displacement of bitumen film from coated road aggregates in the presence of water. In this test 20-12.5 mm size aggregates are coated with 5 per cent bitumen under specified conditions and immersed in distilled water at 40°C for 24 hours. The average percentage area of aggregate surface stripped is assessed visually. The amount of stripped area expressed as per cent, is the stripping value. The permissible maximum limit is 15 per cent.

Stripping value of different types of aggregate is invariable. A higher value indicates possibility of loss of adhsion between aggregate and bitumen in presence of water. The stripping depends upon type of aggregate shape, size, grain size, surface texture, mineralogical composition, moisture, acidity and alkalinity.

(B) Tests on Bitumen Emulsions (IS: 8887)

(i) **Sieve Test on IS 600 Micron Sieve :** This test complements the settlement test. It is a stability test, used to find out amount of bitumen in the form of larger globules in a emulsion, which cannot be determined by settlement test. The larger drops can clog spraying equipment and will not provide uniform coating. A specified amount of sample is poured through a IS 600 micron sieve. After rinsing with distilled water, the sieve and bitumen are dried in oven. The amount of retained bitumen is determined by weighing and reported as residue on sieving.

(ii) **Binder Content :** The binder content in bitumen emulsion can be determined by a distillation test. A specified quantity of emulsions sample (50 g) is distilled under specified test conditions. The binder content is determined by substracting percentage of water content from 100. The residue is used for further testing to check the quality of bitumen in a emulsion.

(iii) **Stability to Mixing with Coarse Aggregates :** This test has a three fold purpose. It determines the ability (i) to coat the aggregate (ii) to withstand mixing action while remaining as a film on aggregates and (iii) to resist washing action of water after completion of mixing. The method is used to determine coagulation value using aggregate (200 g) and emulsion (50 g)

(iv) **Viscosity by Standard Saybolt-Furol Viscometer (IS:3117) :** Viscosity is defined as a fluid's resistance to flow. In the case of emulsion, the Saybolt-furol viscosity test is used as a measure of consistency. Results are reported in Saybolt-Furol seconds. The viscosities of RS (Rapid Setting) and MS (Medium Setting) emulsions are determined in seconds at 50°C and of SS (Slow Setting) emulsions at 25°C respectively.

(v) **Storage-Stability Test :** This test is used to determine the ability of an emulsion to remain as a uniform dispersion during storage. A measured quantity of sample is placed in two cylinders (stoppered) and allowed to stand for 24 hours. A specified sample is siphoned from the top and placed in oven for a set time at a specified temperature. They are removed, allowed to cool and weighed after the top sample is removed but a small portion of bitumen emulsion remaining in each cylinder is siphoned off. A specified portion that is left is put through the same procedure as for the top sample. The storage stability is expressed as the numerical difference between the average percentage of bituminous residue found in two top samples and two bottom samples.

(vi) **Particle Charge :** The particle charge test is conducted to identity cationic emulsion by its positive charge. It is performed by immersing two copper Pates 25x75 mm which are connected to a 12 volt circuit. At the end of specified period of 2 minutes, an appreciable quantity of bitumen is deposited on cathode indicating a cationic emulsion.

(vii) **Miscibility with Water :** This test finds, if MS and SS emulsion can be mixed with water. It is not applicable for RS emulsions. After adding and stirring with distilled water, the emulsion sample is allowed to stand for two hours. It is then examined for any appreciable coagulation of the bitumen droplets in an emulsion. This test is a measure of quality of emulsion.

(viii) **Stability with Cement :** The cement mixing does the same for SS emulsion, as the test does for RS emulsions. In the cement mixing test, a sample is mixed with finely-ground Portland cement and mixture is washed over a IS 1.4 mm Sieve. The amount of material retained may be recorded as per cent coagulation.

(ix) **Test on Residue :** Penetration, ductility and solubility in trichlorothylene tests are conducted after distillation test to check the quality of bitumen. These tests are conducted as per procedures specified in IS:1201-1220.

Appendix 10.6

Determination of Temperature of Binder

The temperature of bituminous binder shall be determined with the help of calibrated standard mercury thermometer or any other type of standard thermometer. The range of thermometer for different type of bituminous materials and their accuracy shall be as under :

(1)	Melted Bitumen : ambient to 200°C	accuracy ± 1°C
(2)	Cutback bitumen : ambient to 100°C	accuracy ± 0.5°C
(3)	Bitumen emulsion : ambient to 80°C	accuracy ± 0.5°C

Appendix 10.7

Rate of Spread of Binder in Surface Dressing and Modified Penetration Macadam

Light metal trays of 20 cm x 20 cm size and 3 cm depth are weighed and numbered. These are placed at intervals along the road in the path of bitumen distributor between the wheel tracks. After the distributor has passed over, the trays are removed and wrapped in weight sheets of paper so that they can be handled, stocked and weighed as soon as convenient. The spacing and the number of trays can be varied to suit the particular conditions at the construction site, but at least five trays should normally be used. The tray test gives a measure of variation in rate of spread of bitumen along the road and a good approximation to the average rate of spread of bitumen.

The trays are weighed correct to first place of decimal. The maximum longitudinal distribution error in rate of spread of bitumen should be within ±10 per cent of the specified rate of spread of bitumen. Similarly transverse distribution of bitumen can be checked by placing a number of trays to collect bitumen sprayed over each 5 cm width of spray bar. The variation in transverse distribution should be within ± 20 per cent from the mean. The extreme 15 cm width at either side of the sprayed area need not be taken into account.

Appendix 10.8

Determination of Bitumen Content in Bituminous Mix

The test is intended for determination of bitumen content in the bituminous mix by cold solvent extraction method. The mineral aggregates recovered from the test can be used for checking their gradation. A representative bituminous mix sample of about 500 gm by weight is accurately weighed and placed in the bowl of extraction apparatus and covered with commercial grade of trichloroethylene. Sufficient time (not more than one hour) is allowed for dissolving the bitumen in solvent. The filter ring of the extractor is dried, weighed and then fitted around the edge of the bowl. The cover of the bowl is clamped tightly. A beaker is placed under the drain to collect the extract. The machine is revolved slowly and then gradually the speed is increased to a maximum of 3600 rpm. The speed is maintained till the solvent ceases to flow from the drain. The machine is allowed to stop, 200 ml of solvent is added and the above procedure is repeated. A number of 200 ml solvent additions (not less than three) are used till the extract is clear and not darker than a light straw colour. The filter ring from the bowl is removed, dried first in air and then in oven at 115°C to constant weight, and weighed. The fine materials that might have passed through the filter paper are collected back from the extract preferably by centrifuging. The material is washed and dried to constant weight as before. The percentage of binder in the bituminous mix sample is calculated as follows:

$$\text{Percentage of Binder} = \frac{W_1 - (W_2 + W_3 + W_4)}{W_1} \times 100$$

Where,

W_1 = weight of sample, gm
W_2 = weight of sample after extraction, gm
W_3 = weight of fine material recovered from the extract, gm
W_4 = increase in weight of filter ring, gm

Appendix 10.9

Determination of In-Situ Density of Bituminous Course

The metallic tray of the field density unit is kept on a level spot of the bituminous surface and a hole, 10 cm in diameter, is cut up to the full thickness of the layer. All bituminous materials removed from the hole are carefully collected and weighed. The thickness of the layer is also recorded.

A known weight of dry standard sand passing 600 micron sieve and retained on 300 micron sieve, is taken in the sand-pouring cylinder. The cylinder is kept directly over the hole, and the shutter of the cylinder is released without any jerk and closed when the hole is filled with the sand. The quantity of the residual sand in the cylinder as well as the quantity filling the cone of the cylinder are separately weighed.

The in-situ density of the layer is calculated as follows:

$$\text{In-situ density} = (A*D)/(W-(W_1+W_2)) \text{ gm /cc}$$

Where,

A = Weight of bituminous materials removed from the hole cut in the layer, gm
W = initial weight of sand taken in the cylinder, gm
W_1 = weight of sand filling the cone of the cylinder, gm
W_2 = weight of sand remaining in the cylinder, gm
D = bulk density of sand, gm/cc.

Prior calibration for depth of hole, is necessary.

Appendix 10.10

Rate of Spread of Aggregates in Surface Dressing

The rate of spread of aggregates by the aggregate spreader or any other suitable means can be checked by measuring the area covered by each lorry/truck/any other device of known capacity. This can also be checked by removing the spread aggregates from small areas of the road surface and weighing them. A 20 cm square metal frame is laid on the new surface dressing, and all the aggregates within the enclosed area are collected, washed in solvent to remove bitumen and then weighed, and the rate of spread of aggregates is calculated. It is measured along the road at intervals of between 4 m to 8 m. The variation in the rate of spread of aggregates should be within ± 20 per cent of the mean.

Appendix 10.11

Checking of Surface Regularity Using a Straight Edge

The procedure to be followed for checking the surface regularity with a straight edge is as follows:

(i) The 3 metre straight edge may be made of steel or seasoned hard wood. When made of wood, it may be 75 mm wide and 125 mm deep and its test face should preferably be lined with a metallic plate. The edge should be perfectly straight and free from warps, rots or defects of any kind.

(ii) Periodically, the straight edge should be checked for its trueness with a string or a metallic master straight edge. The straight edge should be rectified or replaced as soon as the same has lost its trueness.

(iii) The depressions under the straight edge are to be measured with a graduated wedge. The wedge should be preferably be metallic but may alternatively be of seasoned upto 25 mm with a least count of at least 3 mm.

(iv) For recording depressions in the longitudinal profile of the road surface, the straight edge is placed longitudinally, parallel to the centre line of the road. Measurements along two parallel lines may normally be sufficient for a single lane road.

(v) The straight edge has limitations as regards the measurement of undulations at vertical curves. Additional templates or straight edges may be made for this purpose specially if the curves are sharp.

(vi) The straight edge may be placed at the starting point with the wedge inserted between it and the test surface, where the gap is maximum, and the reading is taken. The wedge may then be slided forward by about 1.5 m distance and the wedge reading is recorded. This process is continued. The straight edge need not always be moved forward to record the maximum depression existing at a location. Locations with depressions in excess of the specified magnitude should be marked on the surface.

A team of three persons consisting of two workmen and a supervisor would be required for one straight edge and two graduated wedges. The two workmen will operate the straight edge, while the supervisor will record measurements with the wedges and do the markings on the road.

