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# MANUAL FOR DESIGN, CONSTRUCTION & MAINTENANCE OF GRAVEL ROADS

INDIAN ROADS CONGRESS

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# MANUAL FOR DESIGN, CONSTRUCTION & MAINTENANCE OF GRAVEL ROADS

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# CONTENTS

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(As on 7th November., 2007)

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## ABBREVIATIONS

| | | |
|---|---|---|
| AADT | : | Annual Average Daily Traffic |
| AASHTO | : | American Association of State Highway and Transportation Officials |
| ALD | : | Average Least Dimension |
| CBR | : | California Bearing Ratio |
| cm | : | Centimetre |
| CVPD | : | Commercial Vehicles Per Day |
| ESAL | : | Equivalent Standard Axle Load (18 kips i.e. 80 kN) |
| GWT | : | Ground Water Table |
| HCV | : | Heavy Commercial Vehicle |
| HFL | : | High Flood Level |
| IS | : | Indian Standard |
| km | : | Kilometre |
| m | : | Metre |
| MCV | : | Medium-Heavy Commercial Vehicle |
| MDD | : | Maximum Dry Density |
| MORD | : | Ministry of Rural Development |
| mm | : | Millimetre |
| OMC | : | Optimum Moisture Content |
| PCI | : | Pavement Condition Index |
| PI | : | Plasticity Index |
| PMC | : | Pre-Mix Carpet |
| SD | : | Surface Dressing |
| TRRL | : | Transportation and Road Research Laboratory of UK |
| VDF | : | Vehicle Damage Factor |
| WBM | : | Water Bound Macadam |

# MANUAL FOR DESIGN, CONSTRUCTION & MAINTENANCE OF GRAVEL ROADS

## 1. INTRODUCTION

**1.1.** The Rural Roads Committee (H-5) of the Indian Roads Congress approved the document in its meeting held on 9th June 2007 subject to incorporation of comments of the members by the Sub-Group constituted for the purpose. The draft document was then finalised by the Sub-group comprising S/Shri S.C. Sharma, P.K. Katare, Dr. N.B. Lal and Shri Gurdip S. Khinda. The personnel of Rural Roads Committee (H-5) as on 9th June, 2007 are as follows:

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| Katare, P.K. | ...*Member-Secretary* |

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| DG (RD), | .........MOSRT&H |
| Sinha, V.K. | .........Secretary General, IRC |

The draft Manual finalised by the Sub-group as well as by Convenor, H-5 Committee was placed before the Highways Specifications & Standards Committee (HSS) in its meeting held on 7th November, 2007. The HSS Committee approved the draft with some modifications. The modified draft document was put up before the IRC Council in its meeting held on 16th November, 2007 at Jaipur during 68th Annual Session of IRC and the Council approved the draft document for publishing as IRC document.

## 1.2. Global Acceptance for Low Volume Traffic

**1.2.1.** Internationally, the unpaved roads (i.e. roads without bituminous or cement concrete surfacing) constitute a sizable proportion of the total road length. In several countries, the unpaved road length is more than the paved road length, as can be seen in **Fig.1.1.** In India, however, the unpaved road length constitutes less than half the total road length **(Fig.1.2.).** While in most countries abroad, among the unpaved roads, it is the Gravel Roads, which are most popular, the unpaved roads in India are generally WBM surfaced. More recently, especially with the World Bank assistance in some rural areas of India, Gravel Roads showing good performance even after about 5 years of service have begun to earn the confidence of rural road engineers in the country.

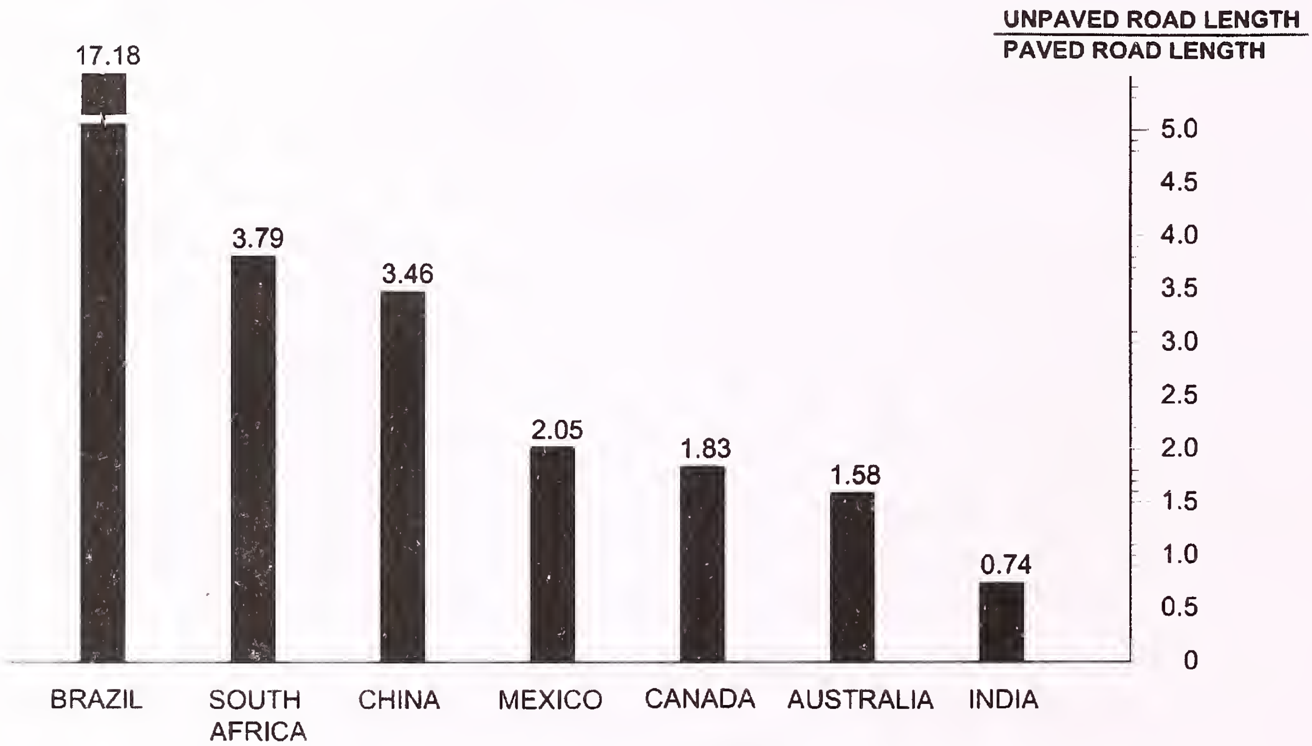
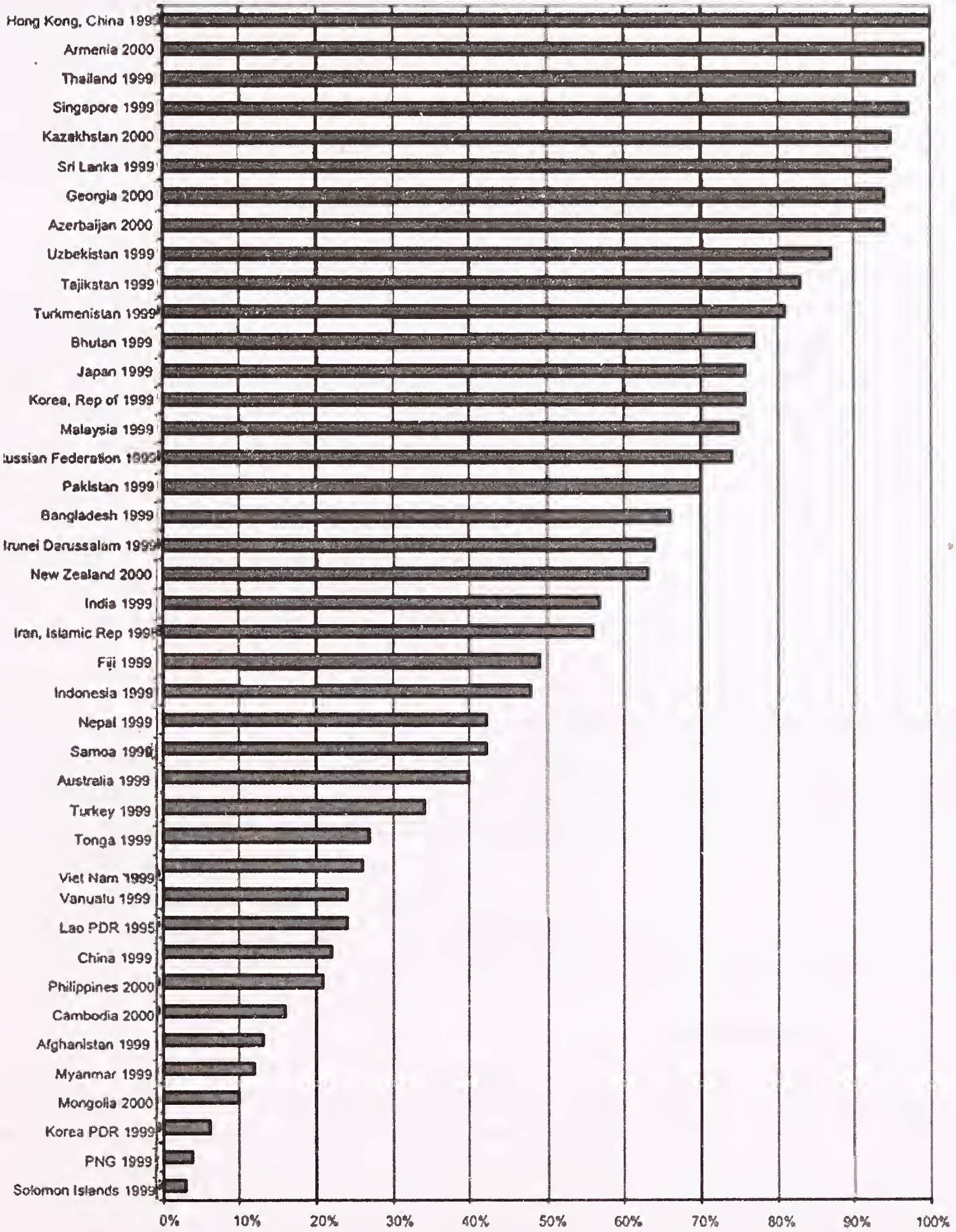



**Fig. 1.1 The Unpaved to Paved Road Length Ratio in Selected Countries (Source : CIA World Fact Book 2005)**

**1.2.2.** As per AASHTO 'For the aggregate surfaced (Gravel) roads (used for many county and forest roads), the maximum traffic level considered is 100,000 ESAL applications' and "The practical minimum traffic level that can be considered for any flexible or rigid pavement during a given performance period is about 50,000 applications". Assuming that commercial vehicles constitute about 25% of the number of vehicles plying per day (and that the heavy commercial vehicles/trucks constitute 20% of all commercial vehicles per day), Gravel Roads are suitable for an ADT upto 200 vehicles day. Further, it implies that unless the daily traffic is of the order of about 125 vehicles per day, paved road (flexible or rigid pavement) is not justified. A recent study shows that for traffic upto 200 vehicles per day Gravel Roads have lower maintenance costs compared to black topped roads.




*Sources: United Nations and ESCAP Statistical Yearbooks, which have used data from Country Statistical Yearbooks. For the Russian Federation these sources were supplemented by the Europa Yearbook and World Highways, September 1998 and for India by the India Statistical Abstract 1999.*

**Fig 1.2 : Proportion of Paved Road in Selected Economies of the ESCAP Region**

**1.2.3.** There are several access roads providing connectivity to smaller habitations with a traffic volume that is likely to be much lower than 200 vehicles per day. In such situations, the most suitable and economical option that emerges is the provision of an aggregate surfaced (gravel) road. It may be appreciated that after the current programme of providing all-weather access to habitations with a population over 500 has been completed, substantial inputs will still be required to provide all-weather access to the smaller habitations with a population less than 500, where the traffic generated would generally be of a much lower order justifying provision of Gravel Roads as a first stage option from both technical and economic considerations.

### 1.3. Life Cycle and Amenability to Stage Development

**1.3.1.** It is also established that well-engineered Gravel Roads perform satisfactorily for low volume traffic conditions provided the needed routine and periodic maintenance are attended to promptly. For most situations, the maintenance requirements are frequent but inexpensive. As in the case of black-topped roads, where bituminous surface renewals are required after about every 5 to 6 years or so depending on traffic, the Gravel Roads too require re-gravelling periodically. If the periodic re-gravelling requirement is attended to a design life of 10 years can be considered for purposes of pavement design. For many low-volume traffic conditions e.g., on link roads connecting habitations of relatively lower population levels, Gravel Roads can continue to serve for long periods of time. If, however, the traffic volume and axle loads increase to a level beyond the traffic load carrying capacity of a Gravel Road and its serviceability level comes down close to the terminal serviceability level, strengthening / rehabilitation with an overlay can be easily implemented to bring it to paved road standards.

**1.3.2.** Thus, one of the biggest advantages of initially adopting a Gravel Road option for low volume traffic conditions is its amenability to providing a thin bituminous surface treatment or strengthening the pavement crust followed by black topping as may be warranted by increased traffic. If a Gravel Road needs to be black topped as warranted by increased traffic and environmental conditions, the bituminous surface treatment can be provided over the gravel base after suitably preparing the surface of the existing gravel base and priming it as per specified procedure. Where warranted by increased traffic considerations, structural strengthening by way of an overlay of gravel / WBM /WMM etc. layer can be provided, treating the existing gravel base as a lower base course or a sub base.

### 1.4. Techno-Socio-Economic Aspects

**1.4.1.** The technical aspects of adopting a Gravel Road option for low volume rural roads include the maximized use of the low cost locally available materials and deployment of low-cost low-capacity equipment/plant both for construction and maintenance. Thus the requirements of materials, plant and equipment for construction and maintenance can be accomplished within the available resources and skills in rural areas. Since no bituminous surface treatment is envisaged at least during the initial few years of its service life, there is no requirement of expensive bituminous materials or the hot mix plants and equipment for manufacture, laying and compaction of the bituminous mix.

**1.4.2.** Studies carried out under the aegis of IRC in nine selected districts on socio-economic impact of rural roads show that a number of social benefits (like access to education and health facility etc.) and economic benefits (improved transportation of agricultural produce, higher yield / acre, quick transportation of perishable crops etc.) accrue from the provision of rural roads. Social and economic benefits accrued from all-weather unpaved gravel roads are practically the same as for black topped roads.

### 1.5. Influence of Environmental Conditions on Performance

Gravel Roads for low volume traffic conditions in rural areas work out to be the most suitable and economical option only under certain environmental conditions. These are:-

**1.5.1. Availability of quality gravel within economic leads:** Where the locally available gravels meet the specified requirements of grading and plasticity for use in the gravel base and surfacing as such, without any further processing, and are available within short leads, say less than 5 to 10 km, Gravel Roads would generally work out to be the most preferred alternative. However, where further processing by way of blending with other local materials or by lime/cement treatment is required, the related costs should be worked out and compared with the cost of other low-cost alternatives like paving with bricks, stones, cement concrete blocks, as feasible. Similarly when the distance of haulage of gravel is too long, the cost of haulage must be considered and compared with the cost of other alternatives.

**1.5.2. Rainfall:** High intensity of rainfall causes high gravel loss on a gravel road as also when the total annual rainfall is high, i.e. over 1500-2000 mm per year. However, it is more meaningful to consider the combined effect of traffic and rainfall on the rate of deterioration of a gravel road surface. Although no systematic performance records of gravel roads for different amounts of rainfall are available, it is observed that under high amount of rainfall, over 1500 mm/ year, a Gravel Road can take upto 100 vehicles per day; for medium rainfall of 1000-1500 mm per year, a Gravel Road can take upto 150 vehicles per day while for low rainfall less than 1000 mm, a Gravel Road can take upto 200 vehicles per day.

**1.5.3. Prolonged dry seasons:** In areas with prolonged dry seasons, say 8 months or more of dry periods during a year, the gravel surface loses, under traffic or by wind, the very fine-sized particles which provide the binding at the surface. As a result, dust nuisance is caused all around the unsealed road. In such situations, it becomes necessary to use dust palliatives. If, however, the cumulative cost of providing dust palliatives works out to be higher than the cost of sealing the surface, a low cost thin bituminous surface treatment can be resorted to.

**1.5.4. Longitudinal gradients:** In the low rainfall regions, with less than 1000 mm/year, the longitudinal gradients should not be steeper than 6%. Where the rainfall is in the range of 1000 to 1500 mm/year, the longitudinal gradients should not be steeper than 5%, provided proper precautions are taken to prevent erosion.

**1.5.5. Traffic volume:** When the traffic volume is upto 100 vehicles per day, (excluding 2-wheelers), Gravel Roads are considered suitable except in case of very poor subgrade. Where the traffic volume is upto 150 vehicles per day (excluding two-wheelers), Gravel Roads are considered suitable except for the weak subgrades upto CBR of 4. For traffic upto 200 vehicles per day (excluding 2-wheers), Gravel Roads are suitable for subgrades with CBR of 5 and above. For traffic volume above 200 vehicles per day (excluding two-wheelers), Gravel Roads are not considered suitable.

### 1.6. The Problems of Local Moorums, Maintenance & Dust Control

**1.6.1. Local moorums:** In India, the term 'Moorum' is commonly used to define soils and gravels of certain types. Contrary to this belief, there is no soil group termed as 'Moorum' in the Indian Soil Classification System or any such classification system internationally.

**1.6.1.1.** It is, therefore, not only desirable but necessary that moorum samples from any source and at various depths from that source must first be classified as per the Soil Classification system before considering them for use in a Gravel Road. It may be pointed out here that many 'moorums' do not even classify as 'Gravels' by the IS Soil Classification System; in fact, several varieties when tested for their particle size distribution and their Liquid and Plastic Limits, get classified as 'Clayey Sands' (SC).

**1.6.1.2.** As per the Indian Soil Classification system, any soil sample that has more than half its weight retained on IS:75 micron sieve is a coarse-grained soil. If any coarse-grained soil has more than half the weight of its coarse fraction retained on IS sieve of 4.75 mm size, it is a 'Gravel', denoted by the symbol "G". All Gravels are further classified as under, by the Indian Soil Classification System:

| | |
|---|---|
| • Well-graded Gravels GW (Percent Fines>5%) | Uniformity Coefficient>4 |
| • Poorly-graded Gravels GP (Percent Fines<5%) | Not Satisfying GW requirements |
| • Silty Gravels GM (Percent Fines>12%) | Below A-line of Plasticity Chart or PI<4 |
| • Clayey Gravels GC (Percent Fines>12%) | Above A-line of Plasticity Chart and PI>7 |

As per the specified requirements, only the gravels classified as GW and GP may be suitable for use in Gravel Base Courses while GM an GC types are not suitable. For use in Gravel Surfacings, GM and GC may or may not be suitable while GW and GP are generally unsuitable.

**1.6.1.3.** In view of the above, it is absolutely necessary for any Gravel Road project, before incorporating local moorums that representative samples from each source and at different depths be tested for their particle size distribution through standard set of sieves and for their liquid limit and plastic limit values. From the classification test data thus obtained, it would be possible to classify them by the Indian Standard Soil Classification System. It is only depending on the classification/soil groups to which the local moorums belong, that it would be possible to decide whether these can be used as such or only after further processing in lubbase, base or surfacing. Where further processing is required, the related costs should be worked out in detail. Comparing the cost of local moorums after processing, with the cost of other alternative low-cost materials like bricks, stone blocks etc, a decision may be arrived at in favour of the most suitable and economical alternative.

### 1.6.2. Maintenance and dust control

**1.6.2.1.** The performance of Gravel Roads is mainly dependent on the quality of materials available for road construction, environmental conditions, proper maintenance and available resources. The main factors for rapid deterioration of Gravel Roads include (i) availability and suitability of gravel (ii) construction standards (iii) environmental and climatic conditions (iv) drainage and (v) traffic. If adequate attention is not given to these factors, the adverse effects on the performance of a Gravel Road are much more serious compared to the performance of black-topped roads. Timely maintenance is crucial in the upkeep of Gravel Roads. While the maintenance cost increases with traffic, still it is less compared to the maintenance cost of bituminous roads for low volumes of traffic upto about 200 vehicles per day. Gravel Roads suffer from loss of gravel, which increases with the use of inferior gravels and also suffer deformation of the transverse profile. While deformations in the transverse profile need to be rectified by periodic grading, excessive loss of gravel would require frequent regravelling.

**1.6.2.2.** Another problem associated with Gravel Roads is the dust nuisance in low rainfallregions, particularly when the surface gravel does not have adequate binding properties. In many countries, dust Palliatives have been successfully used to control dust nuisance in such situations. These aspects have been dealt with in detail in Section 4 of this Manual. In certain situations, eventually bituminous sealing may be warranted to overcome this problem.

## 1.7. Warrants for Sealing

**1.7.1.** Pneumatic tyred fast moving vehicles like the commercial rural vehicles damage unprotected granular base and create dust nuisance. Also, the operating costs of such vehicles are highly influenced by the smoothness of the road pavement. Bituminous surfacing will be advantageous (i) where subgrade is very poor (CBR=2) and the traffic is in the range of 30,000 to 60,000 ESAL applications (ii) where subgrade is poor (CBR less than 4) and the design traffic is in the range of 60,000 to 1,00,000 ESAL applications and (iii) irrespective of the subgrade strength, the design traffic is over 100,000 ESAL applications.

**1.7.2.** As part of the stage development strategy, it is often desirable to postpone the provision of a bituminous surface treatment for the first few years of its service life during which the pavement may undergo any undulations and the entire pavement system, including the drainage system gets stabilized. Surface dressing is considered the most suitable and economical surface treatment. It is always desirable to have some time gap between the application of first coat and the second coat.

## 1.8. Potential for Large Scale Applications and Employment Generation

**1.8.1.** In view of the fact that many of our rural roads are mainly "farm to market" roads, the design traffic is of a very low order and Gravel Roads can adequately cater to such low volumes of traffic. After the current PMGSY targets are achieved, the remaining about 1.7 lakh unconnected habitations with population below 500 will generate even lower volumes of traffic. For such volumes of traffic, Gravel Roads can be quite suitable.

**1.8.2.** The provision of Gravel Roads involving community participation can generate tremendous employment opportunities not only for their construction but also for their maintenance. Furthermore, Gravel Roads would go a long way in capacity building of small local contractors and towards evolving appropriate technology utilizing the increasing number of agricultural tractors for towing water bowsers and trailers, for haulage of materials, simple implements like disc harrows for pulverization of soil clods, rotavators for blending locally available materials and mixing of soil with stabilizers and water etc.

**1.8.3.** It is well established that the labour cost component of the total cost of the black topped conventional pavement is much lower than the labour cost component of the total cost of a Gravel Road. The construction of a Gravel Road maximises the use of locally available materials and adoption of semi-mechanized construction techniques, thus offering significant employment opportunities to the local communities.

**1.8.4.** Although the frequent maintenance requirements are often cited as a negative aspect of providing Gravel Roads in rural areas, in fact these requirements may be considered a big plus point in as much as they provide significant employment opportunities under various employment generating programmes of the Central and State Governments, particularly the National Rural Employment Guarantee Programme.

### 1.9. Demonstration Projects

**1.9.1.** Keeping in view that hardly any well-engineered Gravel Roads are being constructed in India and that such roads are extremely popular abroad, full-scale demonstration projects are warranted. If the construction and maintenance of Gravel Roads is demonstrated in each state, such an experience would go a long way in popularizing Gravel Roads for the low traffic volume conditions in rural areas. It is necessary to get a feedback on the performance of well-engineered Gravel Roads, constructed under different sets of environmental conditions. Data on road condition rating (in terms of PCI), traffic, specific routine and periodic maintenance measures taken and their frequency should all be recorded systematically.

## 2. DESIGN OF GRAVEL ROADS

### 2.1. Geometric Design Standards

**2.1.1. Roadway width:** For the single-lane gravel roads, the roadway width shall be a minimum 7.5 m in plain and rolling terrain. However, 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 etc., the roadway width shall be reduced to 6.0 m. In the mountainous and steep terrain, the roadway width shall be 6.0 m.

**2.1.2. Carriageway width:** For the single-lane gravel roads, the carriageway width shall be a minimum 3.75 m. However, where the traffic intensity is less than 100 motorised vehicles per day and where the traffic is not likely to increase due to situations like dead end etc. or in difficult terrain condition, the carriageway width shall be reduced to 3.0 m.

**2.1.3. Camber on carriageway:** For gravel roads, the camber shall be 3.5% (1 in 30) for annual rainfall less than 1000 mm and 4.0% (1 in 25) for annual rainfall over 1000 mm.

**2.1.4. Crossfall on shoulders:** On earthen shoulders, the crossfall should be 1% more than the camber for carriageway.

**2.1.5. Longitudinal gradients:** Due to the sizable proportion of slow-moving vehicles on gravel roads in rural areas and due to increased gravel loss on steeper gradients, it is necessary to impose restrictions on longitudinal gradients. In plain and rolling terrain, the ruling gradient shall be 3.5% and the limiting gradient of 5.0%, which can be relaxed upto 6%, where annual rainfall is less than 1000 mm. In mountainous and steep terrain, the ruling gradient shall be 5.0% and the limiting gradient of 6%.

**2.1.6. Horizontal alignment:** The requirements of minimum radii of horizontal curves, superelevation rates etc. for low-volume rural roads as contained in IRC:73 shall be adopted for gravel roads. Due to the predominance of slow-moving animal drawn cart traffic on gravel roads in rural areas, the maximum superelevation shall be restricted to 0.07.

## 2.2. Materials

**2.2.1. Roadmaking gravels:** Roadmaking gravel has been defined as 'a mix of stone, sand and fine-sized particles used as sub-base, base or surfacing on a road'. As per the IS Soil Classification System,'Gravel' is a coarse-grained soil (with more than half the total material coarser than 0.075 mm size), having more than half the 'coarse fraction' (larger than 0.075 mm), coarser than 4.75 mm. Sand is a coarse-grained soil with more than half the coarse fraction, finer than 4.75 mm. Silt and Clay are fine-grained soils with more than half the total material finer than 0.075 mm. It is not always possible to find a suitable roadmaking gravel in a natural deposit and often the naturally occurring gravels have to be processed to meet the specified requirements for use in a gravel road. There are few natural deposits of material that have an ideal gradation without being processed.

### 2.2.2. Grading requirements

**2.2.2.1.** As per the MORD Specifications, the gradation requirements of gravel/soil-aggregate for use in base and surface courses of a gravel road are given in **Tables 2.1** and **2.2** respectively. Any of the 3 gradings given in **Table 2.1** for Base Course can be adopted depending upon the availability of materials. These gradings are recommended in case the gravel is sealed by chip sealing or surface dressing using bituminous material.

