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STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

SECTION - I General Features of Design (Eighth Revision)

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100 SCOPE

This Code deals with general features of design of road bridges including immediate approaches and the recommendations of this code shall apply to all types of bridges.

101 DEFINITIONS

Following definitions shall be applicable for the purpose of this Code and other IRC Standard Specifications and Codes of Practice for Road Bridges.

101.1 Abutment

Abutment is a sub-structure component which supports the end of a superstructure and retains part or whole of the bridge approach fills.

101.2 Afflux

Afflux is the rise in the flood level of the channel, immediately on the upstream of a bridge, as a result of obstruction to natural flow caused by the construction of a bridge and its approaches.

101.3 Approach

It is a part of road which connects the road to the abutment of the bridge.

101.4 Approach Slab

An approach slab is a transition slab of reinforced concrete laid on immediate approaches to a bridge with one end resting on dirt wall/abutment.

101.5 Bearing

Bearing is a part of bridge structure which bears directly all the forces from the superstructure above and transmits the same to the supporting substructure.

101.6 Bridge

A bridge is a structure having a total length of above 6 m for carrying traffic or other moving loads across a channel, depression, road or railway track or any other obstruction.

101.7 Camber

Camber is transverse inclination given to the cross-section of the carriageway so as to ensure its proper drainage.

101.8 Causeway

Causeway is a paved submersible structure with or without openings (vents) which allows flood/water to pass through and/or over it.

101.9 Channel

Channel is a natural or artificial water course.

101.10 Clearance

Clearance is the shortest distance between the boundaries at specified positions of a bridge/under pass/over pass.

101.11 Cofferdam

Cofferdam is a temporary structure built for the purpose of excluding water or soil from working area to permit construction without the need for excessive pumping.

101.12 Crash Barrier

A barrier provided at the side of carriageway designed to reduce the risk of serious accidents by guiding the errant vehicles back on the road.

101.13 Culvert

Culvert is a structure having a total length of upto 6 m between outer faces of walls, measured at right angles. Cross drainage structures with pipes will be termed as culvert, irrespective of length.

101.14 Dirt Wall

Dirt wall is a vertical wall projecting from abutment cap to prevent spill of earth/pavement materials and also to support approach slab.

101.15 Effective Linear Waterway

Effective linear waterway is the total width of waterway of bridge at Highest Flood Level (HFL) minus the effective width of obstruction.

101.16 Flyover

A bridge over another road for allowing traffic without interruption, with its approaches on both sides.

101.17 Foot Over Bridge (FOB)

A foot over bridge is a bridge over a road or other obstructions, for exclusive use of pedestrians.

101.18 Foundation

Foundation is that part of a bridge structure, which is in direct contact with and transmitting loads to the founding strata.

101.19 Free Board

Free board at any point is the difference between the highest flood level after allowing for afflux, if any, and the formation level of road embankment on the approaches or top level of guide bunds at that point.

101.20 Full Supply Level (FSL)

Full supply level is the water level corresponding to the full supply of canal.

101.21 Grade Separator

Grade separator is a bridge which facilitates movement of traffic by segregating 'at-grade' conflicting movements to different levels.

101.22 High Level Bridge

A high level bridge is a bridge which carries the roadway above the Highest Flood Level (HFL) of a channel (including afflux) or the high tide level, with appropriate vertical clearance.

101.23 Highest Flood Level (HFL)

Highest flood level is the level of highest flood recorded/observed or calculated from the design discharge, whichever is higher.

101.24 Interchange

Interchange is a system of interconnecting roads (ramps and loops) in conjunction with one or more grade separations that provide for the uninterrupted movement of traffic between two or more roads.

101.25 Invert

An invert is that part of a pipe or sewer below the springing line, generally the lowest point of the internal cross section.

101.26 Kerb

A line of raised concrete section, forming an edge between carriageway and railing/footpath/median.

101.27 Kerb Shyness

Kerb shyness is the imaginary distance by which the driver would generally keep his vehicle away from the kerb in order to avoid brushing with the kerb.

101.28 Lateral Clearance

Lateral clearance is the minimum distance between the extreme edge of the carriageway and the face of nearest obstruction such as abutment, pier, column etc.

101.29 Length of a Bridge

Length of a bridge structure shall be taken as the overall length measured along the centre line of the bridge between inner faces of dirt walls (or between end deck joints or outer edge of deck, where there is no dirt wall).

101.30 Low Water Level (LWL)

Low water level is the level generally prevailing in the stream/river during dry weather.

101.31 Ordinary Flood Level (OFL)

Ordinary flood level is the level to which the stream/river generally rises during monsoon period every year.

101.32 Overpass

Overpass is a bridge carrying another road over a reference road.

101.33 Parapet

Barrier installed on the edge of a bridge from safety considerations and intended to restrain users from falling off the bridge.

101.34 Pier

Pier is an intermediate support of the bridge super-structure.

101.35 Ramp

Ramp is road in slope, connecting roads at different levels.

101.36 Retaining Wall

Retaining wall is a wall designed to retain earth fill.

101.37 Return Wall

Return wall is a wall adjacent to abutment and parallel to road to retain approach embankment.

101.38 Right of Way (ROW)

Right of way is the land made available and/or acquired for development of road.

101.39 Road Over Bridge (ROB)

Road Over Bridge is a bridge built over the Railway tracks.

101.40 Road Under Bridge (RUB)

Road under bridge is a structure built beneath the Railway tracks.

101.41 Safety Kerb

A kerb having width of at least 750 mm for occasional use by pedestrians, where footpath is not provided.

101.42 Skew Angle

Skew angle is the angle between the axis of support and a line normal to the longitudinal axis of a bridge.

101.43 Span

Span is the horizontal distance between the centre line of adjacent supports of a bridge superstructure, or maximum distance between the inner walls of a culvert, measured along its axis.

101.44 Submersible Bridge

Submersible bridge is a bridge designed to be overtopped during floods.

101.45 Substructure

Substructure is the portion of a bridge structure between the foundation and the superstructure.

101.46 Subway

A subway is usually meant for pedestrian use and comprises of structure below a road with stairs/ramps/escalator.

101.47 Super Elevation

Super elevation is transverse inclination given to the cross section of a carriageway on horizontal curve in order to reduce the effects of centrifugal force on a moving vehicle.

101.48 Superstructure

The portion of a bridge structure above bearings, which directly supports pedestrian/vehicular/ other transient loads and transfers the same to the substructure.

101.49 Toe Wall

Toe wall is a wall built at the end of the slope of earthen embankment to prevent slipping of earth and/or pitching.

101.50 Tunnel

Tunnel is an underground closed structure carrying a roadway, through soil or rock.

101.51 Underpass

Underpass is a structure allowing uninterrupted movement of traffic beneath a reference roadway. An underpass is classified as Cattle Underpass (CUP), Pedestrian Underpass (PUP) and Vehicular Underpass (VUP) depending on principal user.

101.52 Vertical Clearance

For a channel, vertical clearance is the height from the design flood level with afflux or high tide level, to the lowest point of the super structure, at the position along the bridge where clearance is being denoted.

For flyover, underpass, overpass, ROB and RUB, the vertical clearance is the height above any point of road way or rail top level to the corresponding point of the overhead structure.

101.53 Viaduct

A viaduct is a bridge structure across dry ground/terrain.

101.54 Wearing Course

It is the top layer of a road surface over deck that protects the main superstructure and takes the wear caused by traffic.

101.55. Width of Carriageway

Width of carriageway is the minimum clear width measured at right angles to the longitudinal center line of the bridge between inside faces of crash barrier/kerbs/median. For divided carriageway, it is measured between inner faces of crash barrier/kerb/median.

101.56 Wing Wall

Wing wall is a splayed return wall, usually at 45° to the road embankment.

102 CLASSIFICATION

Bridges are classified on the basis of their principal function, material used in construction, length, structural form, system of support, construction technology and deck level with respect to highest flood level. The broad details of bridge classification are as follows:

102.1 Function

Based on functions, bridges are classified as under:

- a) River bridge/Bridge over stream
- b) Viaduct
- c) Flyover
- d) Grade separator
- e) Road Over Bridge (ROB)
- f) Road Under Bridge (RUB)
- g) Foot Over Bridge (FOB)
- h) Underpasses
- i) Subways
- j) Overpass

102.2 Length

102.2.1 *Based on Length, Structures are Classified as below:*

- a) Culvert : as defined in clause 101.13
- b) Bridge : as defined in clause 101.6

102.2.2 The bridges are further classified as minor and major bridges as below:

- a) Minor bridge is a bridge having a total length of up to 60 m.
- b) Major bridge is a bridge having a total length of more than 60 m.

102.2.3 Bridges having span length (s) of 150 m or more are classified as 'long span bridges'

102.3 Superstructure

102.3.1 Form of Superstructure

Based on form and type of superstructures, bridges are classified as under:

- a) Arch
- b) Solid slab
- c) Voided slab
- d) T-beam and slab
- e) Suspension
- f) Cable stayed
- g) Extra-dosed
- h) Box girder
- i) Single/Multi-cell Box
- j) Truss

102.3.2 System of Support for Superstructure

Bridges are classified on the basis of systems of support as under:

- a) Simply supported
- b) Continuous
- c) Integral
- d) Balanced cantilever
- e) Cable supported

102.4 Material

Based on material of structure, bridges are classified as under:

- a) Masonry
- b) Reinforced concrete
- c) Pre-stressed concrete
- d) Fibre reinforced concrete
- e) Steel
- f) Composite
- g) Timber

102.5 Construction Technology

Based on technology for construction adopted, bridges are classified as under:

- a) In-situ
- b) Precast or prefabricated
- c) Cantilever
- d) Incremental launching
- e) Span by span
- f) Segmental

102.6 Level

River Bridges/Bridges over streams are classified based on difference in roadway level and Ground Level/High Flood Level (HFL), as under:

- a) High level bridge
- b) Submersible bridge

102.7 Importance

Based on the importance of a bridge in the highway system, bridges are classified as under:

- a) Normal
- b) Important
- c) Critical

103 GENERAL PROVISIONS

General

The design shall be principally based on the limit state design philosophy. Structural components and the connections shall be designed to conform to the requirements of ultimate limit state, serviceability limit state and fatigue limit state requirements of the appropriate clauses of relevant codes of IRC.

Note : Till such time all the IRC codes and standards are changed from Working Stress Philosophy to Limit State Philosophy, the design of structural components shall continue to be carried out as per the existing codes, which may be still following working stress philosophy.

103.1 Performance Requirements

Bridge structure and its components shall be planned, designed, constructed and maintained in such a way that they perform adequately and safely during construction and service life, with following performance requirements:

- a) Structural Safety and Serviceability, i.e. ability of a structure or structural members to perform, with appropriate levels of reliability, adequately for

normal use under all combinations of actions expected during construction and service life.