Form No. BL-3

Format 10.1

Checking Rate of Spread of Binder in Surface Dressing and Bitumen Bound Aggregate Course

Tray Size : 20 x 20 x 3 cm. Date :

Tray No.	Wt. of Bitumen on tray	Rate of spread	Acceptable limit
			± 10% of the specified rate of spread in contract document

Layer	Value	Permissible Limit
		As per specifications

Checked By : Tested By :

Form No. BL-4/GB-1/RP-7

Format 10.2

Aggregate Impact Value of Aggregate [IS:2386 (Part-4)]

Sample No. : Date :
Name of Quarry/Location :
Date of Testing :

Observations	Test Nos. 1	2	3	Av.
Weight of aggregate sample filling in the cylinder = W1 (gm)				
Weight of aggregate passing 2.36 mm sieve after the test = W2 (gm)				
A.I.V. = W2/W1 x 100				

Layer	Value	Permissible Limit
		<30% for wearing course

Checked By : Tested By:

Form No. BL-5/GB-3

Format 10.3

Flakiness Test of Aggregate (IS:2386 Part-1)

Sample No. :
Name of Quarry/Location :
Date of Testing :

Size of aggregate		Wt. of the fraction consisting of at least 200 pieces (gm)	Thickness gauge size, (0.6 times the mean sieve) (mm)	Weight of aggregate in each fraction passing thickness gauge, (gm)
Passing Through I.S. Sieve, (mm)	Retained on I.S. Seive, (mm)			
63	50	W1 =	23.90	w_1 =
50	40	W2 =	27.00	w_2 =
40	31.5	W3 =	19.50	w_3 =
31.5	25	W4 =	16.95	w_4 =
25	20	W5 =	13.50	w_5 =
20	16	W6 =	10.80	w_6 =
16	12.5	W7 =	8.55	w_7 =
12.5	10	W8 =	6.75	w_8 =
10	6.3	W9 =	4.89	w_9 =
Total		W =		w =

$$\text{Flakiness Index (F.I.)} = \frac{w}{W} \times 100 = (\%)$$

Layer	Value	Permissible Limit
		As per Specifications

Checked By :

Tested By :

Form No. BL-7/GB-5

Format 10.4

Water Absorption Test of Aggregate [(IS:2386 (Part-3)]

Sample No. Date of sampling :

Name of Quarry/Location : Date of Testing :

Size of aggregate : Type of aggregate:

Observations	Test Number		
	1	2	Mean value
Wt. of saturated surface dry aggregate in air (W1) gm			
Wt. of oven dried aggregate in air (W2) gm			
Water absorption = (W1-W2) x 100/W2 (%)			
Mean value of Water absorption =			

Layer	Value	Permissible Limit
		Max. 2%

Checked By : Tested By :

Form No. BL-8/GB-2/RP-6

Format 10.5

Data Sheet for Sieve Analysis of Aggregate (IS:2386 Part-1)

Road/Section Details : Date :

Sample No. : Weight of sample taken : (gm)

I.S Sieve designation	Wt. of sample retained (gm)	Per cent of Wt. retained (%)	Cumulative per cent of Wt. retained (%)	Percentage of Passing (%)

Layer	Value	Permissible Limit
		As per specifications

Checked By : Tested By:

Form No. BL-9/BL-14

Format 10.6

Binder Content Test

Name & Category of the Road :

Type of Wearing Course :

Chainage of the Section :

Date of Testing :

Sl. No.	Observations	1	2	3
1.	Wt. of mix taken before extraction (A)			
2.	Wt. of filter paper before extraction (B)			
3.	Wt. of mix after extraction (C)			
4.	Wt. of filler paper after extraction (D)			
5.	Wt. of filler collected from extract after allowing for setting (E)			
6.	Wt. of filler collected in filter paper (B-D) = F			
7.	Wt. of aggregate + filler collected after extraction (C + E + F) = G			
8.	Percentage of Bitumen (in the mix) $\frac{(A-G) \times 100}{A}$			

Layer	Value	Permissible Limit
		As per specifications

Checked By :

Tested By :

Format 10.7

Form No. BL-10/EW-7/GB-6/RP-/SB-5

Depth of Pavement Quality Concrete/Dry Lean Cement Concrete/Dry Lean Cement Flyash Concrete/Roller Compacted Concrete Slabs at the Time of Construction

Sample Identification No.	
Date of Testing:	No. of Reading : At every 3 meter longitudinally and transversely

Sl.No.	Location No.	Measurement of Depth using Wooden Blocks (cm)	Specified Depth (cm)	Deviation to be corrected more than or less than specified (cm)
1.				
2.				
3.				
etc.				
Average Depth (cm)				

Layer	**Value**	**Permissible Limit**	
		Specified depth	Variation shall be within specified limit as mentioned in Quality Control Chapter

Checked By :

Tested By :

Form No. BL-11

Format 10.8

In-Situ Density of Bituminous Course

Location: Date:

(A) Wt. of bitumens material removed from hole cut in the layer gm.	w Initial weight of sand taken in the cylinder, gm.	w1 weight of sand filling the cone of cylinder gm.	w2 weight of sand remaining in the cylinder gm.	D Bulk density of sand gm/cc.	{(AxD)/w-(w1+w2)} x 100 In-situ density	Acceptable Limit
						As per contract document

Layer	Value	Permissible Limit
		As per specifications

Checked By : Tested By :

Form No. BL-12

Format 10.9

Rate of Spread of Aggregate in Surface Dressing

Location : Date :

Area considered for test	Wt. of aggregate	Rate of spread	Acceptable limit
			The variation in the rate spread of aggregates should be within ± 20 per cent of the mean

Layer	Value	Permissible Limit
		As per specifications

Checked By: Tested By :

Form No. BL-13/RP-8

Format 10.10

Soundness Test of Aggregate

Sample No. :

Date of sampling :

Name of Quarry/Location:

Date of Testing:

Type of reagent used:

Number of cycle:

Type of coarse aggregate sample:

Sieve size, mm		Grading of original sample (%)	Wt. of each fraction before test, gm	Percentage passing finer sieve after test (actual per cent loss)	Weighted average (corrected percentage loss)
Passing	Retained				
1	2	3	4	5	6
60	40				
40	20				
20	10				
10	4.75				

Number of particles coarser than 20 mm before test			Number of particles affected, classified as to the number disintegrating, splitting, crumbing, cracking or or flanking		
Passing	Retained	Number before test			
40 mm	20 mm				
60 mm	40 mm				

Layer	Value	Permissible Limit
		Max. 12*% / 18%**

*Sodium sulphate solution **Magnesium sulphate solution

Checked By :

Tested By :

Form No. EW-1/SB-1

Format 10.11

Sieve Analysis [IS:2720 (Part 4)-1985]

Road/Section Details: Date:

Dry Sieving: Weight of soil sample taken: (gm)

I.S. Sieve designation	Weight of sample retained (gm)	Per cent of weight retained (%)	Cumulative per cent of weight retained (%)	Percentage Passing (%)
40 mm				
25 mm				
20 mm				
10 mm				
4.75 mm				

Wet Sieving

Wt. of Sample taken: (gm)

I.S. Sieve designation	Weight of sample retained (gm)	Per cent of weight retained (%)	Cumulative per cent of weight retained (%)	Percentage Passing (%)
2.36 mm				
1.18 mm				
600 micron				
425 micron				
75 micron				

Summary of Results

Clay/silt (-75 micron) (%)	
Sand (-4.75 mm, + 75 micron) (%)	
Gravel (-40 mm, + 4.75 mm) (%)	

Layer	**Value**	**Permissible Limit**
		Not Specified

Checked By: Tested By :

Form No. EW-2/GB-4/SB-2

Format 10.12

Liquid Limit & Plastic Limit Tests (IS:2720 Part-5)

Sample No. :

Date of Testing :

Sample Details:

Type of Soil:

Determination of Liquid Limit (LL):

Sl.No.	No. of Blows	Tin No.	Wt. of Tin (gm)	Wt. of Tin + wet woil (gm)	Wt. of Tin + dry soil (gm)	Loss of water (gm)	Wt. of dry soil (gm)	Moisture content (%)

Liquid Limit (LL) = ... (%)

Layer	Value	Permissible Limit
		< 70%

Determination of Plastic Limit (PL):

Sl. No.	Tin No.	Wt. of Tin (gm)	Wt. of Tin + wet soil (gm)	Wt. of Tin + dry soil (gm)	Loss of water (gm)	Wt. of dry soil (gm)	Moisture content (%)

Plastic Limit (PL) = ...(%)

Plasticity Index (LL-PL) =

Layer	Value	Permissible Limit
		< 40%

Checked By.:

Tested By :

Form No. EW-3/EW-6

Format 10.13

Moisture Content Test of Soil

Name & Category of the Road: Date of Testing:

Location of test point: Type of soil (visual):

Sample No.	Tin No.	Wt. of Tin (gm)	Wt. of Tin + wet soil (gm)	Wet.of Tin + dry soil (gm)	Loss of water (gm)	Wt. of dry soil (gm)	Moisture content (%)

Layer	Value	Permissible Limit
		Not Specified

Checked By: Tested By :

Form No. EW-4

Format 10.14

Proctor Density Test of Soil (IS:2720 Part-7)-1983]

Road/Section Details : Date :

Sample No.: Weight of Dry Soil:

Description of sample	
Type of test	Standard Proctor
Volume of mould (cc)	
Per cent retained on 20 mm IS Sieve	

S. No.	Weight of mould + compacted soil (gms)	Weight of wet soil (gms)	Wet density (gm./cc)	Moisture content determination							Dry density (gm/cc)
				Container No.	Weight of container (gms)	Weight of container + wet soil (gms)	Weight of dry soil (Ws) (gms)	Weight of water (gms)	Weight of container + Dry soil (gms)	Moisture Content (%)	
1.											
2.											
3.											
4.											
5.											
6.											

Layer	Value	Permissible Limit
		Not specified

Checked By : Tested By :

Form No. EW-5(A)/SB-8

Format 10.15

C.B.R. Test of Soil [IS:2720 (Part-16)]

Sample No.: Date of Testing:

Sample Details: Capacity of Proving Ring:

Date of casting of Mould: Value of one divn. In : kg.