**Table 2.1 : Grading Requirements for Base Course**

| Sieve Size | Percent by Mass Passing IS Sieve Grading Designation | | |
|---|---|---|---|
| | A | B | C |
| 53 mm | 100 | | |
| 37.5 mm | 97-100 | 100 | |
| 26.5 mm | | 97-100 | 100 |
| 19 mm | 67-81 | | 97-100 |
| 9.5 mm | | 56-70 | 67-79 |
| 4.75 mm | 33-47 | 39-53 | 47-59 |
| 425 μm | 10-19 | 12-21 | 12-21 |
| 75 μm | 4-8 | 4-8 | 4-8 |

**Table 2.2 : Grading Requirements for Surface Course**

| Sieve Size | Percent by Mass Passing Designated Sieve |
|---|---|
| 26.5 mm | 100 |
| 19 mm | 97-100 |
| 4.75 mm | 41-71 |
| 425 μm | 12-28 |
| 75 μm | 9-16 |

Gravel for base courses should have very small proportion of fine materials (silt and clay) and a relatively larger top-sized aggregate for strength and durability. Surface gravel should have a relatively higher percentage of fines (silt and clay) and relatively smaller top-sized aggregate, so as to readily shed off water falling on the surface of the Gravel Road. Where rounded stones are locally available, crushing of such rounded stones is always suggested since the fractured stones embed into the surface of a gravel road much better than rounded stones.

The percentages of Gravel, Sand and Fines (Silt and Clay) in the gradings A, B and C of **Table 2.1** are as under:

| | **Grading A** | **Grading B** | **Grading C** |
|---|---|---|---|
| Gravel | 53 to 67% | 47 to 61% | 41 to 53% |
| Sand | 25 to 43% | 31 to 49% | 39 to 55% |
| Silt and Clay | 4 to 8% | 4 to 8% | 4 to 8% |

When a single naturally occurring material does not meet any of the specified gradings,'processing' will have to be resorted to, by blending two or more materials to achieve the required grading.

The procedures for determining the appropriate proportioning of different materials for achieving the prescribed grading and also to meet the requirement of Plasticity Index (PI) have been given in **Appendix-A.**

**2.2.2.2.** Where gravel meeting the requirements in respect of grading as per the preceding para 2.2.2.1 is not available within economic leads or cannot be economically processed, 'Gravel' meeting the following *requirements for Base and Wearing Courses can be used (including processing if required):

**(a) Base Course**

| | | |
|---|---|---|
| Percent retained on IS 4.75 mm sieve and passing 80 mm in size (Percent Gravel) | : | 50 - 70% |

| | | |
|---|---|---|
| Percent retained on IS Sieve 75 micron, and passing IS Sieve 4.75 mm (Percent Sand) | : | 25 - 40% |
| Percent passing IS Sieve 75 micron (Percent Slit and Clay) | : | Absolute max. 10%<br>Desirable max. 5% |

**(b) Wearing Course/Surface Course**

| | | |
|---|---|---|
| Percent retained on IS 4.75 mm sieve and passing 80 mm in size (Percent Gravel) | : | 50 - 70% |
| Percent retained on IS Sieve 75 micron, and passing IS Sieve 4.75 mm (Percent Sand) | : | 25 - 40% |
| Percent passing IS Sieve 75 micron (Percent Slit and Clay) | : | 8 - 15% |

*Source : Transportation Research Board, Compendium 7 'Road Gravels'

**2.2.2.3.** Where gravel meeting the requirements in respect of grading as specified in para 2.2.1. and 2.2.2. is not available within economical leads or cannot be economically processed, Soil-Aggregate mixture meeting the following requirements may be used for base and surface courses:

**Soil aggregate mixtures:** Soil-aggregate mixtures may be in the form of naturally occurring materials like soil-gravel, or soil purposely blended with suitable aggregate fractions. The primary criteria for acceptability of such materials are plasticity characteristics and gradation.The material should be smoothly graded for achieving the maximum possible dry density. Fuller's grading rule {Fuller's grading rule is given by percent passing sieve = 100 (aperture size of the sieve/size of the largest particle)$^{1/2}$}, could be used as a guide to work out the optimum grading in different cases. A few typical gradings are given in **Table 2.3**. The first three gradings indicated in this Table are especially suited for base courses whereas the remaining two are suitable both for base course and for surfacing.

**2.2.3. Plasticity characteristics of fines**

**2.2.3.1.** The requirements of plasticity characteristics of fines in surface/wearing courses depend on the climatic conditions of the area. The** requirements of Liquid Limit and Plasticity Index of fines are as under:-

| Climate | | Liquid Limit (Max.) | Plasticity Index (Range) |
|---|---|---|---|
| (i) | Moist temperate and wet tropical | 35% | 4-9 |
| (ii) | Seasonal wet tropical | 40% | 6-15 |
| (iii) | Arid | 55% | 15-30 |

** Source : Low Cost Roads; UNESCO Publications. Butterworths

**Table 2.3 : Typical Grading Limits for Soil-Aggregates Mixture**

| Sieve Size | Percent by weight passing the sieve* Nominal Maximum Size | | | | |
|---|---|---|---|---|---|
| | 80 mm | 40 mm | 20 mm | 10 mm | 5 mm |
| 80 mm | 100 | - | - | - | - |
| 40 mm | 80-100 | 100 | - | - | - |
| 20 mm | 60-80 | 80-100 | 100 | - | - |
| 10 mm | 45-65 | 55-80 | 80-100 | 100 | - |
| 4.75 mm | 30-50 | 40-60 | 50-75 | 80-100 | - |
| 2.36 mm | - | 30-50 | 35-60 | 50-80 | 80-100 |
| 1.18 mm | - | - | - | 40-65 | 50-80 |
| 600 micron | 10-30 | 15-30 | 15-35 | - | 30-60 |
| 300 micron | - | - | - | 20-40 | 20-45 |
| 75 micron | 5-15 | 5-15 | 5-15 | 10-25 | 10-25 |

Note : Less than 10% should be retained between each pair of successive sieves specified for use except for the pair comprising the first two sieves.

*Source : IRC : 63 - 1976

**2.2.3.2.** For use in base courses, the PI must not exceed 10.

**2.2.4. Processing unsuitable materials:** It is to be borne in mind that all types of gravels found in a region are not all suitable for road making, even though they classify as "Gravels" as outlined above. In fact, there are few natural deposits that have an ideal gradation without being processed. It is possible to take two materials, either one or both of them unsuitable alone for highway use, and combine them to produce a granular material of satisfactory gradation. If the gradation of two available materials is known, what combinations of these materials will produce a suitable gradation can be readily determined as per the procedure described in **Appendix-A.** For many locally available materials, an effective combination may be from crushed stone to meet the specified gradation and plasticity requirements.

**2.2.5. Location and evaluation of gravel deposits :** Broadly, the procedure for location and evaluation of gravel deposits involves the following steps:

**(a) Initial Prospecting**

(i) Collect any available information in the form of Soil Maps, Geological Maps, Aerial photographs and findings of the MOST Research Scheme R1 on locally available materials in the region, local enquiries on availability of any granular material, rock outcrops etc.

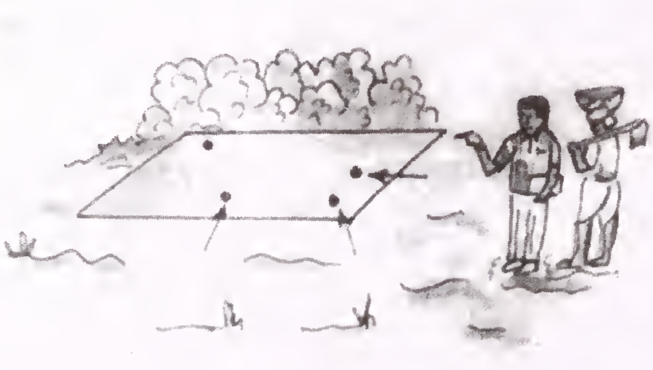
(ii) Study any existing excavations, pits etc, and carry out a visual examination which may warrant further investigations. Enquiries from local farmers and residents if they have encountered any stony materials, often help in identification of any suitable deposits in the area.

(iii) Study rock formations in the region. For example, in case of Igneous rocks, any weathered granite could be a good source of gravel. In Sedimentary rocks, there may be a possibility of gravel deposits in the form of weathered Sand Stone and Conglomerate. Certain Metamorphic rocks with veins of quartz may get weathered to produce gravel. Besides, certain Limestones may lead to the formation of calcareous aggregates like Kankar which have certain amount of cementing action, thus showing good performance. **Fig. 2.1.** shows typical quarries of gravel.

**Fig : 2.1 Typical Gravel Quarry**

**(b) Preliminary investigation**

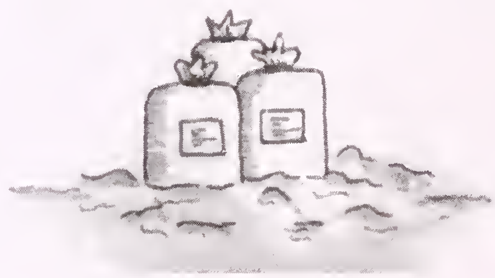
When the initial prospecting gives indication of possible gravel deposits at a particular location, a number of test pits/borings should be made to demarcate the area of possible gravel deposits. From a number of such test pits/ borings, samples should be collected to determine the quality and possible variations in the quality. For deep deposits, the variations in the quality with depth should also be determined. A locality plan should be prepared to show the situation of the deposit, also showing the boundaries of the deposit. The samples collected should be properly packed and labelled **(Fig 2.2)**. The needed laboratory tests on gradation, plasticity etc. should be carried out on the samples collected. If the preliminary test results so warrant, the representative samples should be subjected to detailed investigation. It should be kept in view that the samples not meeting the requirements of surface or base gravel may be suitable for use in the sub-base courses. In order to reduce the number of samples for detailed laboratory investigations, it is desirable to resort to hand-feel tests in the field.



**(a) Locations**

**(b) Collection**

**(c) Filling in sample bags**



**(d) Tagging and marking**

**Fig. 2.2 : Process of Sampling**

(Source : Document on Rural Road Development in India, Vol. II, CRRI, New Delhi, 1990)

**(c) Detailed Investigations**

When the results of preliminary investigations for a deposit are promising, detailed investigations should be carried out. More test pits/borings need to be made on a grid system, the spacing depending on the variability of the deposit as determined during preliminary investigations. In each test pit/boring, the depth of overburden and variations in quality of gravel with depth should be determined. If there are variations in quality with depth, the aspect of mixing of materials from different depths must also be considered. Further testing work should be carried out depending on the variations in the gravel quality from the specified requirement. The detailed investigations will be useful in estimating the quantity of gravel available, the overburden required to be removed and variations in the quality of gravel. Other aspects to be looked into are the work required on clearance, the haul distance to the site of work and availability of access roads for hauling the gravels to the site.

**2.2.6. Materials sampling:** It is most important to get a truly 'representative' sample to the Laboratory for testing. The main problem in getting a 'representative' sample of aggregate/gravel is the problem of segregation. At the stockpile, there will be a tendency for the bigger particles to roll down towards the base. It is, therefore necessary to collect samples close to the top, middle and bottom of the stockpile **(Fig. 2.3)** taking care that a wooden board should be shoved in before collecting the samples, to prevent further segregation. All the three samples thus collected should be mixed together and the final sample for laboratory testing, reduced by the process of 'Quartering'. Alternatively riffle box may be used to reduce total mixed sample to the 'representative' sample for laboratory testing.

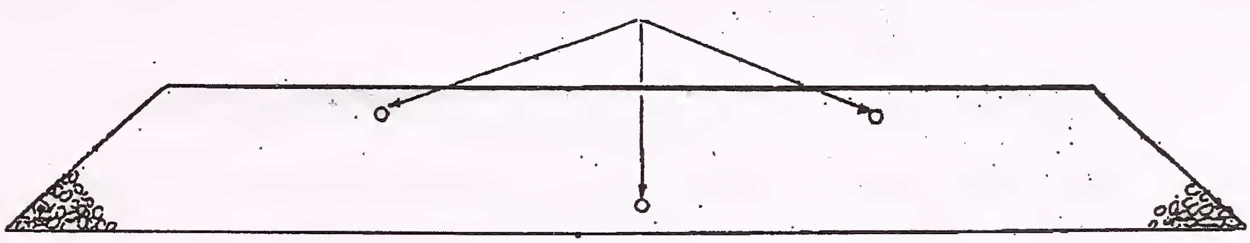


**Fig. 2.3. : Sampling from Flat Stockpiles**

**2.2.7. Methods of testing** : The standard tests commonly used to determine the suitability of a sample of gravel as a pavement material include the following:

(i) Particle size Distribution (IS:2720 Part 4)

(ii) Plasticity Index (IS:2720 Part 5)

(iii) CBR Test (IS:2720 Part 16)

(iv) Wet Aggregate Impact Value (IS:2386 Part 4)

**2.2.8. Handling gravel** : From the time gravel is taken from the quarry, the following should be kept in view while handling gravel:

(i) Remove the topsoil or any vegetation from the surface of material source before beginning to process the materials.

(ii) Since variations in the layers of gravel are common, it is a good practice to remove the material by working a broad area of the face.

(iii) To avoid the problem of segregation, stockpiles should be constructed in layers.

(iv) Hauling and spreading gravel should be treated as a work zone and suitable precautions shall be taken for safety of workers and road users.

(v) After gravel is dropped on the road, the grader operator should place it in a windrow.

(vi) For a new road, prior to laying gravel on a soil subgrade, the subgrade should be properly compacted and finished to the required profile.

**2.2.9. Components of soil-aggregate mixtures/gravels**

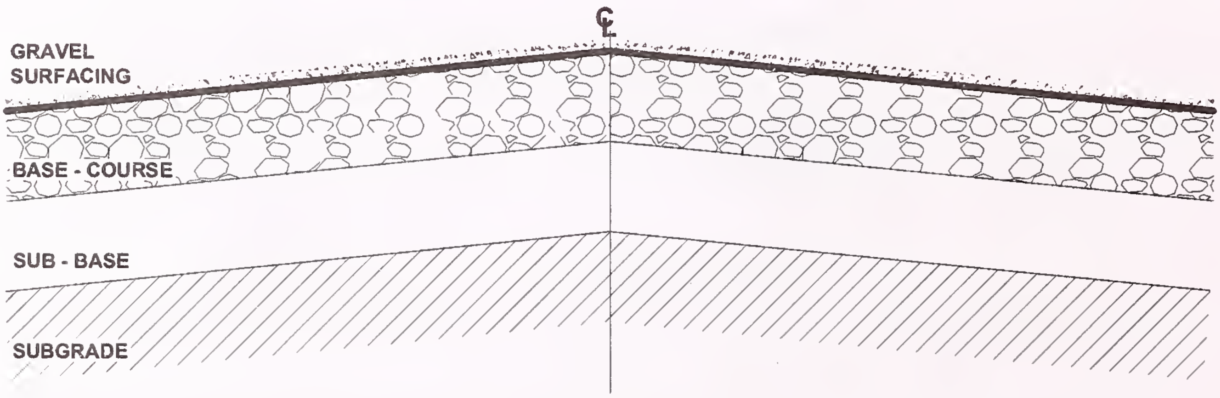
Various constituents of Soil-Aggregate Mixtures forming gravels and their contribution to the strength of the matrix are as under

(i) Gravel and Crushed Stone : Mechanical interlock and internal friction

| | | | |
|---|---|---|---|
| (ii) | Coarse Sand | : | Internal friction, reduces shrinkage |
| (iii) | Medium and Fine Sand | : | Filler with slight capillary action |
| (iv) | Silt | : | Adds to capillarity, produces apparent cohesion |
| (v) | Clay | : | Low permeability; true cohesion; causes shrinkage |

**2.2.10. Soil-aggregate and water interaction:** Ideally, the rate of upward suction of water from ground water below should balance the rate of evaporation from the road surface. A typical cross-section of a Gravel Road is shown in **Fig 2.4.** The water interaction in the various layers of a gravel road can be described as under.

| | Layer | Water Interaction |
|---|---|---|
| (i) | Water-resisting gravel surfacing | Sheds off rainwater |
| (ii) | Base course of gravel | Utilizes suction |
| (iii) | Sub-base and subgrade | Conduct water to the base course |




GRAVEL SURFACING - A WELL BOUND WATER RESISTING TREATMENT ON THE SURFACE OF THE BASE
BASE COURSE - THE MAIN GRAVEL SUPPORTING THE PAVEMENT LOADING
SUB BASE - AN OPTIONAL GRANULAR LAYER
SUB GRADE - 300 mm Thick Select Soil

**Fig. 2.4 : Typical Cross-Section of a Gravel Road Pavement**

**2.2.11. Treatment with lime/cement:** Under certain conditions, it is advantageous to improve the properties of soils and aggregates by adopting soil stabilisation techniques with small quantities of quick/slaked lime or Portland Cement. Clay soils are improved by mixing with lime, resulting in increased strength/CBR, reduced swelling and shrinkage characteristics, reduced water content in natural soil, better workability and improved draining properties.

Addition of a small amount of cement imparts cohesion between particles of gravels and sands. Cement can be effectively used to upgrade poor quality gravels and sands.

## 2.3. Pavement Design for Gravel Roads

**2.3.1. General:** Basically, the methodology to be adopted for the pavement design of

Gravel Roads is the same as given in IRC:SP:72 'Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads' except that gravel/ aggregate-surfaced roads are provided only for very low volumes of traffic. As per this method, the design parameters include (i) Traffic in terms of the number of standard axles (80 kN) to be carried over the design life and (ii) Subgrade strength in terms of CBR. These parameters are discussed in paras 2.3.3 and 2.3.4.

**2.3.2. Design criteria:** The thickness of gravel/aggregate-surface roads shall be based on the following criteria:

(i) the serviceability loss over the design life is limited to 2.0, taking the initial serviceability index to be 4.0 just before opening the road to traffic, and the terminal serviceability of 2.0 when rehabilitation will be due, with or without provision of an overlay.

(ii) the allowable depth of rutting under 3 m straight edge shall not exceed 50 mm.

**2.3.3. Computation of design traffic**

**2.3.3.1. Seasonal variations in traffic:** Most of the rural roads being essentially farm-to-market roads, there are significant variations in traffic volumes as observed during non-harvesting and harvesting seasons. The seasonal variations are shown in **Fig. 2.5**, typically for 2 harvesting seasons of equal duration during a year. The Annual Average Daily Traffic (AADT), duly accounting for seasonal variations can be determined by the simple formula given below:-

$$\therefore \quad AADT = T + \frac{1.2\,(n \times T) \times t}{365}$$

Where,

T = Number of vehicles per day, including both motorized and non-motorized, but excluding all two-wheelers, during the lean non-harvesting season.

t = Duration of a harvesting season in days

n = Number of times by which the number of vehicles per day 'increase at the peak harvesting season, over and above the lean season traffic T.

The values of T and n in the above formula are often readily available from local authorities.

The use of the above formula is illustrated by the following example:

**Example**: (i) Lean season traffic (T) = 50 vehicles per day

(ii) Duration of a harvesting season (t) = 40 days

(iii) Traffic at the peak harvesting season increases by 5 times (i.e, n=5) to 250 vehicles per day over and above the lean season traffic of 50 vehicles per day, i.e. a total of 300 vehicles ply per day at the peak harvesting season.

$$\therefore \quad AADT = T + \frac{1.2\,(n \times T) \times t}{365}$$

$$= 50 + \frac{1.2\,(5 \times 50) \times 40}{365} = 85$$

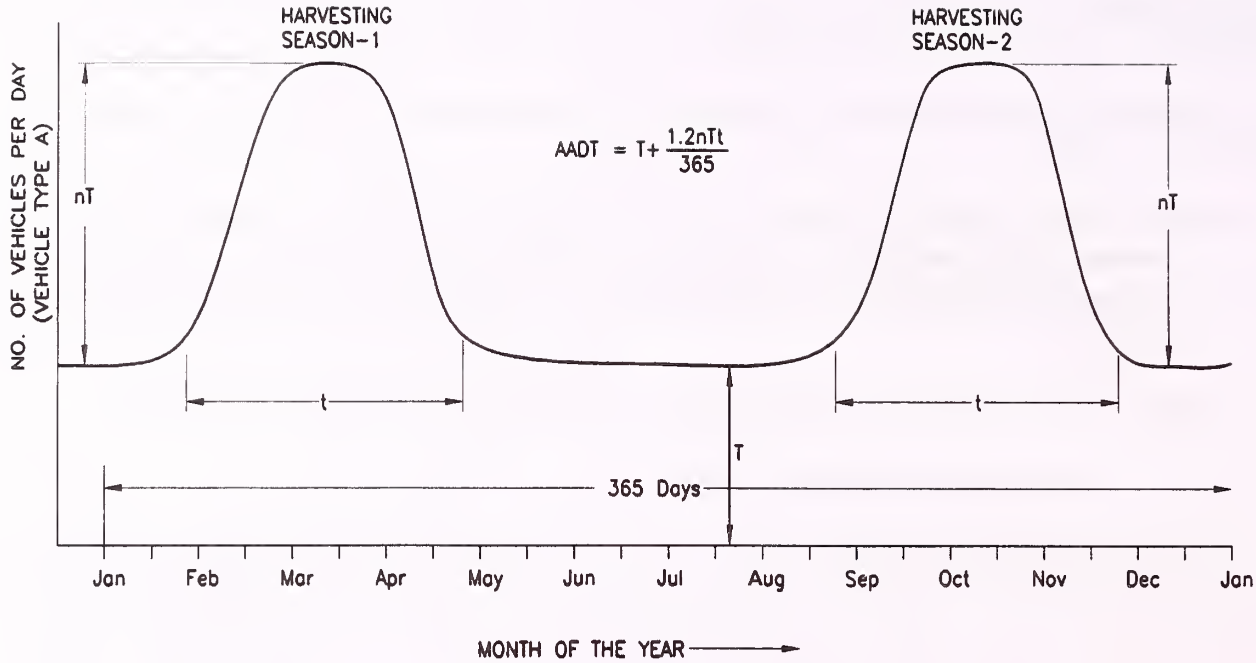



**Fig. 2.5 : Seasonal Variations in Traffic on Rural Roads**

**2.3.3.2. For upgradation of existing roads:** For the upgradation of an existing rural road, ideally, the traffic census should be conducted over a period of atleast 3days, both during the peak harvesting season and also during the lean season. However, if the values of t and n can be obtained from local authorities with reasonable reliability, traffic census during the lean season only will suffice; for lean season traffic, local enquiries can also help.

**2.3.3.3. For new roads**: In case of a new road, an approximate estimate should be made of traffic that would ply on the road, considering the number of villages and their population served along the road alignment and other socio-economic parameters. Traffic counts can be carried out on an existing road in the vicinity with similar conditions and knowing the population served as well as agricultural produce to be transported, the expected traffic on the new proposed road should be estimated. Due consideration should be given to the 'Diverted' and 'Generated' traffic anticipated as a consequence of the development of the proposed road, land use of the area served, the probable growth of traffic and the design life.

**2.3.3.4.Traffic parameters for gravel base thickness design:** For purposes of pavement design, only commercial vehicles with a gross laden weight of 3 tonnes or more along with their axle loading are considered. These include the following:

- Heavy Commercial Vehicles (HCV) comprising heavy trucks and full sized buses.
- Medium-Heavy Commercial Vehicles (MCV) comprising medium-heavy trucks, mini buses, tractor-trailers, pick-up vans etc.

The design traffic is computed in terms of cumulative number of standard axles of 80 kN to be carried during the design life of the road, using the following formula:

$$N = T \times 365 \times \frac{\left[(1+0.01r)^n - 1\right]}{0.01r} \times L \times F$$

Where,

N = Cumulative number of standard axles for design of gravel base thickness

T = Number of commercial vehicles per day in the year of opening the road

r = Annual growth rate of traffic

L = Lane Distribution Factor = 1 for single lane/ intermediate lane

n = Design Life in years

F = Vehicle Damage Factor

The parameters F, r and n are discussed in the following paras.

**2.3.3.5. Vehicle damage factor:** The Vehicle Damage Factor (F) is defined as the "Equivalent number of standard axles per commercial vehicle". While the factor 'F' is arrived at from actual axle load surveys on the existing roads, the project size and traffic volume in the case of rural roads may not warrant conducting an axle load survey. Therefore, indicative F values for HCV and MCV shall be taken as 2.5 and 0.33 respectively when fully laden and 0.3 and 0.02 respectively when unladen. In many situations information regarding laden and unladen commercial vehicles may not the available. The following VDF values shall be used for design purposes, where actual data is not available:

| **Vehicle Type** | **Vehicle Damage Factor** |
|---|---|
| HCV | 2.0 |
| MCV | 0.3 |

**2.3.3.6. Traffic growth rate:** The traffic growth rate depends upon the potential of an area for generating traffic. In the absence of any reliable information on this aspect, a 6% growth rate (r) shall be taken for design purposes. The same annual growth rate of traffic shall be considered from the year when actual field traffic surveys were carried out to the year of opening the road to traffic.

**2.3.3.7. Design life:** Normally, the gravel base thickness requirement shall be worked out for a design life (n), of 10 years. However, depending on factors, such as the limited availability of funds, a lower design life, not less than 5 years, shall be adopted.

**2.3.3.8. Estimating design traffic parameters:** In the absence of adequate data in respect of commercial vehicles and proportions of HCV and MCV, a reasonable estimate of design traffic in terms of cumulative standard axles during the design life of a gravel road shall be obtained as under:

| **AADT*** | **Cumulative ESAL Applications For 10-Year Design Life** |
|---|---|
| 50 | 10,000 |
| 100 | 50,000 |
| 150 | 75,000 |
| 200 | 100,000 |

* Includes both motorized and non-motorized vehicles, except two-wheelers.

While pneumatic tyred carts do not need to be considered for purposes of pavement design, it is always desirable to consider the effect of solid-wheeled (iron-rimmed) carts in estimating traffic for pavement design. For this purpose, the correction factor given in para 3.4.6 of IRC:SP:72-2007 shall be applied.

**2.3.3.9. Traffic categories:** For pavement design of gravel roads, the traffic has been divided into three categories as under:

| Traffic Category | Cumulative ESAL Applications (N) |
|---|---|
| $T_1$ | 10,000–30,000 |
| $T_2$ | 30,000–60,000 |
| $T_3$ | 60,000–100,000 |

### 2.3.4. Subgrade strength

### 2.3.4.1. Design for new roads

### 2.3.4.1.1. Subgrade CBR value

For the pavement design of new roads, the subgrade strength needs to be evaluated in terms of CBR value.

The CBR tests should be conducted on representative samples of subgrade soil compacted by static compaction to 100% Standard Proctor dry density and tested at a moisture content corresponding to the wettest moisture condition likely to occur in the subgrade during its service life. An average of test values obtained from a set of 3 specimens should be reported. If high variations are observed in the test values from the set of 3 specimens, then an average of test values obtained from 6 specimens should be taken.

### 2.3.4.1.2. Selection of moisture content for subgrade strength evaluation

The subgrade moisture conditions can be classified as under:-

| Subgrade Classification | Estimate Subgrade Moisture Content |
|---|---|
| I. Where the GWT is close enough to the ground surface to influence the subgrade moisture content. In non-plastic soils, GWT will influence the subgrade moisture content, if it rises to within 1m of the road surface; in clays of low plasticity (PI<20), if GWT rises within 3 m of the road surface and in heavy clays (PI<40), if GWT rises within 7 m of the road surface. This category also includes coastal areas and flood plains where the GWT is maintained by the sea, by a lake or by a river, besides areas where GWT is maintained by rainfall. | 1. The most direct method is to measure the moisture content in subgrades below existing pavements in similar situations at the time of the year when the GWT is at its highest level.<br>2. The subgrade moisture content for different soil types can be estimated by using the ratio<br>$\frac{\text{Subgrade Moisture Content}}{\text{Plastic Limit}}$<br>which is about the same when GWT and climatic conditions are similar.<br>3. Where such measurements are not possible, the subgrade strength may be determined in terms of 4-day soaked CBR value. |

| | | | |
|---|---|---|---|
| II. | Subgrades with deep GWT but where seasonal rainfall brings about significant changes in moisture conditions under the road. | 1. | The subgrade moisture condition will depend on the balance between the water entering the subgrade through pavement edges/shoulders during rains and the moisture leaving the ground during dry periods. The design moisture content can be taken as optimum moisture content obtained from Proctor Compaction Test IS:2720 (Part 7) corresponding to maximum dry density. |
| | | 2. | The Possibility of local perched G W T and effects of seasonal flooding should, however, also be considered while deciding on GWT depth. Where such situations are encountered, the subgrade strength may be determined in terms of 4-day soaked CBR value. |

**2.3.4.1.3.** The Soaked CBR value of the subgrade can be determined by conducting CBR tests on 4-day soaked samples in the laboratory. Where adequate testing facility is not available, typical presumptive values given in **Table 2.4** can be adopted. Alternatively, soaked CBR value can be estimated using the Nomograph given in IRC:SP:72.