- b) Durability, i.e, ability of the structure to perform during design service life, for its intended purpose with anticipated maintenance but without major repair being necessary.
- c) Economy, i.e, bridges should have least life cycle cost.
- d) Sustainability, i.e. ability of a material, structure or structural member to contribute positively to the fulfillment of the present needs and the needs of future generations.

Above requirements may be met by

- a) the choice of suitable materials,
- b) appropriate design and detailing,
- c) specifying control procedures for design, production, execution, and use relevant to the particular project and
- d) appropriate choice of span arrangement and construction methodology.

103.2 Structural Safety & Serviceability

Structural safety is ability of a structure and its structural members to guarantee the overall stability, adequate deformability and ultimate bearing resistance, corresponding to the assumed actions (both extreme and/or frequently repeated actions and accidental and/or exceptional events) with appropriate levels of reliability for the specified reference periods. The structural safety shall be analyzed for all possible damage states and exposure events relevant for the design situation under consideration;

In the context of performance-based Limit State Design, performance criteria for serviceability and structural safety are specified by:

- a) Serviceability limit state criteria
- b) Ultimate limit state criteria

Limit state shall be related to design situations. They may relate to persistent situations during the service life of the works, transient situations during the construction stage as well as repair stage, extreme actions and environmental influences, including earthquakes. Design principles with respect to the performance-based Limit State Design for structural safety and serviceability as given in relevant design codes of IRC may be adopted.

Serviceability limit state corresponds to the state beyond which specified performance requirements for a structure or a structural component are no longer met.

Ultimate limit state is the limit state associated with the structural collapse leading to loss of life, damage to structure and environment and disruption of operation. Ultimate limit state may arise due to structural components reaching their ultimate strength, fatigue or instability.

103.3 Economy

Economy in bridge design would generally depend upon structural type, span lengths, materials and method of construction, which shall be selected on the basis of life cycle cost. Costs of structural alternatives should be worked out based on long term considerations including inspection, maintenance and repair/replacement. Therefore, cost of future expenditure on repair and maintenance during the whole service life of bridges should be accounted for. Construction cost shall take into account regional factor such as availability of material and labour, fabrication, location, shipping and erection constraints. Cost on account of mitigation of social and environmental impact shall also be taken into account in working of cost comparison. Efforts shall be made to optimize the life cycle cost.

103.4 Sustainability and Loading Considerations

The structures shall contribute towards sustainable development by effective mitigation of social and environmental impacts.

The loads, special local conditions and traffic intensity for which a bridge is to be designed, shall be prescribed by the authorities as per relevant clauses of IRC:6.

Utilities or services, if any, to be carried over the bridge and if so, nature thereof (e.g. Telephone Cables, OFC ..etc.) and relevant information regarding size, arrangement etc. shall be taken as per the requirements or as directed by the authorities.

104 PLANNING CONSIDERATIONS

Planning of a bridge is essential to create a facility which will comply with various technical, administrative, environmental and social requirements including financial justifications and will serve the intended purpose. All requisite information and data shall be collected for proper planning of a bridge project.

104.1 Planning Strategies

104.1.1 *Integration with Road Network*

The first step in the planning of a bridge project is to ascertain its location in the link of the road network and function thereof. The bridge shall fit into the road link in a seamless manner and contribute to its primary function. Most road links have both mobility and accessibility functions in varying degrees, which shall be taken into account while planning.

104.1.2 *Interaction with other Authorities and Public*

It is necessary to interact with authorities and local public who are directly or indirectly connected with the project or whose works or authority will be directly or indirectly affected.

104.1.3 *Siting of a Bridge*

104.1.3.1 *River bridge*

- a. A bridge should ideally be sited across the narrowest width of the river or channel where the course of the channel is straight in considerable length

on both up-stream and down-stream sides of the site and the banks are stable having no history of being out-flanked. A bridge should not be sited across meandering stretches of rivers unless it is established that the banks at the bridge site are the nodal points of the river (i.e. the river has a history of touching these points year after year regardless of change in its course elsewhere). Where one of the banks is not well defined and gets over-topped, the option of training the river by construction of a guide bund can also be considered. In case the active channel of the river, especially the alluvial rivers, changes its course within the river basin, the option of training the river by construction of guide bunds on both banks can be considered after ensuring that the adjoining areas in the upstream do not get flooded or the guide bunds themselves are not under attack. The preliminary site selection can be based on information contained in the topographical sheets of the Survey of India, supplemented by actual survey or study of satellite images of the location, which can be obtained from the National Remote Sensing Agency. A model study may be required for bridging rivers having undefined cross section and huge flood plains.

- b. The cardinal principles to be kept in view at the time of selection of a particular bridge site including river training works are to provide a suitable crossing consistent with safety and economy and acceptable detour from the existing road alignment. The following shall be the guiding considerations in this regard:
 - i) **Bridges up to a length of 60 meters** - The location shall be governed by suitability of alignment of road, unless there are special problems at the crossing with regard to design and maintenance of the bridge.
 - ii) **For bridges having a length between 60 m and 300 m** - Suitability of site of the bridge as well as that of the alignment of approaches shall be considered together.
 - iii) **For bridges having a length more than 300 m** - The requirement of a good site for the bridge shall have the precedence and the alignment of approaches will have to conform to the selected bridge site.
- c. A brief description of the reasons for selection of a particular site for the crossing should be prepared for record, which shall include typical cross-sections of the channel at all alternative sites investigated and rejected.

104.1.3.2 *Grade separators and underpass*

The layout of a grade separator or an Underpass is determined by the alignment and geometry of intersecting roads or traffic, road classification and degree of segregation required.

104.1.3.3 *Bridges in hilly & coastal regions*

- a) For bridges in high altitude, where the road is likely to pass through snow bound areas and avalanche prone slopes, snow removal and avalanche

control should be one of the factors to be considered in the planning stage of the road and bridges. Specialist literature and publications shall be referred to for dealing with such cases.

- b) The coastal bridges are susceptible to highly corrosive environment, storm surge or tsunami and strong cyclonic winds. Specialist literature and publications shall be referred in absence of any relevant IRC standards.

104.1.3.4 Approaches

A length of at least 50 m of approaches on either side of the bridge/grade separator or the defined length up to the end of approach gradient, whichever is larger, shall form part of bridge/grade separator planning. The approaches of a flyover may comprise series of viaduct spans for openness in inhabited locality or wall type structures in remote areas.

S. No.	Component	Design Life
1.	All structural components	100 years (Depending upon importance and criticality of the bridge, a higher design life may be prescribed by the authorities.)
2.	Ancillary items like bearings, expansion joints, wearing course etc.	As per provisions of respective Codes of Practice (Provision for replacement of these items shall be ensured in design and drawings)

104.1.5 Safety

The bridge and its approaches shall be planned to ensure safety of the user and the structure in accordance with Clause 105.2.

104.1.6 Initial Environmental Examination

Initial environmental examination should be carried out to evaluate likely adverse impact of the proposed bridge on environment. The most likely impacts are as under:

- a) Increase in submergence of surrounding area
- b) Likelihood of river bank erosion
- c) Possibility of siltation
- d) Relocation and rehabilitation of people/communities
- e) Effects on historic monuments and heritage structures
- f) Impact on conservation of wild life, flora and fauna
- g) Impact on surroundings

104.1.7 Aesthetics

All bridges and grade separators should be aesthetically pleasing as it has a large impact on the surroundings. Considerations shall be given to various aspects mentioned in Clause 112.

104.1.8 Economic Evaluation

The economic evaluation of different alternatives of a bridge project shall be carried out to determine its relative viability. In some cases, social requirements may prevail over the economic considerations.

104.2 Collection of Data

All detailed information for a complete and proper appreciation of the bridge project shall be included in the project documents. Generally, the following information shall be furnished.

- a) General Data including Maps, Plans and Topographical Features
- b) Hydraulic Data for Selected Bridge Site
- c) Geological and Seismological Data for Selected Bridge Site
- d) Sub-surface Data
- e) Environmental Data
- f) Loading and other Data
- g) Traffic Data
- h) Construction Materials
- i) Special Design Requirements
- j) Existing Services
- k) Labour Accommodation
- l) Other Authorities
- m) Data Regarding Existing Bridges

104.3 Width of Carriageway, Footpath and Median

104.3.1 *Width of Carriageway and Overall Width*

For high level bridges constructed for the use of road traffic only, the width of carriageway shall not be less than 4.25 m for a single lane bridge, 7.5 m for a two-lane bridge and shall be increased by 3.5 m for every additional lane of traffic for a multiple lane bridge. If a median/central verge is constructed in a wide bridge thus providing two separate carriageways, the carriageway on each side of the median shall provide for at least two lanes of traffic and width thereof shall individually comply with the minimum requirements stipulated above. For a bridge on a horizontal curve, the roadway width shall be increased suitably to conform to the requirements stipulated in the relevant IRC Standards.

104.3.2 Width between the outermost faces of the bridge shall preferably be equal to the full formation width of the approaches. However in case of bridges having length more than 60 m in non-urban areas, reduced width may be permitted by the authorities subject to stipulations as given in Clause 104.3.1 above.

104.3.3 Vented causeway/submersible bridges shall cater for at least two lanes of traffic.

104.3.4 Width of Bridge carrying combined highway/Mass Rapid Transport System (MRTS)/Railway corridor.

For bridges carrying combined road and rail or any other special type of traffic, the widths indicated in above clause shall be suitably increased.

104.3.5 *Width of Median*

The median width of the approach road shall generally be carried over the bridge. In case of major bridges, the median width may be reduced, subject to a minimum width of 1.2 m, in which case, crash barriers shall be provided in the median.

104.3.6 *Width of Footpath*

When a footpath is provided, its clear width shall not be less than 1.5 m. For urban and populated areas having large concentration of pedestrian traffic, the width of the footpath shall be suitably increased.

104.4 **Clearances**

104.4.1 *Clearance - Navigational*

Navigational clearances, both vertical and horizontal, shall be provided based on classification of waterway as per the requirements of Inland Waterway Authority of India (IWAI) or the concerned Port authorities.

104.4.2 *Clearance – Over Roads*

104.4.2.1 *Vertical*

The minimum vertical clearance of any structure provided over the project road shall be 5.0 m for non-urban areas and 5.5 m in case of urban areas.

In case of structures over local or collector streets, where only light commercial vehicles are plying and where alternative routes for heavy commercial vehicles and fire tenders are available within a short distance, the authorities may relax the clearance requirements stated above.

At locations where over-dimensional vehicles are frequently plying, the authorities may consider providing increased vertical clearance.