Time of Penetration @ 1.25 mm/Min.	Penetration	Proving Ring Reading			Load Intensity (kg/cm²) (A) x One divn. Value Area of Plunger			Corrected Load Intensity (kg/cm²)			Standard Load Intensity (kg/cm²)	Unsoaked/Soaked C.B.R. (%) C x 100 / D			Average C.B.R. (%)
		(A)			(B)			(C)			(D)	(E)			
Min. Sec.	(mm)	i	ii	iii	i	ii	iii	i	ii	iii	Std.	i	ii	iii	
0 - 0	0.0														
0 - 24	0.5														
0 - 48	1.0														
1 - 12	1.5														
1 - 36	2.0														
2 - 0	2.5										70				
2 - 24	3.0														
3 - 12	4.0														
4 - 0	5.0										105				
6 - 0	7.5										134				
8 - 0	10.0										162				
10 - 0	12.5										183				

Av. C.B.R. at 2.5 mm penetration: (%)
Av. C.B.R. at 5.0 mm penetration: (%)
Av. Saturation Moisture Content: (%)
Av. Swelling: (%)

Layer	Value	Permissible Limit
		Design CBR

Checked By: Tested By :

Form No. EW-5(B)/SB-3

Moisture Content Test of Soil (IS:2720 Part-2)

Sample No. :

Sample Details:

Date of Testing:

Mould Nos.	Tin No.	Tin wt. (gm)	Tin + wet. Soil wt. (gm)	Tin + Dry Soil wt. (gm)	Loss of Water [(B)-(C)] (gm)	Dry Soil wt. [(C) - (A)] (gm)	M.C. $\frac{D}{E} \times 100$
		(A)	(B)	(C)	(D)	(E)	(%)
i.							
ii.							
iii.							
						Average S.M.C. (%)	

Layer	Value	Permissible Limit
		Not any

Checked By :

Tested By :

Form No. EW-5(C)

Format 10.16

Swelling Test of Soil

Sample No. :

Sample Details :

Date of casting specimen :

Date of testing:

Mould Nos.	Height Specimen	Dial gauge reading		L.C. of dial gauge	Total Swelling (C-B) X D	Swelling $\frac{EX100}{A}$
	(mm)	Initial	Final	(mm)	(mm)	(%)
	A	B	C	D	E	
1						
2						
3						

Layer	Value	Permissible Limit
		< 2%

Checked By :

Tested By :

Form No. EW-8/SB-4

Format 10.17

Density of Sand

Date of Testing:

Type of Sand : + 600 μ - 1.0 mm

Sl. No.	Observations	Test Nos. 1	2
1.	Wt. of sand taken (gm)		
2.	Volume of calibrating cylinder (cc)/ml V		
3.	Wt. of sand remaining after filling cylinder and cone (gm)		
4.	Wt. of sand released in cylinder and cone (gm)		
5.	Wt. of sand required to fill the cone (gm)		
6.	Wt. of sand required for filling the cylinder (gm) M		
7.	Density of sand (gm/cc) M/V		

Format 10.18

Field Compaction Test of Soil (IS:2720 Part-28)

Name & Category of the Road:
Location of test point:
Type of layer:

Date of Testing:
Thickness of layer: cm.

Sl.No.	Observations	Test Nos. 1	2
1.	Wt. of sand taken (gm)		
2.	Wt. of wet soil removed (gm)		
3.	Wt. of sand remaining after filling hole & funnel (gm)		
4.	Wt. of sand released (gm)		
5.	Wt. of sand requied to fill the cone (gm)		
6.	Wt. of sand filling the hole (gm)		
7.	Density of sand (gm/cc)		
8.	Moisture content (%)		
9.	Density of soil (gm/cc)		

Moisture content

Sl. No.	Observations	1	2
1.	Tin No.		
2.	Wt. of Tin (gm)		
3.	Wt. of Tin + wet soil (gm)		
4.	Wt. of Tin + dry soil (gm)		
5.	Loss of water (gm)		
6.	Wt. of dry soil (gm)		
7.	Moisture content (%)		

Layer	Value	Permissible Limit
		>97% (Embankment)
		>100% (Subgrade)

Checked By:

Tested By :

Form No. RP-1(A)

Format 10.19

Consistency of Cement by Making Standard Cement Paste

As per IS:4031 (Part-4)-1988

Sample Identification No. :	
Date of Testing:	No. of Samples:

Sl.No.	Specimen No.	Net weight of Cement (gm) (Wc)	Weight of water required for penetration of 5 to 7 mm from the Bottom (gm) (Ww)	Per cent water for standard consistency (%) $= \frac{Ww}{Wc} \times 100$
1.		500		
2.		500		
3.		500		
etc.				
Average Standard Consistency (%)				

Layer	Value	Permissible Limit
		Normal Range of Standard Consistency (%) 25-32%

Checked By :

Tested By :

Form No. RP-1(B)

Format 10.20

Mortar Cube Compressive Strength of Cement As Per IS:4032 (Part-6)-1988

Sample Identification No.	Age (Days) 3, 7, 28 days
Date of Testing	No. of Sample = 3 for each test
Temperature and Humidity	27 ± 20C, Relative Humidity = 90 per cent
Mix Proportion by weight	200 g cement: 600 g Standard sand
Rate of Loading	350 kg/sqcm/minute
Water	[(P/4) +3] per cent by weight of total dry material, where P = Standard Consistency as determined above

Sl.No.	Specimen No.	Plan Area of cube mould 7.06 x 7.06 (cm^2) A_p	Maximum Applied Load Just Before Failure (3/7/28 days) (kg) W_f	Compressive Strength (kg/cm^2) (W_f/A_p) = S_a
1.				
2.				
3.				
etc.				
Average : compressive strength of sample (kg/cm^2)				

Layer	Value	Permissible Limit	
		Specified Compressive Strength of Sample (kg/cm^2) 3, 7, 28 days	Given in the Material Chapter for 33 Grade and 43 Grade Cement As per IS:269 and IS:8112

Checked By:

Tested By :

Form No. RP-1(C)

Format 10.21

Initial and Final Setting Time of Cement by Making Neat Cement Paste As Per IS:4031 (Part-5)-1988

Sample Identification No.:	
Date of Testing:	No. of Samples
Weight of Water (gm)	0.85P, where P = Standard consistency

Sl.No.	Specimen No.	Net Weight of Cement (gm) (W_c)	Time required for penetration of (Minutes)	
			5 ± 0.5 mm from the Bottom for Initial Setting Time	Needle makes an impression while attachment fails to do so for Final Setting Time
1.		500		
2.		500		
3.		500		
etc.				
Average Initial Setting Time (Minutes)				
Average Final Setting Time (Minutes)				

Layer	Value	Permissible Limit	
		Minimum Specified Initial Setting Time (Minutes) as per IS:269-1984/IS:8112-1989	30 Minutes
		Maximum Final Setting Time (Minutes) as per IS:269-1984/IS:8112-1989	600 Minutes

Checked By:

Tested By :

Form No. RP-1(D)

Format 10.22

Fineness of Cement (Blain Air Permeability Method) As per IS:4031 (Part-2)-1988

Sample Identification No. :	
Date of Testing:	No. of Samples

S.No.	Specimen No.	Net Weight of Cement (gm) (W_c) = ρ V (1-e), where p=mass density g/cucm V = Bulk volume of bed of cement, cucm e=Desired porosity	Time required		Permeability as per IS:4032 (Part 2) Sq.cm/gm
			Measured time interval in seconds with cement sample	Measured Time Interval in Seconds with Standard Sample	
1.					
2.					
3.					
etc.					
Average Permeability, Sqcm/gm					

Layer	Value	Permissible Limit	
		Minimum Specified value of fineness sqcm/gm as per IS:269/IS:8112	Details given in Material Chapter

Checked By :

Tested By :

Form No. RP-1(E)

Format 10.23

Soundness of Cement by Making Neat Cement Paste As Per IS:4031 (Part-3)-1988

Sample Identification No.:	
Date of Testing:	No. of Sample
Weight of Water (gm)	0.78P, where P = Standard consistency

Sl.No.	Specimen No.	Weight of Cement (gm) (W_c)	Distance separating the indicator points (mm)	
			Before submerging the mould with sample into the boiling water	As submerging the mould with sample into the boiling water for 3 hours
1.		500		
2.		500		
3.		500		
etc.				
Average distance (mm)				

Layer	Value	Permissible Limit	
		Maximum Specified Distance IS:269/IS:8112	Not more than 10 mm

Checked By:

Tested By :

Format 10.24

Form No. RP-2(A)

Compressive Strength of Concrete Cube as per IS:516-1959

Sample Identification No. :	Age (Days) 7 and 28 days
Date of Testing:	Minimum No. of samples = 3 for each test
Temperature and Humidity	27 ± 2°C, Relative Humidity = 90%
Mix Proportion by weight	As specified or as per mix design IRC:44/IS:10262-1982
Rate of loading	140 kg/sqcm/minute
Workability	As per the requirement of Slump/Compaction Factor

S.No.	Specimen No.	Plan Area of cube mould 15x15 (cm^2) A_p	Maximum Applied Load Just Before Failure 7 and 28 days (kg) W_f	Compressive Strength (kg/cm^2) (W_f/A_p) = S_a	
				7 days	28 days
1.					
2.					
3.					
etc.					
Average Compressive Strength of Concrete Sample (kg/cm^2) at 7 and 28 days nearest to 1 kg/sqcm					

Layer	Value	Permissible Limit	
		Specified Compressive Strength for concrete sample (kg/cm^2) at 7 and 28 days	Individual Variation = ± 15% of the average

Checked By :

Tested By :

Format 10.25

Form No. RP-2(B)

Flexural Strength of Concrete Beam as per IS:516-1959

Sample Identification No.:	Age (Days) 7 and 28 days
Date of Testing:	Minimum No. of Samples = 3 for each test
Temperature and Humidity	27 ± 2°C, Relative Humidity = 90%
Mix Proportion by weight	As specified or as per Mix Design IRC:44/ IS:10262-1982
Rate of loading	7 kg/sqcm/minute or 100 kg/minute
Workability	As per the requirement or Slump/Compaction Factor

Sl.No.	Specimen No.	Size of beam mould 10 x 10 x 50 L = 40 cm B = 10 cm D = 10 cm L - Effective Length B - Breadth D - Depth	Maximum Applied Load Just Before Failure at 7 and 28 days (at two points) as per IS:516-1959 (kg) W	Flexural Strength (kg/cm²) ($W_f L/BD^2$) if a >11 cm ($3 W_f L/BD^2$) if a less than 13.3 cm but greater than 11 cm. a = equals the distance between the line of fracture and the nearest support measured on central line of the tensile side of the specimen 7 days	28 days
1.					
2.					
3.					
Average flexural strength of concrete sample (kg/cm²) at 7 and 28 days, nearest to 0.5 kg/sqcm					
Specified flexural strength of concrete sample (kg/cm²) at 7 and 28 days					

Layer	Value	Permissible Limit	
		Specified flexural Strength of Concrete Sample (kg/cm²) at 7 and 28 days	Individual Variation = ± 15% of the average The flexural strength of concrete for pavement quality concrete or roller compacted concrete for wearing course shall not be less than 40 kg/cm²

Checked By:

Tested By :

Form No. RP-5

Format 10.26

Workability of Concrete

Sample Identification No.:	
Date of Testing:	No. of Sample
Quality of Concrete	Good/Bad
Weight of Water (gm)	

Sl.No.	Specimen No.	Concrete taken from (Place)	Value of slump test or compacting factor test
1.			
2.			
3.			
4.			