**Table 2.4 : Typical Presumptive Design CBR Values**

| Description of Subgrade Soil | IS Soil Classification | Typical Soaked CBR Value (%) |
|---|---|---|
| Highly Plastic Clays and Slits | CH, MH | * 2-3 |
| Silty Clays and Sandy Clays | ML , MI<br>CL, CI | 4-5 |
| Clayey Sands and Silty Sands | SC, SM | 6-10 |

* Expansive clays like BC soil may have a soaked CBR of less than 2%
* A simple Free Swelling Index test (IS:2720 Part 40) should be determined on expansive clays

**2.3.4.2. Upgradation/rehabilitation of existing roads:** The insitu subgrade strength of an existing road will be determined in terms of CBR value obtained on representative subgrade soil samples remoulded to the insitu density at the field equilibrium moisture content, observed after the recession of the rainy season. If, for some reason, it is not found possible to determine the field moisture content immediately after the recession of monsoon, the 4 days' soaked CBR value of the remoulded subgrade soil samples, compacted at field moisture content to field density, may be determined.

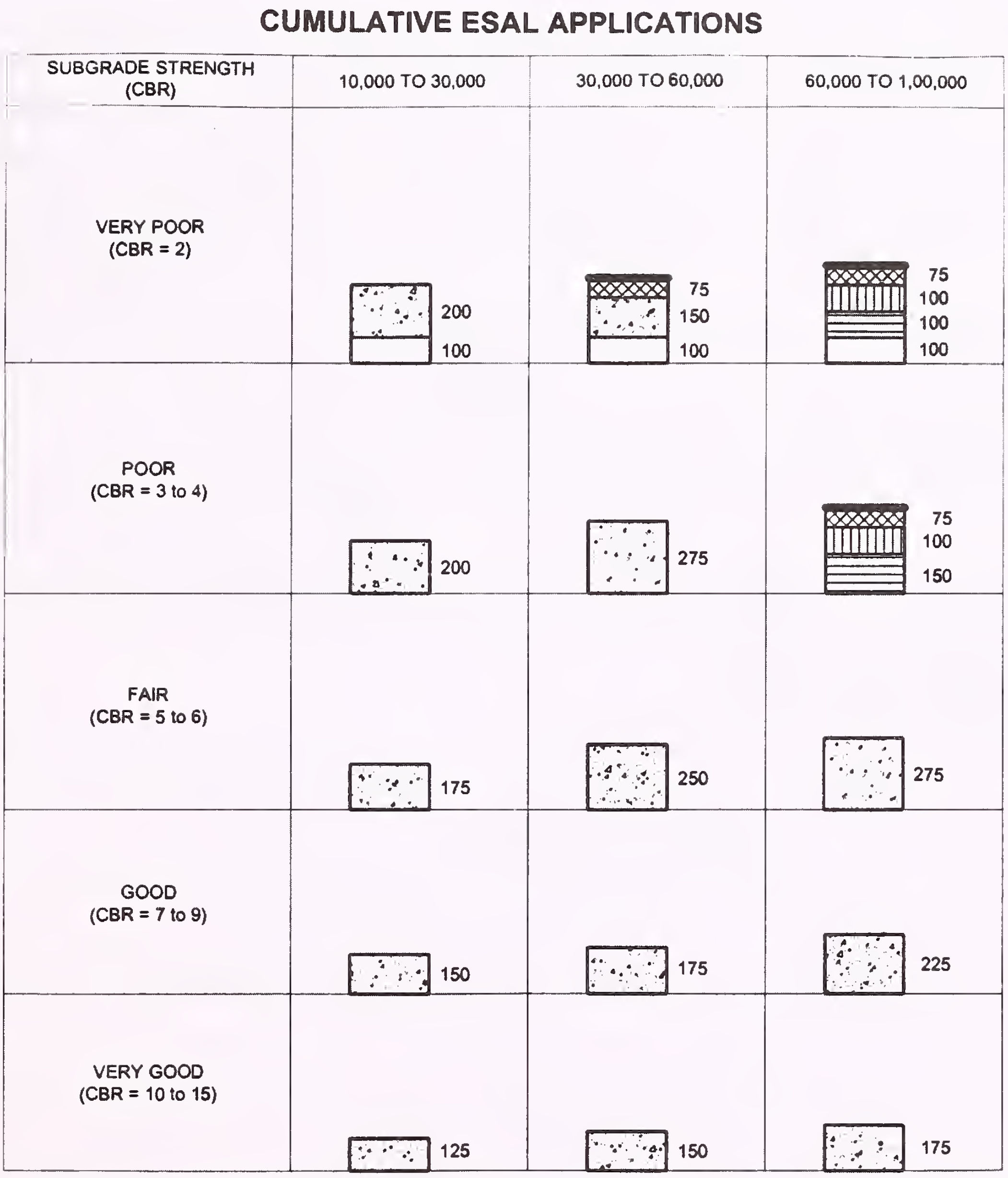
**2.3.4.3. Subgrade strength classes :** In order to use the Design Chart (Para 2.3.5), the subgrade strength is divided into the following classes:

| **Quality of Subgrade** | **Class** | **Range (CBR%)** |
|---|---|---|
| Very Poor* | S1 | 2 |
| Poor | S2 | 3 – 4 |
| Fair | S3 | 5 – 6 |
| Good | S4 | 7 – 9 |
| Very Good | S5 | 10 – 15 |

* Where the CBR of subgrade soil is less than 2, the economic feasibility of replacing 300 mm subgrade with suitable soil needs to be explored and, if found feasible, the pavement should then be designed based on the CBR value of the improved subgrade. Alternatively, a capping layer of thickness not less than 100 mm of modified soil (with CBR not less than 10) should be provided.

**2.3.5. Design chart:** The gravel base thickness required for the five subgrade strength classes ($S_1$, $S_2$, $S_3$, $S_4$ and $S_5$) and for the traffic categories of cumulative ESAL repetitions 10,000-30,000 ($T_1$); 30,000-60,000 ($T_2$) and 60,000-100,000 ($T_3$) are shown in **Fig. 2.6.** A chart to convert a portion of the Aggregate Base Layer thickness to an equivalent thickness of subbase (MORD Specifications Clause 401) with an intermediate CBR value between the base and subgrade is shown in **Fig. 2.7.** It must, however, be ensured that a minimum 100 mm thickness of gravel base is always provided. Besides grading requirements specified for gravel base and surfacing, the minimum soaked CBR of 80 for the gravel base material is often considered an additional requirement. It must be kept in view that if the gravel base material does not meet any of the two requirements (viz grading and soaked CBR value), it may not be able to withstand the design cumulative ESAL applications over the design life, consequently requiring regravelling earlier than designed. It may also be pointed out here that for the recommended designs to perform satisfactorily over the design life, it is implied that all the needed routine and periodic maintenance inputs will be provided.

**2.3.6. Surface gravel:** The thicknesses provided in the Design Catalogue (**Fig. 2.6**) are the Gravel base thicknesses and the base gravel conforms to the requirements given in para 2.2. Base Gravel may not form a durable crust to keep the material bound together on a Gravel Road and is difficult to maintain. It is, therefore, recommended that the gravel base shall be covered with the surface gravel material conforming to para 2.2. The thickness of the surface layer will generally vary from 40 to 50 mm depending on the traffic and quality of material. In some cases, a running course comprising a thin loose layer of approx. 13 mm size gravel or crushed aggregate has been provided over the surface course, acting as a cushion between the wheel load and the pavement surface. In India, there has not been enough experience with such a running course and should first be tried out on an experimental basis.




NOTE: IN SITUATIONS WHERE LOCALLY AVAILABLE/SUITABLY PROCESSED GRAVEL BASE MATERIAL FULFILLS ALL REQUIREMENTS AND THEENGINEER IS SATISFIED THAT THE GRAVEL BASE MATERIAL IS WELL COMPACTED, THE TOP 75 mm WBM LAYER MAY BE DISPENSED WITH, FOR CUMULATIVE TRAFFIC UPTO 1,00,000 ESAL APPLICATIONS.

LEGEND

BITUMINOUS SURFACE TREATED WBM/CRMB

BASE OF GRAVEL/CRMB/WBM; CBR NOT LESS THAN 100 (WHERE 100 mm THICKNESS IS) RECOMMENDED, IT MAY BE MODIFIED TO 75 mm THICKNESS FOR WBM CONSTRUCTION, WITH CORRESPONDING INCREASE OF 25 mm IN SUBBASE THICKNESS).

GRAVEL BASE (CBR NOT LESS THAN 80; IN EXCEPTIONAL CASES) MAY BE RELAXED SUITABLY)

GRANULAR SUB-BASE (CBR, NOT LESS THAN 20; IN EXCEPTIONAL) CASES MAY BE RELAXED TO 15)

MODIFIED SOIL/IMPROVED SUBGRADE (CBR, NOT LESS THAN 10)

**Fig 2.6 : Pavement Design Catalogues**

Example:

Initial Base Thickness DBSi = 27.5 cm
Final Base Thickness DBSf = 15.0 cm
Subbase CBR = 30
Base CBR = 100

Solution : Subbase Thickness required = 20 cm

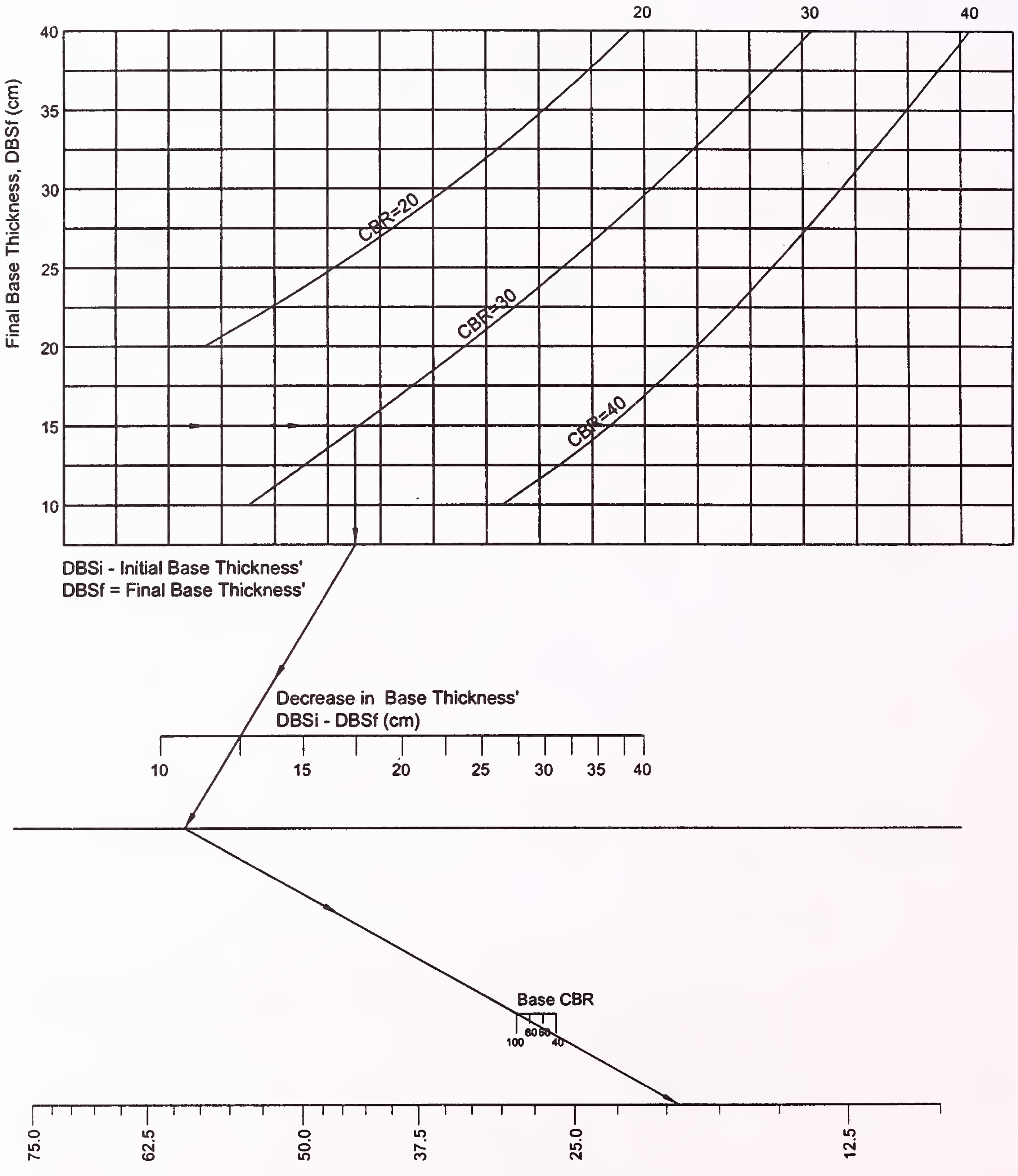



**Fig. 2.7. Chart to convert a portion of the Gravel/Soil-Aggregate Base Layer Thickness to an Equivalent of Subbase (Adapted From : AASTHO Guide for Design of Pavment Structures, AASHTO, 1993)**

### 2.4. Drainage Design

**2.4.1. Principles of good drainage:** Since water is, beyond doubt, one of the critical factors causing failure of roads, the designer should aim at keeping the water away from the road-bed. This can be achieved by following some simple principles of drainage design. They are outlined below:

(i) The surface run-off over the pavement surface and the shoulders should be drained away as quickly as possible, preventing the water from finding entry into the pavement layers from the top and into the subgrade from the top and sides.

(ii) Precipitation over the open land adjoining the highway should be led away from the road through natural drainage channels or artificial drains. Suitable cross-drainage channels should be provided to lead the water across the road embankment which may be cutting across to the natural drainage courses.

(iii) Consideration should be given to deal with the precipitation on the embankment and cut slopes such that erosion is not caused.

(iv) Seepage and sub-surface water is detrimental to the stability of cut slopes and bearing capacity of subgrades. An effective system of sub-surface drainage is a guarantee against such failures.

(v) Landslide-prone zones deserve special investigations for improving drainage.

(vi) Poor embankment soils can perform satisfactorily if drainage is considered in the design.

(vii) Water logged and flood-prone zones demand detailed consideration for improving the overall drainage pattern of the area through which the road is aligned.

**2.4.2. Longitudinal gradient:** Despite the provision of adequate cross-slopes, slight longitudinal drainage is necessary. A minimum 0.3% longitudinal gradient is to be ensured.

**2.4.3. Cross slope/camber:** As specified in para 2.1.3, the crossfall/camber over the carriageway for gravel roads should be 3.5% for low rainfall areas and 4.0% for high rainfal areas.

**2.4.4. Shoulder drainage :** For an efficient and quick drainage of rain water from the roadway, it is necessary to ensure that the shoulder surface is properly sloped and is free from any depressions or irregularities in the surface, where rainwater could get trapped.

On earthen shoulders, the crossfall should be 1% more than the camber for carriageway (refer para 2.1.4).

#### 2.4.5. Roadside drains

**2.4.5.1. Computation of run-off :** All the rainfall which falls on the catchment area does not reach the point where the drainage facility is being designed. This is due to percolation and evaporation losses, which are governed by factors such as soil type, vegetative cover, steepness of slope of the catchment, length of travel, temperature, land-use etc. The following formula, known as the Rational Formula, is generally used for calculation of run-off:

$$Q = 0.028\, P I_c A$$

Where,

$Q$ = Maximum run-off in cum per second

$P$ = A constant depending upon the nature of surface

$I_c$ = Critical intensity of storm in cm per hour occurring during the time of concentration

$A$ = Catchment area in hectares

The value of P is given in **Table 2.5**

**Table 2.5 : Values of Coefficient of Run-off**

| S.No. | Description of Surface | Coefficient of Run-off (P) |
|---|---|---|
| 1. | Steep 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 lightly cultivated or covered and macadam or gravel roads. | 0.30 |
| 8. | Sandy soil, light growth, parks, gardens, lawns and meadows | 0.20 |
| 9. | Sandy soil covered with heavy bush or wooded/forested areas | 0.10 |

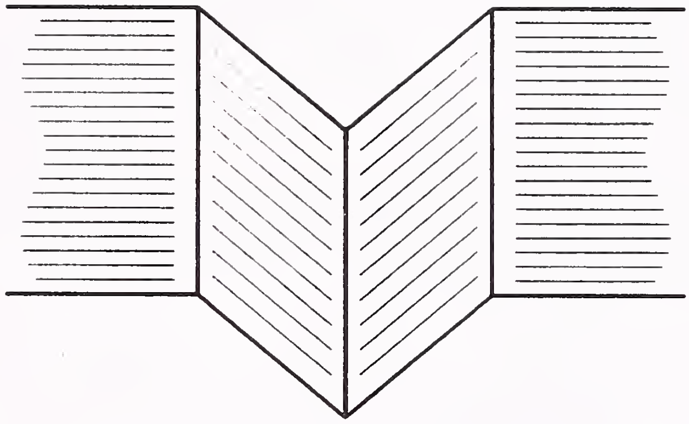
**2.4.5.2. Design of cross-section of roadside drains:** When natural channels for discharging the run-off are not available, it becomes necessary to design and construct artificial channels. Examples of such channels are:

(1) Side drains in cut-sections

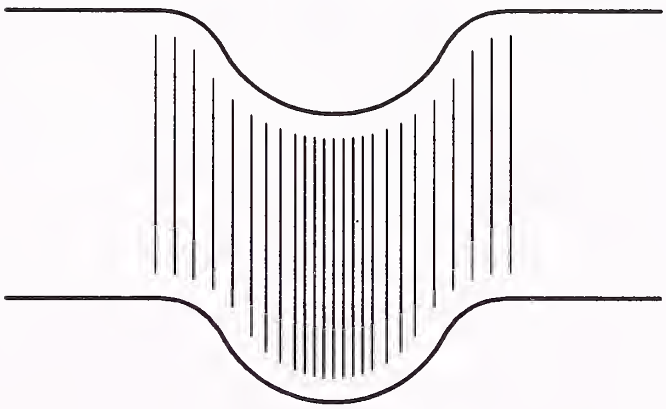
(2) Catchwater drains or Interceptor drains

(3) Longitudinal drains along the edge of embankment to lead run-off water to natural channels/roadside drains /ditches

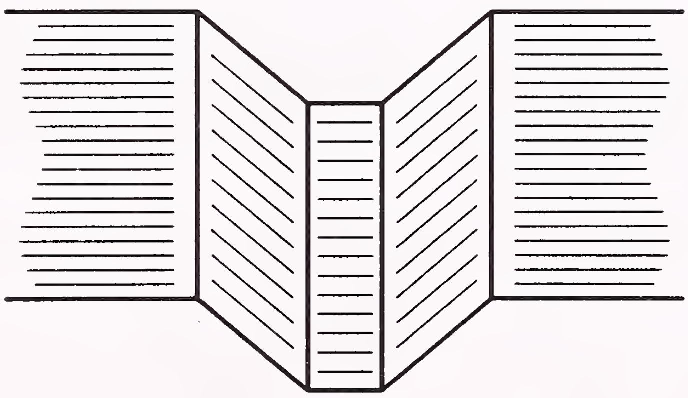
The three main types of cross-sections for roadside drains/ditches are shown in **Fig. 2.8.** Of the three shapes, the parabolic section is hydraulically the best and least subject to erosion, even though not as easy in construction as the triangular and trapezoidal shapes. The triangular section, although easy to construct is very much susceptible to erosion and gets easily blocked with debris. The most commonly used cross-section is the trapezoidal section as it is acceptable from both considerations-hydraulic as well as ease of construction. The side slopes should not be steeper than 2:1, from the view point of ease in grassing. The bottom width should normally be not less than 0.3 m.



TRIANGULAR



PARABOLIC



TRAPEZOIDAL

**Fig. 2.8 Main Types of Cross-Section**

For gravel roads, a return period of one year is to be adopted in estimation of run-off. For design purposes, the storm duration should be chosen equal to the 'time of concentration' based on the assumption that maximum discharge at any point in a drainage system occurs when the entire catchment is contributing to the flow. The 'time of concentration' far from any watershed is 'the time required for a given drop of water from the most remote part of the watershed to reach the point of exit' and comprises of two components (i) entry time and (ii) time of flow (see **Fig. 2.9**). If the drainage point under consideration is at the entry of the drainage system, then entry time is the time of concentration. If, however, the drainage point is situated elsewhere, then time of concentration is the sum of the entry time and the time required to traverse the length of the point under study. **Fig. 2.10** gives a graph for estimating time of concentration for catchement for different lengths, character and slope.

It is to be recognized that shorter the duration of critical rainfall, the greater would be the expected average intensity during that period. For example, during a 60 minute rainfall, some 10 minute period will have an average rainfall intensity far greater than for the whole storm.

For very reliable estimation of critical intensity of rainfall, it would be ideal to have the rain gauge records available at short intervals say 5, 10, 20, 30, 40, 50, 60 minutes. Alternatively, the following equation can be used.

$$i = \frac{F(T+1)}{T(t+1)}$$

Where,

I = intensity of rainfall within a shorter period of t hours within a storm

F = total rainfall in a storm in cm falling in duration of storm of T hours

t = smaller time interval in hours within a storm duration of T hours

The one-hour rainfall maps of India for return periods of 2, 5, 10, 25 and 50 years are available.

For built-up areas, an entry time (or inlet time) of 5 to 10 minutes is normally used, but in the case of grassy plots it may take 10 to 20 minutes for water to flow over a distance of 30 m. This factor decreases in importance as the length of drain increases and entry time (or inlet time) becomes a small proportion of the time of concentration. For a quick estimation of time of concentration, **Fig. 2.10** can be used.

The hydraulic design of such channel is usually done on the basis of Manning's formula:

$$V = \frac{R^{2/3}S^{1/2}}{n}$$

Where,

V = Velocity in m per second

R = Hydraulic mean depth

S = Bed slope

n = Rugosity coefficient

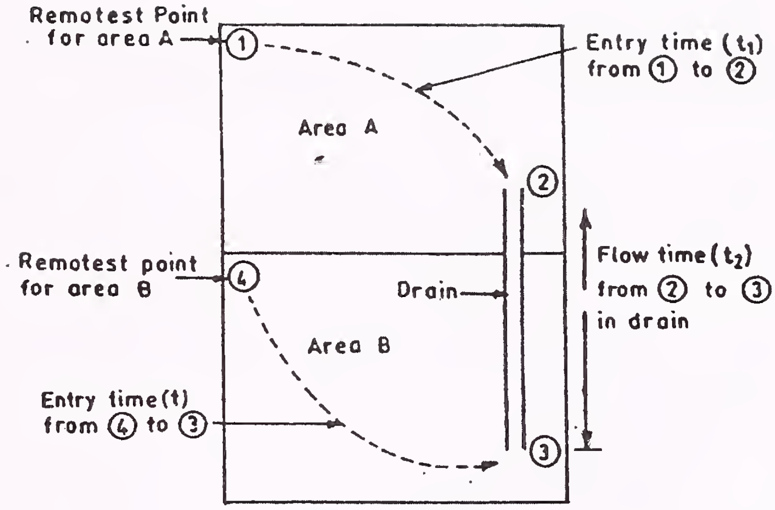



Fig. 2.9 : Time of Concentration

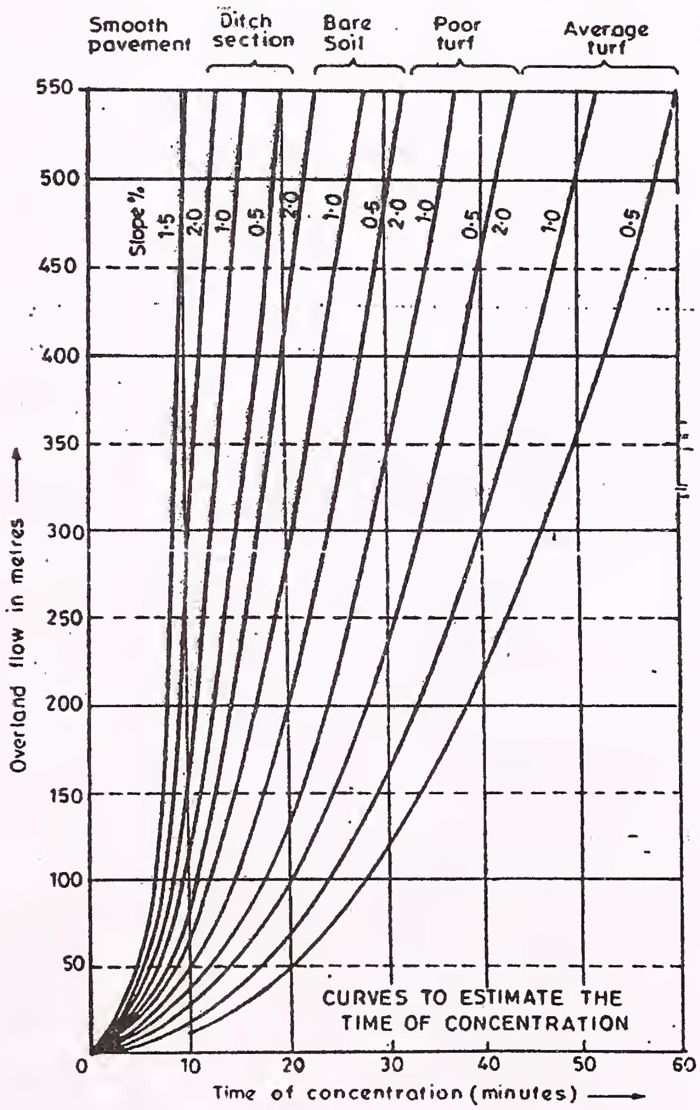



Fig. 2.10 : Chart of Estimating Time of Concentration (IRC:SP:42)

The values of n are given in **Table 2.6.**

The discharge Q is then worked out using the equation:

$$Q=AV$$

**Table 2.6 : Manning's 'n' And Maximum Permissible Velocity of Flow in Open Channels**

| S.No. | Ditch Lining | Manning's 'n' | Allowable velocity to prevent erosion m/s |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| 1. | Natural Earth | | |
| | A. Without Vegetation | | |
| | (i) Rock | | |
| | (a) Smooth and Uniform | 0.035-0.040 | 6 |
| | (b) Jagged and 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 |
| | GM | 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 |
| | SM | 0.023-0.025 | 0.9-1.2 |
| | CL and CI | 0.022-0.024 | 0.6-0.9 |
| | MI and ML | 0.023-0.024 | 0.9-1.2 |
| | OL and 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 eroded 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 eroded soil | 0.070-0.050 | 1.5-1.8 |
| | (c) Clean bottom wit h bushes on 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 |
| 2. | Paved | | |
| | A. Concrete with all surfaces, Good or Poor | | |
| | (i) Trowel finished | 0.012-0.014 | 6 |
| | (ii) Float finished | 0.013-0.016 | 6 |
| | (iii) Formed, no finish | 0.014-0.016 | 6 |
| | B. Concrete bottom, float finished, with sides of | | |
| | (i) Dressed stone in mortar | | |
| | (ii) Random stone in mortar | 0.015-0.017 | 5.4-6 |
| | (iii) Dressed stone or smooth concrete rubble | 0.017-0.20 | 5.1-5.7 |
| | (Rip-rap) | 0.020-0.025 | 4.5 |
| | (iv) Rubble or random stone (Rip -rap) | | |
| | C. Gravel bottom with sides of | 0.025-0.030 | 4.5 |
| | (i) Formed concrete | | |
| | (ii) Random stone in mortar | 0.017-0.020 | 3 |
| | (iii) Random stone or rubble (Rip-rap) | 0.020-0.0238 | 2.4-3 |
| | D. Brick | 0.023-0.033 | 2.4-3 |
| | E. Bitumen (Asphalt) | 0.014-0.017 | 3 |
| | | 0.013-0.016 | 5.4-6 |

### 2.4.6. Surface drain linings

**2.4.6.1. The need:** Unlined, bare earth surfaces of roadside ditches are highly susceptible to erosion unless the flow is limited to a very small amount. It is, therefore, necessary that roadside ditches are provided with protective lining which would avoid serious erosion problems and keep them serviceable. There is a wide variety of different types of linings and the choice of appropriate lining will depend on the site conditions. The most common lining which works satisfactorily in most situations is grass.