For project roads carrying footways and cycle tracks, a minimum vertical clearance of 2.25 m shall be provided.

104.4.2.2 *Horizontal*

While fixing the horizontal clearance, consideration shall be given to safe passage of vehicles on or under a bridge. The minimum clear width between any obstruction shall not be less than that of the approach roadway section, including shoulders or Kerbs, gutters, and sidewalks. No object, other than a road kerb or a crash barrier, should be located closer than 600 mm to the edge of carriageway.

For a bridge constructed on a horizontal curve with superelevated road surface, the horizontal clearance shall be increased on the side of the inner kerb by an amount equal to 5 meters multiplied by the super elevation. The minimum vertical clearance shall be measured from the super elevated level of the roadway. Extra horizontal clearance required for the super elevation will be over and above the increase in width required on a curve.

104.4.3 *Clearance - Over Railway Lines*

For ROBs across railway lines, horizontal and vertical clearances shall be governed by the requirements of the Railway authority.

104.5 *Span Configuration*

105 GEOMETRIC DESIGN CONSIDERATIONS

Choice of a particular span arrangement and the type of structure depends upon several factors such as site characteristics, type of sub-soil strata, height and length of the bridge, riding quality, design and, constructability considerations, availability of construction material and technology etc. In case of urban flyovers, considerations of aesthetics and other functional requirements like openness in inhabited portions, may have overriding effect for viaduct spans vis-à-vis solid-fill portion for approaches.

105.1 *General*

Geometric design for the bridge including immediate approach roads should essentially include integration of vertical and horizontal alignment of the bridge with the highway geometry and should broadly cover the following:

- a) **Preparation of Plan** - showing the horizontal alignment horizontal curves, overall width, width of carriageway, footpath, median, crash barrier, railing, shoulders, side drains, right of way, etc.
- b) **Preparation of Vertical Profile** - showing the vertical alignment, grade line, vertical curves, high flood level, ground/bed profile etc.
- c) **Preparation of Cross-sections** - showing the carriageway, cross camber/ super elevation, side slopes, median, footpath, hydraulic details, structural arrangement, type of superstructure, substructure and foundation, abutment details, protection works, details of return walls, retaining walls etc.

105.2 *Safety Considerations*

105.2.1 *Protection to User*

Railings/Crash Barriers shall be provided along the edges of structures conforming to the requirements stated elsewhere in the code. Footpaths and cycle tracks adjacent to the carriageway shall have crash barrier in between, to safely redirect the errant vehicular traffic.

105.2.2 *Protection to Structure Against Vehicle Collision*

Consideration shall be given for safe passage of vehicles on or under a bridge. The hazard of being hit by errant vehicles within the clear zone should be minimized by locating structural components at a safe distance from the line of users and/or by providing suitable protection to the structural components.

105.2.3 *Protection to Structure Against Barge Impact*

For bridges on streams where barges are plying, the bridge structure shall be protected against vessel collision forces by fenders, protection islands or any other means. Alternatively, the structural system shall be designed to withstand collision force effects as specified in relevant IRC Code.

105.3 **Horizontal and Vertical Alignments**

Horizontal and vertical alignments of road bridges shall conform to relevant IRC Code. While finalizing the horizontal and vertical alignment for the bridge portion, following aspects shall be considered:

105.3.1 To the extent practicable, the alignment of roadways shall be selected to make bridge crossing as nearly square as possible.

105.3.2 Wherever the bridge is in curvature, effort shall be made to provide constant curvature within the bridge portion of the highway. Sudden change of radii and curvature over the bridge shall be avoided to the extent possible.

105.3.3 *Skew Angle in any Bridge should Preferably not Exceed 30°.*

105.3.4 In situations where a replacement/new bridge is to be constructed, adjacent to an existing structure, width of the gap between the two bridges shall be decided on the basis of clearance between the foundations. Not less than 2.5 m clear gap should be provided at any place between the two bridges to allow for working space.

105.3.5 Locating bridges on vertical sag curves shall be avoided as far as possible, as vehicle dynamic effects are increased and appearance is adversely affected.

105.3.6 For bridges, a minimum longitudinal gradient of 0.3% is desirable to provide for drainage of deck.

105.3.7 In case of divided carriageways, finished road levels at the median for both the carriageways shall preferably be same at any cross section.

105.3.8 The combined effect of horizontal and vertical alignments and changes in super elevation shall be considered with regard to the appearance of the bridge structure, especially in urban situations.

105.3.9 The alignment chosen in hilly roads should enable the ruling gradient to be attained in minimum length, besides, minimizing steep gradients and, hairpin bends and avoiding needless rise and fall.

105.3.10 A single vertical curve shall be provided for bridges having total length upto 30 m.

105.4 **Design Speed**

Design speed over the bridge shall be consistent with the design speed on the approach roads. A single design speed should preferably be adopted for the entire bridge structure. In case, however, differential design speed is unavoidable due to presence of sharp curvatures

in specific zones within the bridge, transitions between sections with different Design Speeds shall be designed as per relevant IRC codes.

105.5 Longitudinal Gradient and Cross Slope

105.5.1 The maximum longitudinal gradient on bridge shall be consistent with the gradient of the approach roads as per relevant IRC codes.

105.5.2 The cross slope on bridge deck shall be consistent with the cross slope of the adjoining roadway.

105.5.3 During exiting a bridge, consideration shall be given to stopping sight distance, especially where bridge approaches are constructed close to intersections.

105.6 Super-Elevation

105.6.1 The super elevation and additional widening on the deck of a bridge on a horizontal curve shall be provided in accordance with the relevant IRC code.

105.6.2 Transition from normal cross slope to full super elevation shall be avoided over a bridge as far as possible.

105.7 Approaches to Bridge

105.7.1 The approaches on either side of the bridge for a length of at least 15 m shall continue to have the same horizontal profile as that provided for the bridge. This length may be suitably increased where necessary to provide for the minimum sight distance for the design speed. However, in difficult geometric situations, the minimum length of approaches with same horizontal profile may not be insisted upon, provided user's safety concerns are not compromised.

105.7.2 Where horizontal curves have to be provided on the approaches, beyond the straight portion on either side, the minimum radius of curvature, the super elevation and transition length for various speed and curve radii shall be provided in accordance with stipulations contained in relevant IRC Codes.

105.7.3 If there is a change of gradient in the approaches, suitable vertical curves shall be introduced conforming to stipulations contained in relevant IRC Codes.

106 HYDROLOGY AND HYDRAULIC DESIGN

106.1 Data collection for hydraulic design shall be made in accordance with Clause 104.2 of the Code.

106.2 Determination of Design Highest Flood Level

106.2.1 The design flood level shall be decided on the basis of data collected during reconnaissance survey, aerial survey, satellite maps, detailed survey and hydrological and hydraulic studies and analyses made.

106.2.2 *Design Highest Flood Level shall be the Highest of the following :*

- a) The highest of flood levels as obtained from local enquiries from aged persons. Such local enquiries should be made at 3 different locations at site.
- b) Level of the highest watermarks, left on different old structures or the erosion marks on the banks
- c) Highest flood level that will be able to pass the design discharge as determined from other sources as per clause 106.3
- d) The highest of the levels after considering the effects of confluence, backwater and HFL because of merger of or into any other river in the influence zone upstream or downstream of site.
- e) The highest level as corroborated from the records of HFL available for existing bridges, other structures like dams and spillways and gauge stations etc. on the river in upstream or downstream direction.
- f) Effect of any new structure planned for future in the influence zone of the stream.

106.3 **Determination of Design Discharge**

106.3.1 The design discharge for which the waterway of the bridge is to be provided, shall be based on maximum flood discharge of return period of 100 years. In case where the requisite information is not available, the design discharge shall be the maximum estimated discharge determined by consideration of the following or any other rational method.

106.3.1.1 From the records of discharge observed in the stream at the site of the bridge, or at any other site in its vicinity i.e., the discharge taken for design at any other bridge site and any other irrigation structures like dam or spillway or Gauge Station on this river in the upstream direction.

106.3.1.2 From the rainfall and other characteristics of the catchment:

- i) By the use of an empirical formula, applicable to that region, provided that empirical formula can predict the maximum discharge for given return period.
- ii) By a recognized method, provided it is possible to evaluate, for the region concerned, the various factors employed in that method.

106.3.1.3 From stage discharge curves, if available

106.3.1.4 By the area velocity method with the help of hydraulic characteristics of the channel. In case of the river not confined within banks and flowing in larger widths, the flow width should be divided into suitable zones i.e., main flow channel, side flow channel, slow channel and stagnant or no flow channel depending upon the characteristics and various parameters which should also be considered accordingly for calculation of discharge from that zone.

106.3.1.5 By unit hydrograph method (see appendix-1)

Flood estimation reports in respect of total 21 climatic sub-zones (Appendix-1(a)) in the country have been prepared based on the hydro-meteorological data collected for selected catchments of areas varying from 25 to 1500 sq.km. and are available with the Director, Hydrology (small catchments), Central Water Commission. The methodology recommended in the relevant sub-zone report pertaining to a particular region may be followed for assessment of maximum discharge for the design of bridges.

106.3.2 Where possible, more than one method shall be adopted, results compared, and the maximum discharge fixed by judgment by the engineer responsible for the design. The bridge shall be designed for this maximum discharge. However, for catchment areas covered by sub-zones mentioned in Appendix 1(a), the maximum discharge shall be assessed on the basis of the flood estimation report for the said sub-zone.

106.3.3 Various limitations of the methods for computing the Maximum Design Discharge correctly under different flow, bed and site conditions and for a given return period, should be kept in mind and accounted for adequately while deciding the same.

106.3.4 For minor bridges, where catchment area cannot be defined, reliance may be kept on Area Velocity Method.

106.3.5 The maximum estimated discharge from the catchment area as calculated above or normal peak flood discharge from the dam/spillway if existing or being proposed in the upstream of the bridge (to be ascertained from the Irrigation Authorities), whichever is more, shall be considered for design of the bridge.

Freak flood discharges or exceptional discharge of high intensity due to the failure of a dam or tank constructed upstream of the bridge need not be catered for.

106.3.6 In cases where the design discharge cannot be properly quantified and in spill zones of rivers known for flash floods, the abutments may also be designed and detailed as 'piers' for possible future extension.

106.4 Discharge for Design of Foundation and Protection Works

To provide for an adequate margin of safety, the foundation and protection works shall be designed for a larger discharge than the design discharge given in Clause 106.3, for which reference may be made to the provisions contained in relevant IRC Codes.

106.5 Determination of Waterway

106.5.1 Linear Waterway

106.5.1.1 For natural channels in alluvial beds but with well defined banks and for all natural channels in beds with rigid in-erodible boundaries, the linear waterway shall be distance between banks at HFL, at which the designed maximum discharge determined in accordance with Clause 106.3, can be passed.

