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Government of Jammu and Kashmir
Public Works(R&B) Department
Civil Secretariat Srinagar/Jammu

Subject: J&K Public Works Department "Bridge Manual"

Reference: Administrative Council Decision No:12/01/2022 Dated:29.01.2022.

Government Order No. 43 -PW(R&B) of 2022
Dated: 03 -02-2022

Sanction is hereby accorded for adoption of "J&K PWD Bridge Manual" appended as **Annexure-I** to this Government order and its implementation by Public Works Department while executing bridge works in UT of Jammu & Kashmir. Bridge Manual shall be part of J&K PWD Engineering Manual, 2021 issued vide Government Order No: 40- PW(R&B) of 2021 dated: 25.01.2021.

The Manual shall be updated by the Department regularly to bring out the optimal quality and cost efficiency consistent with mandatory provisions of GFR.

By order of the Government of Jammu & Kashmir.

Sd/-
(Shailendra Kumar) IAS
Principal Secretary to Government,
PW (R&B) Department

No:- PWD-ACCT/24/2022-08-Department of PWD R&B Dated:- 03 -02-2022.

Copy to the:-

1. Joint Secretary (J&K), Ministry of Home Affairs, Govt. of India.
2. Development Commissioner (Works).
3. Director Archives, Archeology & Museum J&K, Srinagar.
4. Chief Engineer PW(R&B) Kashmir/Jammu.
5. Chief Engineer PMGSY Kashmir/Jammu.
6. Chief Engineer DIQC, J&K.
7. Chief Engineer Mughal Road Project.
8. Chief Engineer Mechanical Engineering Department Jammu/Kashmir.
9. OSD to Advisor (B) for information.
10. Private Secretary to Principal Secretary to Government PW(R&B) Department.
11. Govt. Order file. (w.2.s.c).

3/2/2022
Director Finance
PW (R&B) Department

GOVERNMENT OF JAMMU AND KASHMIR

सत्यमेव जयते

BRIDGE MANUAL

PUBLIC WORKS (R&B) DEPARTMENT, J&K

GOVERNMENT OF JAMMU AND KASHMIR

सत्यमेव जयते

BRIDGE MANUAL

PUBLISHED BY

PUBLIC WORKS (R&B) DEPARTMENT
JAMMU & KASHMIR

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1. GENERAL INTRODUCTION

PW(R&B) Department has come up with ***J& K Bridge Manual*** after the successful launch of J&KPWD Engineering Manual 2020, which is yet another achievement of the department in framing the basic guidelines for a scientific and planned development of the infrastructure in the union territory of Jammu and Kashmir.

The Bridge Manual shall work as a document for providing the guidelines for Planning, Design, Construction and Maintenance methodology of the bridges in the UT of Jammu & Kashmir. This manual shall also serve the purpose to promote efficiency in design and construction of the bridges in the UT by providing uniform bridge design/ construction requirements by standardizing all the relevant/ codal details. This manual provides a common platform for all the engineers and stake holders of the UT besides creating a uniform and a standard approach in all aspects of the bridge construction.

The manual has been prepared to form a concise document covering most of the IRC and other related references on bridges so that engineering fraternity of the UT as a whole have a ready reference for day to day use which will also help in creating a scientific aptitude in the engineers over a period of time. The bridge manual shall help in illustrating and understanding the various clauses of the code in detail.

The Manual shall go a long way in helping create a new era of bridge construction in the history of the union territory of Jammu and Kashmir

2. PROJECT PREPARATION

Preparation of a detailed project report is a pre-requisite for proper evaluation of the project, its approval by competent authority and finally its execution. Properly prepared project report is very helpful in ensuring timely completion of the project thereby ensuring fullest advantage of the project avoiding time and cost overruns. Project preparation activity can be divided into the following three broad stages:-

(1) Feasibility Study

(2) Preliminary Project Report

(3) Detailed Project Report

For detailed guidelines reference may be made to Special Publication No.54-"Project Preparation Manual for Bridges" published by Indian Roads Congress.

2.1. Feasibility Study

2.1.1. The project preparation for a bridge work starts with the identification of the project. This phase is known as the pre feasibility stage. For this stage, broad features of the project are identified, the possible locations, nature of crossing, traffic dispersal system for different alternatives are identified. The effect of implementation of the project on the traffic scenario in immediate vicinity is also considered. This reconnaissance visit to the area of the intended site is sufficient at this stage.

2.1.2. In the feasibility stage, preliminary surveys, data collection and investigations are carried out. Alternative sites are investigated; design and rough cost estimates for various alternatives are made. The feasibility report covering the recommended alignment including alternatives considered, span arrangement, preliminary cost estimates, economic and financial viability is prepared. Feasibility study should also cover the following aspects:

(i) The main purpose of the bridge project i.e. the trunk route, economic or interstate importance, access to ports, tourism, agriculture development etc. the place of the project in the road development programme and the priority assigned to.

(ii) The geographic features of the area such as size, economic (industrial and agricultural), other traffic generated activities in the area, main population centers, their size projections and growth rates, and government's economic programme for the developments.

(iii) Measurable and non measurable benefits should be listed. The former may consider reduction in operation costs, reduction in travel time for goods and passengers, reduction in maintenance cost in case an old bridge is replaced. The latter may include social and economic development of the adjacent area consequent to the construction of the bridge.

(iv) A cost benefit analysis should be enclosed and results critically discussed. For calculation of cost benefit analysis, a reference may be made to IRC SP -30: 1993. "Manual on Economic Evaluation of Highway Projects in India (First Revision)".

2.2 Preliminary Project Preparation

Preliminary project preparation involves various stages like recognition of the need, study of maps, reconnaissance survey leading to selection of alternative site, preliminary survey and investigation including subsoil investigation and collection of hydraulic data leading to final site selection and all these activities have to be systematically planned and carried out in their logical sequence.

2.2.1. Bridge siting and road alignment:

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 brands 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.

The considerations which decide the inter-se priority between a suitable bridge site and suitable road alignment will be guided by the following principles: -

(i) The location of a bridge upto a length of 60 meter shall be governed by the suitability of alignment of the road unless there are some special problems at the crossing with regard to design / maintenance of the bridge.

(ii) For bridges having a length between 60 and 300 meters both suitability of site of the bridge that of the alignment of the approaches shall be considered together.

(iii) For bridges having total length more than 300 meters, the requirement of good site for the bridge shall have the precedence and the alignment of the approaches will have to conform to the selected bridge site.