**2.4.6.2. Turfing:** Grass lining is more economical than other linings to establish and with proper maintenance, will provide adequate protection against erosion for most of the site situations. A key factor to the success of grass lining is that it must form a firm, dense turf. For a rapid establishment, of a vegetal lining in ditches, the same principles must be followed as adopted for providing a vegetal protection cover on slopes. In the rainy season and in high rainfall areas where it may be difficult to hold seeds and mulch in the ditch, an open mesh matting of suitable material may be used instead of straw or hay mulch. The matting is laid down after seeding and pegged with staples. Where more than one width of matting is required, as is usually the case, the adjacent stripes should be overlapped (50-75 mm) and stapled at 2 to 2.5 m intervals. It is important to ensure that matting is, elsewhere, in contact with the soil for, if water gets under the matting, the seeds and soil will wash away. The efficiency of this technique depends on making the water flow over the net, as it is matting which prevents erosion until vegetation is established even when large amounts of rainwater flow over it. The roadside ditch can also be lined with sod freshly cut, to a depth of about 20 mm from a well established dense turf. Sod strips should be placed across the ditch rather than length wise. The joints should be staggered and strips pressed firmly against one another. After the sod is in place, it is tamped or rolled to produce a smooth continuous surface. It should be watered for several weeks after placing, as conditions may warrant.

**2.4.6.3. Paved linings:** Experience has shown that under two extreme site conditions on very flat grades and then again on steep grades, the technique of providing grassing as a surface lining does not always prove satisfactory. On very flat grades (less than 0.5 per cent), the flow over a grass lining is too slow, giving rise to the problem of silting or occurrence of deposition which is rather difficult to maintain. and, over steep grades, erosive velocities are reached, which, due to the scouring action, can destroy the grass lining completely.

In these situations, alternative lining of cement concrete, brick/rubble masonry especially on the internal streets passing through a village may be resorted to.

A practical concrete lining is the prefabricated type. In this construction, the panels are cast in standard forms at a convenient central plant **(Fig. 2.11)**.

**2.4.6.4. Velocity of flow:** For efficient functioning of a side ditch, the flow must be fast enough to prevent silting or deposition but at the same time the flow must not be so fast as to cause serious damage by scouring action. Ditches with grass lining should have a slope at least 0.5% to avoid deposition and siltation. The ditch has to have a grade steeper that of the roadway. The ditch, in that case, will have to be deeper as it moves down grade and will also move farther away from the central line of the road, if the side slopes are not changed. One alternative way to overcome the problem of silting or occurrence of deposition is to provide a secondary smaller channel of V shape at the bottom of the ditch **(Fig. 2.12)** to concentrate low flow in a smaller area of cross-section thereby increasing the flow velocity. This secondary channel sustained flow over long periods makes it impossible to maintain grass lining, a half pipe section may be placed in the secondary channel.

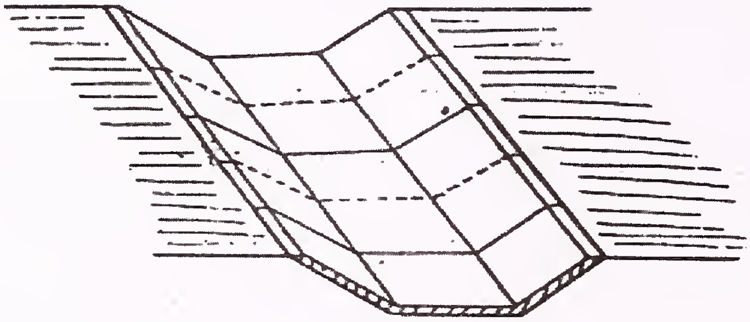


**Fig. 2.11 : Prefabricated Concrete Lining**

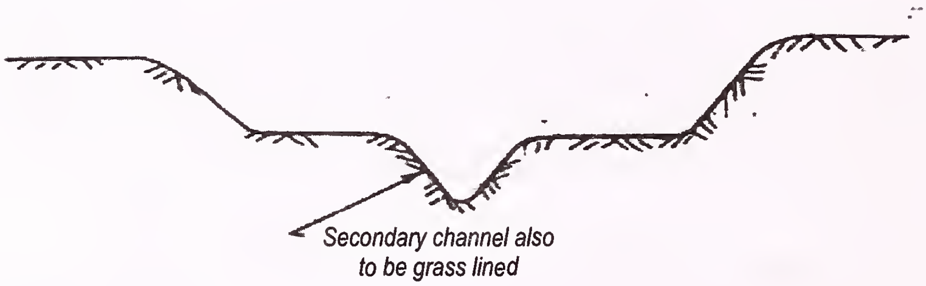



**Fig. 2.12 : Secondary Channel**

**2.4.7. Step-wise procedure for design of open drains:** The design of the channel is done in the following step-by-step manner.

(1) From the known soil type, arrive at the value of Manning's Rugosity coefficient, side slopes and the maximum permissible velocity.

(2) Determine the slope from the topography.

(3) For the given discharge, calculate the hydraulic mean depth from Manning's Formula.

(4) Find out the cross-sectional area from the given discharge and the maximum permissible velocity.

(5) From the results of steps 3 and 4, solve the simultaneous equations to obtain the bottom width and depth.

**2.4.8. Illustrative example:** A longitudinal channel with a trapezoidal cross-section is to be constructed in a cut section. The longitudinal slope is 1 in 250. The soil is clay, with Mannings's Rugosity Coefficient of 0.024. The maximum allowable velocity is 0.6 m/s. Design the drain for a discharge of 0.1 cum/s.

$$\text{Solution } V = \frac{R^{2/3} S^{1/2}}{n}$$

$$0.6 = \frac{R^{2/3}(0.004)^{1/2}}{0.024} = \frac{R^{2/3} x 0.063}{0.024}$$

$$R = \left(\frac{0.6x0.024}{0.063}\right)^{3/2} = 0.12 \text{ m}$$

$$\text{Discharge } Q = 0.1 = V \text{ x } A = 0.6A$$

$$\therefore \quad A = \frac{0.1}{0.6} = 0.16$$

$$\text{Perimeter } \quad P = \frac{A}{R} = \frac{0.16}{0.12} = 1.3 \text{ m}$$

Taking the side slopes of the trapezoidal drain as 2 horizontal : 1 vertical

$$P = b+2d(1+2^2)^{½} = b+4.48 \text{ d} = 1.3$$

Where b is the base width of the drain and d, the depth in metres. For a drain base width of 0.3 m, the depth works out to about 0.22 m. A typical cross-section of the drain is shown in **Fig. 2.13**

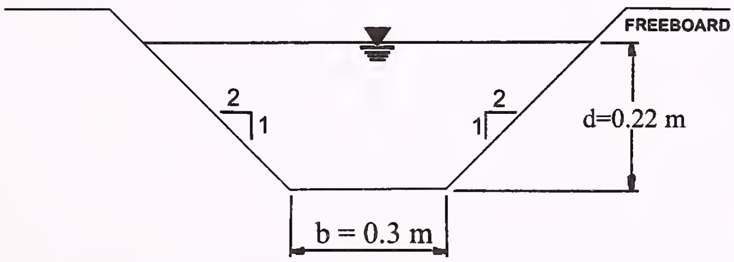



**Fig. 2.13 : Typical Cross-Section for Illustrative Example**

## 2.5. Rehabilitation of Gravel Roads

**2.5.1. Rehabilitation factors:** The various factors to be considered for rehabilitation are as under:-

- Whether an overlay/strengthening layer is required or a non-overlay strategy is appropriate
- Whether new materials are required or the existing material can be improved upon
- Whether full reconstruction or partial reconstruction

The consideration of the above factors will depend on the analysis of field data collected during 'Condition Surveys', 'Traffic Surveys' and 'Drainage Surveys.

**2.5.2. Condition survey data and its analysis:** A condition survey of each gravel road needs to be carried out at least once a year. The condition of each road is evaluated as 'Pavement Condition Index' (PCI) on a rating scale of 5 to 1 as detailed below:-

(a) Based on riding comfort at 40 km/h speed

| | | |
|---|---|---|
| Smooth | - | 5 |
| Comfortable | - | 4 |
| Slightly Uncomfortable | - | 3 |
| Rough and Bumpy | - | 2 |
| Dangerous | - | 1 |

(b) Based on normal driving speed possible (km/h)

| Normal Driving Speed (km/h) | PCI |
|---|---|
| Over 35 | 5 |
| 25-35 | 4 |
| 15-25 | 3 |
| 10-15 | 2 |
| <10 | 1 |

**2.5.3. Drainage survey for rehabilitation:** The condition survey data will often throw up indications of distresses which are moisture related; e.g. rutting, depressions and potholes etc. Even if such moisture-related distresses are not evident, there can exist a potential to cause such distresses. The provisions made for drainage in the original design must be examined in order to determine their adequacy. The longitudinal and transverse grades, width of pavement layers, slopes and dimensions of roadside ditches etc. need to be evaluated for their adequacy. Also, a topographic map of the area must be studied for the surface and subsurface movement of water. The observations on the water level in road side ditches, collection of water on the shoulders, over the pavement and in the adjoining area are very helpful in evaluating the drainage system. The properties of subgrade soil, gravel base and gravel surfacing must also be evaluated as part of the drainage survey. It is only after analyzing the drainage survey data that it is possible to attribute the types of distresses observed in the condition survey, (as also the potential for such moisture-related distresses to develop) to deficiencies in the drainage system.

**2.5.4. Alternative rehabilitation strategies:** After the collection of data from the Condition and Drainage Surveys, alternative rehabilitation strategies can be worked out including inter alia, Reconstruction, Regravelling or Routine Maintenance.

More often than not, lack of proper drainage of gravel roads is the cause of distresses that get manifested over gravel road surfaces. Therefore, it becomes necessary to augment the existing drainage system. Simultaneously deficiencies in the properties of sub-base, base and surfacing materials may also exist, as also structural deficiencies in the thicknesses of various layers to withstand the traffic loads. On the basis of data collected from the Condition Surveys as well as Drainage Surveys, and considering the comparative costs of the various possible alternatives, an appropriate rehabilitation strategy should be arrived at.

**2.5.5. Selection of most appropriate rehabilitation strategy:** As per the design criterion for gravel roads, the performance level should not be allowed to fall below a PCI of 2.0. If, however, proper maintenance has been neglected, the following guidelines may be followed for rehabilitation:-

| PCI | Rehabilitation Measures |
|---|---|
| 1 | Reconstruct Immediately |
| 1 to 2 | Regravel Immediately;<br>Routine maintenance to continue |
| 2 to 3 | Regravel within 1 year;<br>Routine maintenance to continue |
| >3 | Routine Maintenance |

Overlay thickness requirement of a Gravel Road can be worked out for upgradation/ rehabilitation as per the procedure given in Para 2.3.4.2

# 3. CONSTRUCTION AND QUALITY CONTROL

## 3.1. Choice of Technology

For rural road construction and maintenance, it is advisable to adopt an intermediate type of technology, somewhere in between the purely manual methods on the one hand and total mechanization on the other.

Since agricultural tractors are increasingly becoming popular in the rural areas, it would be both suitable and economical to deploy them for rural road works by suitably scheduling the operations between agricultural operations and road works. **Figs. 3.1** and **3.2** bring out the advantages of adopting tractor-bound technology.

The appropriate technology recommended for various task operations in rural road development works is outlined in **Table 3.1**.

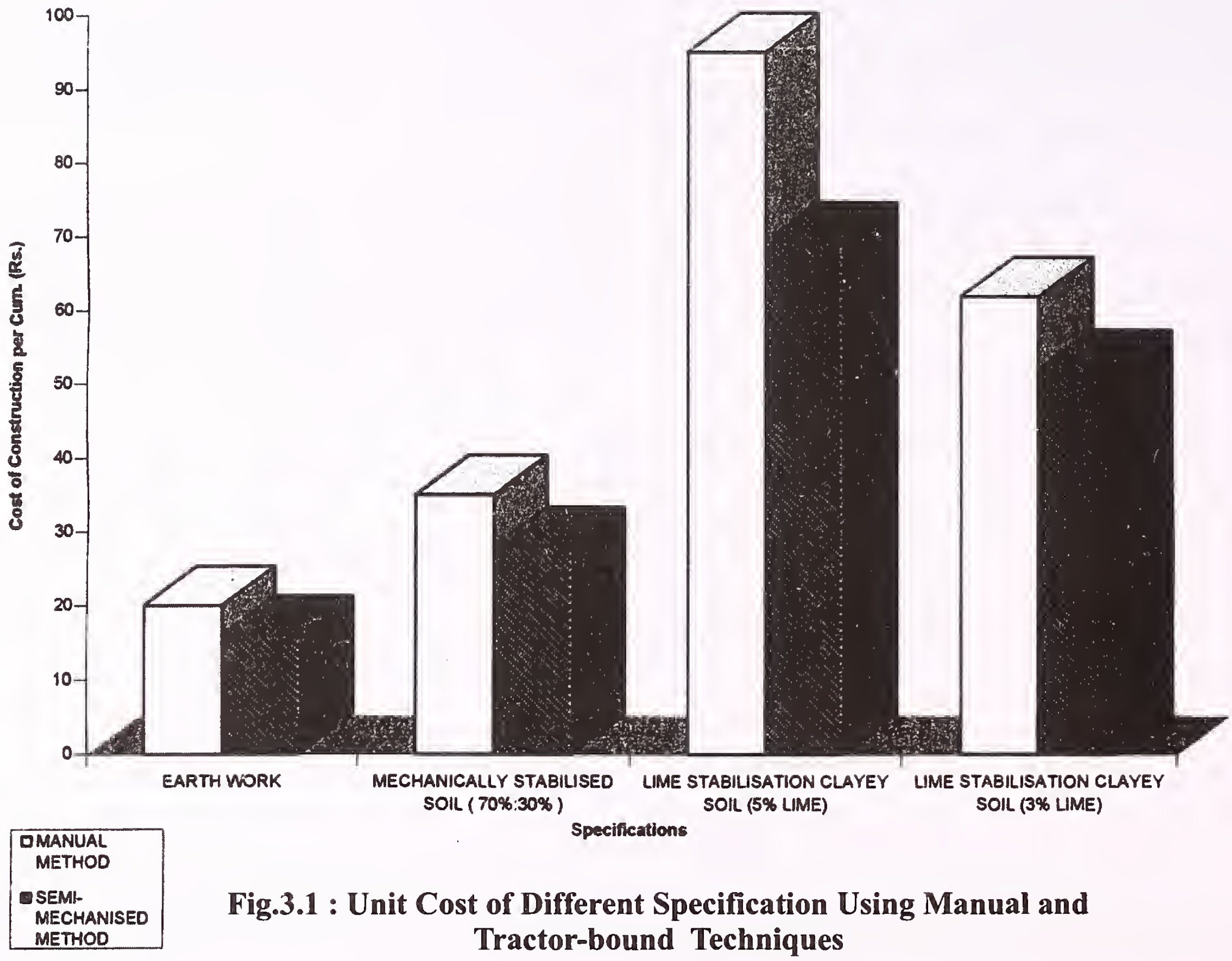



**Fig.3.1 : Unit Cost of Different Specification Using Manual and Tractor-bound Techniques**

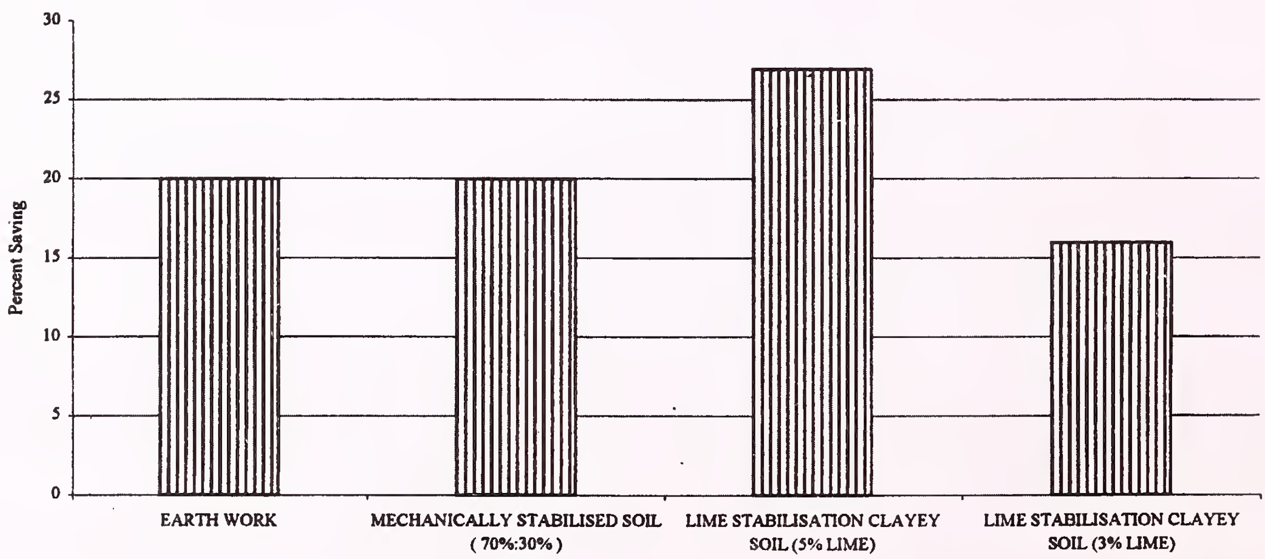



**Fig. 3.2: Percent Saving in Carrying Out Various Operations by Using Tractor-bound Technology**

(Source : Use of Low Cost Agricultural Implements in Low Volume Road Construction Transportation Research Record, USA)

**Table 3.1 Choice of Technology For Rural Roads**

| S. No. | Item of Work | Tools/Equipment Suitable | | | Recommended Technology for Rural Roads |
|---|---|---|---|---|---|
| | | Labour Based Technology | Intermediate/Semi - Mechanized Technology | Equipment Oriented Technology | |
| 1. | Clearing and grubbing | Pickaxe, Hoe, Hand shovel, saw, plough | Rippers towed by agricultural tractor | Dozers, Rippers attached to Dozers | Labour based technology is quite efficient, generates employment, is cheap and hence recommended. |
| 2. | Excavation for borrowing soil or natural gravel for embankment// sub -base/ base construction | Pickaxe, Hoe, hand shovel | Rippers towed by agricultural tractor | Excavator, Dozer, Shovel, Scraper | Labour based technology is quite efficient, for the small volume of work, generates employment, is cheap, and hence recommended. |
| 3. | Excavation in soft rock | Pickaxe, Crowbar Wedging tools | - | Dozer, Ripper, Excavator | Labour based technology is quite efficient, adequate for the small volume involved, generates employment, is cheap, and hence recommended. |
| 4. | Excavation in hard rock | Hand drilling and blasting | - | Air compressor, Jack hammers, and blasting | For small jobs, hand drilling and blasting is adequate. For large jobs, use of equipment is recommended. |
| 5. | Loading and unloading of earth, natural gravel , stone materials | Shovel, Hoe | Shovel, Hoe | Loader | Manual methods are adequate for the small quantities involved, because of employment generation and relatively low cost. |

## Table 3.1 Choice of Technology For Rural Roads

| S. No. | Item of Work | Tools/Equipments Suitable | | | Recommended Technology for Rural Roads |
|---|---|---|---|---|---|
| | | Labour Based Technolobgy | Intermidiate /Semi-Mechanized Technology | Equipment Oriented Technology | |
| 6. | Hauling of earth, natural gravel , stone materials<br>1) Lead 0-100 m | Head basket and wheel barrow | — | — | Labour based technology is recommended. |
| | 2) Lead 100-1000 m | Pack animals | Animal cart, agricultural tractor-trailer, trucks | Scraper, Loader, Dumper, Trucks, | Labour based or immediate technology is recommended recommended. |
| | 3) Over 1 km | — | Agricultural tractor-trailer, trucks | Scraper, Loader, Dumper | Intermediate technology is recommended |
| 7. | Spreading of soil or pavement materials in layers | Hoe, Rake | Blader attachment towed by agricultural tractor | Grader, Dozer | Manual method or intermediate technology is recommended. |
| 8. | Breaking clods for soil stabilisation | Wooden Mallet | Disc harrow or ripper towed by agricultural tractor | Disc harrow or ripper towed by dozer or tractor | Intermediate technology using agricultural implements is recommended. |
| 9. | Watering | Watering cans | Water Browser towed by agricultural tractor | Self propelled Water Tanker | Intermediate technology using a water bowser towed by an agricultural tractor is recommended. |
| 10. | Mixing stablizer like lime/cement and soil | Hoe, rake | Disc harrow and ripper towed by agricultural tractor | Single pass Stabliser | Intermediate technology using agricultural implements towed by agricultural tractor is recommended because of its low cost. |

| S. No. | Item of Work | Tools/Equipments Suitable | | | Recommended Technology for Rural Roads |
|---|---|---|---|---|---|
| | | Labour Based Technolobgy | Intermidiate /Semi-Mechanized Technology | Equipment Oriented Technology | |
| 11. | Production of stone aggregates 1) For Water Bound Macadam | Hammer | Mobile crushing plant with manual loading | Crushing Plant with screens, conveyors and loaders | Manual breaking of stones is recommended for small jobs. For larger jobs, small mobile crushing plants are recommended. |
| | 2) For Wet Mix Macadam, Concrete and bituminous surfacing | Not recommended | Mobile crushing plant with manual loading | Crushing Plant screens, conveyors and loaders | Intermediate Technology using mobile crushing plant and manual loading is recommended. |
| 12. | Compaction of earthwork sub - base, WBM and aggregate base | Rollers pulled by animals or human labour | 8/10 t Static Smooth Wheel Roller | Vibratory Roller | 8/10 t Static smooth wheel roller is recommended. |
| 13. | Prime Coat/ Tack Coat | Hand held cans with holes | Hand held lance provided with a sprayer, operated by compressor | Self propelled Bitumen Pressure Distributor | Intermediate technology using hand held lance with a sprayer and operated by compressor or hand pump is recommended |
| 14. | Application of binder for surface dres sing i) Emulsion | Hand held cans with holes | Hand held lance with sprayer, operated by compressor | Self propelled Bitumen Pressure Distributor | Hand held lance with sprayer, operated by compressor or hand pump is recommended. |
| | ii) 80/100 Pen. Grade Bi tumen | Hand held cans with holes | Hand held lance with sprayer, operated by compressor | Self propelled Bitumen Pressure Distributor | Hand held lance with sprayer, operated by compressor or hand pump is recommended. |
| 15. | Heating Bitumen | Bitumen Boiler of Small capacity | Bitumen Boiler of small capacity | High capacity Bitumen tanks | Bitumen boiler of small capacity is recommended. |

| S. No. | Item of Work | Tools/Equipments Suitable | | | Recommended Technology for Rural Roads |
|---|---|---|---|---|---|
| | | Labour Based Technolobgy | Intermidiate /Semi-Mechanized Technology | Equipment Oriented Technology | |
| 16. | Bitumen Premix Carpet | Not recommended | Mini-Hot Mix Plant of 6 t capacity | Mobile Hot Mix Plant of 20 t capacity | Mini Hot Mix Plant of 6 t capacity is recommended. |
| 17. | Application of chips for surface dressing | Manual, by basket, and spreading by rakes | Spreader box towed by agricultural tractor | Self propelled Chip spreader | Mannual or intermediate technology is recommended. |
| 18. | Laying of Premix Carpet | Manual, by rakes | Manual by rakes | Paver Finisher | Mannual spreading by rakes is recommended. |
| 19. | Rolling of<br><br>i) Chips for surface dressing | Hand operated Roller Not recommended | 8/10 t static smooth wheel roller | 8/10 t static smooth wheel roller | 8/10 t staic smooth wheel roller is recommended. |
| | ii) Premix Carpet | Not recommended | | | |
| 20. | Production of Cement Concrete | Hand mixing Not recommended | Small concrete mixers, with weighing facility | Small Batching Plants | Small concrete mixers with weighing facility are recommended |
| 21. | Vibration of concrete | Rodding Not recommended | 1 Needle vibrators<br><br>2 Screeds for concrete pavement<br><br>3 8 /10 t Roller for Roller Compacted Concrete. | 1 Needle vibrators<br><br>2 Screeds<br><br>3 Vibratory Roller for Roller Compacted Concrete. | 1 Needle vibrators for RCC slabs, beams, mass concrete.<br>2 Screeds for concrete pavement.<br>3 8/10 t static roller or vibratory roller for Roller Compacted Concrete. |

(Source : Kadiyali, Dr. L.R and Lal, Dr. N.B 'Principles and Practices of Highway Engineering Khanna Publishers, New Delhi, 2006)

### 3.2. Plant Selection and Usage

**Table 3.2** gives the plant/equipment considered appropriate and economical for various field operations in the construction of gravel roads.

**Table 3.2 Appropriate Plant/Equipment for various Field Operations**

| Construction Operation | Appropriate Plant/Equipment |
|---|---|
| i) Clearing, Grubbing and Excavation. | Ripper towed by agricultural tractor. |
| ii) Hauling of Earth | Agricultural tractor-trailor. |
| iii) Spreading of soil/gravel in layers | Blade attachment towed by agricultural tractor. |
| iv) Adding water to soil | Water Bowser towed by agricultural tractor. |
| v) Mixing of soil with water | Agricultural tractor towed disc harrows. |
| vi) Mixing of different locally available materials for mechanica l stabilization | Agricultural tractor towed Rotavator. |
| vii) Pulverization of soil clods | Agricultural tractor-towed disc harrows. |
| viii) Mixing of stabilizer (lime or cement) and water with soil. | Agricultural tractor-towed Rotavator. |
| ix) Compaction | 80-100 kN Static smooth-wheeled Road Roller. |

**3.3. Sequence of Construction Operations :** First and foremost in the sequence of construction operations is the site preparation, as per specified procedure. After site preparation, the cross drainage works (culverts, causeways etc.) and the surface drains need to be provided as per the Drainage Plan requirements. The Earth work and Subgrade preparation are then taken up, (discussed in para 3. 4). For a sub-base course, where required to be provided, the materials to be blended are placed in the required proportions, mixed thoroughly and spread to the desired thickness and shape, (para 3.5). After compacting the sub-base, the materials to be blended for the gravel base are placed in the required proportions, mixed thoroughly, spread to the required loose thickness and shape and compacted to the desired density. The compacted gravel base is finished to the desired profile (described in para 3.6). Thereafter, a gravel surface course is laid, compacted and finished to the desired profiles.