106.5.1.2 For natural channels in alluvial beds and having undefined banks, the linear waterway shall be determined from the design discharge using some accepted rational

formula at the discretion of the engineer responsible for the design. One such formula for regime conditions is:

$$W = C\sqrt{Q}$$

Where,

- W = regime width in meters (equal to effective linear waterway under regime condition)
- Q = the maximum design discharge in m³/sec;
- C = a constant usually taken as 4.8 for regime channels but it may vary from 4.5 to 6.3 according to local conditions.

106.5.1.3 The formula which is applicable for alluvial soils in regime conditions, should not be applied for clayey, bouldery or such strata. The waterway in such cases should be decided on the basis of study and analysis of site and flow conditions by adopting some rational approach (like performance of existing bridge nearby, on the same river).

106.5.1.4 In meandering flood plains and in deltaic regions, the waterway proposed may be as in above clauses, but guide bunds, flood embankments or other river training works should be provided to train the river to flow through the bridge. Hydraulic or Mathematical model studies may be required to ascertain the flow conditions, and design parameters for the training works and the required waterway.

106.5.1.5 If the river is of a flashy nature and the bed does not submit readily to the scouring effects of the flood, the linear waterway should be determined by the area velocity method, taking into account the design flood level and its water spread, the characteristics of the bed materials and the water surface slope.

106.5.1.6 In a hilly terrain, the minimum waterway under the bridge should be kept same as the linear waterway at HFL.

106.5.1.7 In sub-hilly terrain/trough terrain, waterway should be decided after carefully studying the past history of river behavior and flow conditions, as river is usually unstable and changing course periodically resulting in a fan shaped delta type formations, requiring more waterway than normally required by formula.

106.5.1.8 In case a new bridge is to be constructed, close to an existing bridge for the purpose of widening or providing extra carriageway, the waterway provided in the new bridge should usually be kept the same as in the old bridge unless there are specific reasons. If the waterway is to be kept different, then bridges should be provided with smooth inlet and outlet transitions.

106.5.1.9 For artificial channels (irrigation, navigation and drainage), the linear waterway should be adequate to pass the full discharge at designed velocity, but concurrence shall invariably be obtained from the authority controlling the channel. If it is proposed to flume the channel at the site of the bridge, this fluming shall be subject to the consent of the same authority and in accordance with the essential requirements.

106.5.1.10 The waterway, as worked out from the formula or decided otherwise, should be compared with linear waterway at HFL corresponding to the design flood discharge and the

difference in the two should be analyzed and reconciled before finally deciding the waterway to be provided.

106.5.2 *Restricted Waterway*

106.5.2.1 The linear waterway as calculated above can be restricted by careful consideration of the resulting effects on flow conditions, scour, afflux and other site condition in the individual cases. No restriction in waterway should be considered for well defined and confined flow.

106.5.2.2 In hilly terrain the linear waterway at HFL should not be restricted because that will cause undesirable hydraulic jumps as the flow in such a terrain is usually super critical.

106.5.2.3 For unstable meandering rivers flowing through a number of sub channels separated by land or shallow section of nearly stagnant water and having width much in excess of the regime width, or channels flowing over large widths with small depths, the restriction of waterway may be considered. In such cases, it may be necessary to constrict the channel by providing training and protection works to prevent the main channel from wandering about freely and for minimizing the resultant oblique attack on bridge foundations and approaches. The extent of constriction and the design of training works in such cases should, preferably, be decided on the basis of model studies, keeping in view the ultimate economy, safety, durability and aiming at optimal recurring maintenance needs of structure as well as river training works.

106.5.2.4 In case of bridge being located at bends, curves or oblique to flow, the waterway gets restricted. The available waterway normal to the flow should be worked out and this should be accounted for in the design.

106.5.2.5 The restriction of waterway will result in afflux on the upstream of bridge. The effect of this afflux on the velocity, scour and submergence of surrounding area should be considered in the design. The consideration of these effect and comparison of consequent costs in the two cases, will decide the limit of restriction in the linear waterway.

106.5.2.6 If the waterway has to be restricted to such an extent that the resultant afflux will cause the channel to discharge at erosive velocities, protection against damage by scour shall be afforded by providing deep foundations, curtain or cutoff walls, rip-rap, bed pavement or other suitable means.

106.5.3 *Effective Linear Waterway*

106.5.3.1 The linear waterway or restricted waterway worked out as above shall be reduced because of the obstruction caused by piers or obliquity of flow in the river at the bridge site.

106.5.3.2 For calculating the effective linear waterway the width of obstruction due to each pier shall be taken as the mean submerged width of the pier and its foundation up to the normal scour level. The obstruction at the ends due to the abutments or pitched slopes duly protected shall be ignored. For other flow conditions, actual obstruction due to pier and foundation normal to the flow should be worked out and considered in design.

106.5.3.3 Effect of presence of Dams, Barrages, Weirs, Sluice Gates etc. on the hydraulic characteristics like causing obliquity and concentration of flow, scour, silting of bed, change

in flow levels, bed levels etc. should be studied and analysed while deciding the waterway. These should invariably be decided after collection of data from the concerned regulatory authorities and after discussions with them.

106.5.3.4 The effect on linear waterway and hydraulic particulars should be taken care of in the design of a bridge, if constructed in the close proximity of an existing bridge.

106.5.3.5 In case of tidal zones, where it is decided to adopt measures likely to affect the volume of the tidal flow and other characteristics of the tide, it shall be ensured that no port or harbor or other installations in the proximity of the bridge are adversely affected.

106.6 Determination of Afflux

106.6.1 If the waterway is restricted as per Clause 106.5.2, it will cause afflux at the bridge and design HFL will accordingly be raised.

106.6.2 The afflux shall be calculated by using any suitable method based on conservation of energy or momentum. In absence of any rigorous method, the afflux may be calculated by using Molesworth formula as given below :

$$h = (V^2/17.88 + 0.015) \times ((A/a)^2 - 1), \text{ where :}$$

h = afflux (in meters)

V = average velocity of the water in the river prior to constriction (in m/sec)

A = unobstructed sectional area of the river at proposed site (in sq. m)

a = constricted area of the river at proposed site (in sq. m)

106.6.3 The effect of afflux on the velocity, submergence area and scour etc shall be worked out and accounted for in the design.

106.7 Freeboard

106.7.1 The freeboard for the approaches to high level bridges, where water spreads along the approaches, shall not be less than the minimum values specified in relevant IRC code for road designs.

106.7.2 For the aggrading rivers in Himalayan foot-hills and flood-prone areas or North-Eastern States, North Bengal etc. and where ever required for some specific reason, the freeboard shall be suitably increased.

106.8 Vertical Clearance over HFL

106.8.1 The vertical clearance shall ordinarily be provided as given in the following clauses.

106.8.2 For openings of high level bridges, which have a flat soffit or soffit with a very flat curve, the minimum clearance shall be in accordance with the following table. The minimum clearance shall be measured from the lowest point of the deck structure inclusive of main girder in the central half of the clear opening unless otherwise specified.

Discharge in Cumecs	Minimum Vertical Clearance in mm.
Upto 0.3	150
Above 0.3 & upto 3.0	450
Above 3.0 & upto 30.0	600
Above 30.0 & upto 300	900
Above 300 & upto 3000	1200
Above 3000	1500

106.8.3 For arched openings of high level bridges having overhead decking, the clearance below the crown of the arch shall not be less than one tenth of the maximum depth of water plus one-third of the rise of the arch intrados.

106.8.4 No part of the bearings shall be at a height less than 500 mm above the design highest flood level, taking into account afflux.

106.8.5 In the case of artificial channels having controlled flows and carrying no floating debris, vertical clearances lesser than that specified in Clause 106.8.2 & 106.8.3 above may be provided.

106.8.6 In the case of bridges in sub-mountainous region and across aggrading rivers, silting of the bed of the river should also be taken into consideration while fixing the vertical clearance.

106.8.7 In case of bridges across tidal rivers, creeks, sea, the vertical clearance shall be provided keeping in view the HTL and normal wave/splash effects.

106.9 Determination of the Maximum Depth of Scour

106.9.1 The probable maximum depth of scour to be taken for the purpose of designing foundations for piers, abutments and river training works shall be estimated after considering all local conditions over a reasonable period of time.

106.9.2 Wherever possible, soundings for the purpose of determining the depth of scour shall be taken in the vicinity of the site proposed for the bridge. Such soundings are best taken during or immediately after a flood before the scour holes have had time to silt up appreciably. Allowance shall be made in the observed depth for increased scour resulting from:

- i) The design discharge being greater than the flood discharge.
- ii) The increase in velocity due to obstruction in flow caused by construction of the bridge.
- iii) The increase in scour in the proximity of piers and guide bunds.

106.9.3 Scour

106.9.3.1 The following theoretical method may be adopted when dealing with the natural channels flowing over scourable beds for the estimation of mean depth of scour ' d_{sm} ' in meters.

$$d_{sm} = 1.34 \times \left[\frac{D_b^2}{K_{sf}} \right]^{1/3}$$

Where :

D_b = The discharge in Cumecs per meter width. The value of " D_b " shall be the maximum of the following:

- i) The total design discharge divided by lower of the effective linear waterway between abutments or guide bunds, and theoretical linear waterway.
- ii) The value obtained taking into account any concentration of flow through a portion of the waterway assessed from the study of the cross-section of the river. Such modification of the value may not be deemed applicable to minor bridges of length upto 60 m.
- iii) Actual observations, if any.

K_{sf} = the silt factor for a representative sample of the bed materials obtained down to the maximum anticipated scour level and is given by the expression $1.76\sqrt{d_m}$ in case of sandy soils (having particle size between 0.04 mm to 2.00 mm), where " d_m " is the weighted mean diameter of the bed material in mm.

Clayey beds having weighted diameter less than 0.04 mm offers more resistance to scour than sand. In absence of any accepted rational formula or any data of scour at the site of the proposed bridge, the following theoretical calculations may be adopted :

- i) In case of soil having $\phi < 15^\circ$ and c (cohesion of soil) $> 0.2 \text{ Kg/cm}^2$, ' K_{sf} ' shall be calculated as follows :

$K_{sf} = F(1+\sqrt{c})$, where ' c ' is in Kg/cm^2

Where,

$F = 1.50$ for $\phi > 10^\circ$ and $< 15^\circ$
 $= 1.75$ for $\phi > 5^\circ$ and $< 10^\circ$
 $= 2.00$ for $\phi < 5^\circ$

- ii) Soils having $\phi > 15^\circ$ will be treated as sandy soil even if ' c ' is more than 0.2 Kg/cm^2 , and silt factor will be as per provision for sandy soil.