(iv) Where existing two lane highway is proposed to be widened to four lane width, the location of the additional two lane bridge shall be governed by factors mentioned in para 2.2.3.1 (ix) below:

2.2.2 Reconnaissance survey:

In case of an entirely new alignment, the site selection may have to start with the study of available maps before starting the reconnaissance. Usually, topo sheet in the scales 1:2,50,000 and 1: 50, 000 are available from the Survey of India. In case of bridges upto 300 m length, two or three possible road alignment should be marked on the topo sheets considering the topography of the land, land use, soil type, waste bodies, marshes, control points, river profile, straightness of the reach, width of crossing, presence of high banks etc. The two or three possible alignments may have to be considered for reconnaissance. Some landmarks for easy identification during reconnaissance may also have to be marked on topo sheets. The use of google maps shall be allowed as part of the reconnaissance assessment/investigations thereof. However, all critical site specific assessments shall be based upon thorough site specific survey/investigation and its confirmation viz-a-viz GTS survey maps.

2.2.3 Factors deciding site selection.

2.2.3.1 Adequate efforts made in selection of good site for locating a bridge will be amply rewarded in the form of reduced cost of the project and trouble free performance of the bridge. The factors that have to be considered in the selection of a site are indicated below. Though it may not be feasible to satisfy all desirable attributes simultaneously, the selected site should represent the most desirable mix of the attributes consistent with overall economy, including the cost of approaches.

(i) Permanency of the channel: it has to be ascertained from different maps prepared over a long period of time that the river does not have any tendency to mender at the proposed site.

(ii) Presence of high and stable banks: the presence of high non erodible banks generally offers an ideal site, which reduces the cost of approach embankments and their protection work.

(iii) Narrowness of the channel and large average depth compared to maximum depth: this ensures large average depth of flow compared to maximum depth of flow and reduced water way which greatly reduces the overall cost of the bridge structure.

(iv) Straight reach of the river u/s and d/s of the proposed site: straightness of the reach both u/s and d/s ensures uniform distribution of discharge/velocity. Curvature in the stream especially on the u/s leads to obliquity and concentration of the flow on the convex side leading to higher scour, and consequent cost of foundation and protection works. If the bank on the convex side is erodible it may lead to heavy recurring expenditure in protecting the abutment and the embankment on that side.

(v) Freedom form islands or any form of obstruction both u/s and d/s: any shoal formation disturbs flow characteristics. Gradual silting of one or more channels results in increased concentration of flow in other channels leading to higher scour or bank erosion, channels leading to higher scour or bank erosion, outflanking of the bridge etc. the site should also be away from confluence of tributaries where turbulence and obliquity of flow can be expected which results in higher unpredictable scour and water current forces on substructure.

(vi) Possibility of right angled crossings: Right angled crossings offer minimum possible bridge length and reduce chances of obliquity of flow with respect to the substructure.

(vii) It is preferable to site the bridge on u/s of the existing cause way, if any.

(viii) Possibility of good approach alignment: curves except gentle ones are preferable to be avoided on approaches and bridges, proper from visibility and safety considerations.

(ix) Where existing two lane highway is proposed to be widened to four lane width, the additional two-lane bridge shall be sited as close to existing bridge as possible. However, in case of bridges having well foundations, distance sufficient for generation of passive resistance of soil shall be provided.

2.2.3.2 Sitting of grade separators: Sitting of bridges which act as rail/road grade separators will be largely decided by good alignment of the approaches, availability of land and other constraints imposed by rail lines, services etc. at skew crossings, skew angle of more than 45 degrees should generally be avoided.

2.2.3.3 Distance between rail and road bridges: the distance between rail and Road Bridge should be as large as possible but not less than 400 m in any case.

2.2.4 Preliminary survey, subsoil investigations and hydraulic survey:

Once the possible alternative sites are selected on the basis of reconnaissance survey and the criteria for site selection enumerated in para 2.2.3 above, the next step is to conduct the preliminary survey, subsoil investigations and hydraulic survey at each of the alternative sites:

2.2.4.1 Preliminary Survey:

The data to be collected during the preliminary survey are:-

(i) The names of the state / UT, district, nearest town/village, and river across which the bridge is proposed.

(ii) The chainage of the highway, location of nearest GTS bench mark with level, latitude and longitude of the site as measured from the survey of India maps.

(iii) Details of the existing bridges or causeways on the same river in the vicinity which should include:-

- Description with sketches showing relevant dimensions. - length and depth of submergence, number and sizes of vents, and frequency (including duration) of interruptions to traffic in case of causeways.
- Number and length of spans, clear waterway, adequacy or otherwise of waterway with special reference to silted up spans or signs of undue scour or attacks on abutments" and approaches in case of bridges.

(iv) An index map of the site on a scale of 1: 50,000 indicating the name and chainage of the highway. The name of the river, name of the nearest town/village marking of the alternative sites, location of the nearest GTS benchmark if possible, name of district and state, direction of flow, nature of land-use, general topography of the area and north line.

(v) Site plans of the bridge for the alternative sites indicating the north line, alignment of the road and the river, the angle of crossing, water spread at LWL, HFL case. Chainage of the proposed bridge at crossing of the river, the direction of flow at maximum discharge, private land boundaries, services, location of deep channels, ponds, places of worship, graveyards, if any, near to the proposed site. Location and reduced level of the temporary bench mark used as datum, location of the L.S. and C.S. of the road and the stream taken within the area of the plan, location of trial pits/borings with their identification number and location of nallah's wells, buildings, rock out crops etc. which may affect the approach alignments.

2.2.4.2. Hydraulic Survey:

Hydraulic data collected for the purpose of the preliminary project report (PPR) has to be good enough for the detailed engineering also. No separate hydraulic data collection is envisaged for detailed engineering except that for model studies, if any, conducted for bridges across major rivers. Wherever practical, the hydraulic data as may be formally facilitated by the Irrigation & Flood Control Department may be utilized. The hydraulic data collected at PPR stage should include:-

(i) A catchments area map on a scale of 1:50,000 indicating the drainage channels and the land-use pattern including built up areas, barren land, cultivated land, forests, hilly areas etc. and its area in square kilometers. For preparation of the catchment area GTS maps of largest available scale may also be referred for tracing the ridge line.

(ii) HFL ascertained from watermarks, if any, on the permanent objects on the banks supplemented by local enquiry from nearby inhabitant as to the highest flood levels reached during their living memory'.

(iii) Information about velocity of flow and presence of floating debris etc. from local enquiry. Velocity of flow is best ascertained during floods by the use of floats by determining the time to traverse two fixed points at measured distance apart.