Layer	Value	Permissible Value	
		Slump	10-25 mm
		Compacting Factor	$0.87 \pm .03$

Checked By:

Tested By :

Format 10.27

Form No. SP-1

Water Absorption of Paver Blocks

Sample Identification No.:	Age (Days)
Date of Testing:	No. of Samples

Sl.No.	Specimen No.	Wet Weight of Block (gm) (W_w)	Dry Weight of Block (gm) (W_d)	Per cent Water Absorption $\frac{W_w - W_d}{W_d} \times 100$
1.				
2.				
3.				
etc.				
Average Water Absorption of Sample (%)				

Checked By :

Tested By :

Form No.SP-2

Format 10.28

Compressive Strength of Paver Blocks

Sample Identification No.	Age (Days)
Date of Testing:	No. of Samples

Sl.No.	Specimen No.	Plan Area (cm^2) A_p	Maximum Applied Load Just Before Failure (kg) W_f	Apparent Compressive Strength (kg/cm^2) $(W_f/A_p) = S_a$	Corrected Compressive Strength (kg/cm^2) S_a x Factor From Table 10.12 as applicable
1.					
2.					
3.					
etc.					
Average Corrected Compressive Strength of Sample (kg/cm^2)					

Checked By:

Tested By :

Chapter 11

MAINTENANCE

11.1. Introduction

Road maintenance is a routine work performed to upkeep pavement, shoulders and other facilities provided for road users, as nearly as possible in its constructed conditions under normal conditions of traffic and forces of nature. The maintenance is essential to get optimum service from the pavement structure during its life period. All pavements require maintenance as they are subjected to the traffic and environmental effects. Maintenance helps in preserving the pavement surface, and prevents untimely rehabilitation. Also, the maintenance of shoulders, CD works and road furniture is equally important. Unsealed roads get deteriorated at faster rate as compared to the sealed roads and hence needs greater attention. Also maintaining the cross profile (for proper surface drainage) and repair of pot holes need special attention. Maintenance requirements are also dependent on traffic, terrain, soil type etc. However, there are proven maintenance methods, which are applicable to the different regions in the country.

11.2. Distresses/Defects in Pavements

Various types of distress/defects of pavements are listed below:

I. Flexible Pavements

(i) **Cracks:** Separation of the pavement due to natural causes, traffic action, or reflections from an underlying pavement.

(ii) **Alligator Cracks:** Interconnected cracks forming a series of small blocks resembling an alligator's skin or chicken wiremesh

(iii) **Bleeding:** The upward movement of bitumen in a bituminous pavement resulting in the formation of a film of bitumen on the surface.

(iv) **Corrugations:** A form of plastic movement typified by ripples across the pavement surface.

(v) **Depression/Settlement:** Localised low areas of limited size that may or may not be accompanied by cracking.

(vi) **Disintegration:** The breaking up of a pavement surface from its original shape.

(vii) **Ravelling:** The progressive separation of aggregate particles in a pavement from the surface downward or from the edges inward.

(viii) **Rutting:** channelised depressions that may develop in the wheel tracks of the bituminous pavement.

(ix) **Potholes:** Bowl shaped holes of varying sizes in the pavement, resulting from localised disintegration.

(x) **Shoving:** A form of plastic movement resulting in localised bulging of pavement.

(xi) **Upheaval:** The localised upward displacement of a pavement due to swelling of the subgrade or some portion of the pavement structure.

II. Semi-Rigid and Rigid Pavements

(i) **Blow-up:** The localised buckling or shattering of a rigid pavement occurring usually at transverse crack or joint.

(ii) **Pumping:** The ejection of mixture of water, sand, clay and/or silt under passing wheel loads, along transverse or longitudinal joints and cracks and along pavement edges.

(iii) **Reflection cracks:** Cracks in the asphalt overlays that reflect the crack pattern in the rigid pavement structure underneath.

(iv) **Scaling:** The peeling away or disintegration of cement concrete pavement.

(v) **Spalling:** The excessive joint deformation in concrete pavement leading to over-hang of slabs at joints and subsequent cracking.

11.3. Definitions of Maintenance Activities

Some of the terms related to the maintenance activities are defined below :

(i) **Fog Seal:** A light application of slow-setting asphalt emulsion diluted with water. It is used to renew old asphalt surfaces and to seal small cracks and surface voids.

(ii) **Prime Coat:** An application of a single coat of liquid bituminous material, like an emulsified asphalt (low-viscosity cutback in case of locations at sub-zero temperatures). It is used only on an untreated base prior to placement of the asphalt pavement.

(iii) **Seal Coat:** A thin asphalt surface treatment used to waterproof and improve the texture of an asphalt wearing surface. Depending on the purpose, seal coats may or may not be covered with aggregate. The main types of seal coats are fog seals, aggregate seals, slurry seals, and sand seals.

(iv) **Bituminous Surface Treatments:** Applications of bituminous materials to any type of road or pavement surface, with or without a cover of mineral aggregate, that improve the surface condition and produce an increase in thickness of less than 25 mm.

(v) **Tack Coat:** A very light application of bituminous material applied to an existing bituminous or cement concrete surface, used to ensure a bond between the surface being paved and the overlying course. Bituminous emulsion diluted with water is the preferred bituminous material.

11.4. Investory of Road and Inspection

Frequent close inspection of pavement (at least once in 3 months) is necessary to ascertain the needs of the maintenance of the pavement. Generally, there should be a pre and post-monsoon inspections of the road to assess the maintenance requirements. An important step towards planning of maintenance activities and working out their relative priorities is to have inventory of different roads in a given area in terms of categories, physical features, condition, structural capacity, etc. to cover the following:

(i) Classification/category of road.

(ii) Location of protection works, streams, CD works, etc.

(iii) Type of surface.

(iv) Lane width of the road

Apart from visual inspection the evaluation of pavement may be made on the basis of deflection, roughness etc. to decide about rehabilitation for high traffic roads.

11.5. Types of Maintenance

The maintenance activities are divided into two categories:

(i) Preventive maintenance

(ii) Corrective maintenance

Preventive maintenance activities includes repairs to small sized potholes, crack sealing, maintenance of shoulders, drainage systems, etc. Corrective maintenance includes patch repairs, surface treatments, renewal and overlays.

11.6. Classification of Maintenance Activities

As per IRC:82, maintenance operations can be classified as 1) Routine maintenance, such as, pothole filling, filling the cracks, etc. round the year, 2) Periodic maintenance covering renewals, which are required to be done at periodic interval every few years, and 3) Rehabilitation and strengthening, which includes major restoration or upgrading of pavement through reconstruction or application of overlays to correct the structural deficiencies. Maintenance of rural roads, like, other roads, will generally include activities as given under:

(a) Routine Maintenance/Ordinary Repairs

(i) Routine maintenance and up-keep of road components such as road formation, retaining walls, breast walls, culverts, bridges, causeways, pavement and other appurtenances.

(ii) Clearance of landslides/slips caused by rains or other natural causes in hilly terrain.

(iii) Clearance of snow in high altitude/snow bound areas.

Periodicity of various activities under routine maintenance is given in ***Appendix-11.1***.

(b) Periodical Renewals

Periodical activities will include those activities which are not of routine nature and are taken up at certain periodicity, specified or otherwise, to maintain the health of the road components. One such periodical activity is the renewal of wearing course of carriageway based on guidelines on life cycle and specifications of the road. List of tools and plants frequently required for maintenance is given in ***Appendix-11.2*** (A and B).

(c) Special Repairs

Damages resulting from usage, accident, comprising of repairs and rehabilitation, which can be covered under the scope of ordinary repairs/routine maintenance, but of a relatively large magnitude is included as special repairs. Special requirements of high rainfall and snow bound areas are given in ***Appendix-11.3***.

11.7. Maintenance

For maintenance purpose rural roads are classified into four types:

(i) Unsealed roads

(ii) Sealed roads

(iii) Roads with rigid/RCCP

(iv) Roads with special pavement

11.7.1. Unsealed roads : Following types of roads are considered under this category:

(i) **Earth Roads:** These roads are constructed generally by using local material available from borrow areas along the road alignment. These roads are not all-weather roads and get damaged heavily due to rains and traffic. They are generally upgraded with the availability of resources.

(ii) **Gravel Roads:** Gravel roads are basically earth roads covered or rolled with moorum or gravel which is available nearby. The performance of these roads is slightly better than the earth roads. The types of defects associated with earth roads also occur in the gravel roads.

(iii) **WBM Roads:** The WBM roads have the top layer of broken stone aggregate or good quality overburnt brick ballast (when stone is not available) of suitable size. The thickness of this layer depends on the volume and type of traffic. The thickness of the stone layer varies from 75 mm or more.

11.7.1.1. Assessment of defects and maintenance measures : The unsealed roads deteriorate fast as compared to sealed roads under traffic. Various defects and their measurements are as under.

(i) Loss of Profile, Camber and Cross Fall

(ii) Corrugations

(iii) Rut Formation

(iv) Ditches and Potholes

(v) Dust

(vi) Erosion Gully

(i) **Loss of Profile:** The camber is measured using 2 m camber board or template fitted with a spirit level. The measurement should be made on both sides of the centre line. The loose material from the sides can be scrapped and filled in ruts, deep potholes and the profile can be re-sectioned properly with the help of spade, pick-axes, or grader, etc. The loose material is then rolled properly after sprinkling of water over it. If required, the top layer can be provided with admixture of sand and moorum. Such a treatment would provide adequate strength to the top layer. It is essential that only non-plastic type of moorum should be used, at least for the top layer.