### 3.4. Earthwork and Subgrade Preparation

#### 3.4.1. Earthwork

**3.4.1.1.** The cost of earthwork generally constitutes 40 to 60% of the total road construction cost. It is, therefore, essential that careful consideration is given towards site planning and various operations involved in the execution of the earthwork for economizing the cost of road construction. Since gravel roads are often upgraded later to black-topped flexible pavement standards as the traffic grows, it is both difficult and uneconomical to make up any deficiencies in earthwork at a later stage, pointing to the need for strictly adhering to the specifications laid down in Clause 301 of MORD Specifications. The main activities involved in earthwork operation are:

(i) Soil survey and laboratory investigations for suitability of material and for determining the OMC and MDD of embankment material compaction

(ii) The construction of embankment.

**3.4.1.2.** Test pits should be dug in borrow areas from where the embankment materials are to be obtained and representative samples tested for determining their suitability as a fill material as per the requirements laid down in Clause 301.2.3 of MORD Specifications. Ordinarily borrow pits along the road should be discouraged. Where permitted by the Engineer, the requirements laid down in Clause 301.4.1 of MORD Specifications must be complied with.

**3.4.1.3.** Prior to the construction operations, the formation for embankment construction should be prepared as laid down in Clause 301.4 of MORD Specifications. The various construction operations should be carried out as per Clause 301.5 of MORD Specifications. The soil for embankment construction at the time of placement should be at proper moisture i.e., ($\pm$)2% of OMC. Additional water should be added if required and the soil should be turned 2 to 3 times so that the water is quite uniformly dispersed. In case the soil contains excess moisture, the soil should be allowed to dry to bring it the optimum before compaction.

**3.4.1.4.** For earthwork filling, in layers, the compacted thickness of the soil layer should not exceed 150 mm when static smooth wheeled rollers of 80 to 100 kN static weight are used. When the earthwork has reached a stage when the general form of the final shape of the embankment has been obtained, the spreading of the earth should be done, in straight reaches, to a crowned shape, and to appropriately superelevated 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. The clods should be broken to less than 75 mm size. The equipment for compaction should ordinarily be a 80-100 kN tonne smooth-wheeled power roller. For the control of moisture prior to compaction, a truck mounted water tanker should be used, but in the absence of such a water tanker, a tractor-towed water bowser could be used **(Fig 3.3)**.

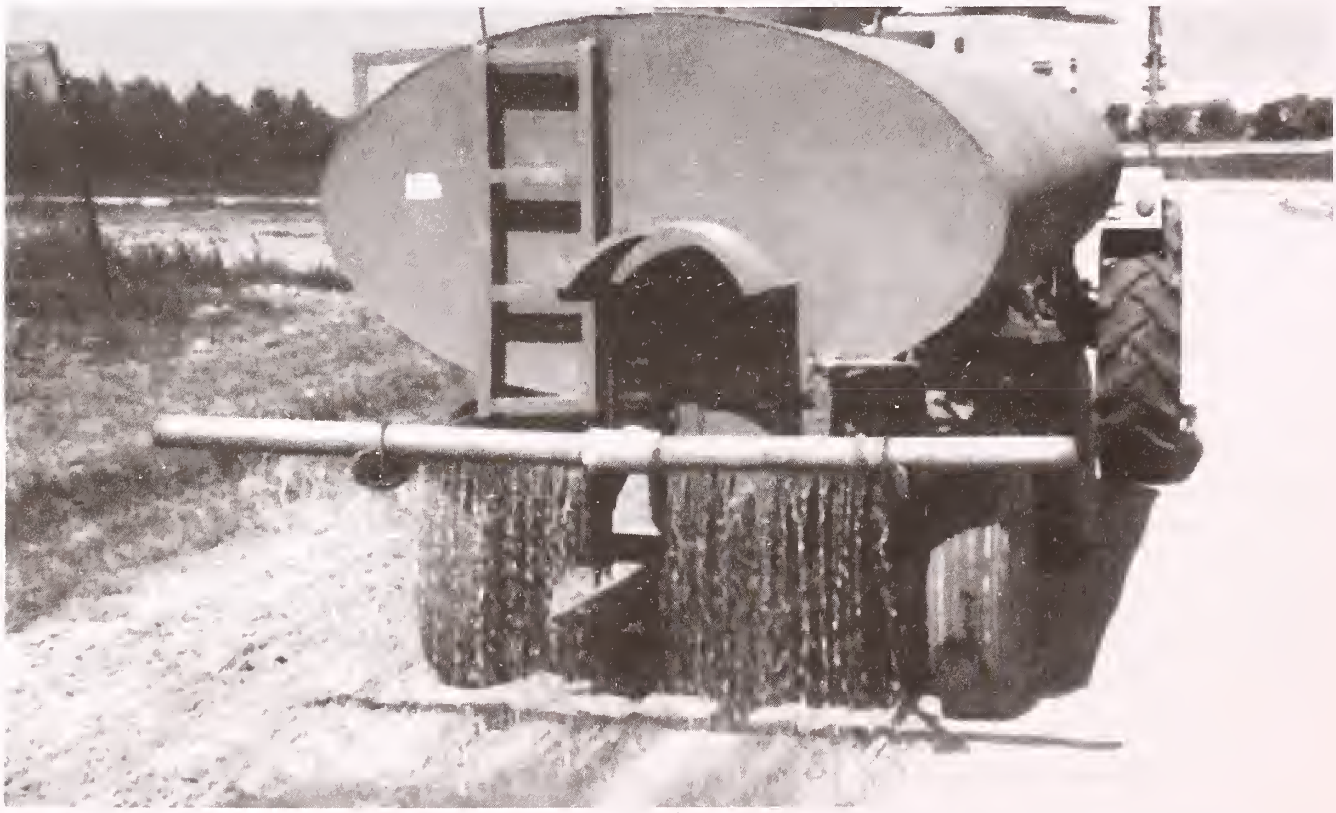


**Fig. 3.3 : A Tractor-towed Water Tanker for Control of Moisture Prior to Compaction**

**3.4.1.5.** The tolerance limits of variations from the specified moisture content are normally ±2% of OMC. 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 plant, in accordance with Clause 301 of MORD Specification. Each compacted layer shall be tested in the field for density, and accepted before operations for the next layer commence. The field density in the body of the embankment shall not be less than 97% of standard Proctor density and 100 percent in the top 300 mm of the embankment (Subgrade). Expansive clay (such as black cotton soil) possessing high volumetric changes should be compacted at a moisture content, wet of the optimum and to a density not exceeding 90 percent of the laboratory standard Proctor density. The overall profile should be improved with each successive layer so that as the subgrade level is approached, the profile of the formation is as per lines and grades.

The related quality control requirements are detailed in the Quality Assurance handbook for Rural Roads, 2007.

**3.4.2. Subgrade preparation:** The top of embankment which is to receive the hard crust is called subgrade. The subgrade soil layer shall preferably be made from good soil available locally. The soil shall be free from vegetative matter and rubbish. In case the reach is at grade or in cutting and insitu soil is to be used for subgrade, the method consists in loosening the soil to 300 mm depth, bringing the moisture to proper value and compacting it with a suitable roller to maximum Proctor density. The compaction process should commence at the edges and progress towards the center. When the reach is in filling, it is necessary to ensure that atleast the top 300 mm of the embankment constituting the subgrade of the pavement should be compacted to 100 percent Proctor density in two layers at controlled moisture. The subgrade should be finished to the desired profile; a camber board should be used to check the cross profile **(Fig. 3.4)**.

The related quality control requirements are detailed in the Quality Assurance Handbook for Rural Roads.

### 3.5. Sub-Base Construction

In Gravel Roads, generally a gravel base of required thickness, as per the Design Catalogue, **Fig.2.6** in Section 2, is provided directly over the subgrade, except for the very weak subgrade (CBR=2), where a capping layer is provided. However, a part of the gravel base thickness can be converted into a subbase **(Fig. 2.7, Section 2)** layer having a CBR value in between the CBR values of the subgrade and the gravel base. The sub-base can be a Granular Sub-base (GSB) as per Clause 401 of MORD Specifications or Lime-treated soil sub-base, as per Clause 403 of MORD Specifications or Cement-treated soil sub-base as per Clause 404 of MORD Specifications, depending on the locally available materials. The salient features of construction of the above three types of sub-base courses are outlined in paras 3.5.1, 3.5.2 and 3.5.3 below.

**3.5.1. Granular sub-base:** Where the locally available materials meet the grading, plasticity and other requirements as laid down in Clause 401 of MORD Specifications, these

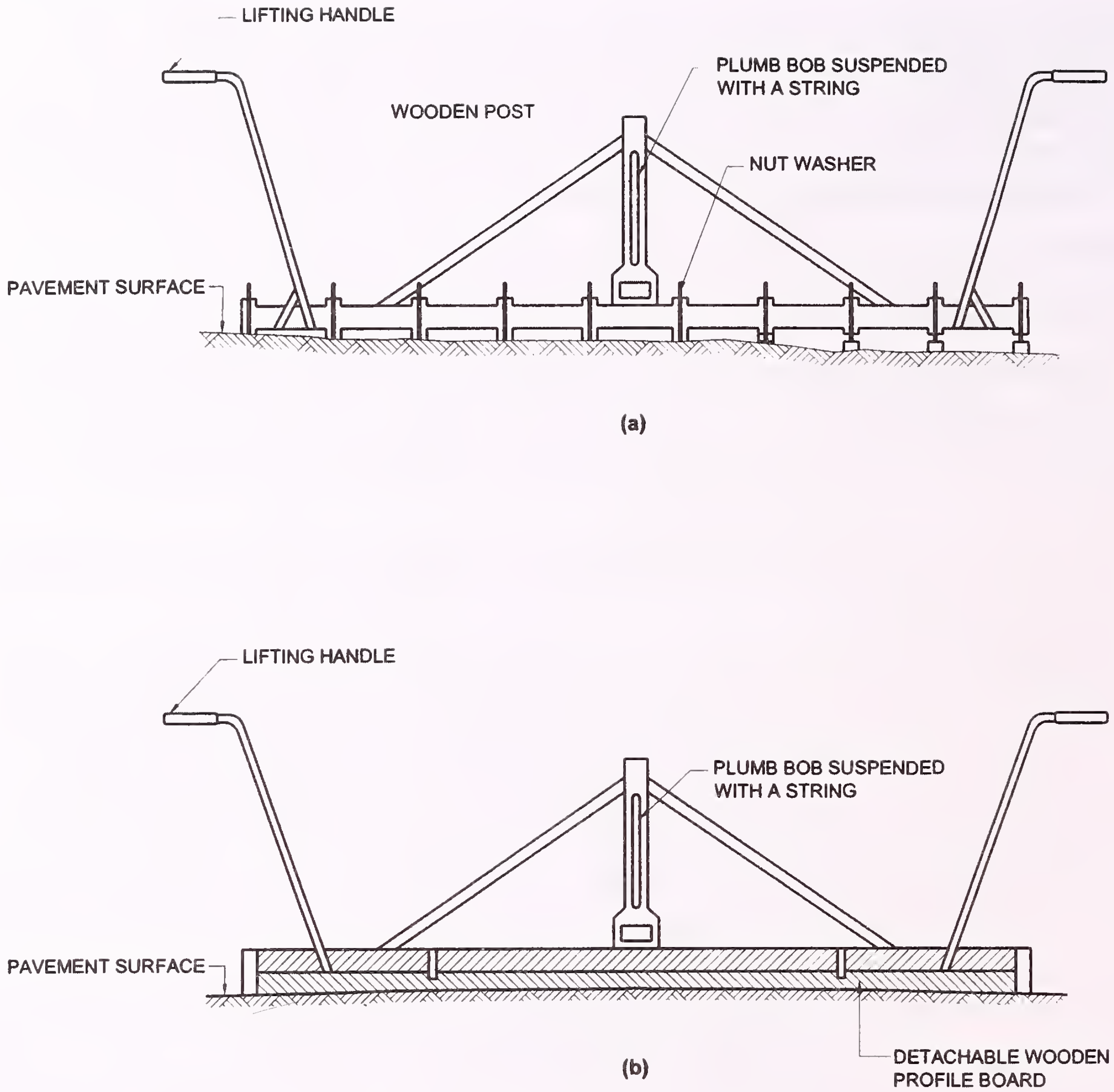



**Fig. 3.4 : (a) and (b) Two Designs of Camber Board**

materials can be used directly without any processing'. However, where the locally available materials do not meet the various requirements without any processing, the following mechanical stabilization techniques can be resorted to:

(a) Stabilization of clay with sand, involving the mixing of clay with sand so that the resulting mixture will have controlled plasticity (PI < 6) and minimum 30% sand content. The clay shall be excavated and clods broken by 4 to 6 passes of tractor-towed disc harrows **(Fig. 3.5)** to meet the specified pulverization requirements. The soil should be spread in place to the required loose-thickness. The requisite quantity of sand transported from local sources is then added. The required quantity of water is added to bring the moisture content to the optimum. Depth blocks should be used for the control of required layer thickness **(Fi.g 3.6)**. The mix should then be compacted by 80 to 100 kN smooth-wheeled roller to 100% Proctor density.

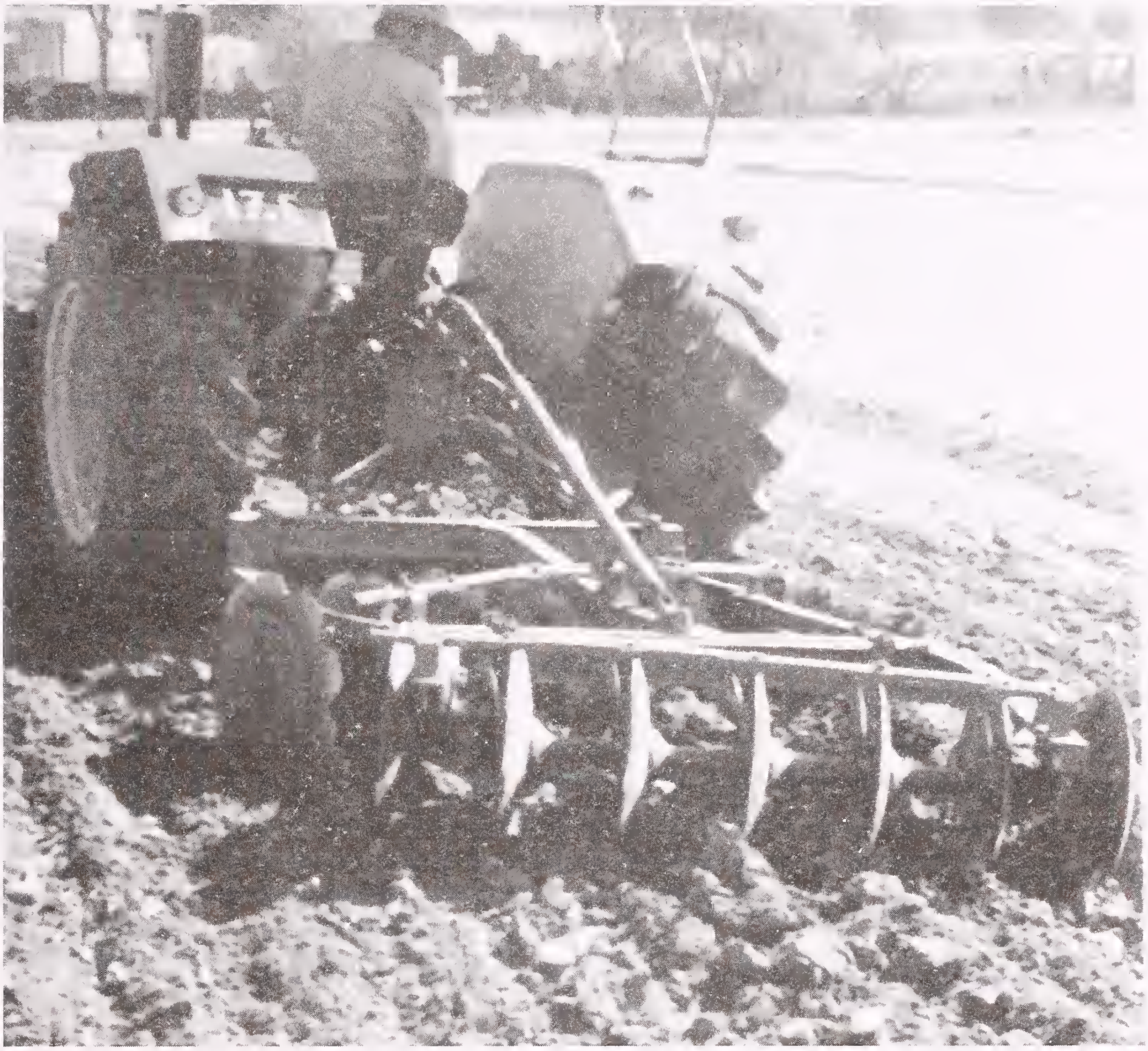


**Fig. 3.5 : Tactor-towed Disc Harrows for Pulverization of Clay Clods**

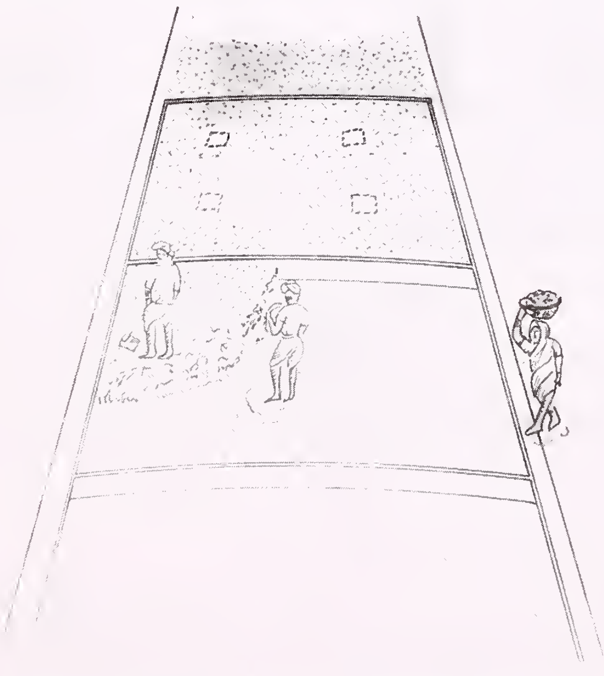


**Fig. 3.6 : Use of Depth Blocks for Control of Layer Thickness**

(b) Stabilization of soil with soft aggregates (such as brick bats, kankar and laterite) is similar to the mechanical stabilisation of clay with sand as at (a) above. The soft aggregates to be added to the blended soil mixture shall be of size less than 30 mm and have wet AIV not more than 50%. The blended soil and aggregate should be mixed together in the ratio 7:3 by volume.

(c) Soil-Gravel/Soil-Moorum mixes shall contain a fair proportion of all particle sizes together with sufficient clay to provide proper cohesion as per technical grading limits. The maximum aggregate size should not exceed one-third the thickness of stabilized layer. The construction shall otherwise be carried out in the same manner as for other mechanically stabilized soil construction. Care should be taken that the layer is thoroughly compacted and laid to proper profile.

### 3.5.2. Lime stabilized soil construction

The specification for lime stabilized soil construction shall apply essentially to stabilization of alluvial soil, moorums, clays and black cotton soils. As mentioned earlier, the borrow areas may be previously watered for easy excavation. The excavated soil shall be pulverized, so that all soil clods pass the ISS 26.5 mm sieve and more than 80% through ISS 4.75 mm sieve using tractor-towed disc harrows. In case of black cotton soil, the borrow areas shall be previously watered and the clods which are generally in the size range of 100-150 mm should be pulverized with agricultural equipment (disc-harrows), and Rotavator **(Fig. 3.7)**. The pulverized soil (alluvial/moorum/ black cotton soil) shall be spread on the prepared receiving surface, and slaked lime spread over it in the required quantity **(Fig. 3.8)** as per the guidelines provided in Clause 403 of MORD Specifications. For the safety of workers, hand gloves should be provided while handling lime. The laid material shall be cut and mixed thoroughly, using a tractor-towed Rotavator. The mass shall then be spread to the required loose thickness to proper profile. The compacted thickness of a layer shall not exceed 150 mm if 80-100 kN smooth wheeled roller is used. The laying width shall extend by 150 mm on either side, beyond the pavement width on top. The layer shall then be thoroughly compacted without much delay (within 3 hours) after mixing with lime with a 80-100 kN smooth-wheeled roller giving 6-8 coverages as for earthwork. The subbase layer shall be checked for compaction. All controls and permitted tolerances shall be as given in Clause 403 of MORD Specifications. The surface after compaction shall be cured for 7 days by sprinkling water periodically, covering by wet gunny bags **(Fig. 3.9)** soon after which subsequent pavement courses shall be laid to prevent the surface from drying out and becoming friable. The traffic shall not ply directly over the stabilized layer during the period of curing. The related quality control requirements are detailed in the Quality Assurance Handbook for Rural Roads.

### 3.5.3. Cement stabilized soil construction

For cement stabilized soil construction, the various construction operations and the equipment deployed are essentially the same as for lime stabilized soil construction except that compaction should be completed within 2 hours after mixing.

**Fig. 3.7 : A Tractor-towed Rotavator for Pulverization of Clods and Mixing of Soil with Stablizer**

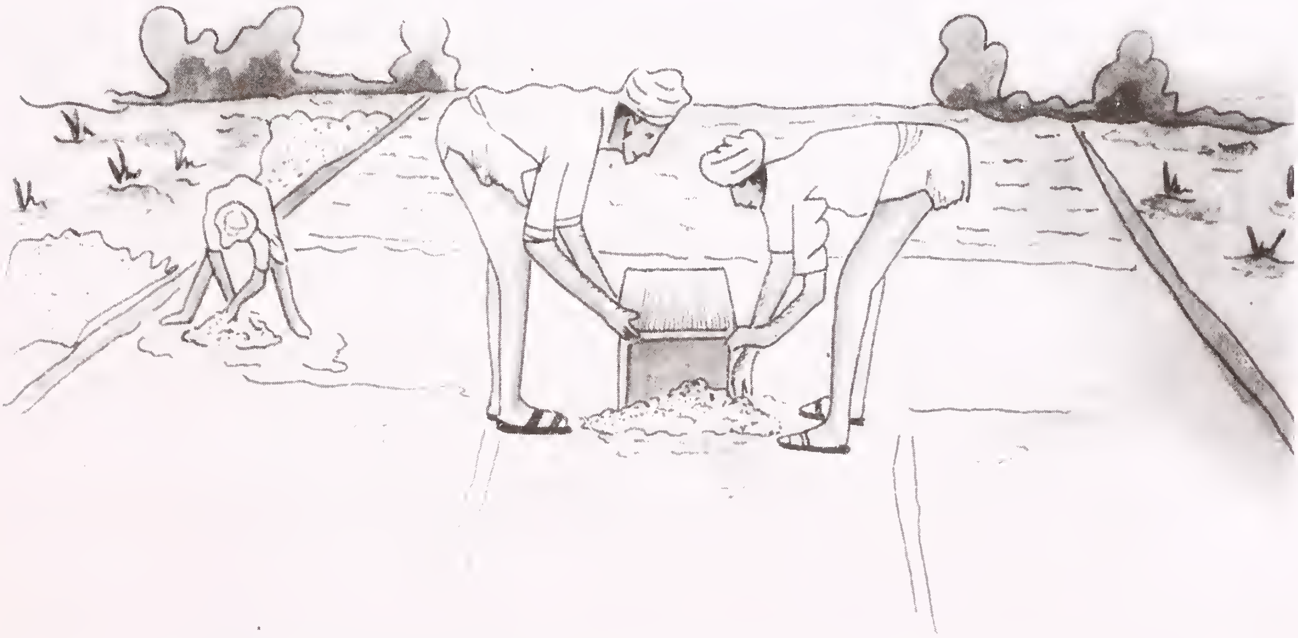


**Fig. 3.8 : Spreading of Slaked Lime in Required Quantity over the Soil**

**Fig. 3.9 : Curing by Covering the Compacted Stablized Soil Surface with Wet Gunny Bags**

## 3.6. Gravel Base/Surface Course Construction and Quality Control

While detailed specifications are contained in clause 402 of MORD Specifications, the salient features of the Methodology to be adopted and the Quality Control requirements are given below:

### A. METHODOLOGY

1. The Gravel/Soil-Aggregate in base and surface course shall meet all the physical requirements set forth in Para B and conform to the gradings given in **Table 2.1** of Section 2 for base course and in **Table 2.2** of Section 2 for surface course.
2. Before receiving the Gravel/Soil-Aggregate material, the subbase/base, as the case may be, shall be prepared to the specified lines and crossfall. Any existing ruts, predominant irregularities or soft yielding places should be corrected and rolled until a firm surface is obtained.
3. The Gravel/Soil-Aggregate material meeting all the specified requirements shall be spread on the prepared surface with the help of a grader of adequate capacity, for maintaining the required slope and grade.
4. Where combination of different materials is required for obtaining the Gravel/Soil-Aggregate meeting the specified requirements, mixing shall be done mechanically by the mix-in-place method.
5. The equipment for mix-in-place shall be a tractor-towed rotavator or similar equipment capable of mixing the materials to the desired degree.

6. It must be ensured that prior to compaction, the moisture content is within 2 percent of the optimum moisture content, making due allowance for evaporation losses. After adding the required quantity of water, the material should be processed by mechanical means like tractor-towed disc harrows/rotavators until the layer is uniformly wet.
7. Rolling shall be carried out as per Para 402.4.2 of MORD Specifications.
8. The density to be achieved should be 100% of the maximum dry density for the material determined as per IS:2720 (Part 7).
9. Any loose, segregated or otherwise defective areas should be made good to full thickness of layer and re-compacted.

## B. QUALITY CONTROL REQUIREMENTS

1. **Materials**

   (i) The grading for Gravel/Soil-Aggregate Base shall conform to the requirements given in Table 2.1 of Section 2 while the grading for Gravel/Soil-Aggregate Surface Course shall conform to the requirements given in Table 2.2 of Section 2.

   (ii) Wet Aggregate Impact Value (IS:5640) shall not exceed 40 and 30 when used in base and surfacing respectively.

   (iii) The needed gradation shall be obtained by crushing, screening and blending processes as necessary.

   (iv) Fine aggregate material passing 4.75 mm sieve shall consist of natural or crushed sand and fine mineral particles.

2. **Horizontal Alignment**

   The edges of the Base shall be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm for hilly areas. The edges of the carrigaeway with Gravel/Soil-Aggregate Surfacing shall be correct within (±) 20 mm in plain and rolling terrain and (±) 30 mm in hilly terrain.