(iv) In case a causeway or the existing bridge is of insufficient waterway resulting in afflux, the extent of such afflux is ascertained for arriving at the rough assessment of discharge.

(v) Names and approximate discharges of all tributaries joining the river within a reasonable distance upstream of the site under consideration.

(vi) Skew angle of crossing, if any, should be ascertained correctly. Skew angle should be measured in relation to the direction of flow at/near HFL and not in relation to the bank line.

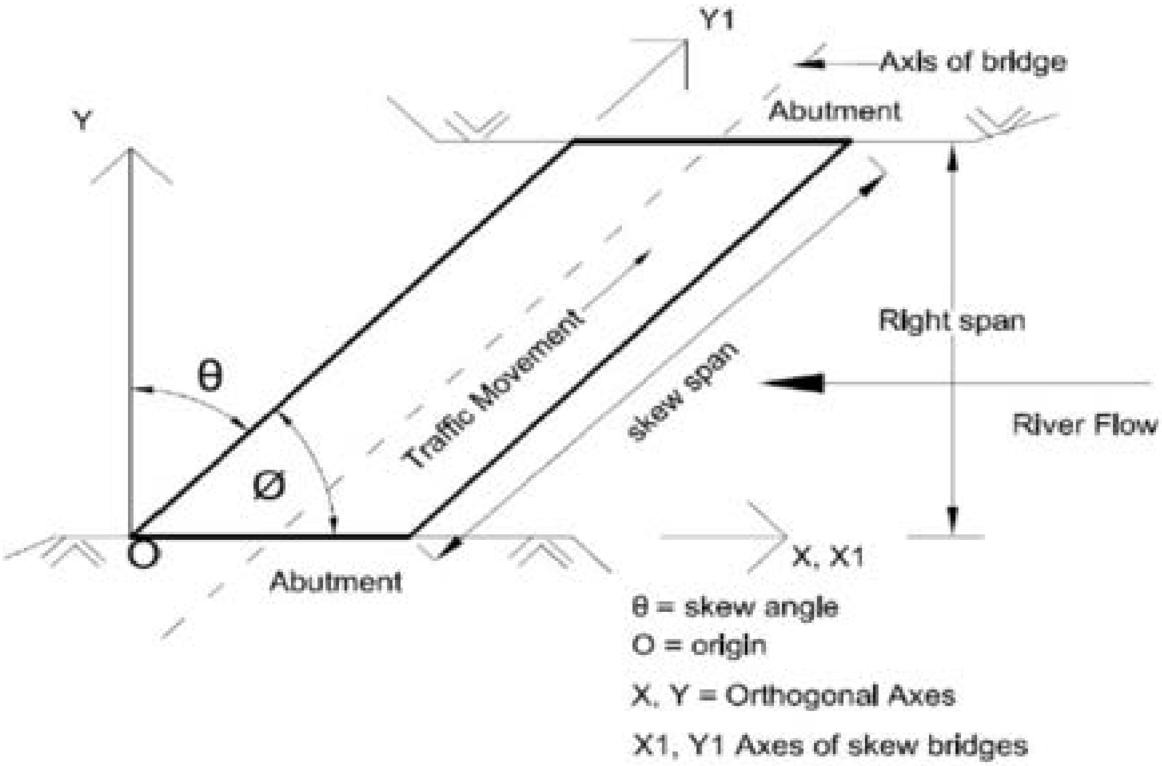


Fig. 2.0 Skew Angle of Bridge

(vii) The approximate depth of the deep scour hole below HFL mentioning its location, whether general or localized, near any hard obstruction or caused by whirlpool. Information about scour around piers and abutments of any other bridge across the same river in the vicinity from records or by soundings taken near the proposed site during receding floods will be very useful in cross checking the calculated scour and thereby avoiding gross errors.

(viii) The khadir width in case of wide/meandering alluvial rivers. The width and depth of the channel during dry weather flow, OFL and HFL should be noted, as well as the radii of the larger meanders scaled from the map.

(ix) Cross section of the river on a vertical scale of about 1/100 and horizontal scale of 1/10000 at the proposed sites indicating:

- Name of the river and the site.

- The (road) chainages and bed levels with reference to the temporary benchmark and ground levels for sufficient distance beyond the edge of the channel
- Nature of the subsoil in the bed, bank approaches and location of the trial bores.
- LWL, OFL and HFL
- Low and high tide levels where applicable.

It should also include one or two additional cross sections at 300 to 500 m u/s and d/s for small and large rivers respectively.

(x) A longitudinal section of the stream showing the proposed site, HFL, OFL, LWL and bed levels at suitably placed intervals along the approximate centre line of the deep water channel. The horizontal scale shall be same as for survey plan and vertical scale not less than 1:1000.

(xi) Rainfall data indicating

- Maximum precipitation in one hour and 24 hours.
- Rainfall distribution in catchment.
- Duration, frequency of floods.
- Rain gauge data of storms for which corresponding stream gauge data is available (data for unit hydrograph)
- Average annual rainfall characteristics (append relevant meteorological records).

The observations and calculations shall be based on the procedure as laid down in IRC SP 13 ,IRC 5 AND IRC 78. Wherever practical, the rainfall data as may be formally facilitated by the Meteorological Department may be utilized.

(xii) Stream/channel characteristics

- Seasonal or perennial
- Braided, meandering or straight
- Other classifications like bouldery, flashy, well defined, presence of pools, weeds etc.
- Highest flood and other major floods and their year of occurrence delineating the areas
- flooded
- Afflux if observed

2.2.4.3. Preliminary subsoil investigation

(i) Preliminary subsoil investigations should include adequate number of trial bores/trial pits for obtaining realistic data for deciding the span arrangement, type of foundation and scour level as specified in IRC 78/IS 1892 for making the preliminary design of the bridge. The exploration shall cover the entire length of the bridge and also extend at either side for a distance of about twice the depth below bed of the last main foundations. It should also include study of available information on the geological formations from geological maps, site reports of existing bridges, aerial photography etc. If significant difference in the foundation strata is anticipated, few bores at alternative sites may also be required sometimes, so as to help in the final selection of the site.

(ii) Depth of exploration: The depth of exploration should be at least 1 ½ times the minimum width of the foundation below the proposed foundation level in case of open foundations and deep well foundation. Where such investigation end in any unsuitable or questionable foundation material, the exploration shall be extended to a sufficient depth into firm and stable soil or rock but not less than four times the minimum depth of foundation below the earlier contemplated foundation level. In case of good sound rock, the stipulation of minimum depth may be decreased based on difficulty to conduct core drilling, however minimum depth should not be less than 3 meters.