Note:

- i) The effective linear waterway shall be determined in accordance with Clause 106.5.3, and in no case shall exceed the value assessed as per Clause 106.5.1.2.
- ii) A typical method of determining " d_m " is set forth in Appendix-2.
- iii) The value of K_{sf} to be adopted for the purpose of design should be determined after laboratory testing of the representative samples of bed materials collected during the sub-soil exploration.

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106.9.3.2 If there is any predominant concentration of flow in any part of waterway due to bend of the stream in immediate upstream or downstream or for any other reason, like wide variation in type of bed material across the width of channel, then mean scour depth may be calculated dividing the waterway into compartments as per the concentration of flow.

106.9.3.3 Maximum scour depth

The maximum scour depth below the highest flood level (HFL), which is to be considered for the purpose of design of foundations, protection works, river training works etc. shall be in accordance with relevant IRC Standards, duly taking into account the mean scour depth d_{sm} and obstructions due to piers and abutments.

106.9.3.4 If a river is of flashy nature and the bed does not lend itself readily to the scouring effect of floods, the formula for d_{sm} given in the Clause 106.9.3.1 shall not apply. In such cases the maximum depth of scour shall be assessed from actual observations.

106.9.3.5 Bridge located across streams having gravel or boulder beds (normally having weighted diameter more than 2.00 mm), there is yet no rational formula for determining scour depth. However, the formula given in Clause 106.9.3.1 may be applied with a judicious choice of value of D_b and K_{sf} and the results compared with the actual observations at the site or from experiences on similar structure nearby and their performance and decision taken based on sound engineering judgment.

106.9.3.6 Obstruction in the channel bed, likely to divert the current or cause undue disturbed flow or scour and thereby endanger the safety of the bridge, shall be removed as far as practicable from within a distance upstream and downstream of the bridge not less than the length of the bridge subject to a minimum of 100 meters in each direction. Attention shall be given to river training and protection of banks over such lengths of the river as required. In case it is not possible to remove such obstructions, its effect on scour shall be considered.

106.10 River Training and Protection Works

106.10.1 The slopes, in front of abutments and the portion of bridge approaches falling in the flood zone, shall be provided with suitably designed pitching and launching apron.

106.10.2 In case of the uncertain and changing flow conditions, adequate river training works shall be provided for protection of banks, embankments and directing the river to flow under the bridge.

106.10.3 After collecting the required data, studying and analyzing the river flow conditions etc. and necessary model studies, wherever required, the protection works shall be designed as per provisions of IRC:89 or other specialist literature.

106.11 Hydraulic and Mathematical Model Studies

106.11.1 *These Studies should be Carried Out Wherever Necessary, such as :*

- in case of big rivers with large discharge having uncertain and complex flow conditions and for other abnormal situations
- when the linear waterway and scour cannot be accurately calculated or

- when the protection and river training works cannot be designed reliably because of the uncertain or complex conditions.

106.11.2 The studies should be carried out at the reputed, reliable and accredited institutions only where requisite facilities are available.

106.11.3 The Site and Contour surveys for these studies should be done very carefully, with precision and it should be ensured that these along with bed materials are correctly represented in the Model.

107 GENERAL DESIGN REQUIREMENT

107.1 Structural System and Configuration

The structural scheme, structure type, span arrangement, member size and shape for a bridge shall be made considering the following aspects :

- a) Operation and maintenance requirements
- b) Functional requirements, related to the purpose of the structure
- c) Structural requirements aimed at handling different external actions, such as gravity loads, wind, temperature, seismic, barge impact, vehicle collision, wave pressure loads, etc.
- d) Construction requirements aimed at completing the construction within the stipulated time, with least disturbance to the existing traffic and surrounding environment.
- e) Environmental requirements, necessary for achieving sustainability.
- f) Durability requirements, with respect to the design service life.
- g) Aesthetic requirements.
- h) Future widening requirements.
- i) Requirement to reduce energy input by various possible methods (such as using less cement and more cementitious substitution with fly ash or blast furnace slag, using recycled aggregates, utilizing more industrial byproducts, etc.).
- j) Requirement to have construction technology that leads to fast track construction.
- k) Encouraging use of Integral or Continuous bridges from consideration of riding comfort and long term performance.
- l) Avoiding bridges with sharp plan curvature (i.e. $R < 90$ m) and with high degree of skew (i.e. Skew angle $> 30^\circ$) wherever possible.
- m) Detailing to minimize staining or discoloration.

107.2 Bridge Foundation

Bridge foundation can be open, pile or well type. The structural, hydraulic, and geotechnical aspects of foundation design shall be coordinated prior to finalization of the conceptual design and foundation type. Consideration should be given to the following:

- a) Interdependence of design for foundation, substructure and superstructure.
- b) Type of sub-strata,
- c) Hydraulic and Hydrological considerations
- d) Constructability
- e) Effect of protection works on foundation design.

107.3 Bridge Substructure

- a) Bridge piers can be of various configurations such as wall, circular, trestle or any other shape with solid or hollow sections.
- b) Bridge abutments can be of various configurations such as spill-through type and non-spill-through type with solid wall, counter-fort wall, box type or bank seat type.

107.4 Bridge Superstructure

The superstructure can be of various types as given in Clause 102.3 of the code. The choice of superstructure would largely depend upon the functional, aesthetic and techno-economic criteria, suited to the location of the bridge.

107.5 Retaining Walls

Wing walls for a bridge can be splayed type, at an angle to the bridge axis or return wall type, parallel to the bridge axis or it can be cantilever type projecting out of the abutment. Reinforced Soil walls or Gabion walls can also be provided as per the site conditions.

108 CONSTRUCTION AND CONSTRUCTABILITY CONSIDERATIONS

108.1 Constructability Considerations

Constructability considerations aim at optimum use of required construction knowledge and experience in planning, design, procurement, and field operations, to achieve overall project objectives. Constructability drives consideration of the entire construction process during the conceptual design stage. Dimension and reinforcement of components in a bridge, many a times are dictated by the construction and erection phase requirements rather than the service stage requirements. The design therefore must consider various factors, which influence the constructability of the bridge. A typical check list of factors is given below:

- Access to work areas and remote areas,
- Access to emergency vehicles and routine maintenance of site,

- Availability of land for plant/equipment and machinery,
- Availability of required and alternative materials,
- Simplicity of design & clarity in detailing,
- Ease of fabrication of steel members,
- Standardization of design elements to the extent possible,
- Weather conditions and working periods,
- Conflicts with existing traffic,
- Conflict with services and utilities,
- Availability of skilled manpower,
- Social and Environmental issues,
- Region e.g. mountainous, proximity to sea, desert, marine clay etc.
- Height above Water Level/Ground Level.

108.2 Construction Considerations

108.2.1 Bridge construction involves managing the entire logistics of construction, including construction operations of both permanent as well as temporary works that are needed for safe and efficient building of the structures. Efficient construction would require appropriate knowledge and experience in planning, design, detailing, procurement of materials and plant and equipment, besides site operations to achieve overall project objectives. Construction shall be carried out by personnel having appropriate skills to ensure quality as envisaged. Adequate supervision and quality control shall be provided during all stages of construction.

108.2.2 The design process must include the necessary detailing and construction knowledge and experience to realize the full potential of construction benefits without compromising the integrity of structure or design consideration. The choice of structural system and the design and detailing of the structure therefore shall be made by appropriately qualified and experienced persons having thorough knowledge of design and construction. For many bridges, the design is construction driven, in which case construction methodology as considered in design must be reflected in the design drawings and be implemented. In case methodology of construction is required to be changed during implementation, due to any unforeseen reasons, its impact on design must be investigated and accounted for before carrying out construction.

108.2.3 Suitable materials and methodology of construction including use of suitable specialized equipment shall be adopted for completion of bridge within the given time frame.

108.2.4 Design shall consider the method of construction which will be carried out through project management, involving, planning, scheduling and controlling including safety, in accordance with a work program which is required to be prepared for each bridge project.

- i) Planning commences with the analysis of the type and scope of work to accomplish the task as well as the specifications for the work, construction methods, materials, equipment and man power.

- ii) Scheduling establishes a sequence of operations and accounts for inter relation of operations at the job site as well as allocation of man power, material and equipment.
- iii) Controlling consists of procuring materials as per construction sequence and stage, dictating overall construction procedures, inspection and test procedure and maintaining complete records of daily progress etc. In order to ensure proper quality of work, a suitable quality plan needs to be developed before taking up construction.
- iv) Safety during construction will include safety of various operations encompassing the safety of works, work personnel, equipments as well as traffic in the work zone.

109 AUXILIARY COMPONENTS

109.1 Provision for Utilities

109.1.1 A bridge structure shall cater for fixtures for electric posts, lamp posts and suitable ducts for carrying electric cables etc. as required to cater for utility services.

109.1.2 Utility services like cables and pipelines for water, gas, petroleum products directly on bridge structure should be avoided. These may be placed on a structure supported on piers and abutments.

109.1.3 While planning, there is need for proper accessibility of the services utilities for inspection and maintenance without hindrance to traffic movements.

109.2 Drainage

109.2.1 General

The bridge deck and its immediate highway approaches shall be designed to provide safe and efficient conveyance of surface run-off, in a manner that causes minimum damage to the bridge and ensures safety of the passing vehicle. Transverse drainage is achieved by providing a suitable camber or super elevation, sufficient for positive drainage.

109.2.2 Bridge Deck Drainage

Drainage spouts shall be provided at suitable spacing, depending upon the width of carriageway, to drain off the water from the carriageway during rains. For wider carriageways having width more than 3 lanes in each direction, special design of deck drainage (including extra roughening of the deck surface) may be needed to reduce the potential for hydroplaning.

The underside of the outside edge of bridges shall be designed with continuous drip grooves to prevent staining of the surface. In case of bridges across a stream or a river, the rain water can discharge into the river bed through drainage spouts provided at suitable spacing. The surface drainage collected at deck drain locations shall be directed through the superstructure by individual vertical or near-vertical deck drain pipes.

In situations, where it is not possible to discharge into the underlying water course, consideration should be given to conveying the water in a longitudinal storm drain affixed to the underside of the bridge and discharging it into appropriate facilities on natural ground at bridge ends.

Runoff from the bridge deck at the abutments shall be intercepted either immediately beyond the end of the bridge approach slab or before the end of the curb or barrier, by catch basins or other suitable means. The water so intercepted shall be directed past the embankment slopes and abutments in order to control embankment erosion.