3. **Surface Levels**

   The tolerance in surface level for Gravel/Soil-Aggregate Base and Surface will be restricted to (±) 10 mm. A grid of 10 m by 2.5 m may be formed to check the surface level.

4. **Surface Regularity**

   The maximum permitted difference between the Gravel/Soil-Aggregate layer and 3 m straight edge shall be 12 mm for longitudinal profile and 10 mm for cross profile. The cross profile should conform to the prescribed camber.

5. **Degree of Compaction**

   Density shall be 100 per cent of maximum dry density for the material determined as per IS:2720 (Part 7).

## 6. Quality Control Tests

The quality control tests and their frequency for gravel/soil-aggregate base and surface construction shall be as per **Tables 3.3, 3.4 and 3.5**, as laid down in the Quality Assurance Handbook for Rural Roads.

**Table 3.3 : Quality Control Tests Prior to Construction**

| | Type of Test | Frequency |
|---|---|---|
| 1. | Soil Classification as per IS: 1498.<br>1. Wet Sieve Analysis, except for cohesionless soil.<br>2. Liquid Limit and Plastic Limit | One test from each source identified by the Contractor. |
| 2. | Combined Grading and Plasticity tests on materials from different sources, mixed in the design proportions. This shall be done when materials from more than one source are combined. | One test on the combined material. |
| 3. | Proctor compaction Test (IS:2729 Part 7) | One test on the material from each source or on the combined material, as the case may be. |
| 4. | Wet Aggregate Impact Value Test (IS: 5640) where soft/marginal aggregates are used e.g., Laterlite, Kankar etc. | One test from each source identified by the contractor. |
| 5. | CBR test (IS:2720 Part 16) on representative sample compacted at 100% Proctor dry density. | One test per km length. |

*Note : Where materials from more than one source are to be combined in the desired proportions, the tests at Sl. Nos. 2, 3 and 5 should be carried out on the combined material.*

**Table 3.4 : Quality Control Tests During Construction**

| | Type of Test | Frequency |
|---|---|---|
| 1. | Wet Sieve Analysis (IS:2720 Part 4) on the GSB material combined in the design proportions from various sources | Atleast one test to be carried out daily. |
| 2. | Liquid Limit and Plastic Limit tests (IS:2720 Part 5) | -do- |
| 3. | Placement Moisture Content (IS:2720 Part 2) | Atleast 3 tests to be carried out daily, well spread over the day's work. |
| 4. | Insitu Density measurements (IS:2720 Part 28) | -do- |

**Table 3.5 : Quality Checks by AE/EE**

| Stage | Test | Frequency | Designation of Inspecting Officer |
|---|---|---|---|
| 1. Top of the First Layer before placing the next Gravel layer | i) Degree of Compaction (IS:2720 Part 28) | i) Minimum 3 tests for each km length or part thereof; | AE |
| | | ii) Individual test values of the degree of compaction attained shall not be less than 1% of the specified degree of compaction. For example, for the required degree of compaction of 100% Proctor Density, the individual test values shall not be less than 99% of Proctor Density and the average of three (or more) tests carried out in a day shall not be less than 100% Proctor Density). | AE |
| | ii) Surface Regularity and Transverse Profile | Random Checking | AE |
| 2. Finished Gravel Layer | i) Degree of compaction (IS:2720 Part 28) | i) One test for each 250 m length or part thereof. | AE |
| | | ii) One test for each 500 m length or part thereof. | EE |
| | ii) Surface Regularity and Transverse Profile | Random Checking | AE |

## C. DO'S AND DON'TS

| Do's | | Don'ts | |
|---|---|---|---|
| 1. | While preparing the subbase/ base, where predominant irregularities exist, make sure that the surface profile is corrected before spreading the Gravel/ Soil-Aggregate Mix. | 1. | Do not permit any organic or deleterious material. |
| 2. | For the equipment used for mix-in-place construction, carry out trial runs to establish the suitability for the work. | 2. | Do not allow manual mixing, unless the width of laying is not adequate for mechanical operations, as in small-sized jobs. |
| 3. | Look for soft patches, if any and rectify them by removing or adding fresh material and compacting the same throughly. | 3. | Do not allow the speed of the roller to exceed 5 km per hour. |
| 4. | For obtaining the needed uniformly of mixing of water with Gravel/Soil-Aggregate, sufficient passes of mechanical equipment like tractor-towed disc harrows/ rotavators should be ensured. | 4. | Do not allow sharp turns with the compaction equipment because they can cause surface roughness. |
| 5. | Adopt Tractor-Bound Technology, using the local agricultural tractors. | 5. | Do not leave the side slopes un-turfed, otherwise rain cuts would be formed. |
| 6. | Make sure that the earth used in the earthen shoulders has the requisite properties and is compacted to 100% Proctor Density and that proper cross slopes (1% steeper than camber) are provided. | 6. | Do not forget to provide a well-designed drainage system, with properly identified outlets. |

### 3.7. Providing Gravel Surface

Over the finished base course, a gravel surfacing material meeting the specified requirements given in Chapter 2 is spread to the required loose thickness, compacted to the required density and finished to the desired profile.

It is good practice to place a thin layer of about 12 mm size broken stone or gravel. This layer is intended to act as a "Cushion" between the wheel load and the base course. It is supposed to absorb some of the abrasive forces of a passing wheel. The use of this thin layer is optional, but in many cases it has been noted that if a running course is not separately provided, it will develop naturally on its own. In light grading, the motor grader or drag works on the running course and thus does not cut into the base course with its water resistant crust. If maintained evenly spread over the carriageway, then the rest of the pavement should last a long time and should not dry out very quickly in dry weather.

In general, running course is a protection against erosion caused either by climate or vehicle loadings.

### 3.8. Sealing a Gravel Road

**3.8.1.** Before applying bituminous surface treatment, any existing surface gravel with a PI exceeding 10 shall be scarified and removed and the existing surface brought to proper transverse profile. Any irregularities in the longitudinal and transverse direction must be removed. If any granular layer overlay is required, the same should be implemented. Prior to applying the bituminous treatment, the prepared gravel surface must be primed by spraying a Slow Setting Bituminous Emulsion with a kinematic viscosity of 250-500 Centistokes at 60°C at the rate of 12-15 kg per 10 sqm area. Surface Dressing is considered a preferred surface treatment for low volume rural roads. The selection of the size of stone chippings should be based on the anticipated traffic and the type of surface to be provided with the bituminous surface treatment. The design of surface dressing may be done in accordance with the design procedure recommended in IRC:110-2005 Standards specifications and Code of Practice for Design and Construction of Surface Dressing.

### 3.9. One-Coat and Two-Coat Surface Dressing

**3.9.1.** Whether one-coat or two-coat surface dressing is to be provided on a rural road shall be decided on the basis of anticipated traffic and climatic conditions.

**3.9.2.** The cover material shall consist of crushed stone, crushed gravel (shingle) or other stones. It should be clean, strong, durable and of fairly cubical fragments, free from disintegrated particles, vegetable matter, dust and adherent coatings.

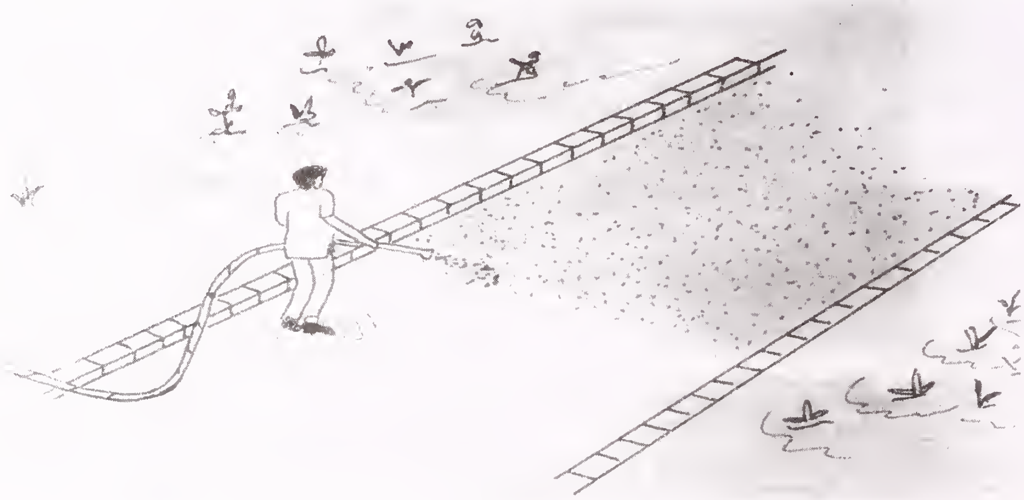
**3.9.3.** The surface dressing work shall preferably be carried out when the atmospheric temperature in shade is 10°C or above. The bituminous material shall not normally be applied when the surface or the cover material is damp, weather is rainy or during dust-storm. The underlying course on which surface dressing is to be laid shall be prepared, shaped and conditioned to a uniform grade. The surface should be swept clean free of caked earth and other foreign matter with hard brushes, then with softer brushes and finally blown off with sacks or gunny bags to remove fine dust. When the base to be treated is gravel or stabilized soil, a bituminous primer coat shall be applied uniformly at the specified rate. After priming the base, the bituminous binder shall be spread at the rate determined as per IRC:110-2005. Immediately after the application of bituminous material **(Fig. 3.10)** the cover material shall be spread in required quantities by suitable means so as to cover the surface completely. The surface shall be broomed to ensure uniform spreading.

**3.9.4.** The entire surface shall then be rolled immediately after the application of cover material with a suitable roller. The rolling shall begin at the edges and proceed towards center, except on the super-elevated portions, where the rolling should proceed from the inner to the outer edge. Additional aggregates shall be spread in whatever quantities may be required to fill irregularities and to prevent picking up of the aggregate by the roller.

**3.9.5.** The finished surface shall be opened to traffic on the following day. If under some special circumstances, the road has to be opened to traffic immediately after rolling, speed of traffic shall be limited to 16 km per hour until the following day.

**3.9.6.** The quality of materials, construction etc. for two coat surface dressing shall be similar to one coat surface dressing. Prior to the application of second coat, the surface shall be cleaned properly. Binder, heated to appropriate temperature, shall be sprayed, preferably with a mechanical sprayer, at the specified rate.

**3.9.7.** Immediately after the application of binder, the cover material shall be spread by suitable means at the specified rate to cover the surface completely. The rest of the process of rolling, finishing and opening to traffic shall be similar to one coat surface dressing.



**(a) Spraying Bituminous Material over Prepared Surface**

**(b) Spraying Cover Material**

**Fig. 3.10**

### 3.10. Step-wise Procedure for One-Coat and Two-Coat Surface Dressing

(a) The material viz. aggregates and binder should be checked for specification requirements.

(b) All depressions and pot holes etc. on the receiving surface should be corrected.

(c) The receiving surface should be cleaned by brushing to ensure that there is no loose material before binder is applied.

(d) If bituminous primer coat is applied, it should be cured before laying surface dressing.

(e) No surfacing work shall be carried out if –
  (i) atmospheric temperature in shade is less than 10ºC or
  (ii) base is damp or
  (iii) construction materials are damp or
  (iv) the weather is foggy, rainy or dusty;

(f) The work should be so organized that no traffic or dust gets on to the cleaned or bitumen painted base.

(g) The rate of spray of binder should be regularly checked using tray method. The ends of the stretch should be covered with thick paper so as to avoid double spraying of binder. The temperature of binder at the time of application should also be checked.

(h) Immediately after application of binder, the aggregates should be uniformly spread; if needed, use brooms for spreading.

(i) The rolling on aggregates with approved roller shall commence immediately from the edges progressing gradually towards the center parallel to the center line. At super-elevation, it should proceed from inner edge to outer edge.

(j) Rolling operations should be continued till aggregates are firmly embedded in binder.
(k) Second coat, if specified, can be laid after 2 to 3 weeks.
(l) Finished surface should be checked for cross and longitudinal profiles using 3 m straight edge.
(m) No traffic should be allowed for 24 hours. If cutback/emulsified bitumen is used, the finished surface should be closed to traffic till the binder is adequately cured/set.

**3.11. Step-wise Procedure For Providing 20 mm Bituminous Premix Carpet**

(a) The materials viz., aggregates and bituminous binder should be checked for specification requirements.
(b) The underlying surface on which the bituminous surfacing is to be laid should be suitably prepared, with all depressions and potholes etc. corrected, shaped and conditioned to the specified lines, grades and cross-sections.
(c) The receiving surface should be cleaned by brushing to ensure that there is no loose material on the surface.
(d) A prime coat where needed should be applied as per specified procedure, using hand held lance provided with a sprayer, operated by compressor. Use of hand held cans with holes should not be permitted.
(e) Tack coat should be applied at the specified rate uniformly on the prepared base, using hand held lance provided with a sprayer, operated by compressor.
(f) Mixing of aggregates and bitumen in specified quantities should be carried out in a Mini Hot Mix Plant of preferably around 6 t/hour capacity, carefully controlling the specified temperature of heated aggregates and bitumen and the mixing temperature.
(g) The hot mix should be immediately transported from the mixer to the point of use in suitable vehicles or hand barrows. The vehicles should be clean and the mix being transported should be covered in transit.
(h) The pre-mixed material should be spread even to specified thickness and camber, making due allowance for any extra quantity required to fill up depressions. The cross-fall should be checked by camber boards and any irregularities leveled out.
(i) Rolling should begin at the edges and progress towards the center longitudinally, except that on superelevated and uni-directional cambered portions, it should progress from the lower to upper edge parallel to the center-line. Wheels of the roller should be kept moist.
(j) Rolling should be continued until the entire surface has been rolled and all roller marks eliminated.
(k) A seal coat where specified should be applied to the surface immediately after laying the surfacing.
(l) The finished surface should be checked for line, level and regularity using camber board/straight edge.
(m) Traffic may be allowed on the surface once it has reached ambient temperature, but speed must be rigorously restricted to not more than 16 km per hour.

# 4. MAINTENANCE METHODS AND MANAGEMENT SYSTEM

## 4.1. General

**4.1.1.** While proper maintenance of all types of road pavements is important, it is a matter of crucial importance for the satisfactory performance of Gravel Roads. Even though Gravel Roads require more frequent maintenance interventions than black-topped roads, these interventions are relatively inexpensive and simple, within the available resources and skills in rural areas. Specially designed studies as well as experiences all over the World show that for low volumes of traffic upto about 200 vehicles per day, the maintenance costs of gravel roads work out to be lower than for black-topped roads, while for higher volumes of traffic, it is the other way round. It is mainly the neglect of proper maintenance that is responsible for gravel roads not gaining popularity in the vast rural areas of India with low to very low volumes of traffic. With simple inexpensive maintenance interventions, gravel roads can be easily maintained in good condition. The simple and labour intensive maintenance methods also hold considerable potential for employment generation.

**4.1.2. Causes of deterioration :** A gravel road deteriorates in its level of service ability with age, basically due to following factors:

(a) Traffic: The traffic operating on the facility can cause different types of distress like rutting, corrugations, loss of materials, and structural deformation. The extent of deterioration depends upon the intensity of traffic, especially the wheel load and its repetitions. Solid-wheeled cart traffic can be very damaging to the road, since the solid wheels cut into the pavement causing deep ruts.

(b) Environment: The external influence of environmental factors such as rainfall and snowfall, can also cause deterioration of the pavement. Rainfall causes erosion of shoulders and slopes and ingress of water into the pavement structure and subgrade and affects the performance of drainage structures. Snowfall can cause ingress of moisture into the pavement structure and subgrade and result in frost action. The influence of the environment on a gravel road is much more severe than on black-topped/ concrete roads.

**4.1.3. Maintenance operations**

(a) The various maintenance operations on gravel roads can be broadly classified into the following categories:-

   (i) Routine maintenance, comprising patch repairs; dragging, grading, maintenance of shoulders and repairs to roadside drains, road signs, culverts etc., and collection of data such as road condition and traffic surveys, which are required to be carried out by the maintenance staff once or twice every year.

   (ii) Periodic maintenance, which consists of work items such as 'Regravelling' to be carried out periodically every few years.

   (iii) Special repairs, and flood and rain damage repairs, which consist of repairs to the embankment, pavement, culverts, road furniture, etc. necessitated by landslides, earthquakes, cyclones, heavy rains/cloud bursts, floods etc; the nature and extent of such repair works could not be foreseen or predicted.

(b) Before starting with the work, it should be ensured that adequate arrangements (like erection of barriers, signs and red flags/light/reflectors) **(Fig. 4.1)** are made for the safety of traffic, workmen, pedestrians, cattle etc. The work should be planned in such a way that inconvenience caused to the traffic is minimal. Wherever possible, the work should be confined to half the pavement width at a time, leaving the other half to traffic.

### 4.1.4. Economic benefits of maintenance operations

Timely and proper maintenance of Gravel Roads can lead to significant economic benefits. These include:

(i) Reduction in level of future maintenance and rehabilitation costs.

(ii) Improved safety and reduction in road closures.

(iii) Reduction in vehicle operating costs and accident costs.

## 4.2. Surface & Structural Defects on Gravel Roads

**4.2.1.** The defects observed on Gravel Roads are essentially the result of complex interactions between the materials used, traffic type and volume, climatic conditions, construction methods and quality control exercised. Broadly, the various defects can be classified as: –

(a) **Surface defects,** observed in the upper layers of the pavement are due to factors like poor compaction, unsatisfactory grading, climatic conditions, poor quality of materials, inadequate drainage, neglect of routine and preventive maintenance measures etc. or a combination of these. The surface defects result in poor riding quality. The more common surface defects are:

- Corrugations
- Potholes
- Rutting
- Ravelling/Loose Material
- Surface Erosion/Dust Generation/Loss of Surface Material
- Slippery Surface
- Soft Spots

(b) **Structural Defects,** are deep seated problems caused by overstressing of the subgrade and/or the pavement. One of the common causes is lack of drainage, other causes being substandard materials used and inadequate thickness of the pavement for the design traffic. These defects are often characterized by shear failure in form of large settlements and upheavals.

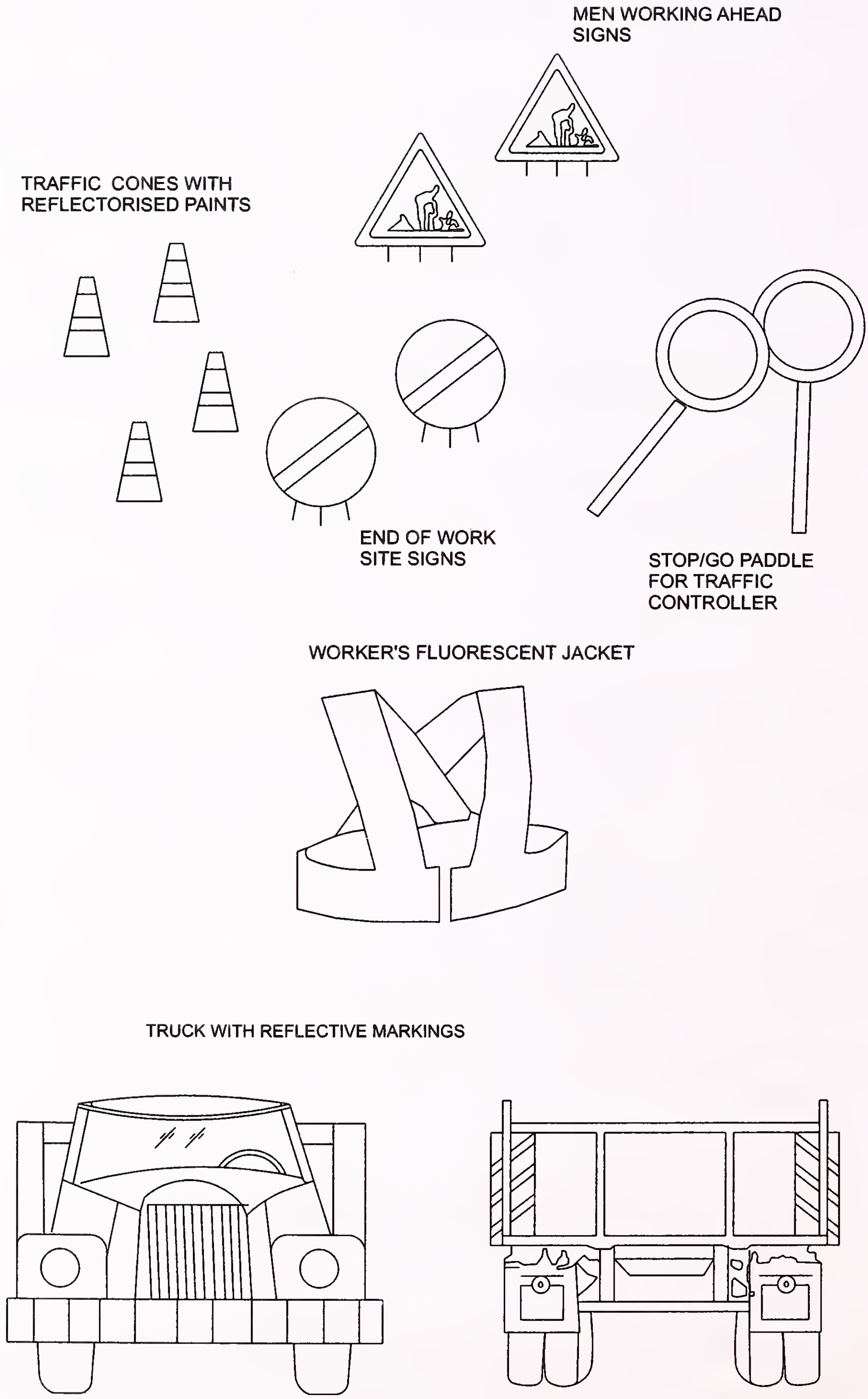



**Fig. 4.1 : Some Safety Devices for the Workmen**
(Source:International Road Maintenance Hand Book Vol. II, Maintenance of Unpaved Roads, PIARC, Published by TRRL, UK)

**4.2.2.** Surface defects can be removed by grading or planing the surface. However, gravel roads with structural defects would require a more detailed investigation and treatment including rehabilitation.

**4.2.3.** During the Condition Survey of any Gravel Road, it is necessary to make an assessment of the severity of surface defects in terms of the severity being 'High', 'Mediun' or 'Low'. Such an assessment can be accomplished as under:

**(a) Surface Roughness/Riding Quality (Refer para 2.5.2 Section 2)**

An assessment shall be made in terms of the 'Pavement Condition Index' (PCI) on a rating scale of 5 to 1 as under:

| Normal Safe Driving Speed (km/h) | PCI |
|---|---|
| Over 35 | 5 |
| 25–35 | 4 |
| 15–25 | 3 |
| 10–15 | 2 |
| Less than 10 | 1 |

**(b) Corrugations**

A visual assessment of the corrugations shall be made by the bumps experienced while travelling on the gravel road in a jeep or passenger car as under:

| | | |
|---|---|---|
| (i) | Bumps can be felt and heard and significant reduction in speed is required | High severity |
| (ii) | Bumps can be felt and heard and some reduction in speed is required | Medium severity |
| (iii) | Bumps can be felt and heard but no reduction in speed is required | Low severity |

**(c) Potholes**

A visual assessment of the severity of 'Potholing' shall be carried out as under:

| | | |
|---|---|---|
| (i) | Depth of pothole more than 50 mm | High severity |
| (ii) | Depth of pothole in the range 25 to 50 mm | Medium severity |
| (iii) | Depth of pothole less than 25 mm | Low severity |

**(d) Rutting**

The ruts or depressions of the surface in the wheel tracks shall be measured in mm and an assessment of the severity level made as under:

| | | |
|---|---|---|
| (i) | Depth of rutting more than 50 mm | High severity |
| (ii) | Depth of rutting 25 to 50 mm | Medium severity |
| (iii) | Depth of rutting less than 25 mm | Low severity |

**(e) Ravelling**

An assessment of the percentage area of the ravelled surface shall be made and severity level recorded as under:

| | |
|---|---|
| (i) Percentage area of ravelled surface over 50 | High severity |
| (ii) Percentage area of ravelled surface 25 to 50 | Medium severity |
| (iii) Percentage area of ravelled surface < 25 | Low severity |

**(f) Surface Erosion**

Gravel roads are susceptible to longitudinal/transverse erosion by flow of water over the road surface. An assessment of the severity level can be made by the bumpiness experienced while driving in a car or jeep over the eroded surface, as under:

| | |
|---|---|
| (i) Bumps can be felt and heard and significant reduction in speed is required | High severity |
| (ii) Bumps can be felt and heard and some reduction in speed is required | Medium severity |
| (iii) Bumps can be felt and heard but no reduction in speed is required | Low severity |

**(g) Dust Generation**

An assessment of the dust nuisance shall be made by driving in a car/jeep at a speed of 30-40 km/h and taking observations as under:

| | |
|---|---|
| Dangerous loss of visibility – significant discomfort | High severity |
| Some loss of visibility – no discomfort | Medium severity |
| No loss of visibility | Low severity |

### 4.3. Maintenance of Gravel Roads

The maintenance methods commonly adopted for Gravel Roads are Grading, Dragging Patching, Regravelling and use of Dust Palliatives, described in sub-paras 4.3.1 to 4.3.5.

#### 4.3.1. Grading

**4.3.1.1.** It is a matter of vital importance that a good camber is always maintained on a gravel road surface to enable the water to shed off readily. Such a maintenance effort can be accomplished by regular 'Grading'. For Gravel Roads, the 'Grading' is also needed to restore gravel from the shoulders which has been lost from the Gravel Road surface and the gravel thus restored can be used to fill potholes and corrugations etc. Grading can be used to correct the following defects:

- Loss of Shape
- Ruts
- Potholes
- Corrugations

- Erosion Gullies
- Silted or Blocked Ditches

**4.3.1.2.** Grading is a 'Routine Maintenance' activity and can be carried out by tractor-towed graders. The gravel road surface to be graded should first be prepared by patching of large potholes or depressions and draining out areas of standing water etc. It may be necessary to scarify the existing surface to cut to the bottom of any surface defects and loosen the material for reshaping. The process of grading can be carried out by tractor-towed grader **(Fig. 4. 2)**. Grading can be of three types, as under:

- **Light Grading :** When the gravel surface crust is not broken and it is a matter of only spreading or raking back loose surface material to provide a "running course" as protection of the surface crust. A light Grader or Drag can serve the purpose.
- **Normal Grading :** This is done when the surface crust is cut and it is necessary to remove surface defects such as corrugations, ruts or potholes. In this case a 8-10 tonne Grader is suitable.
- **Heavy Grading :** This is required when the road is out of shape and in the process of repair, and fairly heavy scarifying is required. This reshaping operation requires a Grader in the 10-12 tonne mass range.

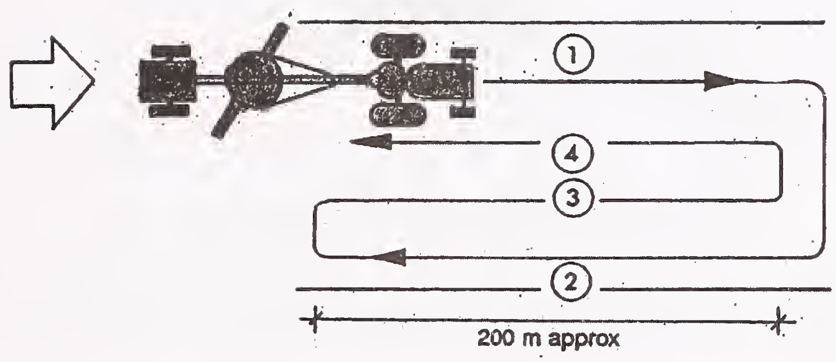
**4.3.1.3.** The Grader works on one side of the road at a time and works in passes about 200 metres long to convenient and safe turning points (Ref. 1). Light Grading will normally require 4 passes to reshape the road **(Fig. 4.3)**. Heavy Grading will require additional passes to achieve the required camber. Work should be completed on one side of the road at a time. An even number of passes should be used to avoid a flat finished crown. The initial passes cut to the bottom of the surface irregularity and deposit a windrow just beyond the centre line. If required, water should be sprayed over the windrow. In order to avoid flattening the centre, the final pass should not be made down the centre of the road with the grader blade horizontal **(Fig. 4.4)**.