(ii) **Corrugations:** Corrugations are transverse undulations located closely at regular intervals. These are formed under dry condition due to cyclic pounding action of tyres of the vehicles crossing irregularities. Corrugations are measured at 200 m interval along the road. The depth of corrugations is measured with a calibrated wedge.

(iii) **Rut Formation:** The ruts are the longitudinal depressions that tend to follow the path of rolling vehicular wheels usually associated with the settlement of pavement under traffic stress and/or the dislodging of material. The depth of rut is measured using a straight edge and wedge scale. Measurements are made at 200 m interval along the road. The straight edge is placed transversely across each wheel track and the rut depth is measured with calibrated wedge.

(iv) **Potholes:** These are irregularly shaped depressions of various sizes and depth on the road surface and result from variety of causes, like :

- Poor initial compaction
- Poor quality of material
- Infiltration of water
- Degradation of pavement surface

Potholes are counted and recorded for every 100 m length of road. The counts are recorded as the number of potholes per 100 m length of the road.

(v) **Dust:** One of the most common defects of the unpaved road is dust. Dust comprising of the fine particles of soil rises up in the air under moving action of the vehicles. At high speeds the dust particles form a cloud of dust thereby reducing the visibility of the driver. The dust problem is maximum in the summer. It is more prominent with the earth road as compared to the WBM road.

(vi) **Erosion gully:** Erosion gullies are formed on earth/gravel roads on shoulders/slopes by rainwater. Gully formation is a complex process. The size and shape of the gully depends on the quantum of runoff. In general the gullies are deep when the rainfall is high and concentrated.

11.7.1.2. Maintenance measures : The following various measures are suggested to rectify defects of various types of unsealed roads:

(a) Earth Roads

Dust Control: To check the dust nuisance on the earth roads, the following measures are recommended:

- Application of calcium chloride in solution or in powder form at the rate of 0.25 to 1.25 kg/sqm depending upon the climatic conditions.
- Crude oil/used crude oil heated to 95°C is applied with sprayers at the rate of 2.5 to 4 lit. per sqm.
- Waste from sugar mills, pulp and paper mill is applied uniformly over the road surface. The surface is scarified to some extent and the waste material is thoroughly mixed. The surface is then compacted at or near OMC.

Patch Repairs, Ruts, Potholes, Corrugations Erosion Gullies: These defects can be rectified by patching or grading the road surface:

- Depression is filled with earth of same quality as that of earth road and water is sprinkled if needed, followed by compaction with light roller or ram with hand tamper.

(b) Gravel Roads : Gravel for repair work should be atleast as good in quality as that of material used in the construction. The suggested measures are as below:

Dust Control : To check the nuisance of dust on the gravel roads, the following measures are recommended.

Calcium chloride is applied in solution or in powder form at the rate of 0.25 to 1.25 kg/sqm depending upon the climatic conditions:

Patching: The following steps should be followed:

- Gravel is stacked on the shoulder near the spot.
- Loose material and water are removed from the patch to be repaired.
- The sides are cut vertical to reach the sound base.

- Patch should be filled with gravel of 100 mm thickness.
- If material is too dry, water is sprinkled to facilitate compaction and the layer is then compacted by a roller or hand tamper.
- Procedure is repeated as above to fill the entire patch.
- Finally the patch is filled with gravel upto 30 mm above the road surface, spread and raked to correct shape.
- Finally the layer is compacted by a roller or hand tamper to give surface slightly protruding above the surrounding level.

Loss of Shape, Corrugation, Potholes, Ruts: These can be rectified the same way as given under, patch repair for earth roads as above.

Renewal of Gravel Roads: Renewal of the surface is done when the surface is badly damaged due to potholes, corrugations and ruts and it is uneconomical to repair the defect individually. Gravel of the same quality as used in the road construction is obtained from the borrow area.

The surface to be renewed is scarified and the material is collected. Collected material is mixed with fresh material to the estimated quantity. To this mixed material water is added to achieve the desired water content. The wet mixed material is then laid on the surface to the required loose thickness and then compacted with 8 to 10 tonne roller or manually. The required camber and profile is maintained.

Resurfacing: Initial pass is made on each side of the roadway with motor grader scarifying/cutting the surface to depth of 100 mm.

- Material is placed to required depth.
- Material is spread with a blade to the required cross slope.
- Water (if needed) is sprinkled and compacted using a roller.
- It is ensured that the cross slope of shoulder is the same as that is required.
- The road surface is then cleaned.

The repairs to other defects shall be the same as for earth roads.

(c) WBM roads : A sizeable length of rural roads falls under this category. WBM surface develops various defects like potholes, ravelling, corrugations, etc., as the surface undergoes various stresses due to grinding action of solid iron-wheeled carts and also abrasion and pumping action due to fast moving pneumatic tyred traffic. Once a portion of WBM surface is disturbed, loose metal inflicts further damage to the adjoining WBM surface and thus a chain of damaging effect sets in. If the filler used for WBM surface is excessive and plastic in nature as in wet areas and non-plastic as in dry areas, the situation gets further aggravated in adverse weather conditions. Timely removal of the dislodged metal from the surface and blinding the surface with appropriate material like sand or moorum can save the road from deterioration. The works to be carried out under ordinary repairs and routine maintenance of WBM road can be listed as under:

(a) Collecting and stacking the picked up metal and periodically blinding the surface with binder
(b) Filling of potholes
(c) Re-sectioning of surface by pick and roll method.
(d) Collecting and stacking the picked up metal and blinding the surface by screening periodically.

Periodical blinding: It is observed that particularly in dry season the metal from the WBM surface gets dislodged. Due to traffic this loose metal abrades with the WBM layer and further dislodgement of metal takes place. In due course of time, the whole stretch of the road gets damaged. It is, therefore, essential to pick-up this loose metal and stack it properly by the roadside. This metal can be further used for filling of potholes. After picking up of the loose metal the surface should be covered with a thin layer of binder such as sand or moorum. Timely provision of binder would provide good riding quality to the road surface.

Filling of Potholes: The following procedure should be followed:

(i) The loose material in the affected spot is removed up to firm base.
(ii) The sides of potholes are trimmed vertical and the area is shaped to rectangular as far as possible.
(iii) The cavity is then filled-up with stone aggregates (similar in size used originally) keeping the filling slightly above the surrounding area.
(iv) The filler material (screenings/moorum/sand) is then spread on the filled-up aggregate.
(v) The aggregate layer is compacted by hand rammer.
(vi) Water is sprinkled on the hand compacted aggregate layer.
(vii) The layer is again compacted by hand ramming followed by road roller, if available.

Repairs to Ravelling by Pick and Roll Method: When the ravelling of the road surface is quite prominent and when the funds are not adequate to carry out full-fledged periodical renewal, resurfacing by 'pick and roll method' is resorted to. This is a cost-effective solution for maintenance of WBM surface of rural roads. In case of minor ravelling, patch repairs may be carried out.

(i) The stretch, which craves for resurfacing is, selected which should preferably be of adequate workable length. In this length about 20-30 per cent of the quantity of the aggregates required for providing full-fledged renewal of WBM coat, is collected depending on the extent of ravelling. The required quantity of moorum/screenings is also collected as a filler.
(ii) The whole surface is then picked up with a pickaxe to a depth of 40-50 mm as is done during resurfacing.
(iii) The depressions, ruts and potholes are filled-up with the metal collected earlier and the surface is brought to the desired grade and camber.
(iv) The surface is then rolled in dry condition with the help of 8-10 tonne roller.
(v) The moorum/screenings are then spread over the compacted surface. The surface is then adequately watered.
(vi) The wet rolling of the surface is carried out.
(vii) The balance quantity of moorum is provided as a binder to the surface.

This type of resurfacing has proved to be very cost effective. However, this treatment may not be adequate in heavy BC soil/clayey soils, water logged areas and sugarcane areas. In such areas periodical renewal may be the only way of maintaining the WBM road.

Periodical Renewal of WBM: In this process fresh WBM layer is provided over the existing deteriorated WBM surface. With the advent of pneumatic tyre vehicles, WBM surface deteriorates fast and the renewal of existing surface (after every 2-3 years) become necessary. The process of periodical renewal is the same as that of construction of new WBM layer. Untill now, 8-10 tonne static rollers were being used for WBM compaction. If vibratory rollers are used for WBM consolidation, the life of the renewed surface may be increased to some extent.

The common defects, their causes and needed maintenance measures applicable to unsealed roads are given in Table 11.1.

11.7.2. Sealed roads : Requirement of maintenance of sealed roads may not be same as that of unsealed roads. Major maintenance activities include:

- Maintenance of shoulders, drainage and structures
- Maintenance of surface defects
- Renewals and rehabilitation.

11.7.2.1. Maintenance of shoulders, drainage structures and causeways : The detailed information on maintenance of shoulders, drainage structures and causeways is given in ***Appendix-11.4***.

TABLE 11.1. COMMON DEFECTS, CAUSES AND MAINTENANCE MEASURES IN UNSEALED ROADS

Defect	Cause	Maintenance Measure
Ditch cross-section destroyed	Plying of vehicle/movement of animals	Reshaping/re-grading of ditch
Ponding in ditch and on shoulder	Insufficient ditch cross-section	Deepening of ditch
Silting of drain	Water flows slowly as the invert slope	De-silting of ditch and/or provision of turn out
Uneven ditch invert	Blockage caused by debris/vegetation	Clearing, cleaning and re-grading
Erosion of sides and bottom of ditch	Too steep gradient	Reinforcing of ditch slopes regarding or realignment of drain, ditch
Destruction of lined or precast drain	Poor alignment or change in flow direction	Erosion control and realignment of drain
Ditch lining damaged	Settlement/erosion of soil under ditch	Erosion repair and lining repair
Ponding, erosion	Insufficient lateral drainage	Provision of lateral drainage
Silting, blockage by debris of culvert	Too flat gradient, incorrect positioning of culvert	Clearing of debris and provision of debris arrester.

11.7.2.2. Maintenance and repairs of surface defects : The more common defects of bituminous surface of rural roads are:

(i) Potholes (iii) Cracking (v) Ravelling and bleeding
(ii) Deformations (iv) Edge damages

The road length to be maintained should be inspected at suitable interval to determine:

- Location where the defect usually appear
- Number and size of defect
- Apparent cause leading to defect
- Consequences likely if not repaired immediately
- Remedies to be applied
- Quality/type of material needed

The defects commonly occurring in bituminous surfaced roads, their causes and maintenance measures are given in Table 11.2.