Discharge from deck drains shall be channelled by means of down pipes and downspouts to locations that can be protected from erosion. Down-take pipes, wherever provided, shall be of a rigid corrosion-resistant material. Downpipe systems shall be designed so that water is not discharged onto the traffic or facilities below the deck, such as roadways, pedestrian paths or navigation channels. Changes in direction in down-take pipes shall be not greater than 45°. Cleanouts shall be provided near bends or at intervals to permit access to all parts of a downpipe system.

109.2.3 *Storm Water Drainage Design*

The design of the drainage system involves:

- a) Estimation of the run-off flow rate using rational method &
- b) Fixing the slope and dimension of the drain to have adequate capacity to carry the discharge and afford proper maintenance.

Reference shall be made to special literature/IRC code for design.

109.2.4 *Drainage at the Foot of Flyovers*

Due to the longitudinal slope of ramp of a flyover, there is a tendency for the rain water to flow in longitudinal direction rather than in cross direction resulting in very large quantity of water reaching the valley curve area where it meets the ground level road. Suitable system of drainage shall be adopted to avoid ponding in such cases.

109.2.5 *Drainage for Underpasses*

For underpasses, the possibility of designing the storm water drainage based on gravity flow shall be the first choice. In case the surrounding levels do not permit a gravity based system of drainage, suitable arrangement for pumping the water shall be provided.

109.3 **Bearings**

109.3.1 *General*

- a) Bearing is provided to transfer vertical and/or lateral loads from superstructure while itself undergoing rotations and/or movements. Appropriate type and arrangement of bearings shall be selected on the basis of geometry and type of superstructure, nature and magnitude of vertical and horizontal loads and direction and magnitude of rotation and translator movements.

Bearing system shall be designed to ensure stability of the superstructure and desired performance of the structure as a whole.

- b) It shall be easy for installation and inspection.
- c) Bearings shall be robust and durable
- d) Provision shall be made for replacement of bearings, since the design life of bearings is less than the design life of a bridge.
- e) Materials for bearings are generally, elastomer, iron, steel and PTFE or their combination.
- f) Bearings may not be provided for spans upto 10 m. In such cases, separation layer of paper impregnated with bitumen or equivalent may be provided between superstructure and substructure.

109.3.2 Bearings shall be designed and installed as per relevant IRC codes and standards.

109.4 Expansion Joints

109.4.1 General Features

- a) The expansion joints shall cater for expected movements and rotation of the structure at the joints and provide smooth riding surface.
- b) It shall also be easy for inspection and maintenance.
- c) Expansion joints shall be robust, durable, water-tight and replaceable.
- d) The expansion joint shall be provided and designed as per relevant IRC Publications.

109.5 Wearing Coat

Wearing coat over deck of bridge superstructure shall be either bituminous wearing coat or concrete wearing coat. Concrete wearing coat may be provided in case of bridges located in remote areas and in situations where accumulation of water is expected (e.g. in Underpasses).

109.6 Crash Barriers

109.6.1 Suitably Designed Crash Barriers shall Generally be Located on:

- a) All high level bridges, flyovers, interchanges and ROB's.
- b) Approaches to bridge structure, where embankment height is more than 3 m
- c) High containment barrier shall be provided mainly on bridges on busy railway lines, complex interchanges and other similar hazardous and high risk locations.

109.6.2 The Crash Barrier shall be of the following types:

- a) **Flexible Barrier:** These are yielding type such as wire rope fencing
- b) **Semi-rigid Barrier:** These offer required resistance to errant vehicles by deflection of the longitudinal member to an acceptance limit (e.g. metal beam crash barriers).
- c) **Rigid Barrier:** these do not deflect on impact and hence take full severity of impact (e.g. reinforced concrete crash barrier).

109.6.3 Typical shapes and dimensional details of crash barriers and their locations on the bridge decks with or without footpaths are shown in **Figs. 1 to 5**. These may be suitably modified and augmented depending on the developments in design and future functional requirements in individual cases. Design shall conform to relevant IRC standards and specialist literature.

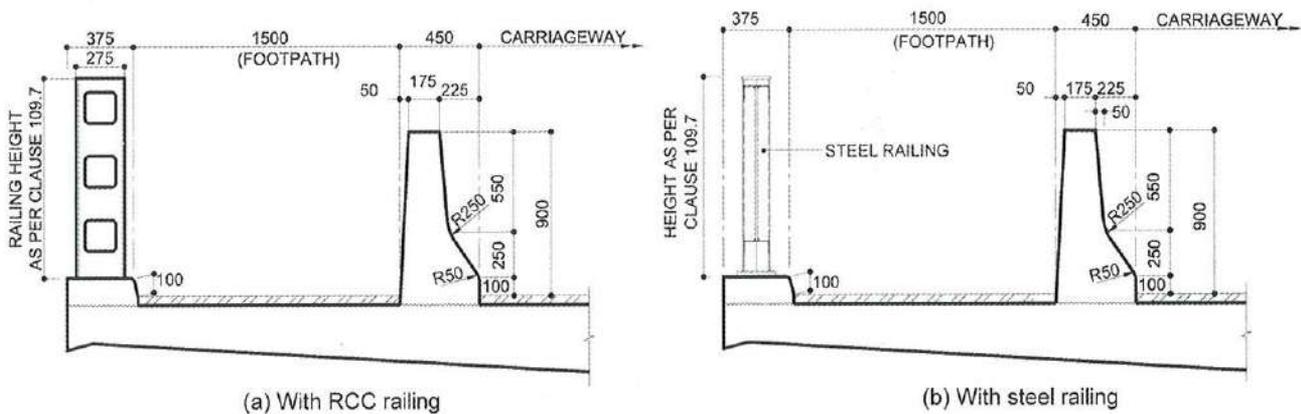


Fig. 1 Details of Concrete Crash Barrier & Railing for showing Bridge with Footpath

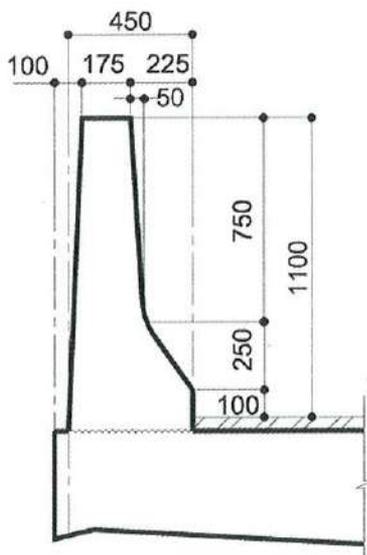


Fig. 2 Details of Crash Barrier for Bridges without Footpath

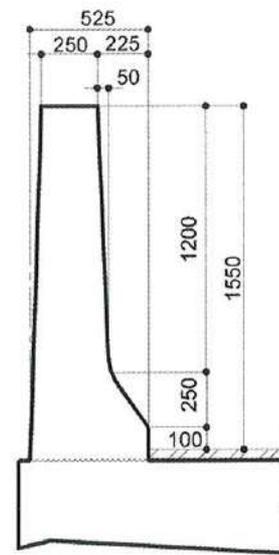


Fig. 3 Details of High Containment Crash Barrier

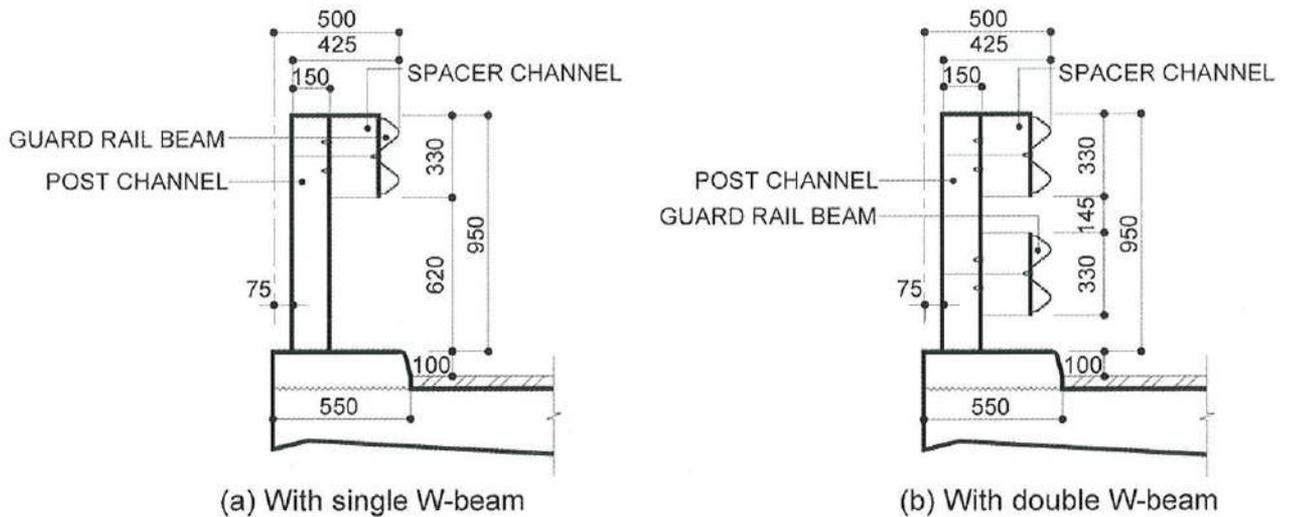


Fig. 4 Details of Metallic Crash Barrier

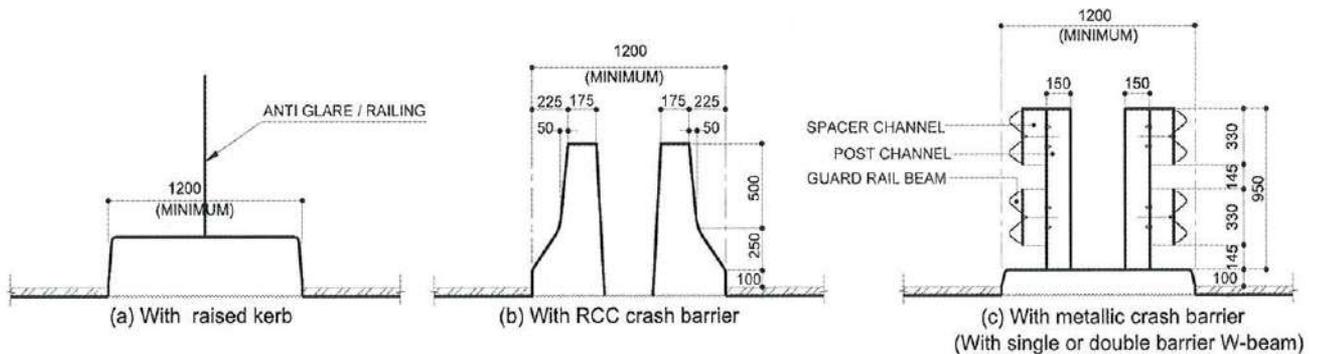


Fig. 5 Median Details

109.6.4 Flexible and semi rigid barriers shall not be provided on bridges without footpath on outer side of the carriageway.