**4.3.1.4.** On sections where grading has been completed, the road roller should follow. Normally about 8 passes of the roller are required to achieve full compaction, working towards the centre. Shoulders should be treated as part of the running surface. Camber should be checked with a Camber Board at about 100 m intervals. On bends, the surface should be straight at 4 to 6 % from shoulder to shoulder. The shape of the road over the culverts should be maintained to avoid a hump **(Fig. 4.5)**. Where required, material should be brought from either side of the culvert to maintain the required cover to the top of the culvert.

**4.3.1.5.** The number of times during the year each Gravel Road will need grading will depend upon the amount of traffic using the road, climatic conditions in the area, local topography and other physical features. In the absence of adequate experience in the area, the Grading Frequency Chart developed by the TRRL of UK **(Fig. 4.6)** may be used.

Fig. 4.2 : Tractor-towed Grader

LIGHT GRADING




HEAVY GRADING

**Fig. 4.3 : Light and Heavy Grading**

(Source: International Road Maintenance Hand Book Vol. II, Maintenance of Unpaved Roads, PIARC, Published by the TRRL, UK)

**Fig. 4.4 : Avoid Flattening at the Centre (Ref 1)**

(Source : International Road Maintenance Hand Book Vol. II, Maintenance of Unpaved Roads, PIARC, Published by the TRRL, UK)

**Fig. 4.5 : Avoid Hump at Culvert**

(Source : International Road Maintenance Hand Book Vol. II, Maintenance of Unpaved Roads, PIARC, Published by the TRRL, UK)

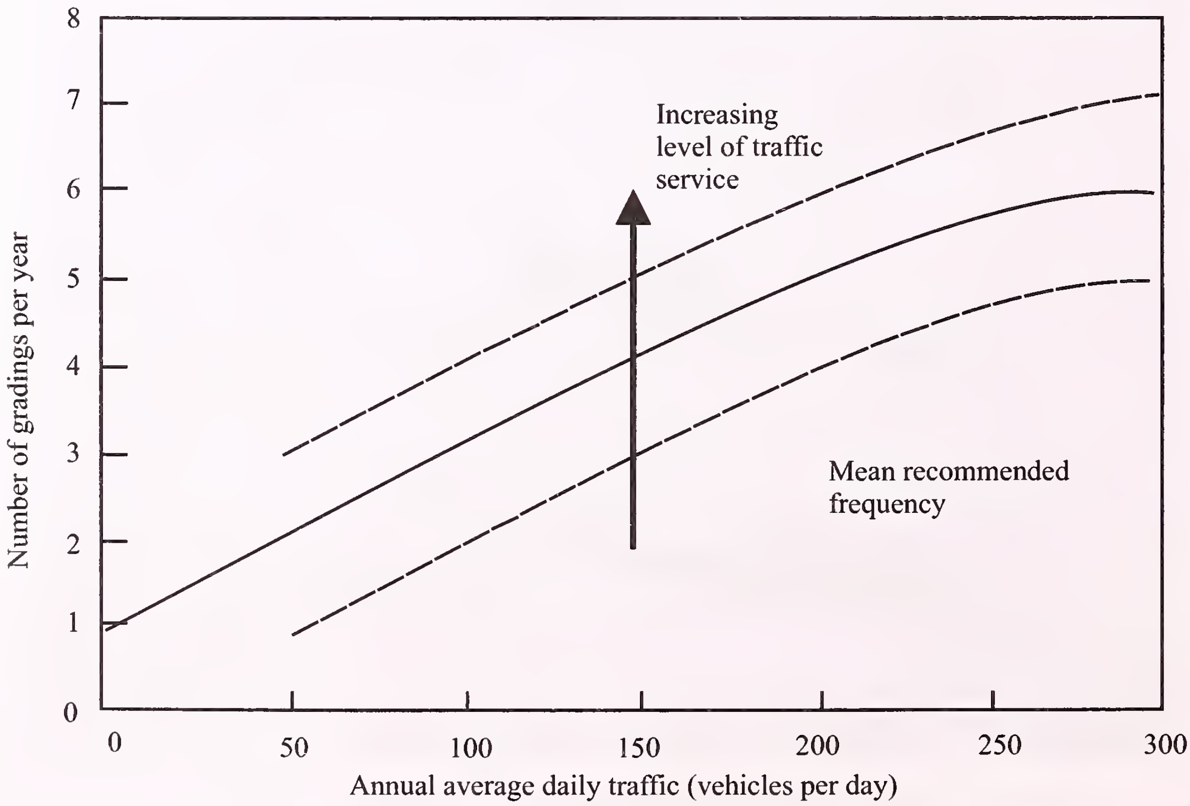



**Fig. 4.6: Grading Frequency Chart**

### 4.3.2. Dragging

**4.3.2.1.** Dragging is normally a Routine Maintenance task used to improve the gravel road surface. Regular Dragging smoothens out minor defects in the road surface and removes loose material from the surface. Where a running course of sand/gravel is used to cover the base material for protection from traffic wear, frequent dragging is used to redistribute the running course material disturbed by traffic plying over the surface.

**4.3.2.2.** Specially made drags towed by agricultural tractors can be used for Dragging. Where the traffic plying on a rural road is of a low order, frequent dragging can reduce the need for Grading. It is generally after a number of dragging operations that Grading is required. Dragging will not remove corrugations once they are formed, nor will it restore camber or lost material.

**4.3.2.3.** Dragging may be considered suitable only when development of road has been carried out to a level when the pavement is structurally sound and where the loose running course is less than 25 to 30 mm in depth.

**4.3.2.4.** For various road conditions, the recommended plants are given below:

| Road Condition | Recommended Plant |
|---|---|
| Roads with depths of loose material in excess of 20 mm | Broom drag<br>Cutting drag using old grader blades.<br>Towed grader or light power grader. |
| Roads with roughness levels* less than 6000 mm/km with no appreciable loose material | Timber framed drag or broom drag<br>Light grader or planer |
| Roads with roughness levels greater than 6000 mm/km | Cutting drag using old grader blades.<br>Light grader, planer or medium grader |

* *Roughness measured using Bump Integrator*

Drags should not be towed at speeds above 10 km/h and preferably should be towed at 5km/h. A broom drag and roller can be seen in **Fig. 4.7**, while a typical tractor and timber drag are shown in **Fig. 4.8.** In **Fig. 4.9**, it can be seen how a drag can be used to shift material from different parts of the pavement.

**4.3.2.5.** It must be emphasised that Drags must be used at frequent enough intervals to smoothen the road surface. Drags should not be used on roads which have deteriorated, due to lack of frequent maintenance interventions, to a level where only heavy grading or reshaping is the answer. **Fig. 4.10** shows a multi-purpose tractor-towed equipment enabling an operator to carry out a wide range of maintenance activities.

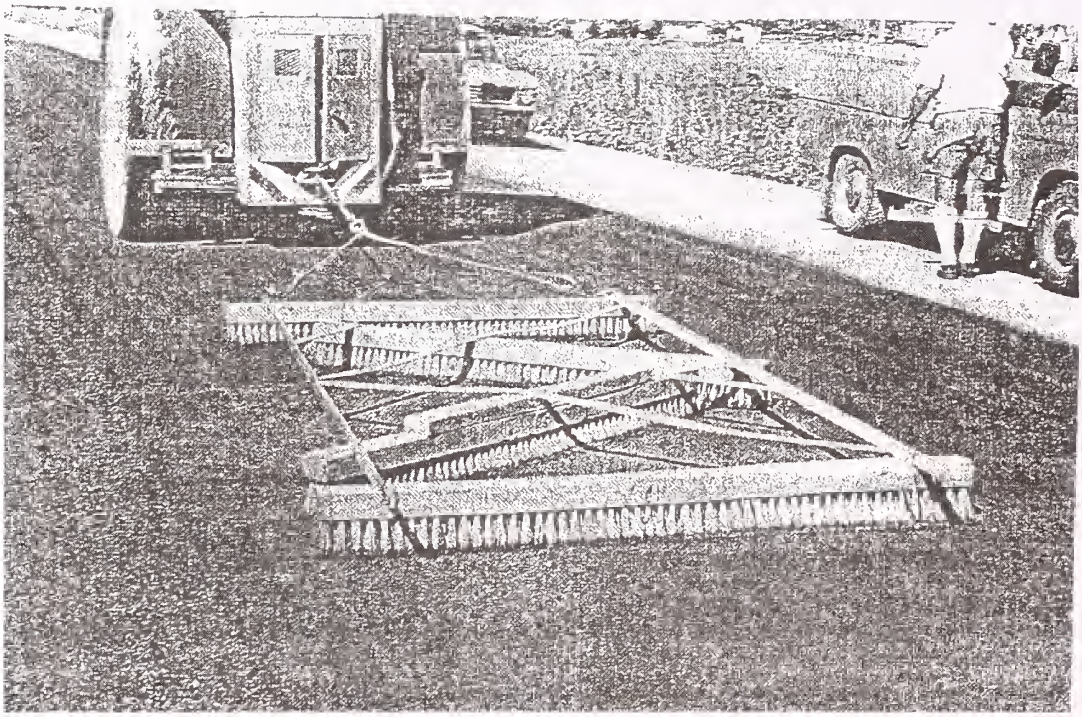


**Fig. 4.7 : A Broom Drag**
(Source:Unsealed Roads : A Manual of Repair and Maintenance for Pavements, National Roads Board, New Zealand)

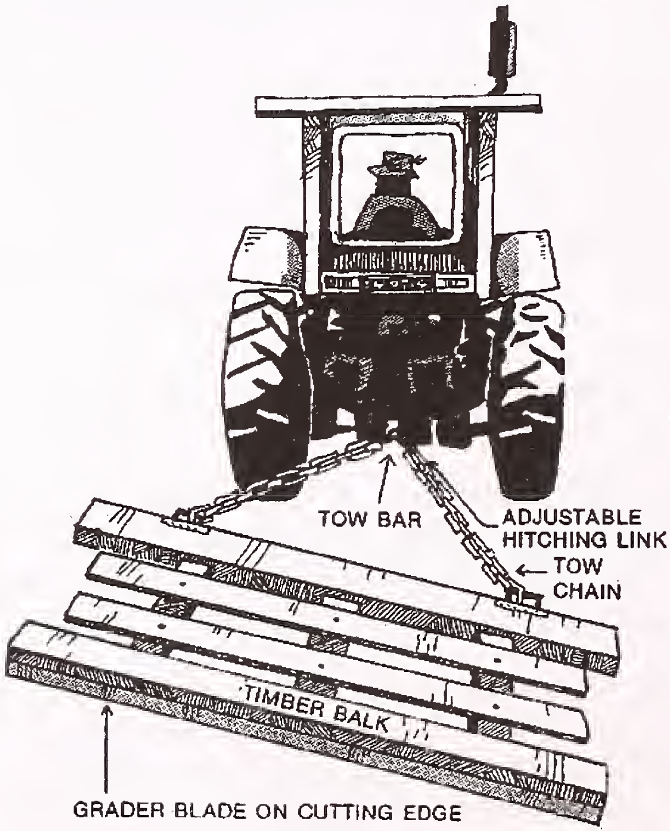



**Fig 4.8 : Typical Tractor Towed Drag**
(Source:Unsealed Roads : A Manual of Repair and Maintenance for Pavements, National Roads Board, New Zealand)

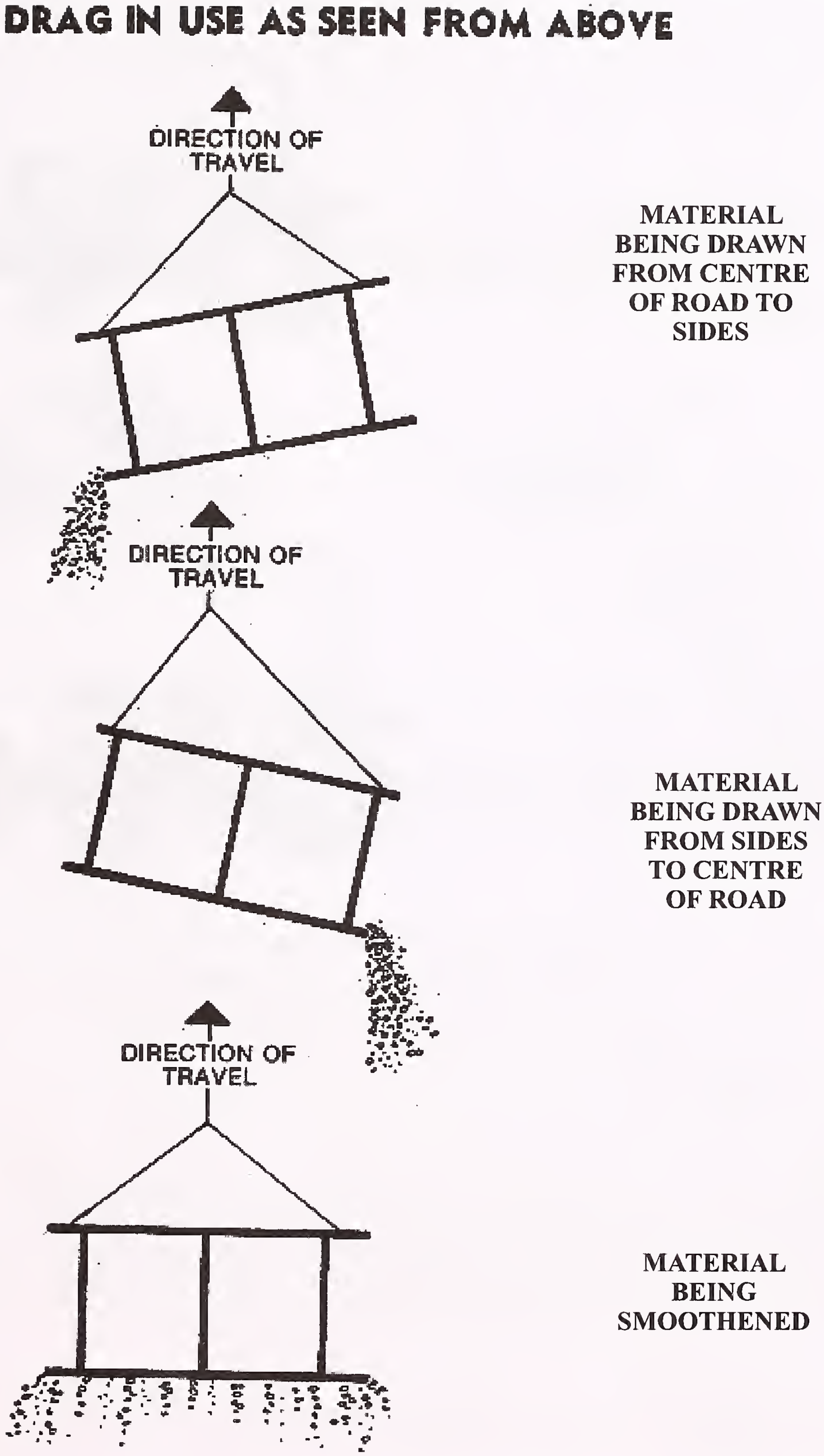



**Fig. 4.9 : Use of Drag in Drawing Material from Different Parts of Pavements**
(Source:Unsealed Roads : A Manual for Repair and Maintenance for Pavements, National Roads Board, New Zealand)

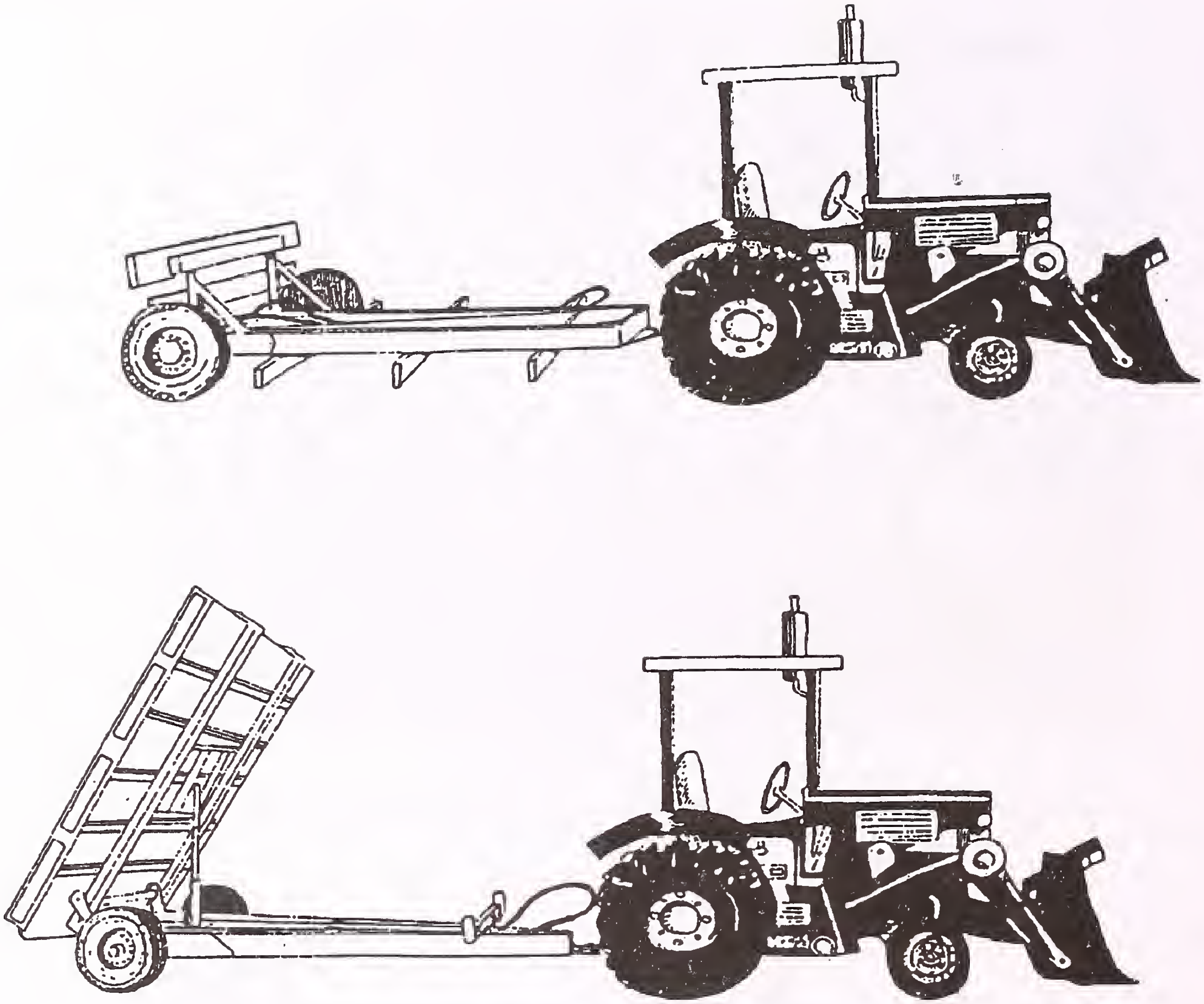


**Fig. 4.10 : A Tractor-Towed Equipment Enabling the Operator to Carry out a Variety of Maintenance Operations**
(Source:Unsealed Roads : A Manual of Repair and Maintenance for Pavements, National Roads Board, New Zealand)

### 4.3.3. Patching

**4.3.3.1.** Where potholes or depressions on the gravel road are large, patching is required before grading. Sometimes, patching is required between grading or reshaping operations. Patching can be used to repair eroded areas or can be used to restore areas which become soft when wet. When the work involves material less than a truck or two, the repair work is termed patching, while for large scale work, it is termed Spot Gravelling or Regravelling. Patching cannot be used for repairing Corrugations but can be used to correct:

– Erosion Gullies

Where the potholes are large in numbers, scarifying will be needed with a grader and possibly Regravelling.

**4.3.3.2.** Gravel to be used for patching should be dumped by the road side where it is required to be used. The quality of gravel should be at least as good as the gravel already used in the road surfacing. The gravel should be dumped on the shoulder **(Fig. 4.11)** adjacent to the location where the patching work is to be carried out. Care must be taken to see that the material should not be dumped on the road surface.

**4.3.3.3.** In the pothole or rut, where patching work is to be carried out, any loose material or standing water should be brushed out **(Fig. 4.11).** Where the potholes are large in size or are very deep, the sides should be cut back to be vertical.

**(a)** **(b)**

**Fig. 4.11:(a) Dump the material on the shoulder adjacent to location of patching work (b) Brush out any loose material or standing water**
(Source: International Road Maintenance Hand Book Vol. II, Maintenance of Unpaved Roads, PIARC, Published by the TRRL, UK)

**4.3.3.4.** Check the moisture content of the material. If it is dry, the area to be patched should be sprinkled with water and also water should be added to the material to be used for patching. The area should be filled with gravel to a depth of about 100 mm. If the material is dry, it should be sprinkled with water to assist compaction.

**4.3.3.5.** The 100 mm layer at a water content close to OMC, should be compacted using a roller or a hand rammer. In this manner, patching is built up in layers. The patched area is thus filled up with gravel to about 30 mm proud of the surface level and is spread and raked to the correct shape. The patch is compacted by a roller if the area is large and by hand rammer if the area is small. Even for large areas, hand rammers will be required for the short edges and corners.

### 4.3.4. Regravelling

**4.3.4.1.** Regravelling is a periodic maintenance operation. Well before any significant reduction in base thickness takes place and before the PCI rating reduces to the terminal PCI of 2.0, the task of 'Regravelling' must be accomplished. Regravelling can be carried out to correct the following defects:-

- Loss of shape
- Ruts
- Potholes
- Erosion Gullies

Grading or Reshaping should be carried out before the regravelling operation.

**4.3.4.2.** Gravel obtained from a quarry or gravel pit must meet the specified quality requirements and the needed approval obtained before commencement of the work. The sections where Regravelling is required should be marked at the site. The existing road surface must be graded to provide a firm regular surface and the edges should be boxed to provide lateral support for the fresh gravel. The graded surface should be watered to have the water content close to OMC and roller compacted. The camber should be checked with a Camber Board and it should fall within the specified range.

**4.3.4.3.** The Drainage System should be checked and repaired where necessary. The excavated gravel should be stockpiled in low heaps to prevent segregation. After the initial grading of the road is complete, the gravel should be transported to the regravelling site. The dumping of gravel should start at the far end of the site so that the gravel heaps do not come in the way of trucks delivering later loads.

Materials should be dumped at correct spacing on one side of the road only.

A Weekly Gravelling Plan should be prepared to indicate hauling distance etc.

**4.3.4.4.** Spreading of the gravel can start when there is a working length of at least 200 m of dumped material. Initially the road is sprayed with water. The Regravelling material is then spread across the road using the grader. The material is then alternately spread by the grader and watered until its moisture content is close to OMC. The material is then graded to produce the specified camber. The camber should be checked with the Camber Board at approx. 100 m intervals along the road. If the desired camber is not achieved, the process of grading should be repeated.

After the correct camber has been achieved, rolling can start, commencing at the edge towards the centre. The roller should progress section to section at the same rate as the Grader. About 8 passes are generally required to achieve full compaction.

**4.3.5. Use of dust palliatives**

**4.3.5.1.** The main disadvantage being cited against gravel roads, is the dust generation, considered as a safety hazard and pollutant to the environment. Besides being a safety hazard, a very significant implication of dust generation is the loss of fines from the surface gravel which leads to increased gravel loss and consequently more frequent maintenance. If, however, the generation of dust can be controlled, the expenditure on gravel road maintenance can be significantly reduced.

**4.3.5.2.** There is a wide variety of dust palliatives available which can be divided into 7 basic categories, as under:

(a) Water

(b) Water absorbing products (hygroscopic)

- Calcium Chloride brine and flakes
- Magnesium Chloride brine
- Sodium Chloride (Salt)

(c) Organic Petroleum Products

- Asphalt emulsion
- Cutback Asphalt (Liquid Asphalt)
- Dust oils
- Modified Asphalt Emulsions

(d) Organic Nonpetroleum Products

- Animal Fats
- Lignosulphonate
- Molasses/Sugar Beet
- Tail Oil Emulsions
- Vegetable Oils

(e) Electrochemical Products

- Enzymes
- Ionic Products
- Sulphonated Oils

(f) Synthetic Polymer Products

- Polyvinyl Acetate
- Vinyl Acrylic

(g) Clay Additives

- Bentonite
- Montmorillonite

**4.3.5.3.** The selection of type has to be based on the quantity of fines in the surface material, climatic conditions and traffic volume. The following four categories of dust palliatives appear suitable for Indian conditions:

(I) Water

(ii) Water absorbing products (hygroscopic)

(iii) Organic petroleum products

(iv) Clay additives

**4.3.5.4.** Prior to applying dust palliatives, all the surface defects should be removed, gravel added to provide the correct shape/camber/superelevation and the surface compacted. The surface should be dampened (except when non-emulsified petroleum products are used). The dust palliative should then be applied uniformly over the surface. After light compaction, traffic may be allowed if chlorides are used while for other products, some time may be required for the product to get absorbed before allowing traffic. Field trial sections need to be laid and their performance monitored to evaluate the efficacy of a product.