(iii) Depth of exploration for pile foundation should be as per Section 1100,1200 and 2100 of MoRT&H Specifications for Road and Bridge Works.

2.2.5. Design discharge and linear waterway

2.2.5.1. Design discharge

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. Normally, in the absence of reliable data for "statistical analysis of floods, design discharge may be fixed on the basis of any rational method. Empirical methods are less reliable and may be used with caution. Various methods for calculating discharge are given in IRC-SP 13.

2.2.5.2. Linear Waterway.

For rivers with defined firm banks, the linear waterway is preferably kept equal to HFL (HFL should be obtained from gauge/gauge data or rating curve using design discharge) spread at the site. However, when the depth of flow near the banks is low in comparison with deep channel portion, constriction of waterway upto 2/3rd of the HFL spread is resorted to form considerations of economy. But careful consideration has to be given on the possibility of excessive scour of the banks or beds on the d/s of the bridge or of excessive afflux on the u/s before deciding on any constriction of waterway.

The likely mean depth and velocity of flow shall be the main guiding factors for deciding the linear waterway to be provided for any bridge. Hence for effective functioning of the waterway, afflux of 10 to 30 cms may be allowed with the due consideration for any possible adverse effects on the upstream.

For rivers with alluvial beds and no defined banks, the effective linear waterway can also be derived from the formula:

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

Where, Q is discharge and C is a constant usually taken as 4.8 for regime channels, but varying between 4.5 to 6.3 according to local conditions and for further clarification on the value of C IRC 5 may be referred. The formula should be used judiciously only after ascertaining the soil characteristics in the river bed and regime of the river.

For meandering rivers with several active channels separated by islands or shallow sections, it may become necessary to considerably restrict the waterway by providing training works. The design of the training works and the effective linear waterway are to be preferably based on the model studies.

The effective linear waterway may be compared with that provided under other bridges in the vicinity over the same river after duly considering their performance.

2.2.5.3. Scour depth.

2.2.5.3.1. 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 as per IRC 5.

Wherever possible, depth of scour shall be assessed on the basis of actual soundings taken at the proposed site or near it during the receding phase immediately after high flood conditions with necessary allowance for:-

- **(i)** The design discharge being higher than the one for which observation has been made.
- **(ii)** The increase in velocity due to constriction of waterway.
- **(iii)** The increase in scour in the proximity of piers and guide bunds.

2.2.5.3.2. In the absence of actual soundings, the mean depth of scour d_{sm} in meters below HFL may be theoretically calculated from the equation:-

$$d_{sm} = 1.34 \times \sqrt[3]{\frac{D_b^2}{K_{sf}}}$$

Where D_b is the discharge in cumecs per meter width which shall be taken as maximum of the following:-

- **(i)** Total design discharge divided by the effective linear waterway. Where effective linear waterway is the total width of waterway of bridge at HFL minus effective width of obstruction as per IRC 5.
- **(ii)** Discharge per meter calculated after considering concentration of flow, if any, through a portion of the waterway in case of major bridges.
- **(iii)** Actual observation, if any.

and K_{sf} is the silt factor which is equal to

$$K_{sf} = 1.76\sqrt{d_m}$$

d_m being the weighted mean diameter of the representative sample of the bed material upto the anticipated scour level. In the absence of sieve analysis, IRC:78 prescribes following values of silt factors (Table 2.1).

Type of Bed Material	d_m Weighted Mean Diameter of Particle in mm	Value of K_{sf} Silt Factor
Fine Silt	0.081	0.500
Fine Silt	0.120	0.600
Fine Silt	0.158	0.700
Medium Silt	0.233	0.850
Standard Silt	0.323	1.000
Medium Sand	0.505	1.250
Coarse Sand	0.725	1.500
Fine Bajri and Sand	0.988	1.750
Heavy Sand	1.290	2.000

Table 2.1 Value of K_{sf} Silt Factor

2.2.5.3.3. For the design of foundation of piers and abutments located in the straight reach and having individual foundations without protection works, the maximum depth of scour shall considered as follows:-

(i) In the vicinity of piers = 2.00 d_{sm}

(ii) In the vicinity of abutments = 1.27 d_{sm} (when approaches are retained)

= 2.00 d_{sm} (when approaches are washed / with scour all around)

2.2.5.3.4. For the design of floor protection measures and for raft or shallow foundations, the maximum depth of scour shall be considered as follows:-

(i) In straight reach = 1.27 d_{sm}

(ii) At moderate bend = 1.50 d_{sm}

(iii) At severe bend = 1.75 d_{sm}

(iv) At right angled bend = 2.00 d_{sm}

The above values of scour may be suitably modified where actual observed data is available on similar structures in vicinity of the proposed bridge.

2.2.5.3.5. In case of flashy rivers and boulder strata, the scour is likely to be less what is given by the formula. In such cases, scour depths may be based on actual observations.

2.2.5.3.6. For bridges proposed d/s of a reservoir, the clear water will have higher scouring effect and in such cases also, scour depths shall be based on actual observations.

2.2.5.3.7. For seismic case, scour to be considered in design shall be 0.9 times the maximum design scour depths.

For other details and afflux, refer relevant clauses of IRC-5 and IRC-78.

2.2.6. Clearance

2.2.6.1. Vertical clearance above HFL.

Clearance shall be allowed according to navigational or anti-obstruction requirements in consultation with the concerned authorities for all controlled and natural water courses/channels. For inland waterways, Inland Waterways Authority has framed regulation for classification of inland waterways in India and has recommended minimum clearance for various categories of waterways, which should be referred.

For high level bridges having flat soffit or a soffit with a very flat curve, the minimum vertical clearance to be provided above affluxed HFL shall normally be as follows (Table 2.2):-

Table 2.2: Vertical Clearance

Discharge in Cumecs	Minimum Vertical Clearance in mm
Upto 0.3	150
Above 0.3 and upto 3	450
Above 3 and upto 30	600
Above 30 and upto 300	900
Above 300 and upto 3000	1200
Above 3000	1500

Where high level bridge is a bridge which carries the road way above the HFL of a channel (including afflux) or the high tide level, with appropriate vertical clearance as per IRC 5.

2.2.6.1. Clearance for traffic

(i) The minimum vertical and horizontal clearances (clear height and width respectively available for passage of traffic) to be provided on bridges shall be as specified in IRC-5.