TABLE 11.2. COMMON DEFECTS, CAUSES AND MAINTENANCE MEASURES IN SURFACED ROADS

Defect	Causes	Maintenance Measure
Bleeding Surface	Excess/Unsuitable binder	Spreading of aggregate chips
Surface and pavement structure cracks	Poor quality of material/workmanship Insufficient pavement crust excessive loads	Local sealing or filling in of cracks Strengthening
Ruts and depression	Poor quality of material inadequate pavement or subgrade strength	Slight rutting : filling Deep rutting : local restoration of pavement
Edge subsidence	Inadequate or badly maintained shoulders	Slight subsidence: filling of ruts and depressions and restoration of shoulders
Rutting	Loss of strength due to water penetration	Deep subsidence: Local restoration of pavement, improvement of drainage
Edge damage	Poor drainage Narrow road Shoulder damage due to action of water	Local restoration of pavement Repairs of shoulder
Potholes	Degradation of pavement structure, Poor quality of material, Infiltration of water Traffic	Cutting and removal of material upto affected depth, filling and compaction by ramming
Shoving	Failure of subgrade/sub-base, Water ingress, Poor materials, Poor workmanship, Heavy traffic	Cutting and removal of material upto full depth of affected area and refilling with appropriate materials in layers and compacting

Repairs of Potholes: If the bituminous surface is defective, then shallow potholes will develop on roads. The affected area is cut into a regular shape, preferably a rectangle with vertical sides. All the loose material is removed and tack coat of bitumen or bitumen emulsion is thoroughly applied on the exposed surface.

The premixed material prepared by mixing metal chips and bitumen is then placed layer by layer. The surface filled-up with premixed material is kept slightly proud of the surrounding area. The surface is then compacted by hand rammer followed by road roller, if available. The liquid seal coat or bitumen surface dressing is then applied to seal the surface. When the potholes are deep the affected area is cut into a regular shape preferably a rectangle with vertical sides, the loose material is removed from the potholes and the surface is properly cleaned with wire brush. The potholes are then filled-up by grouting method. The tack coat is applied at the base as well as on all sides of the potholes. The stone metal of 40 mm size is then spread and compacted, and then grouted by pouring required quantity of bitumen on it and then key aggregates are spread over it. Again, the required quantity of bitumen is applied to grout these layers. The material is compacted with hand rammer. This method is resorted to fill the potholes layer by layer till the finished surface of the pothole filling stands raised to the surrounding area. The top layer is then covered with a suitable bituminous mix and rolled by roller into the proper camber and profile.

Rectification of Deformations

- **Depressions:** The surface of the affected area should be scarified properly. The sides of the depressions are then cut to vertical. The tack coat is applied to the cut area and the depression is filled-up with premix bituminous material. The filling is then rolled properly with the power roller and the top surface is sealed by liquid seal coat. If the depression is large such as due to failure of sub-grade/base/sub-base, proper strengthening of the base or sub-base, as the case may be, is resorted to including providing proper drainage layer, if required.
- **Hump or heaving:** During high temperature, the bitumen from top layer flows to sides because of pressure of wheels especially in hot weather. This results into formation of humps at the edges and depressions at the centre. Such humps are to be removed by pick axes. The exposed surface is then properly treated with premix material and the road is brought to desired level and then rolled properly.
- **Camber correction:** The camber correction or cross slope of the pavements should be brought to the required standards with suitable bituminous levelling course. The thickness of layer depends on the extent of correction. Separate provision of profile correction layer should be made in the estimate. The camber correction must be made so that there is no stagnation of water on pavement surface during rainy season as it may lead to deterioration of the flexible pavement.

Sealing of Cracks: The cracks are opened and cleaned with brush. Tack coat of hot bitumen is then applied under pressure to fill-up the cracks. The treated surface is then covered with premix material. Hair cracks can be repaired by applying slow setting cationic emulsion evenly at the rate of 5 to 9 kg/sqm. Light tamping to the coat of bituminous emulsion is recommended.

Repairs of edge damages: Edge damages are observed in the following forms:

- Cutting of edges
- Sinking of edge strips and depressions
- Cutting of edges takes place when the road is narrow or proper side support is not available to the edge of the road from the well-compacted shoulders. If the shoulders are in a bad shape or depressed, the edges are damaged badly under moving wheels. These are repaired by cutting the damaged edges or digging the crust under the damaged portion. The crust is then rebuilt by grouting the metal layer and repairing the edges with premix bituminous mix. The shoulders are built-up simultaneously with moorum and duly compacted
- When edge strips sink heavily the reason could be that the shoulders are built-up in impervious material and they are preventing draining out of water from the subgrade. In such an eventuality the damaged portion needs to be opened up right up to sub-base layer. The layer shall then be removed and replaced with material having good drainage properties. Cross shoulder drains shall also be built to proper slopes to drain out sub-soil water effectively. The crust is then built-up layer by layer after proper compaction with a power roller. The shoulders shall also be built-up simultaneously. The top layer is then provided with BM layer, which is further, covered with a premix carpet layer.

Ravelling: If ravelling of the road surface is observed, then emulsified bitumen is applied to the surface, which is then topped with sand or slurry seal.

Bleeding: When excess quantity of binder is used in the surfacing, it tends to work to the top and then spread sideways. The spot or patch where bleeding has occurred becomes soft. The corrective measures are taken by spreading fine sand or metal chips over the soft spots and ramming it by hand rammer or rolling it with power roller, if available.

Periodical renewals: Periodical renewal consists of provision of a surfacing layer over the existing surface of the pavement at regular interval of time so as to preserve the required serviceability of pavement and offset the wear and tear caused by the traffic and climate stress. Based on the experience in the country, the following specifications are suggested for periodical renewals of rural roads:

- Single coat or two coat surface dressing as per IRC:17
- 20 mm thick premix carpet with seal coat as per IRC:14
- Mix seal surfacing as per Clause 508 of MoRT&H Specifications.

The specifications and thickness of renewal course should be such that the road surface is restored close to its original condition as far as possible. The following broad guidelines are recommended for the type and periodicity of renewals given in the Table 11.3.

TABLE 11.3. TYPE AND PERIODICITY OF RENEWALS

Traffic CVPD	Type and periodicity of renewal		
	Low Rainfall (1500 mm/year)	Medium Rainfall (1500-3000 mm/year)	High Rainfall (> 3000 mm/year)
<150	Surface dressing; 6 years	Surface dressing; 6 years	Surface dressing; 6 years
150-450	Surface dressing; 5 years	Surface dressing; 4 years	Surface dressing; 3 years
>450	OGPC/MSS; 6 years	OGPC/MSS; 5 years	OGPC; 4 years

Note: The Table is adopted from the Report of the Committee on Norms for Maintenance of Roads in India, Ministry of Road Transport and Highways, Govt. of India, October 2000.

Special Repairs: Under special repairs, the repairs, such as, filling of large potholes, side settlements, pavement rectification, etc. are carried out. The type of treatment to be adopted for special repairs needs to be carefully designed, so as to avoid recurrence of particular damage. Also if special repairs are carried out as per the requirements, it helps in sustaining the life of pavement.

Rebuilding and strengthening of existing pavement: The road pavements are designed for a particular design life. After this period, the pavement needs to be rebuilt or strengthened. Under rebuilding, a new pavement is constructed. In case of strengthening of existing pavement, overlays are laid over the existing road pavement for increasing the strength of the existing pavement. The requirement of overlays for strengthening of the existing pavement needs to be worked out on the basis of CBR method (IRC:37) of pavement design or Benklemen Beam Deflection method (IRC:81) based on the surface deflection measured normally on sealed roads. For these, separate IRC guidelines are available. The design of strengthening of the existing road pavement should also include the correction to the drainage facilities of the existing pavement, if any. The design of strengthening of existing pavement needs to be done by an experienced road engineer.

11.7.3. Semi-rigid and rigid/roller compacted concrete pavements (RCCP) : A rigid pavement roller compacted concrete pavement normally does not require any major maintenance, except maintenance of joints and riding surface only, when it is meticulously designed and constructed with precision for the designed traffic. In semi-rigid pavements and rigid/RCCP, the major defect is of riding quality, which can be maintained by laying with the same type of concrete over poor riding surface, after applying cement paste so that a monolithic slab can be formed. Care shall be taken to reduce the stresses at the interface (existing concrete surface shall be just wet when a coat of cement paste as primer is applied). However, at later stages, cracks may appear due to

many reasons. It is essential to examine the reasons for appearance of cracks, before any available repair measure is adopted. The condition of a pavement structure must be known, prior to attempting its repairs or maintenance. To know the condition of pavement structure, it is necessary to carry out its structural and functional evaluation to examine the various factors, which contribute to its failure or distress. There may be different types of distress in cement concrete pavements. These distresses contribute to many types of cracking, e.g., reflection cracking, corner cracking, longitudinal and transversal cracking, shrinkage cracking, elastic cracking, map cracking, warping of slabs, scaling and spalling of joints. In case of RCCP and semi-rigid materials, there are very less chances of shrinkage cracking as very less quantity of water is required for the construction of both the pavements. Methodology for the maintenance of semi-rigid pavement is almost similar to the methodology adopted for RCCP as concrete for both of them are compacted with road roller.

Joints are the weakest part in the cement concrete slabs. Filler and sealing materials shall be intact at joints. During summer, sealing materials are squeezed out of dummy contraction joints due to expansion of the slabs. During winter, gap opens out. Therefore, periodic maintenance of the joints is essential at expansion and dummy contraction joints as part of the routine maintenance work. The opened up joints are cleaned with brush and refilled with suitable joint sealer either with hot sealing or cold sealing compound. The cracks developed in rigid/RCCP may be classified in two groups:

(i) Temperature cracks which are initially hairline cracks between the dummy contraction joints of a slab and are formed due to warping and shrinkage stresses in the slab, and

(ii) Structural cracks are formed due to combined wheel-loads and warping stresses.

Many factors are responsible for the deterioration of rigid/RCCP. The causes for the same must be examined in details for further perfection of the design and maintenance.