### 4.4. Maintenance of Shoulders, Drainage and Structures

**4.4.1.** Inspection of drainage system, shoulders etc. in both dry and rainy seasons is necessary for effective identification of various defects. In the dry season, structural damages can be better identified and in the rainy season, actual functioning of the drainage system can be evaluated. Any field supervisor must evaluate the extent of damage in order to quantify the needed maintenance measures; such an evaluation can best be done by inspection on foot. The supervisory staff should look for:

(i) Ditch cross-section destroyed

(ii) Ponding in the ditch and shoulders

(iii) Silting

(iv) Uneven ditch invert, varying x-section

(v) Invert and sides of ditch eroded

(vi) Drain destroyed

(vii) Ditch lining damaged

(viii) Ponding/erosion

**4.4.2.** Given below are the common defects, their causes and measures needed for rectification:

| SL. NO. | DEFECTS | CAUSES | MAINTENANCE MEASURES |
|---|---|---|---|
| 1. | Ditch cross section destroyed | Plying of vehicles/movement of animals | Reshaping/ Regrading of ditch |
| 2. | Ponding in ditch and on shoulder | Insufficient ditch x-section | Deepening of ditch |
| 3. | Silting of drain | Water flows slowly on the invert slope | Desilting of ditch |
| 4. | Uneven ditch invert | Blockage caused by debris/vegetation | Clearing, cleaning and regrading |
| 5. | Erosion of sides and bottom of ditch | Too steep gradient | Reinforcing of ditch slopes, regrading or realignment of drain, ditch checks |
| 6. | Destruction of lined or precast drain | Poor alignment or change in flow direction | Erosion control and realignment of drain |

| | | | |
|---|---|---|---|
| 7. | Ditch lining is damaged | Settlement/erosion of soil under ditch | Erosion repair and lining repair |
| 8. | Ponding, erosion | In-sufficient lateral drainage | Provision of lateral drainage |
| 9. | Silting, blockage by debris of culvert | Too flat gradient, in-correct positioning of culvert, floating debris lodged in culvert | Clearing and cleaning and provision of debris rack. |
| 10. | Erosion of stream bed at culvert outlet | Water flow very fast/culvert invert on a flat grade | Erosion repair |
| 11. | Settlement cracks on the culvert | Settlement of soil below | If minor cracks, only repair of cracks. In case of major settlement, the culvert must be reconstructed. |
| 12. | Rusting of steel in culvert | Weathering, poor quality material | Repair of steel section |
| 13. | Cracks in paved surface of causeways | Settlement | Sealing of cracks |
| 14. | Obstruction on shoulders | Operational | Removal of obstruction |
| 15. | Level of shoulders higher than carriageway | Transportation of carriageway material by raffic, swelling of soils, vegetation growth. | Regrading of shoulders and surface vegetation control. |
| 16. | Ruts, depressions or Inadequate Cross-slope in shoulder | Erosion, plying of vehicles | Patch work, reshaping and camber correction |
| 17. | High vegetation on shoulder | Unchecked growth of vegetation | Vegetation control |
| 18. | Level of shoulder lower than carriageway | Erosion/settlement of carriageway | Replenishment of shoulder |
| 19. | Vegetation overgrowth on slopes | Lack of grass cutting, trimming | Vegetation control |
| 20. | Erosion of slopes due to surface water | Rain water accumulation at the top of the slopes | Erosion repair by cut off ditch, collector drains, chutes, berms, vegetation cover and masonry protection |

Source : Document on Rural Road Development in India Vol. II, CRRI, 1990

**4.4.3. Activities**

(i) **Reshaping/Regrading/Deepening of Ditches/Drains:** These can be done manually. Alignment should be set by string line and the materials within the string line should be cut and removed. Cross section, grading and depth should be checked and corrected. Wherever possible, motor grader can be used for these activities. The excess material must be removed from site and in no case should be spread on the road surface.

(ii) **Clearing and cleaning of Ditches/Drains:** Any object which can interfere with water flow should be removed. These objects should be disposed of well away from the road so that these cannot impede the water flow again.

(iii) **Repair of Drain Erosion:** This should be done by replacing and back filling the lost soil. Permanent measures like masonry lining or precast drain can be considered.

(iv) **Repair of Drain lining:** Settled or damaged precast sections or loose stone should be removed and underlying soil compacted. After addition of fresh soils, the levels should be corrected and then only fresh stones or precast drain should be laid.

(v) **Vegetation control:** Except in arid areas, once a year, grass and weed cutting and bush clearance on the shoulders is a must. In case of earth or gravel roads these activities may be required to be done more frequently. Tractor-towed mower can be employed where available, but ordinary manual method should be sufficient for the purpose. Dead or leaning trees should be removed from the roadside. Use of chemicals or burning of the roadside vegetation should be avoided as these are harmful.

**4.5. Special Problems of Hill Road Maintenance**

**4.5.1.** Some of the special problems of hill road maintenance are:

(1) Snow clearance

(2) Slips and landslides

(3) Drainage

**Snow Clearance**

The roads in the Himalayan hill region get covered with snow. Snow clearance can be done manually or by special equipment (dozers, snow masters and snow blasts).

**Landslides and Slips**

Landslides and slips are a common feature of hill roads. Road maintenance in areas subjected to landslides and slips poses severe problems. The greatest of them is quick removal of debris and restoration of traffic. Mechanical equipment like dozers becomes very necessary.

**Drainage maintenance**

Maintenance of drainage structures is an important task in hill road maintenance. The quick and efficient removal of water prevents slips and landslides and road deterioration. Drainage arrangements such as catchwater drains, cross-drainage structures, side drains and subsurface drains should be inspected before the monsoons and cleared of all obstructions.

### 4.6. Maintenance Management

#### (a) General

The objectives of maintenance management are to plan and programme the maintenance activities making optimal use of the resources of men, materials, machinery and money so that the planned works are performed to a traffic-worthy condition. The steps to achieve these objectives are discussed below.

#### (b) Road Data Banks

A proper management decision could be taken only when sufficient data are available on the problem. Hence it is of vital necessity to collect and compile all relevant data about the road and its environment and the resources available to maintain the road network. These data should also be updated regularly. It is recommended that the following data may be made available in the road data banks.

(i) Road cross-section including pavement composition (type and thickness), shoulders, height of embankment, side slope etc.

(ii) Geometrics of alignment

(iii) Details of various structures along the road viz., cross drainage structures, roadside drains, breast walls, retaining walls, kilometre stones, traffic signs, godowns etc.

(iv) Condition of the road–pavement surface condition (rutting, potholes etc.) condition of shoulder, and side drains.

(v) The maintenance history of the road – the date and type of maintenance put in and its subsequent performance.

(vi) Traffic volumes and the quarterly rate and type of accidents.

Some of the road features are of a permanent nature like geometric design features, cross-sectional details etc. and require to be updated only when there is a major reconstruction. However, the road condition surveys (in terms of PCI) and traffic counts etc. need to be updated at reasonable frequency. Each State should possess a suitable machinery to collect, analyse and compile such data which can be of immense use in maintenance management. A system of road registers for each road can also be introduced.

#### (c) Standards of Maintenance

The next step in maintenance management will be to evolve reference standards to help the maintenance staff to take the right decisions. In a systems concept, there are three distinct types of reference standards:

(i) Performance standards which define the level of quality below which the various components of the road should not fall, so that the road users are given a satisfactory level of service from the technical and economic points of view. These standards are the basis for determining when and what type of maintenance activities are to be provided to the road network. Rutting, potholing etc. are the parameters used to assess the performance level;

(ii) Quantity standards, which indicate the resources required to achieve the necessary level of service; and

(iii) Operational standards, which specify the working method and crew requirement consistent with a reasonable level of productivity for each maintenance activity possible. These standards can be revised and improved based on the achieved possible output in the field.

**(d) Operational Management**

For proper management of the resources allocated for maintenance, the objectives to be aimed at should be reduction in costs for a defined quality of work, better work performance within the same cost and proper deployment of men and machinery to ensure an optimal utilisation of the available resources. For this, it is necessary to identify the basic maintenance activities, quantum of work needed in relation to road performance standards and the resources needed to fulfil these tasks in terms of materials, machinery and man-hours. Having done this, it would be easy to prepare a work schedule for weekly, monthly, quarterly and yearly operations. In this way, it will be possible to move from a purely financial accounting system to a rational process of analytical management.

Modernisation of maintenance management may involve radical changes in traditional working methods. Mobile system of gangs in the place of the time-honoured labour groups, who are practically immobile and have little or no equipment will go a long way in streamlining the routine maintenance work. The maintenance personnel should also be given periodic training.

A simplified Rural Road Maintenance Management System is given below (**Fig. 4.12**).

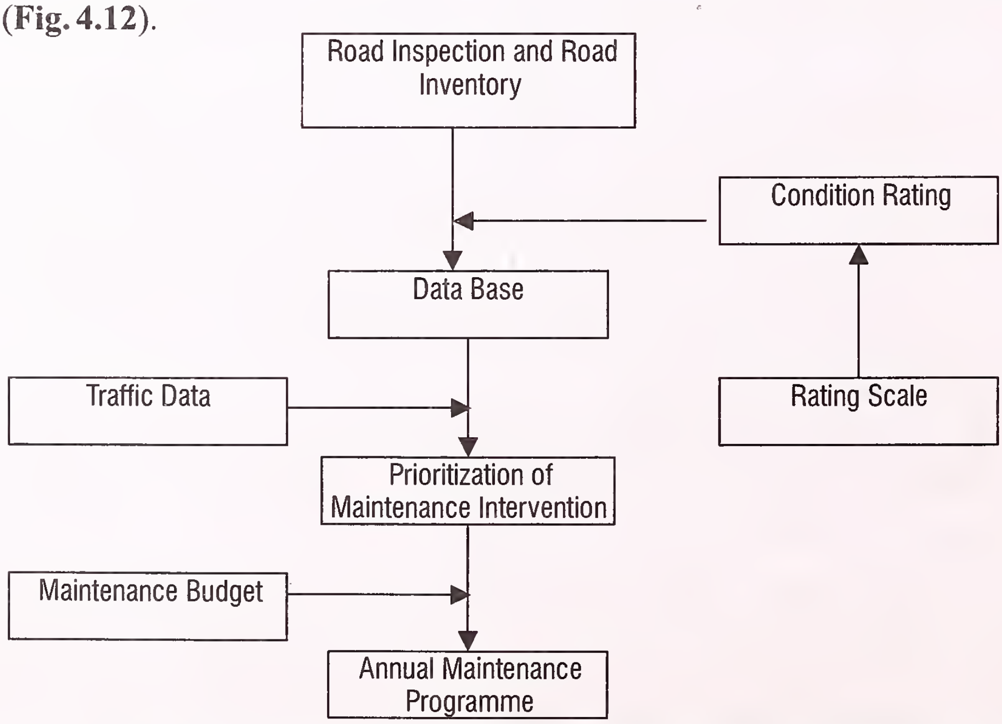



**Fig. 4.12 : Flow Chart for Rural Road Maintenance Management System**

**(e) Condition Rating in Terms of Pavement Condition Index (PCI)**

The most simple rating scale for the Pavement Condition Index, is roughly, derived from the speed of travel, as under:

| Normal Driving Speed (km/h) | PCI |
|---|---|
| Over 35 | 5 |
| 25 to 35 | 4 |
| 15 to 25 | 3 |
| 10 to 15 | 2 |
| Less than 10 | 1 |

Alternatively, the riding comfort observed when driving at a design speed of 40 km/h can be assessed as under:

| Riding Comfort at 40 km/h | PCI |
|---|---|
| Smooth and Pleasant Ride | 5 |
| Comfortable | 4 |
| Slightly Uncomfortable | 3 |
| Rough and Bumpy | 2 |
| Dangerous | 1 |

**(f) Prioritization of Maintenance Interventions**

The following prioritization scheme for maintenance intervention may be adopted.

| SI. No. | Condition of Road | PCI | Type of Intervention |
|---|---|---|---|
| 1. | Ridability is very poor and the surface is very rough and uneven | $\leq 1$ | Reconstruct immediately |
| 2. | Ridability is poor and the surface is rough and uneven | 1 to 2 | Regravel Immediately; routine maintenance to continue |
| 3. | Ridability is fair with intermittent rough and uneven sections | 2 to 3 | Regravelling within 1 year; routine maintenance to continue |
| 4. | Ridability is good with a few slightly rough and uneven sections | 3 to 4 | Routine maintenance |
| 5. | Ridability is very good | $< 4$ | Routine maintenance |

### 4.7. Organizational Aspects of Maintenance Management

It is necessary to have a suitable organisational set-up for an effective implementation of various maintenance measures. There should be a separate maintenance unit for rural roads in each district, to carry out the monthly maintenance work programme. Depending on the nature of the maintenance activities, the work could be outsourced to local people. The required implements/plant/equipment could be provided to the local contractors. Concerted efforts are required to organise suitable training programmes for the staff of the Maintenance Units and for capacity building of the local contractors.

### 4.8. Do's and Don'ts

| | Do's | | Don'ts |
|---|---|---|---|
| 1. | Determine the cause of any surface defect before taking any remedial action. | 1. | Do not undertake any maintenance operations without Safety Measures at work sites. |
| 2. | During periodic maintenance and resurfacing operations, restore the correct crossfall and superelevation. | 2. | Do not attempt to compact fresh gravel by traffic, without using proper compaction equipment. |
| 3. | Carefully select surface gravel to minimize dust problems. | 3. | Do not overlook the maintenance of the drainage system. |
| 4. | Make all efforts to maintain a good drainage system. | 4. | Do not decrease or increase the existing superelevation during maintenance operations. |
| 5. | Scientifically decide upon the number of times during the year that each unpaved road will need grading, based on a range of factors. | 5. | Do not disturb roadside vegetation while carrying out various maintenance tasks. |
| 6. | Retain superelevation on curves during maintenance operations. | 6. | Do not decide upon the Dragging frequency arbitrarily without practical tests. |
| 7. | Prefer simple maintenance equipment e.g, towed grader over a motor grader. | 7. | Do not ignore the maintenance of any grass lining/ turfing provided to control erosion. |
| 8. | Carry out a Condition Survey to determine PCI, atleast once a year, preferably twice, before and after rainy season. | 8. | Do not undertake any maintenance task without considering the data obtained during the last condition survey. |
| 9. | Adopt a systematic maintenance management system as recommended in the Manual. | | |
| 10. | Combine heavy grading with regravelling to restore thickness of gravel surface. | | |

**APPENDIX-A**
**(Para 2.2.2.1 and 2.2.4)**

# PROPORTIONING DIFFERENT MATERIALS FOR ACHIEVING THE PRESCRIBED GRADING

## A-1. Combining two materials

When only two materials are to be combined, a simple graphical method described below can be followed:

**Steps:**

It is required to blend sand (A) and silt-clay (B) to obtain the following gradation:

| Sieve designation | Percentage passing | Material (A) | Material (B) |
|---|---|---|---|
| 4.75 mm | 100 | 100 | – |
| 2.36 mm | 80–100 | 91 | – |
| 1.18 mm | 50–80 | 34 | 100 |
| 425 micron | 30–60 | 10 | 84 |
| 300 micron | 20–45 | 3 | 59 |
| 75 micron | 10–25 | 2 | 36 |

(i) On a convenient size of rectangular graph, scale off top linearly from 100 to 0 as percentage of A in mix. Scale off the base corresponding from 0 to 100 as percentage of B in mix. Scale off the vertical ordinate from 100 at top to 0 at bottom on the left and 0 at top to 100 at bottom on the right, representing the percentages passing sieve **[Fig A-1]**.

(ii) On the left ordinate, mark off percentages passing the given sieves for material A. On the right ordinate mark off percentages passing the given sieves for material B.

(iii) For each sieve size, connect by a straight line the points, representing the respective percentages passing each material. The intersection of each sieve line by any vertical line will define the combined grading of the two materials mixed in the proportions shown in the top and bottom horizontal scales.

(iv) On each sieve line, the specified percentage passing limits are marked by small circles. The intercept lying between the circles represents, for any particular sieve line, the range of proportion that will comply the specification.

(v) If mixtures within the specification limits are possible, vertical lines can be erected such that their intersection points with all sieve lines lie on the acceptable intercepts. The highest and the lowest percentages of either material at which this can be done represent the limiting mixtures which conform to the specifications. The mid-point between the limiting mixtures will usually provide the best mixture.

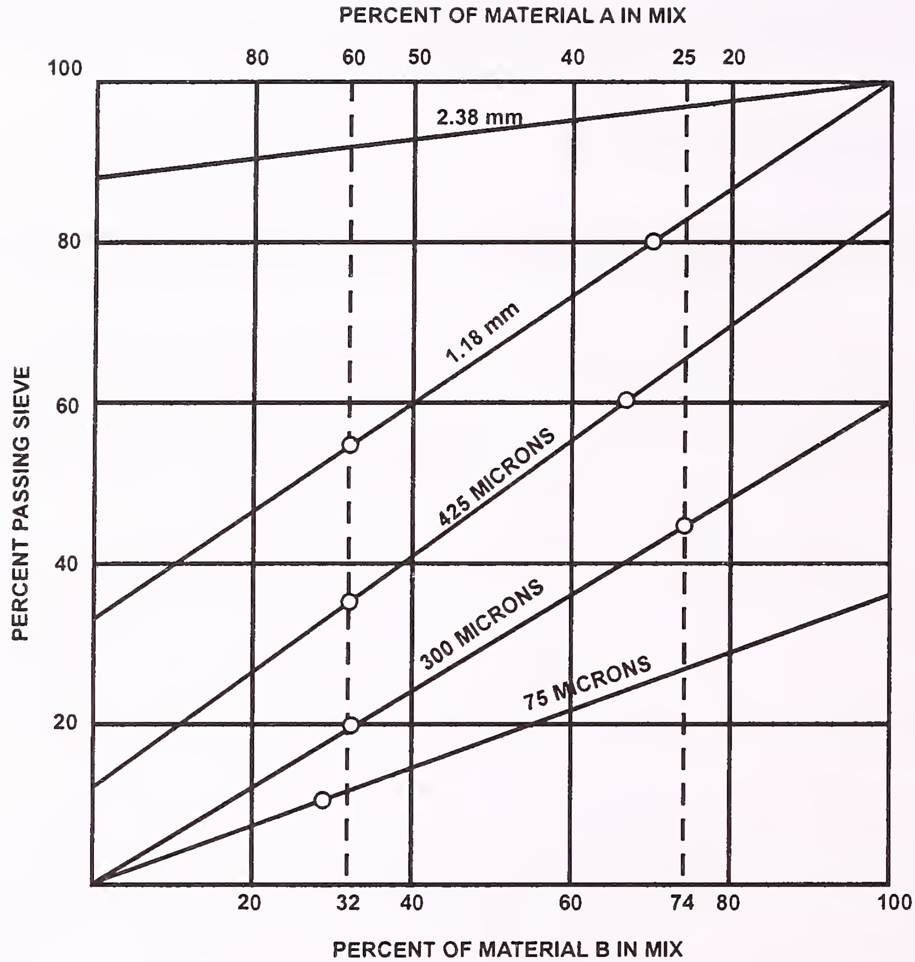



Fig. A-1GRAPHICAL METHOD OF COMBINING TWO AGGREGATES

(vi) In the limits indicated are (i) 68 per cent A, 32 per cent B and (ii) 26 percent A, 74 per cent B. In practice, the acceptable properties would lie in the range of A:B=2:1 to A:B=1:3. Probably a ratio of A:B=1:1 would be the best.

## A-2. Combining Three Materials

In dealing with mechanical stabilisation, it is often found necessary to combine different materials to obtain the finally desired gradation. Rothfuch's graphical method is a reasonably quick, accurate and simple method, and is used, for design of cement concrete mixes, bituminous mixes and granular mixes. The method consists of the following stages:

(i) Using the desired aggregate gradation, a distribution curve is plotted with the percentage passing as linear ordinates and the sieve sizes on the horizontal scale. In order to mark the sieve sizes on the horizontal scale, an inclined line (OA in **Fig. A-2**) is first of all drawn. By marking the known percentages passing each size sieve on this line and dropping vertically the intersection point to the horizontal axis, the location of the sieve size on the horizontal axis is determined.

(ii) The particle size distributions of the given materials to be blended are plotted on this scale. The distribution curves will not generally be straight lines (Lines OB, CDE and CF GA in **Fig. A-2**).

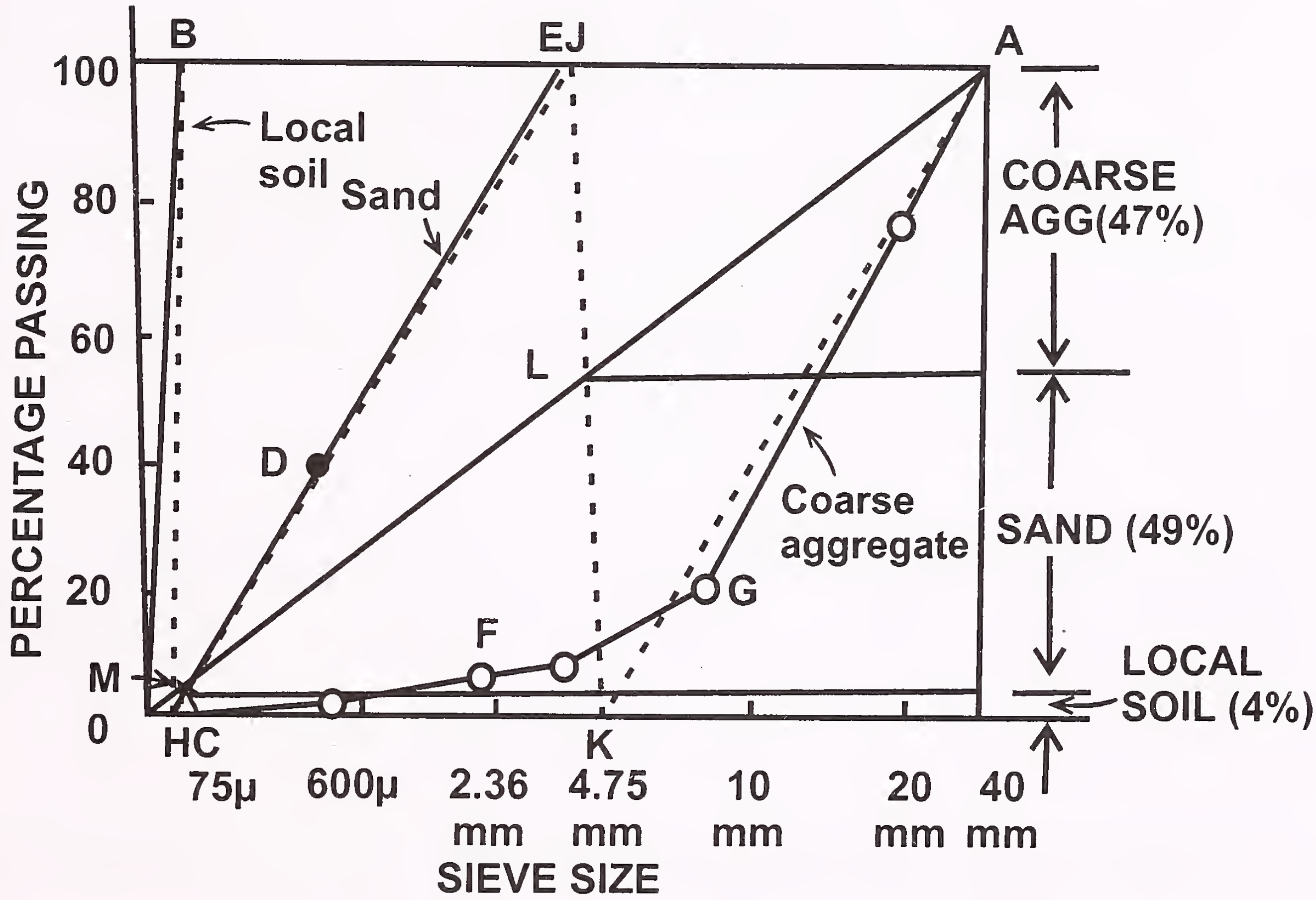



**Fig. A-2 : Rothfuch's Graphical Method of Combining 3 Materials**

(iii) With the aid of a transparent straight edge, straight lines are drawn representing the particle size distribution in the best possible manner (Lines HJ and KA). This means that the areas enclosed between the distribution curve and the straight line should be minimum and are balanced about the line.

(iv) The opposite ends of these lines are joined together (Lines BH and JK).

(v) The proportions for blending can be read off from the points where the joining lines cross the straight line representing the mixture. These points are L and M.

The method is illustrated by the following example :

Cols. 1 and 2 in the Table below give the gradation limits for various sieve sizes of a stabilized soil mixture. Three materials are available, whose gradations are given in Cols. 4, 5 and 6. Work out the blending proportion.

**Blending of Materials**

| Sieve designation | Percentage passing | | | | | |
|---|---|---|---|---|---|---|
| | Required Gradation Limits | Average | Materials Available | | | |
| | | | Coarse Aggregates (A) | Sand (B) | Local Soil (C) | 47% A 49% B 4% C |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 40 mm | 100 | 100 | 100 | – | – | 100 |
| 20 mm | 80-100 | 90 | 75 | – | – | 88 |
| 10 mm | 55-80 | 67.5 | 20 | – | – | 62 |
| 4.75 mm | 40-60 | 50 | 8 | 100 | – | 53 |
| 2.36 mm | 30-50 | 40 | 6 | 80 | – | 42 |
| 600 mm | 15-30 | 22.5 | 2 | 40 | – | 21 |
| 75 micron | 0-10 | 5 | Nil | 2 | 100 | 5 |

A reference to Fig. A-2 will illustrate the stages involved in the graphical method. The percentages of various materials as scaled out are:

Material (A) : 47%

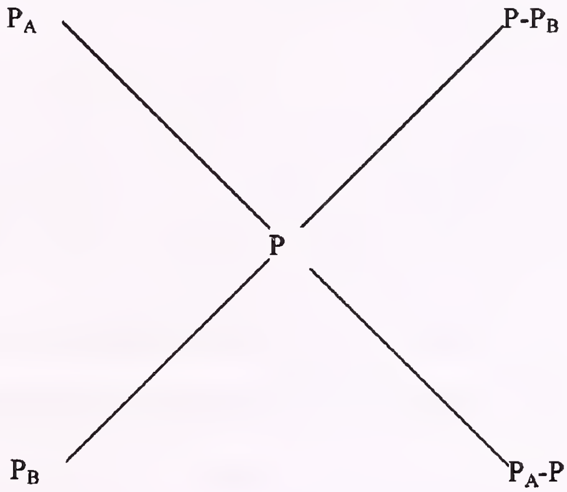
Material (B) : 49%

Material (C) : 4%

The gradation of the final mixture on the basis of above blending indicated in Col. 7 of the Table.

### A-3 Combining two Soils for Producing the Mix Meeting Require Dplasticity Index

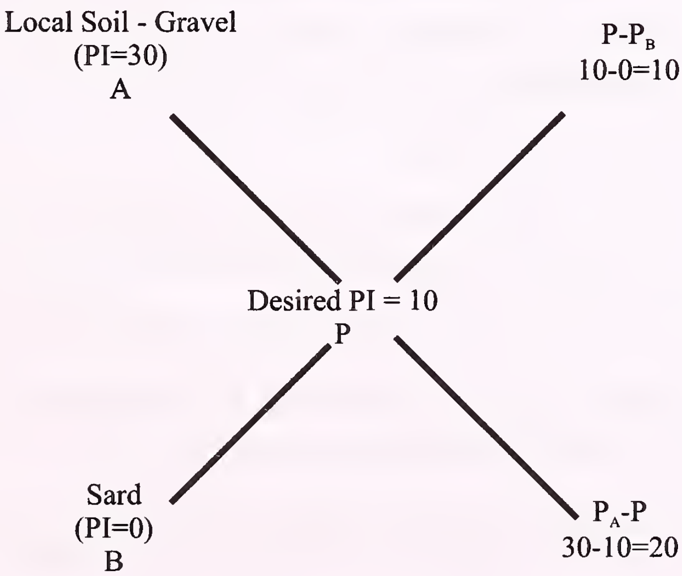
Two Soils A and B with Plasticity indices $P_A$ & $P_B$ can be proportioned to produce a material having the required plasticity index P. Record the values of $P_A$ and $P_B$ at the top ends of across, P at the crossing point. Determine the numerical differences $P_A$-P and P - $P_B$. The ratio in which the two soils should be mixed are indicated at the lower ends.




$$\text{Mat . A : Mat . B} :: P - P_B : P_A - P$$

**Example :**

The local soil-gravel in an area has a Plasticity Index (PI) of 30. Sand (PI = 0) is also locally available from a nearby stream. What are the proportions in which the two can be blended to obtain a PI of 10 in the mix?




In the Mix, 10 parts of Local Soil – gravel (PI-30) need to be mixed with 20 parts of Sand (PI = 0) from the nearby stream.

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(The Official amendments to this document would be published by the IRC in its periodical, 'INDIAN HIGHWAYS', which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified there in)