(ii) For bridges constructed on horizontal curve with super-elevated road surface, the horizontal clearance shall be increased on the side of the inner kerb by a margin equal to 5 meters multiplied by the super elevation; the maximum vertical clearance being measured from the super elevated level of the roadway. The above extra horizontal clearance required is over and above the increase in width required for the design of road on curve.

(iii) For footways and cycle tracks, the minimum vertical clearance shall be 2.25 meters.

(iv) For vertical and horizontal clearances at under passes and / rail over bridges the essential provisions IRC: 5 may be referred.

2.2.7. Width of carriageway, footpath and median

2.2.7.1. General (for all roads except national highways):

The provisions given in clause 104.3 of IRC:5-2015 may be applied for all bridges except for National Highways for which para 2.2.7.2 may be referred to.

The carriageway width shall not be less than 4.25 m for a single lane bridge and 7.5 m for a two lane bridge, which shall be increased by 3.5m for every additional lane of traffic for a multiple lane bridge. In addition, the cross section of two lane and multi lane bridges shall satisfy the following:-

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 60m in non-urban areas, reduced width may be permitted by the authorities subject to stipulations as given in clause 104.3.1 of IRC-5-2015.

For bridges on horizontal curve, the roadway width shall be increased suitably to conform to the requirements stipulated in the relevant IRC Road standards.

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

2.2.7.2. For bridges on National Highways:

All bridges should have width between outer most faces of the railing kerbs equal to the roadway width of the approaches irrespective of their length or location. For details, MoRT&H Circular No. RW/NH-33044/2/S8-DO.II dated 09/05/2000 may be referred to.

Footpaths: In urban areas, minimum footpath width of 1.5 m may be provided. In case of divided carriageways, footpath shall be provided only on the left side of the carriageway for each direction of traffic, wherever footpath is not provided, safety kerb of 750 mm width has to be provided as per IRC:5. In case of very high volume of pedestrian traffic, the provision of footpaths of more than 1.5m width or a separate pedestrian bridge may be considered depending on site conditions.

Crash Barriers: Crash barriers shall be provided for all bridges on National Highways to safeguard against errant vehicles. For bridges with footpath, crash barrier "shall be so located as to separate the main carriageway from the footpath for the safety of pedestrians". For further details, IRC-5 "General Features of Design" may be referred to.

Extra width on curves: In case of bridges lying on a curve or a horizontal profile, extra width on bridge shall be" provided as per IRC codal provisions applicable for road section.

2.2.8. Fixation of span arrangement and selection of the type of structure

2.2.8.1. General consideration in selection of type of bridges and span arrangement

Specific site characteristics like width of crossing, nature of stream, depth of flow during different seasons, subsoil characteristics, and the capabilities of contracting agencies who would be interested in building the structure including availability of skilled and unskilled labor are mostly the major considerations in selecting the type of structure and span arrangement in specialized structures like long span bridges. The attempt of the engineers should be towards minimizing the overall cost of the total structure including approaches within the site specific constraints as obtained. For normal simply supported structures, it has been observed that the total cost of the bridge project tends to be the minimum, when the cost of superstructure approaches to that of foundation and substructure put together which may be applied as a thumb rule for initial trial. Followings recommendations should be kept in mind during fixation of span arrangement and selection of type of structure;

- Bridges as far as possible shall be designed as continuous structures to have better redundancy, economy, less maintenance and higher safety.
- The number of continuous versus simple spans shall be based on considering moment balanced span-ratio for reasons of having uniform requirement of girder depth, i.e., span ratio leads to equal mid-span moments in exterior and interior span lengths of the bridge.
- Limitations on prefabrication of pre-stressed or box-type and other types of girders can decide span length.
- For the aesthetical point of view central pier can be avoided in the middle of the waterway in some cases.
- Justified span/depth ratios as per IRC codal recommendations can decide span lengths and arrangement.
- The hydraulic design for safe passage of flood discharge allowing safe passage of the extreme 100 year frequency flood discharge with freeboard clearance (accounting for obstructions on account of piers etc.) can be decisive on bridge length and economical span arrangements.

2.2.8.2. Economical range of span lengths for different types of superstructures

Apart from the estimated cost based on schedule of rates, costs as quoted during tendering may be used for constantly updating the cost analysis data. The ranges of span length within which a particular type of superstructure can be economical along with other considerations of foundation etc. are given below:-

(i) R.C.C. single or multiple boxes	1.5 to 5 m
(ii) Simply supported RCC slabs	3 to 10 m
(iii) Simply supported RCC T beam	10 to 24 m
(iv) Simply supported PSC girder bridges	25 to 45 m
(v) Simply supported RCC voided slabs	10 to 15 m
(vi) Simply supported/ continuous PSC voided slabs	15 to 30 m
(vii) Continuous RCC voided slabs	10 to 20 m
(viii) RCC box sections simply supported/ Balanced cantilever continuous	25 to 50 m

(ix) PSC box sections; simply supported / Balanced cantilever	35 to 75 m
(x) PSC cantilever construction / Continuous	75 to 150 m
(xi) Cable stayed bridges	100 to 800 m
(xii) Suspension bridges	300 to 1500 m
(xiii) Truss bridges simple supported	30 to 375 m
(xiv) Truss bridges with cantilever combination	upto 550m
(xv) Simple supported steel plate girder bridge	10 to 40m

However, whenever an economical span arrangement and type of structure is decided, it has to be ensured that the required infrastructural facilities, design and construction capabilities, specialized materials etc. are available.

For fixation of number of girders, girder spacing, lateral load distribution methodologies, analysis and design of skew and horizontally curved bridges IRC 112/ relevant literature may be referred to.

Bailey bridges: These refer to bridge superstructures nominally made up of assemblable units which can be carried in units (Fig. 2.1), assembled and launched in a short period over a gap. They may be provided for the short-term movement of an army or also be used in case of damage to a permanent bridge due to the approaches or even a part of the bridge having been damaged leaving a wide gap, or if the traffic has been suspended and permanent repairs to the bridge are likely to take a long time.