11.7.3.1. Causes of deterioration : Many of the causes producing deterioration may be attributed to the following:

- Material failures due to poor quality of the material used
- External and internal forces of disruption in the pavement
- Moisture movement
- Unsupported corner
- Cracking/breaking and sinking of slab corners
- Environmental factors, sub-soil water table and rain water; and drainage failure
- Salt content in natural soil and water
- Harmful reactions of cement with aggregates; and salt action
- Porosity, and permeability
- Erosion of the base course and shoulders
- Failure of the joint sealing compound

11.7.3.2. Structural and functional evaluation : Before taking-up any maintenance or rehabilitation work of semi-rigid, rigid/RCCP pavement, it is essential to carry out the functional and structural evaluation.

Structural Evaluation: Data is required to be collected on the aspects of residual strength also.

(i) Sampling of hardened concrete

(ii) Crack-width and depth estimation

Decision about reconstruction (inlay), rehabilitation, overlay, or restoration of the riding quality through surface repairs and maintenance of joints has to be based on these data on distress.

Functional Evaluation: It takes into account the data produced by the following tests:

- Rideability (RCCP riding surface is not equally even as that of conventional concrete pavement. However, as per prevailing loading conditions in rural roads riding quality obtained with RCCP is sufficient for the low speed vehicles)
- Surface roughness (anti-skid braking)
- Apparently sound condition and no cracking
- Faulting, and rocking chunk formation
- Cracking types – small, medium, large, D-type, alligator or map type
- Alkali-aggregate reaction type
- A blow up of the edge-faces at joints of the adjoining slabs
- Faulting of slabs

11.7.3.3. Maintenance procedure : After having the pavement assessment and evaluation done, maintenance and rehabilitation can be considered, including full-depth patching, joint sealing and sub-surface drainage. Some suggested remedial measures may be adopted for rehabilitation of distressed semi-rigid, rigid and RCCP. These can be:

- Sealing/repairing of cracks
- Repairing of spalled joints
- Grout-jacking of slabs
- Replacing of distressed slabs with precast concrete slabs

Patch repair: All patches before repairs, shall be prepared preferably full depths, skewed and doweled (if the thickness of slab is more than 15 cm, dowels are generally provided at the neutral axis in the interior of the slab as per IRC:15) or undercut to achieve load transfer. Mis-aligned-dowel bars create high load-transfer stresses at the joints from one slab to the adjoining slab. Rust on the exposed tie (if provided between two lanes) or dowel bar is removed before repair is undertaken. Loose debris shall be removed with compressed air or a vacuum cleaner or air pump as per the availability. A seal coat is then applied. Repair material having adequate pot life (10 minutes to 30 minutes) and compressive strength 10 to 20 MPa at 24 hours may be used for filling up the void, such as, Epoxy or Magnesium Phosphate cement mortar or High Performance Concrete.

Scaling: Scaling of the slab surface is sometimes caused by poor construction techniques, such as bleeding and over-waters in the surface when finishing and compacting. The chloride and sulphate contents in the concrete, required for rehabilitation or maintenance shall not be more than the values permitted in IS:456-2000 "Code of Practice for Plain and Reinforced Concrete".

Joint Spalling: It is general deterioration of joints caused by excessive compressive stresses, which may be related to joint infiltration or to pavement growth caused by reactive aggregates. In this case, the aggregate expands because the reaction products occupy greater volume than the original aggregate structure. The general type of aggregate problem can lead to serious deterioration of joints subject to those that react adversely with other components of concrete mixtures. Joint spalling can be prevented by the use of high quality concrete, use of good construction practices, and by keeping joints well sealed. Spalls range from very small edge spalls to large spalls reaching several inches back into the slab or down into the joint. Small edge spall may be repaired with cement sand mortar with additives whereas for large spall, methodology adopted for blow-up repair may be used.

Joint and Crack Resealing: The resealing of in-service joints takes place in a totally different environment from sealing on newly constructed pavements. Guidelines for joint resealing have been provided by the IRC:57 and IS:11433-1980.

Medium cracks of 3-5 mm width should be dry and cleaned with compressed air and then treated with easily workable bituminous substances such as bituminous emulsion. Similarly cracks of width ranging from

5-25 mm should also be dry and cleaned with compressed air and then treated with hot sealing compound. Cracks greater than 25 mm width should be dry and cleaned with compressed air and then filled by caulking with a suitable filler material (wooden piece, sheet, small sized precast concrete blocks, jute etc.), and then sealed with sealing compound. The step-by-step procedure for repair of cracks is given as:

- **Brushing:** Joint must be thoroughly cleaned by brushing out loose dust, blowing out the cracks or joints with compressed air.
- **Removal of tightly packed debris:** When joints in an old road are to be resealed, they must first be cleaned of old sealing compound, broken pieces of concrete etc., with a pick.
- **Drying of joints:** Joints can be dried by a naked flame or hot air drier by fully competent workman.
- **Primer:** The bond between sealing compound and concrete can be improved by the use of primer, a viscous and sticky material (viscosity about 30 seconds). It may be 80/100 penetration grade bitumen to 20 per cent kerosene.
- **Sealing compound:** Filling the prepared crack/joint with suitable bitumen sealing compound.

Blow-ups: These are compressive joint failures brought about by excessive expansion related to high temperatures, high moisture contents, or a combination of the two. These become likely when normal joint movement is restricted by infiltration. Increase in concrete volume brought about by elevated temperatures and moisture contents create longitudinal thrust that may overcome the compressive strength of the weakest joint in the section. Blow-up tendency is more pronounced on pavements with long slabs where individual joint movements are greatest. The treatment should consist of either widening the sealing crack upto 30-40 mm to include failed area and re-sealing or cutting out all unsound material and forming a chase of roughly rectangular cross-section along side of the joint. Due measures are taken prior to allowing for reforming the joint seal, placing, compacting and curing a suitable repair material. Such a repair material is often pavement quality concrete or high performance concrete (which is generally obtained by adding 10 per cent silica fume as replacement of cement and 1-2 per cent super-plasticizer by weight of cement in conventional concrete) The maximum size of aggregate shall be 10 mm. Surfaces should be primed with cement grout immediately before application of fresh concrete.

For the maintenance, the slabs forming the joints shall be cut on each side of the blown-up joint. The cuts are made to full depth of the slab thickness and parallel to the joint with a diamond-blade concrete-cutting machine. The inlay space is thoroughly cleaned, oil applied on the open vertical faces of the slabs to prevent bonding with the parent slabs and the space is filled-up with M-35 grade cement concrete. The compaction and finishing should be done as per the normal practice.

Pumping: Closely related to joint faulting is the phenomenon known as pavement pumping. Pumping is the process of expulsion of water from under a pavement caused by the action of repetitive wheel-loads. Unfortunately, fine materials from the sub-base or subgrade often go into suspension and are expelled along with water. Solutions that are more permanent may be achieved by the restoration of load transfer and by the provision of positive drainage systems. Corner breaks are the result of excessive pumping or overloading.

Available repair material for patching: Generally, the materials used for crack, spall and patch repair are polyester and epoxy acrylate, early strength cements (jet set cements and admixtures), magnesia-based cement – Magnesium Oxy- Chloride (MOC) and Magnesium Poly-Phospahate Cements (MPC), Sulphur-sand mortars and special concrete. Methodology for repair of concrete is described in IRC:77 "Tentative Guidelines for Repair of Concrete Pavements Using Synthetic Resins". Based on the techno-economical feasibility study material for repair may be selected.

Rehabilitation: Five different pavement rehabilitation alternatives are generally considered quite common.

- Routine maintenance
- Concrete slab restoration
- 25 mm thick premix carpet as an overlay over concrete slab
- 40 mm thick bituminous macadam overlay in special case of weak soil
- Rehabilitation by 150 mm thick roller compacted concrete.

Maintenance shall start from the day one after the completion of the construction of a road. Once a road is constructed it must be maintained at least to a minimum level of acceptable serviceability. The amount of maintenance required by a well designed and well-constructed concrete road is small. More attention should, however, be given to maintenance so that any defects can be treated at an early stage and the amount of deterioration reduced. To repair the deterioration especially cracks, there are advantages of using bitumen as it enables the work to proceed more quickly and economically. Bitumen provides a seal, which retards the ingress of water.

11.7.4. Special pavements

11.7.4.1. Concrete block/interlocking concrete block pavement (CBP/ICBP) : CBP/ICBP failure can mainly be in the form of excessive/uneven settlements, damage to paving block, opening up of joints due to lack of support by edge restraint, and washing away of joint filling sand before development of inter-lock/ bond between blocks. To restore the original profile, all damaged edge restraints, if any, should be replaced with new ones. The block surfacing should be dismantled, the base course profile should, be rectified and the blocks should be replaced on coarse bedding sand and re-compacted. During this process, the damaged blocks should be replaced. In order to ensure that sufficient block of the chosen type and thickness are available for future maintenance needs, about 5 per cent excess blocks should be produced for safe storage. Care should be taken to ensure that the reconstructed area has slightly higher level than adjacent paved areas, so that after a few days' traffic it achieves the same level.

11.7.4.2. Stone-sett pavement/brick pavement : Maintenance requirement for stone set/brick pavement is very minimal. Loose edge stones/bricks, if any, have to be fixed. Depression/sinking of pavement should be rectified by dismantling/removal of the stones/bricks, reconstructing the subgrade/base to the required profile, re-paving and compacting the stones/bricks on bedding sand and sealing the joints with appropriate material.

11.8. Norms of Maintenance Cost

The maintenance of roads is classified into various sub-heads. It includes ordinary repairs, periodical renewals, special repairs, flood damage repairs, maintenance and repair of major bridges, etc. Ministry of Road Transport & Highways (MoRT&H), Govt. of India constituted various committees for framing the norms of maintenance and repairs of different category of roads. These study groups have suggested norms for maintenance and repairs for various categories of roads. On similar lines many States in the country have appointed study groups to suggest norms for maintenance and repairs to different category of roads. For general guidance, the MoRT&H has issued norms for maintenance of roads of different types. The norms recommended for rural roads are given in Table 11.4. However, if the States have their own norms, those can be applied with the approval of the Engineer-in-Charge.

TABLE 11.4. NORMS OF MAINTENANCE COST FOR SINGLE LANE ROAD

Category of Roads	Norms approved by MoRT&H Rs. per km
Rural Road (ODR+VR)	17100 to 20200
Unsurfaced Road (Unsealed Road)	11300 to 13600

A scientifically planned approach for maintenance is always effective. Thus, organisational inputs for maintenance may be in the form of gangs or otherwise as decided by the engineer. The maintenance for rural roads can be handled using manual, semi-mechanised or fully mechanised methods. Further, the modern concept of maintenance by contractual arrangement may also be adopted where it is appropriate.