109.7 Railings, Parapets and Guide Posts

109.7.1 General Features

- a) The bridge railings or parapets shall include the portion of the structure erected on and above the kerb/deck for the protection of pedestrians or cyclists.
- b) Railing or parapet may be of the following type:
 - Steel rolled section
 - Tubular steel
 - Cast-in-situ concrete
 - Pre-cast concrete
- c) The railing or parapet should be fixed and placed to correct alignment and camber throughout their length to ensure proper form, line and level.

- d) Proper contraction/expansion gaps, compatible with main supporting structure shall be provided in railing or parapet, to ensure that they function properly
- e) The railing or parapet should be designed for loads and forces as per relevant IRC codes.

109.7.2 Railings for High Level Bridges, Flyovers, Interchanges and ROBs

109.7.2.1 Substantial railing or parapets along each side of the bridge shall be provided for the protection of pedestrians or, cyclists from falling over. Railings or parapets should be avoided for protection of vehicular traffic except in case of small bridges or culverts.

109.7.2.2 Importance shall be given to the architectural features of the railing or parapet to obtain proper proportioning of its various members and its harmony with the structure and the environment as a whole.

109.7.2.3 Railings or parapets shall have a minimum 1.1 meter height above the adjacent roadway or footway safety kerb surface. For bridges exceeding 300 meters in length, the height of railings, determined in the manner stipulated above, shall be increased by 0.1 meter. For ROBs across railway lines, the height shall be governed by Railway's requirements.

109.7.2.4 Where a road provided with cycle tracks, is carried on a bridge and the cycle track is located adjacent to the bridge railing or parapet, the height of the railing or parapet shall be minimum 1.25 meters.

109.7.2.5 The clear distance between the bottom most rail and the top of the kerb shall not exceed 150 mm unless the space is filled by vertical or inclined members, the clear distance between which is not more than 150 mm, The strength of the bottom most rail shall be at least as much as that of the top rail. The space between the bottom most rail and the top rail shall be filled by means of vertical, horizontal or inclined members, the clear distance between which shall be fixed with due regard to the safety of those using the structure.

109.7.2.6 Guard rail shall be provided at the high approaches. The design, layout and materials chosen for the rails shall suitably blend with the surroundings.

109.7.3 Railings for Submersible Bridges and Vented Causeway

109.7.3.1 *Railing shall be either collapsible or removable.*

109.7.3.2 Collapsible railing shall be installed where the bridge is to be opened to traffic soon after a submerging flood has receded. Care shall be taken in the structural design of these railings to ensure that they sit well in their grooves and are not liable to displacement by floods.

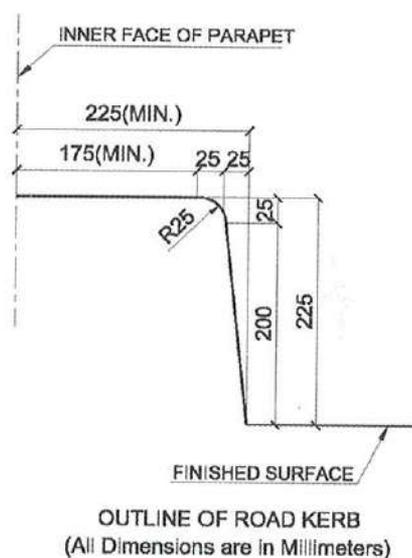
109.7.3.3 Removable type of railings may be adopted when there is no danger to the traffic using the bridge for short periods without railings. Care shall be taken in the structural design of these railings to ensure that the various members are interchangeable and can be easily removed and refitted.

109.7.3.4 Collapsible or removable railings shall be designed to resist the same forces as specified in relevant IRC codes for railings or parapets on high level bridges.

109.7.3.5 Guide posts/ stones may be used in lieu of railings, if the submergence of the road surface over the causeway is frequent and use of removable or collapsible railings becomes unsatisfactory.

109.8 Kerbs

109.8.1 The section given below shall be generally adopted for surmountable road kerbs. In case of un-surmountable road kerbs the section shown shall be suitably modified.



109.8.2 The section of the kerb should be so designed that it would be safe for vertical and horizontal loads as per relevant IRC Codes.

109.8.3 A safety kerb will have the same outline as that of a road kerb, except that the top width shall not be less than 750 mm.

109.9 Noise Barriers

Suitable type of noise barriers shall be provided at select sensitive locations (e.g. near hospitals, academic institutions etc.) to mitigate the impact of excessive noise generated by road traffic.

110. ILLUMINATION

110.1 All bridges should have provision for illumination. Provision for cabling, mounting and installation of luminaries shall be considered in design and detailing. Support system provided for the bridge lighting shall be adequately designed for the expected loadings. The support system shall be detailed so that it does not sacrifice the kerb and crash barrier running profile, maintaining its continuity. The support system, mountings and other fixtures required for illumination of the bridge shall not impair the functionality of other road furniture.

110.2 Illumination plan for bridges, grade separators, under-passes and interchanges shall be considered during initial planning. The arrangement of the masts/poles i.e. its height

and spacing, should be such as to achieve the following values of Average Maintained Luminance, E_{av} :

- Main Carriageway = 50 lux
- Footpath/Cycle Track = 20 lux
- Underpass = 70 lux

Minimum Uniformity Ratio, E_{min}/E_{av} shall not be less than 0.5, where E_{min} is the minimum luminance in the area.

Maintenance factor, which is the ratio of average illumination on the working area, given by an installation with decreased effectiveness due to dust, pollution, line voltage drop, ageing of lamp, product tolerance etc., to that of a new installation shall be considered as 0.75

110.3 While deciding the illumination plan, consideration shall be given to energy efficiency, environmental pollution, aesthetic and economical aspects. The selection of lighting system and the layout should add to the overall aesthetic of the bridge.

110.4 The installation, lighting arrangement, method of control, switches etc. shall conform to the provision contained in IS: 1944.

110.5 Adequate lighting shall be provided at specific locations, such as loops, ramps, signal free interchanges, merging zones, rotaries, pedestrian crossing etc. Ramps and approaches should be lit to the same level as main lanes.

110.6 At highway interchanges, different lighting arrangements, viz. lighting Poles or high masts or combination of both, may be considered and the one which gives optimum results from the view points of aesthetics, safety, illumination and ease of maintenance may be adopted.

110.7 Illumination levels for the vehicular and pedestrian subways/underpasses may be kept the same as those on the approaches at either end of the subway/underpass.

110.8 At night, the level of luminance in a subway/underpass, should be constant and equivalent to the level on the road leading into the subway/underpass. However, since there is a high level of external light during the day, it is necessary to increase the level of luminance at the entrance of the subways/underpasses, mainly to avoid a black hole effect leading to a reduction in visual perception. At the exit of subways/underpasses, the level of luminance should also be increased to avoid drivers being subjected to glare effects by the light outside. Thus the illumination layout of a subway/underpass shall be planned considering the various zones (viz. Threshold, Transition, Interior and Exit zones). A symmetric or pro-beam lighting systems shall be used except in the transition zone where it may be counter beam type.

Wherever feasible the vehicular/pedestrian/cattle underpasses in remote areas should have provision of skylight to get the light inside underpass during the day.

111. ROAD SIGNS AND SIGNALS

Appropriate plan for road markings, signage, delineation and signals (where necessary) shall be made and integrated with the overall bridge planning. These should be provided

on bridges, flyovers grade separators and their approaches to facilitate smooth and safe movement/operation of traffic without creating any confusion among users and also to minimize the possibilities of serious damage to the bridge structure or any of its components in the event of accidents. Provisions should be made in the structures for supporting of signals, signages and delineators.

111.1 Road Markings

- a) The road marking symbols, patterns, sizes, colour and legends shall be adopted in accordance with Code of Practice for Road Marking, IRC:35.
- b) Where the number of lanes on the bridge and on approaches are different (e.g. a two lane bridge on a three lane approach or vice versa), a transition taper should be given. The excess carriageway width in the transition zone should be appropriately chevron marked to ensure that it does not form part of the traveled way. There should be a corresponding sign as well to indicate narrowing or widening of carriageway.
- c) Hazard markers and/or crash cushions shall be provided at beginning of median or crash barrier clearly indicating start of a bridge/flyover or loop emerging from main carriageway.
- d) Chevron Markings/Painted Islands shall be provided at all exits to slip roads from main highway before a bridge/flyover or vice versa.

111.2 Signals

- a) Signals, near or on the bridges, shall be provided as per specific requirement of the any particular project, conforming to the requirements of IRC:93.
- b) Signals can be either electrically operated or solar powered.
- c) Flashing beacons shall be provided at the beginning of median or crash barrier, clearly indicating start of a bridge/flyover or loop emerging from main carriageway. Provision of cables for power supply to any such signal shall be considered in addition to the regular illumination.

111.3 Road Signs

- a) All multi-lane bridges, complex interchanges and grade separated structures shall be provided with overhead signs, well in advance and, if required, on the structure, conforming to the provision specified in IRC:67. Only retro-reflective signs shall be permitted. Non-Luminous signs, shall not be permitted.
- b) The location of sign board, barrier kerbs and supporting system should be designed and planned along with the project and detail of the scheme shown in a drawing drawn to a scale of 1:500.
- c) Support system for signs and signals required on bridge decks shall preferably be placed behind rigid type crash barriers. The sign supports shall

be structurally safe and properly anchored to the bridge deck. The bridge deck shall be designed to withstand all such loads.

- d) Wherever signs are to be illuminated or signals to be operated, necessary arrangements shall be made for cable ducts.

111.4 Delineators

Delineators (also referred to as guideposts) shall be provided as per safety requirements. These shall be installed along the side of the roadway in a series to indicate the alignment of the roadway. Delineators are particularly beneficial at locations where the alignment might be confusing or unexpected, such as at lane reduction, transitions and curves.

112. AESTHETICS

112.1 Bridges have large visual impacts on their surroundings. To achieve aesthetically pleasing view of bridge and its surroundings, it is essential that attention should be paid to produce a clear, simple, well-proportioned structure form, blending harmoniously with its surroundings. Larger the length of a bridge, greater is its visual impact. Therefore, specialists in architecture and landscaping may be engaged for bridges having lengths of 500 m or more.

112.2 Bridges should complement their surroundings, be graceful in form and present an appearance of adequate strength. Bridge designers must, therefore, consider appearance as an important design consideration. Attention should be given to appearance while looking towards the bridge as well as that while moving on the bridge.