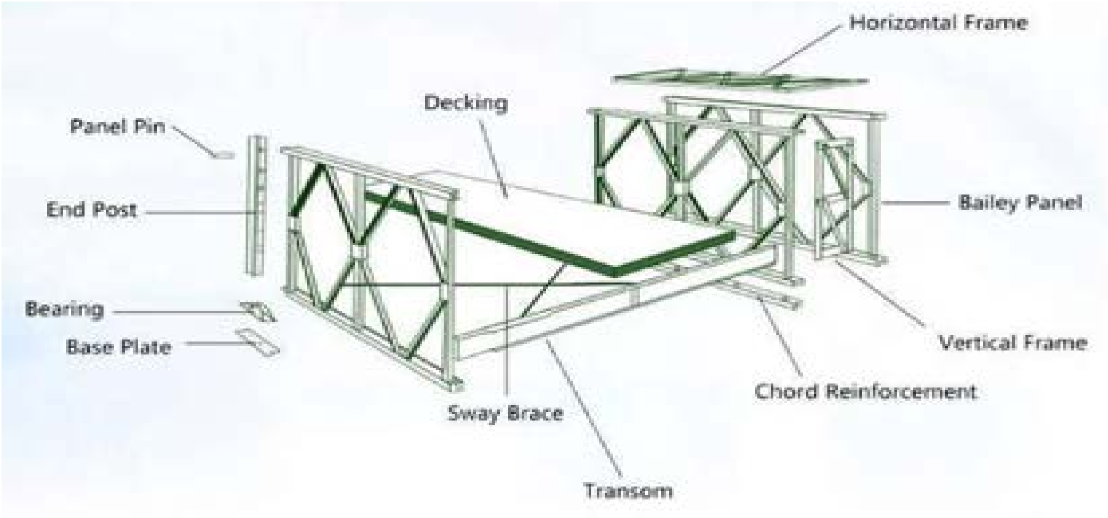


Fig. 2.1 Bailey Bridge

2.2.8.3. Type of foundations

The subsoil characteristics obtained at a particular site and consequently the type of foundations feasible is one of the major considerations in selection of type of structure and span arrangement as already mentioned:

(i) Shallow foundations: Isolated open foundations are feasible where an SBC of about 15 t/m^2 or more is available at shallow depths with non erodible substratum. Here again, open excavation is feasible only upto a depth of 3 to 4 m where the subsoil is porous and water table is high. In cases, where the SBC is still less and where smaller spans are economical from other considerations, raft foundations or box structures with floor' protection and curtain walls are the other options.

(ii) Deep foundations: Where suitable founding strata is available at a depth of 6 m or more with substantial depth of standing water, highly pervious substratum and large scour depth, it may be advisable to go for deep foundation like (a) well, or (b) piles.

- ❖ Well foundations: This is one of the most popular types of deep foundations in our Country, due to various reasons like its simplicity, requirement of very little of equipment's for it's execution, adaptability to different subsoil conditions and difficult site conditions like deep standing water and large depths to good founding strata. Caissons are an adaptation of well foundations to sites with deep standing water.
- ❖ Pile foundations: Pile foundations are another type of deep foundations which are suited for adoption in the following situations, availability of good founding strata below large depth soft soil. Need to have very deep foundations beyond the limit of pneumatic operations usually depth beyond 35 meters or so. In some cases of strata underlying deep standing water and the strata being very hard not permitting easy sinking of wells or based on economic factors deciding the use of piles as compared to wells. However, pile foundations are not preferred within the flood zone of the river with deep scour.

(iii) Classification of piles

- ❖ Precast driven piles
- ❖ Driven cast-in-situ piles
- ❖ Bored cast-in-situ piles
- ❖ Bored precast piles and
- ❖ Driven steel piles

The design and construction of piles shall be done as per the procedure laid down IS-2911, IRC-78 and IRC-112. However general recommendations are summarized as below:

For the satisfactory design and construction of bored cast in-situ piles the following information would be necessary:

- ❖ Site investigation data as laid down under IS 1892. Sections of trial boring, supplemented, wherever appropriate, by penetration tests, should incorporate data/ information down to depth sufficiently below the anticipated level of founding of piles but this should generally be not less than 10 m beyond the pile founding level. Adequacy of the bearing strata should be ensured by supplementary tests, if required.

- The nature of the soil both around and beneath the proposed pile should be indicated on the basis of appropriate tests of strength, compressibility, etc. Ground water level and artesian conditions, if any, should also be recorded. Results of chemical tests to ascertain the sulphate, chloride and any other deleterious chemical content of soil and water should be indicated.
- For piling work in water, as in the case of bridge foundation, data on high flood levels, water level during the working season, maximum depth of scour, etc, and in the case of marine construction, data on high and low tide level, corrosive action of chemicals present and data regarding flow of water should be provided.
- The general layout of the structure showing estimated loads and moments at the top of pile caps but excluding the weight of the piles and caps should be provided. The top levels of finished pile caps shall also be indicated.
- All transient loads due to seismic, wind, water current, etc, are to be indicated separately.
- In soils susceptible to liquefaction during earthquake, appropriate analysis may be done to determine the depth of liquefaction and consider the pile depth accordingly.

As far as possible all informations given above shall be made available to the agency responsible for the design and/or construction of piles and/or foundation work. The design details of pile foundation shall give the information necessary for setting out and layout of piles, cut-off levels, finished cap level, layout and orientation of pile cap in the foundation plan and the safe capacity of each type of pile, etc.

(iv) Equipments and Accessories

- The equipments and accessories would depend upon the type of bored cast in-situ piles chosen for a job after giving due considerations to the subsoil strata, ground water condition, types of founding material and the required penetration therein.
- Among the commonly used plants, tools and accessories, there exists a large variety; suitability of which depends on the subsoil condition and manner of operation, etc.
- Boring operations are generally done by percussion type rigs or rotary rigs using direct mud circulation or reverse mud circulation methods to bring the cuttings out. In soft layers and loose sands, bailers and chisel method should be used with caution to avoid the effect of suction.
- For percussion boring using bailer chisel and for rotary rigs, stabilization of bore holes may be done either by circulation or suspended mud.

(v) Design Considerations

- ❖ General Pile foundations shall be designed in such a way that the load from the structure can be transmitted to the sub-surface with adequate factor of safety against shear failure of sub-surface and without causing such settlement (differential or total), which may result in structural damage and/or functional distress under permanent/transient loading. The pile shaft should have adequate structural capacity to withstand all loads (vertical, axial or otherwise) and moments which are to be transmitted to the subsoil and shall be designed according to IS 456.
- ❖ When working near existing structures care shall be taken to avoid damage to such structures. IS 2974 (Part 1) may be used as a guide for studying qualitatively the effect of vibration on persons and structures

  For detailed analysis and design, IS-2911 may be referred to.