Appendix 11.1

Periodicity of Routine Maintenance Activities

Sl. No.	Name of item	Frequency of operation in the year
1.	Clearing of road side gutters	Twice
2.	Pothole filling (WBM & BT)	Once
3.	Filling up edges of asphalt surface of excavating borrow pit.	(i) Single lane (a) T.I. 0-1000 Twice (b) T.I. 1000-5000 Four times (ii) One and Half lane T.I. 0-1000 Once T.I. 1000-5000 Twice T.I. Over 5000 Four times (iii) Two lane T.I. 1000-5000 Once T.I. Over 5000 Twice
4.	Dressing of berms	Once
5.	White washing guard stones	Twice
6.	Fixing disturbed caution board/Village name board/ Speed limit board, etc.	Once
7.	Refixing displaced guard stones	Once
8.	White washing and geroo pending of trunks of trees	Once
9.	Cutting of branches of trees, etc.	Once
10.	Topping of W.B.M. blindage operation including picking of loose metal	18 times
11.	Maintenance of catch water drains	Once
12.	Clearance of C.D. works	Twice
13.	Clearing of wild seasonal growth on berms	Once
14.	White washing parapets of C.D. Works	Once
15.	Earthwork in berms, desilting of drains, etc.	As per requirement

Note : T.I. stands for Traffic Intensity in tonnes per day.

Appendix 11.4

Maintenance of Shoulders, Drainage Structures and Causeways

1. Maintenance of Shoulders

1.1. Properly built-up and well maintained shoulders provide lateral support to the pavement. The slow moving vehicles, like, bullock carts or hand driven carts tend to ply over the shoulders. The shoulders are also used for parking of vehicles.

1.2. The shoulders shall be kept free from obstructions, like, logs, shrubs, deep cuts, boulders, etc. The wild growth on them shall also be removed from time to time. In hill roads located in high rainfall zones, the overgrowths on both the hillsides and the valley side must be cleared twice a year, at least once before the onset of winter. The extent of clearance area should be enough to provide six hours of sunshine to the road surface during fair weather. It must, however, be seen that the roots of the grass are not removed, so that rains hitting on the exposed surface do cause erosion and induce landslides. The debris of leaves, branches and stems of the cut trees shall be cleared from the drain, pavement and the shoulder of the road and removed beyond the road edge on the valley side by at least 2 m. The shoulders should be kept flush with the pavement edge and then given slightly steeper slopes than the pavement to facilitate effective draining of rainwater flowing across the pavement. The shoulders shall be maintained by filling moorum or sand and scrapping the heaved-up portion wherever necessary.

Since the shoulders also form part of the body of the road, they shall be kept free from encroachments.

2. Maintenance of Road Furniture

2.1.Traffic signs are the principal means of conveying information about the road to the road users. Signs which are erected at proper places and which are in good condition free from any obstruction can be properly understood and they inspire confidence in the minds of the road users. Damaged, missing or obliterated signs shall be replaced promptly. The signs shall be inspected and cleaned at least twice a year. At the junctions of two or more roads proper information boards or information pillars giving information about various destinations would be of immense help. They shall preferably be located at least 200 m ahead of the junctions to guide the road users.

2.2.Guard rails, guard walls, parapets of bridges, guard stone delineators, etc. shall also be maintained properly. If they are damaged due to moving vehicles, the same shall be repaired or replaced promptly.

2.3.Kilometre/200-metre/boundary stones shall be painted twice in a year. The wild growth along the kilmetre/200-metre boundary stones, which obstructs the visibility shall be removed. Delineators and header stones on the curves shall be properly painted and kept in good condition to guide the driver properly at these locations.

3. Maintenance of Cross Drainage Structures

3.1.Structures are provided for effective drainage of runoff water etc. It is, therefore, essential that the cross drainage structures shall be maintained effectively and it shall be ensured those drainage elements, waterways remain free of obstructions and retain their intended cross-sections and grades. They must function properly so that surface water and ground water can drain freely and quickly away from the road or under the road. Water is the worst enemy of every road element. It can erode soil, weaken the pavement and subgrade, and destroy shoulder and slope, even wash out cross drainage structures or bridges.

3.2. The parapet, railing, guard stone etc. of the CD work should be repaired if broken. These should be properly painted for improving visibility during night.

3.3. In the following paragraphs maintenance of mainly culverts and causeways is discussed as these are usually used as cross drainage structures on rural roads.

3.4. **Inspection :** Inspection of drainage system and structures shall be a routine task. If it is not possible then the inspections should be carried out at least on four occasions. Firstly before onset of monsoon, Secondly, during monsoon particularly after first flash floods, Thirdly after heavy floods, and Fourthly after monsoon.

3.4.1. **Inspection before monsoon :** Following points shall be inspected:

(i) Waterway is clear and not blocked by debris or silt
(ii) Settlement cracks in foundations or in superstructure
(iii) Cracks or damages in pavement
(iv) Guide stones are properly fixed and pointed
(v) Warning signs are placed on both sides of cross drainage structures giving clear warning that when water is flowing above the guide stones, vehicle shall not cross the cross drainage structure
(vi) Approaches are in sound condition and there is not erosion
(vii) Debris arrestors if provided is properly fixed.

3.4.2. **Inspection after first flash flood :** It is generally observed that during first flash flood or during next two, three spells, there is substantial load of floating debris along with floodwater. If the vents are not of sufficient opening, then waterway is blocked by the debris and water starts flowing on approaches or by breaching the adjoining road sections. It is, therefore, essential to remove this blocked debris from pipe vents or waterway immediately so that there will be minimum damages in subsequent floods. In view of this, close and repeated inspections are essential during rainy season.

3.4.3. **Inspection after heavy floods :** During heavy floods, causeways are generally over topped. This results in heavy damages to pavement, approaches as well as scouring on down streamside of structures. In some cases there is breaching of approaches. All these points shall be closely inspected after every heavy flood, so that timely protective measures can be taken.

3.4.4. **Inspection after monsoon :** Once the monsoon season is over, the structures shall be inspected closely for any damage, any heavy silting or scouring to pavement damages to guide stones etc. Repairs to these damages shall be carried out promptly.

4. Maintenance of Culverts

4.1. **Defect : Silting, Sanding and Blockage by debris**

If a culvert structure is constructed too low, resulting in deposition of silt or sand. Vegetation or floating debris gets blocked in vents of culvert. Blockage of waterway leads to ponding and heading up of floodwater, which results in over flooding the embankment. This damages the embankment or causes breaching in roadway. Slopes of bed shall be corrected by Nalla training properly: Debris arrestors shall be provided on upstream side so that floating debris will not enter the vents and there will be no blockage of vents. It is also comparatively easy to clear the debris from arrestors.

4.2. **Defect : Erosion of Streambed on Downstream Side**

Due to flowing water or overtopping of water from culvert, the downstream side bed sometimes gets eroded. Due to heavy scouring, the foundations of headwalls are also exposed and endangered. Due to steep slope of bed or vents or due to inadequate waterway, the velocity of flowing water increases on downstream

side and results in erosion below headwall, wings walls or even approaches. This may result in collapse of headwall or wing walls in due course of time. Protection work to the bed with properly designed apron at downstream side shall be provided. Also adequate waterway shall be provided.

4.3. **Defect : Settlement Cracks in Masonry Structure**

Settlement of foundations takes place due to weak founding strata. If the settlement is negligible then the damages can be checked and repaired. But, if the settlement is major in nature, then reconstruction of structure will be only the remedial measure.

5. Maintenance of Causeways

5.1. **Defect : Cracks in Paved Surface**

Settlement of fill below pavement, dislocation of stones in stone sett pavements, scouring of filler material due to eddy currents. Damaged area shall be opened, refilled and compacted properly and then pavement shall be re-laid. In case of stone pavements, dislocated stones shall be re-fixed properly. If there is scouring below fill, then it shall be sealed properly so that there will be no damage due to eddy current.

5.2. **Defect : Blockage of Vents Due to Debris**

Floating debris block the vents. Debris arrestors shall be provided on upstream side.

5.3 **Defect : Damages Due to Overtopping of Water**

Structure is not properly designed or provision of inadequate waterway or inadequate protection measures. The geometry of the structure shall be properly designed. Water way shall be provided in such a way that it shall effectively pass at least 20 per cent of high flood discharge. The Road Top Level shall be properly protected with pitching on upstream and downstream side as well as at top of formation extending upto high flood level. If possible RCC Wearing Coats must be provided.

5.4 **Defect : Damages to guide stones, information boards**

Due to floodwater, or due to vandalism such damages are experienced. Guide stones, information boards, and kerbstones shall be a replaced promptly. If neglected, when the pavement gets submerged during floods, the edge of pavement can not be seen, more over if guide stones are missing, the depth of water on road top level can not be judged. This may result in serious accidents.

6. Maintenance of Drainage Features

For proper upkeep of drainage features, maintenance should take care of the following:

Camber : A proper camber needs to be maintained for surface water. Whereas it is found improper or inadequate, corrective measures need to be taken. In case of unsealed roads, blading, grading and shaping may be required. For sealed roads, a profile corrective course may be provided on the existing surface.

Shoulder and Side Slope : The shoulder on both sides should have required outward slope starting from the edge of pavement. Also, side slope is to be maintained at the end of shoulders, especially on high embankments.

Longitudinal Drainage : A lined or unlined longitudinal drain provided in a rural road, as the case may be, shall be cleared of any accumulated debris. The blockage of the drains by silting also may be cleared regularly.

Appendix-11.5

Typical Maintenance Cost Norms for Rural Roads

Typical maintenance norms for rural roads in zone II are given below. These are based on the "Report of the Committee on Norms for Maintenance of Roads in India" MoRT&H, October 2000.

Details of M & R cost in Rupees per kilometer for single lane road per year for rural roads (ODR/VR) in Zone II (as per MoRT&H Committee Report) are given in Table below by rounding off the values. The cost per single lane has been deduced from cost per double lane given in the report with a factor of 0.625 as suggested in the Report.

Category	Traffic in CVPD		
	<150		150-450
	BT	WBM	BT
Ordinary Repairs	23100	19900	23500
Periodical Renewal	53100	47500	57900
Flood Damage	11400	10100	12200
Special Repairs	15200	13500	16300

Note: Zone-II represents the areas of the country having the cost of aggregates in the range Rs.350-400 per cum.