112.3 The visual appeal of the bridge can be attributed to its form, texture, colors and other details. Every visible component of a bridge has a role to play. Aesthetics of a bridge must be considered both in the conceptual planning stage as well as in the detailed design stage.

112.4 Considerations at Conceptual Planning Stage of a Bridge

Geometry, layout and concept are major determinants of appearance and should be addressed at the initial stages of a project. Following points shall be given due consideration at the conceptual stage of the project:

112.4.1 *Simplicity*

Generally bridges seem aesthetically more pleasing if they are simple in form, superstructure are sleek in proportion to their spans, the lines of the structure are continuous and the shapes/sizes of the structural members reflect the flow of forces.

112.4.2 *Dimensions and Proportions*

Dimensions of various elements should generally develop harmony with the surrounding landscape and environment.

112.4.3 *Symmetry of Structure*

Symmetrical bridges are often more aesthetically pleasing than non-symmetrical bridges, except in specific cases.

112.4.4 *Order and Rhythm*

Developing a rhythm in a bridge is also important. The cumulative effect of all bridge elements including lighting poles, barrier supports and piers should be considered.

112.4.5 *Unity of Design*

Various elements viz. parapets, safety barriers, light poles, deck, pier, approaches, immediate landscape and all the associated signage etc. are integral elements of the whole bridge design and should be considered in unison.

112.4.6 *Form or Appearance in Totality*

Visual forms of bridges, viaducts or flyover structures etc. should be selected with care to be in harmony with the general landscape and local architecture.

112.5 *Considerations at Design Stage of a Bridge*

The following points shall be given due consideration with respect to various components during design stage. This section deals with the basic elements that form a bridge structure. It deals with each element as a separate component. However, the designer must never lose sight of how each unit fits into the overall expression that is desired.

112.5.1 *Parapet*

The outer face of the parapet can be one of the most important aesthetic elements of a pleasing bridge and often the most dominant in long distance views. The top of the parapet should slope towards the road, to channel rainwater onto the bridge, minimizing staining of the outside face. Treatment of fascia elevation by using serrations (grooves)/physical breaks or by changing relative brightness using surface slopes can make the bridge look slender than it really is. If the deck soffit is visually complex, consideration may also be given to hiding this complexity, by extending the parapet soffit below the deck soffit.

112.5.2 *Girder Elevation*

Haunched girders are expressive and responsive to the forces in the bridge. They can often be more distinctive and elegant than single depth beams. Abrupt changes in depth of superstructure should be avoided and be made gradual with flowing lines

112.5.3 *Girder Cross Section*

The major visual design goals of the superstructure are apparent slenderness, continuity of lines and relationship with the substructure. The cross sectional shape of the girder should be considered keeping in view the effect of light, shade and texture.

112.5.4 *Scale and Proportions*

The structure should be in scale with its surroundings as well as with other parts of the structure. The primary structural elements, e.g., span lengths, girder depth, pier and abutment

heights, should have good proportional relationships to each other and their structural chore. Generally, no single element should dominate the visual composition. The collective design of the structure should be in scale with the site and environmental considerations. The structure form should have an appearance of lightness.

112.5.5 *Pier Cross Section*

Pier shapes will be largely influenced by the span arrangement, width of superstructure, height of piers and the nature of surroundings. When bottom section of pier is influenced by ground level conditions (e.g. median verge of a flyover) special shapes varying along height should be considered.

112.5.6 *Pier Caps*

Pier cap width and length are influenced by functional considerations but its visual integration with the pier below and deck above must receive the due attention.

112.5.7 *Abutments*

In an open landscape setting, spill through or bank seat abutments are generally preferable, as walled abutment structures can block views. If unavoidable the use of plantation should be considered to hide the abutment walls.

112.5.8 The space around and under the bridge must be given due consideration as aesthetic aspect of the bridge depends a lot upon the beauty of its surroundings.

112.6 Standard details when used need to be reviewed for their appropriateness to each project. They should be regularly updated.

112.7 New bridges generally become part of a family of other bridges along a route. The impact and relationship to this family should be considered. The new bridge should respect the role, form and design of the existing parallel bridge.

113. OPERATION & MAINTENANCE

A structure will properly serve its intended design life only when it is regularly inspected and maintained in accordance with the IRC codes and guidelines.

Proper attention shall be given to ensure all critical components of the structure can be properly accessed and inspected. Therefore, proper access/arrangement for inspection of bearings, anchors, interior of box girders and the like, should be thought of at design stage. Bearing replacement scheme, where applicable, shall be planned at design stage and corresponding forces should be considered while designing various components of the bridge.

A maintenance manual shall be prepared for the bridge project.

Exposed parts of steel structures shall be accessible for inspection and periodic painting. Design documentation shall include indicative procedures for replacement as well as repair of bridge components, like bearings, corroded anchors, expansion joints, drainage spouts etc.

APPENDIX- 1

Clause 106.3.1.5

UNIT HYDROGRAPH METHOD

The Unit Hydrograph, frequently termed as the unit graph, is defined as the hydrograph of storm run-off at a given point in a river, resulting from an isolated rainfall of unit duration occurring uniformly over the catchment and producing a unit run-off. The unit run-off adopted is 1 cm depth over a catchment area.

The term "Unit-Rainfall Duration" is the duration of rainfall excess resulting in the unit hydrograph. Usually, unit hydrographs are derived for specified unit durations, say, 6 hours, 12 hours etc., and derived unit hydrographs for durations other than these are converted into unit hydrographs of the above unit durations. The duration selected should not exceed the period during which the storm is assumed to be approximately uniform in intensity over various parts of the catchment. A 6 hours unit duration is suitable and convenient for studies relating to catchments larger than 250 sq.km.

The unit hydrograph represents the integrated effects of all the basin constants, viz., drainage area, shape, stream pattern, channel capacities, stream and land slopes.

The derivation and application of the unit hydrograph is based on the following principles:

- 1) All the characteristics of the catchment of a river are reflected in the shape of the hydrograph of run-off.
- 2) At a given point on a river for all storms having the same duration of rainfall excess above this point and uniformly distributed with respect to time, the discharge ordinates of the hydrograph are proportional to the total volumes of storm run-off. This implies that rainfall excess of, say 2 cm, within the unit of duration will produce a run-off hydrograph having ordinates twice as great as those of the unit hydrograph. Also, if individual hydrographs are obtained from separate periods of uniform rainfall excess that may occur throughout a storm period, and these are properly arranged with respect to time, the ordinates of the individual hydrographs can be added to give ordinates representing the total storm run-off hydrograph for the entire storm period.

Three methods are generally available for giving unit hydrographs at any point in a river.

- i) By analysis of rainfall and run-off records for isolated unit storms;
- ii) By analysis of run-off compound hydrographs;
- iii) By computation of synthetic unit hydrographs, when sufficient rainfall and run-off data are not available.

The determination of design flood, after the unit hydrograph has been derived, involves the following steps:

- a) Division of catchment into sub-areas, if necessary.
- b) Derivation of design storm and its apportionment to sub-area.
- c) Determination of minimum retention rate and calculation of rainfall excess of design storm.
- d) Arrangement of design storm
- e) Application of rainfall excess to unit hydrographs for each sub-area.
- f) Routing of flood for each sub-area to the point of collection of the whole catchment.

A rational determination of critical design storm for a catchment requires a comprehensive study of major storms recorded in the region and an evaluation of effects of local conditions upon rainfall rate. This is particularly necessary in the case of design storms, covering a large area of several thousand square kms.

In the case of areas less than a few thousand square kms, certain assumptions can be made regarding rainfall patterns and intensity variations without being inconsistent with meteorological causes. They simplify design-storm estimation, but would entail high degree of conservatism.

APPENDIX- 1(a)

Clause 106.3.2

REPORTS BROUGHT OUT BY CENTRAL WATER COMMISSION**UNDER LONG TERM PLAN**

Sl. No.	Name of Sub-Zone	Sub-Zone No.
1.	Luni sub-zone	1(a)
2.	Chambal sub-zone	1(b)
3.	Betwa sub-zone	1(c)
4.	Sone sub-zone	1(d)
5.	Upper Indo-Ganga Plains sub-zone	1(e)
6.	Middle Ganga Plains sub-zone	1(f)
7.	Lower Gangetic Plains sub-zone	1(g)
8.	North Brahmaputra basin sub-zone	2(a)
9.	South Brahmaputra basin sub-zone	2(b)
10.	Mahi and Sabarmati sub-zone	3(a)
11.	Lower Narmada and Tapi sub-zone	3(b)
12.	Upper Narmada and Tapi sub-zone	3(c)
13.	Mahanadi sub-zone	3(d)
14.	Upper Godavari sub-zone	3(e)
15.	Lower Godavari sub-zone	3(f)
16.	Indravati sub-zone	3(g)
17.	Krishna & Pannar sub-zone	3(h)
18.	Kaveri Basin sub-zone	3(i)
19.	Eastern Coast sub-zones	4(a), 4(b) & 4(c)
20.	West Coast region sub-zones	5(a) & 5(b)
21.	Western Himalayas zone	7

APPENDIX- 2

Clause 106.9.3.1

**TYPICAL METHOD OF DETERMINATION OF WEIGHTED
MEAN DIAMETER OF PARTICLES (d_m)**

Representative disturbed samples of bed materials shall be taken at every change of strata upto the maximum anticipated scour depth. The sampling should start from 300 mm below the existing bed. About 500 gms of each of the representative samples so collected shall be sieved by a set of standard sieves and the weight of soil retained in each sieve is taken. The results thereof are then tabulated. A typical test result is shown below (**Tables I & II**).

Table - I

Sieve Designation	Sieve Opening (mm)	Weight of Soil Retained (gm)	Percent Retained
5.60 mm	5.60	0	0
4.00 mm	4.00	0	0
2.80 mm	2.80	16.90	4.03
1.00 mm	1.00	76.50	18.24
425 micron	0.425	79.20	18.88
180 micron	0.180	150.40	35.86
75 micron	0.75	41.00	9.78
Pan	-	55.40	13.21
		Total 419.40	

Table - II

Seive No. (1)	Average Size (mm) (2)	Percentage of Weight Retained (3)	Column (2) x Column (3) (4)
4.00 to 2.80 mm	3.40	4.03	13.70
2.80 to 1.00 mm	1.90	18.24	34.66
1.00 to 425 micron	0.712	18.88	13.44
425 to 180 micron	0.302	35.86	10.83
180 to 75 micron	0.127	9.78	1.24
75 micron & below	0.0375	13.21	0.495
		Total	74.365

$$\begin{aligned} \text{Weighted mean diameter } d_m &= \frac{74.365}{100} \\ &= 0.74365 \\ &\text{Say } 0.74 \end{aligned}$$