2.2.8.4 Aesthetic and environmental considerations: Aesthetics and environmental considerations are increasingly becoming major factors in the selection of the type of structure including its foundation to be adopted for a specific site. To achieve aesthetically pleasing view of bridge structure, attention should be paid to produce a clean, simple, well proportioned structured form. In most cases, achieving the desired structural quality may add little to the overall cost of structure. Aesthetic considerations include harmony with the general topography of the site, optimisation in the use of materials etc. Environmental considerations include limitation of noise levels and during and after construction of the bridge and the level of pollution due to air and water during construction and service, conservation of flora and fauna etc.

2.2.8.5 Guidelines on aesthetics: A few important characteristic elements to bridge aesthetics are cited below. These involve some fundamental aspects and lay down the basic principles of good aesthetic design. The basic knowledge of these aesthetic principles is essential to all levels of bridge design and management. Reference to specific literature for elaborate self-study is recommended.

(i) Proportion: Proportion (Harmony) is classified into 3 principle systems:

- ❖ Arithmetic Proportion 1/3, 1/9 etc.
- ❖ Harmonic Proportion - a/b = c/d etc.
- ❖ Geometric Proportion i.e. equilateral/isosceles/Egyptian triangle.

Harmony in proportion is a primary aesthetics consideration and termed as the first order aesthetic dimension. In relation to bridges, proportion may pertain equally to structure, environment ensemble, the structure total or elements of the structure. Proportion between linear dimension like length, width, and height between masses and voids between areas in light and shadow etc. are to be considered important.

(ii) Contrast: As opposed to harmony in proportion, contrast can heighten values of some elements in comparison with others. A contrast of volumes, surfaces or linear dimensions, a contrast in materials and their colour, a contrast of light and shadow etc. are the aspects to be kept in view.

(iii) Scale: The absolute real dimensions of the structure defining its scale play a dominant role in aesthetic study. The quality of bridge structure is judged from the different points of view like compatibility with its environment or compatibility with its constituent elements.

(iv) Order: Order in bridge structure is the key aesthetic quality. Order in line is achieved by limiting their directions in space to the minimum practicable. Symmetry in proportion and shape is an important element of order. Repetition of shapes, lends an order which provides rhythm. However, when overdone, it can lead to monotony which has to be avoided. Simplicity and cutting down unnecessary accessories will lead to a good order.

(v) Character: The character of a bridge structure as an element of the man made environment is expressed by its effect on the humans using it. The desired character is determined by societal objectives which may vary. The structure today needs to reflect technological excellence and look modern, but this should stimulate qualities of buoyancy and relaxation.

(vi) Colour: Colour has a significant aesthetic effect. In bridges with concrete as the most used material, the choice is limited. However, the surface texture, weathering quality etc. have added importance in this context which has to be kept in view for aesthetic considerations.

(vii) Functionalism: In bridges form follows function. Functional efficiency never conflicts with form. It generates simplicity in form and aesthetic quality, given the attention due to it. Added ornamentation like a stone facing to hide concrete or redundant pylons, pilasters or arches is irrelevant to modern bridge forms. Ornamentation of large surfaces of piers, abutments, retaining walls by suitable treatment or texturing can enhance the aesthetic quality and character of bridges especially in urban environment. These potentials should be recognized and made full use of.

(i) Environmental integration: The integration of the bridge structure with the environment is the most important aesthetic need of the modern bridges. Simplicity in form may suit open rural lands. Wide river crossings may demand bridges with character compatible with the majesty of the river, structure built in urban or metropolitan environment should have special aesthetic qualities because of their large impact on people and their habitat.

(ii) Complexity: Complexity belongs to the second order aesthetics. The Complexity rightly used can build tension with subsequent release and produces a pattern more dynamic than static. It has application potentials in bridge design specially in case of large structures.

(iii) Third order aesthetics: Intuitive, artistic sensibility of artistically gifted designer can build beauty in structures including bridges. Obviously, this higher level aesthetics combine the first and second order characteristics of harmony and complexity; something more is added to produce elegance.

2.2.9 Preliminary design of various components of bridge

The Preliminary design should include all calculations needed for finalizing the cross section of the superstructure including the checks for the maximum bending stress and shear stress. It should also include preliminary design of the critical abutment and pier on the basis of preliminary subsoil investigations.

2.2.9.1 Loads on bridges

The following are the various loads to be considered for the purpose of computing stresses, wherever they are applicable.

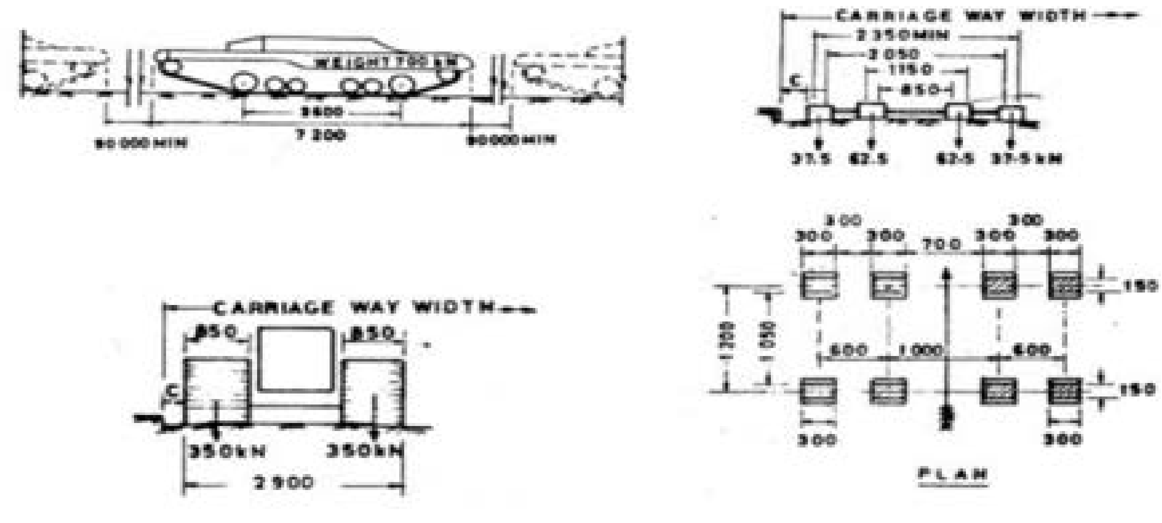
- Dead Load
- Live load
- Impact load
- Longitudinal force
- Thermal force
- Wind load
- Seismic load
- Racking force
- Forces due to curvature.
- Forces on parapets
- Frictional resistance of expansion bearings
- Erection forces

(i) **Dead load –** The dead load is the weight of the structure and any permanent load fixed thereon. The dead load is initially assumed and checked after design is completed.

(ii) **Live load** – Bridge design standards specify the design loads, which are meant to reflect the worst loading that can be caused on the bridge by traffic, permitted and expected to pass over it. In India, the Railway Board specifies the standard design loadings for railway bridges in bridge rules. For the highway bridges, the Indian Road Congress has specified standard design loadings in IRC section II. The following few pages brief about the loadings to be considered. For more details, refer to the IRC 6.

Highway bridges: In India, highway bridges are designed in accordance with IRC bridge code. IRC: 6 - 1966 – Section II gives the specifications for the various loads and stresses to be considered in bridge design. There are three types of standard loadings for which the bridges are designed namely, IRC class AA loading, IRC class A loading and IRC class B loading.

Fig 2.2: IRC AA Loading



(a) Tracked vehicle (a) Wheeled vehicle

IRC class AA loading consists of either a tracked vehicle of 70 tonnes or a wheeled vehicle of 40 tonnes with dimensions as shown in Fig. 2.2. The units in the figure are mm for length and tonnes for load. Normally, bridges on national highways and state highways are designed for these loadings. Bridges designed for class AA should be checked for IRC class A loading also, since under certain conditions, larger stresses may be obtained under class A loading. Sometimes class 70 R loading given in the Appendix - I of IRC: 6 - 1966 - Section II can be used for IRC class AA loading. Class 70R loading is not discussed further here.

Class A loading consists of a wheel load train composed of a driving vehicle and two trailers of specified axle spacings. This loading is normally adopted on all roads on which permanent bridges are constructed. Class B loading is adopted for temporary structures and for bridges in specified areas. For class A and class B loadings, reader is referred to IRC: 6 - 1966 – Section II.

Foot Bridges and Footpath on Bridges: The live load due to pedestrian traffic should be treated as uniformly distributed over the pathway. For the design of footbridges or footpaths on railway bridges, the live load including dynamic effects should be taken as 5.0 kN/m^2 of the footpath area. For the design of foot- path on a road bridges or road-rail bridges, the live load including dynamic effects may be taken as 4.25 kN/m^2 except that, where crowd loading is likely, this may be increased to 5.0 kN/m^2.

(iii) Impact load: The dynamic effect caused due to vertical oscillation and periodical shifting of the live load from one wheel to another when the locomotive is moving is known as impact load. The impact load is determined as a product of impact factor, I, and the live load. The impact factors are specified by different authorities for different types of bridges. The impact factors for different bridges for different types of moving loads are given in IRC 6.

(iv) Longitudinal forces – Longitudinal forces are set up between vehicles and bridge deck when the former accelerate or brake. The magnitude of the force F, is given by

$$F = \frac{W}{g}\frac{\delta V}{\delta t}$$

Where, W – Weight of the vehicle

g – Acceleration due to gravity

ðV – Change in velocity in time dt

This loading is taken to act at a level 1.20 m above the road surface. No increase in vertical force for dynamic effect should be made along with longitudinal forces. The possibility of more than one vehicle braking at the same time on a multi-lane bridge should also be considered.

(v) Thermal forces: The free expansion or contraction of a structure due to changes in temperature may be restrained by its form of construction. Where any portion of the structure is not free to expand or contract under the variation of temperature, allowance should be made for the stresses resulting from this condition. The coefficient of thermal expansion or contraction for steel is 11.7 x 10^{-6} / °C

(vi) Wind load – Wind load on a bridge may act

- ❖ Horizontally, transverse to the direction of span
- ❖ Horizontally, along the direction of span
- ❖ Vertically upwards, causing uplift
- ❖ Wind load on vehicles

Wind load effect is not generally significant in short-span bridges; for medium spans, the design of sub-structure is affected by wind loading; the super structure design is affected by wind only in long spans. For the purpose of the design, wind loadings are adopted from the maps and tables given in IS: 875 (Part III). In case of structures with opening the effect of drag around edges of members has to be considered.

(vii) Racking force – This is a lateral force produced due to the lateral movement of rolling stocks in railway bridges. Lateral bracing of the loaded deck of railway spans shall be designed to resist, in addition to the wind and centrifugal loads, a lateral load due to racking force of 6.0 kN/m treated as moving load. This lateral load need not be taken into account when calculating stresses in chords or flanges of main girders.

(viii) Forces on parapets - Railings or parapets shall have a minimum height above the adjacent roadway or footway surface of 1.0 m less one half the horizontal width of the top rail or top of the parapet. They shall be designed to resist a lateral horizontal force and a vertical force each of 1.50 kN/m applied simultaneously at the top of the railing or parapet.

(ix) Seismic load – If a bridge is situated in an earthquake prone region, the earthquake or seismic forces are given due consideration in structural design. Earthquakes cause vertical and horizontal forces in the structure that will be proportional to the weight of the structure. Both horizontal and vertical components have to be taken into account for design of bridge structures. IS:1893 – 1984 may be referred to for the actual design loads.

(x) Forces due to curvature - When a track or traffic lane on a bridge is curved allowance for centrifugal action of the moving load should be made in designing the members of the bridge. All the tracks and lanes on the structure being considered are assumed as occupied by the moving load.

This force is given by the following formula:

$$C = \frac{W V^2}{12.7 R}$$

Where, C - Centrifugal force in kN/m

W - Equivalent distributed live load in kN/m

V - Maximum speed in km/hour

R - Radius of curvature in m

(xi) Erection forces – There are different techniques that are used for construction of railway bridges, such as launching, pushing, cantilever method, lift and place. In composite construction the composite action is mobilised only after concrete hardens and prior to that steel section has to carry dead and construction live loads. Depending upon the technique adopted the stresses in the members of the bridge structure would vary. Such erection stresses should be accounted for in design. This may be critical, especially in the case of erection technologies used in large span bridges.

2.2.9.2 Minimum depth of foundations: The following minimum depths may be ensured:

(i) Shallow foundations in erodible strata: Such foundations may be taken to a minimum depth of 2.0m if they support an arch superstructure or 1.20 m in other cases provided adequate SBC is available at that depth to support a individual foundation or rafts as the case may be and the foundations are protected against undermining by suitably designed flooring, cut off walls and launching aprons.

(ii) Deep foundations in erodible strata: Such foundations shall be taken to such depth where the base pressures calculated based on any rational design method is less than the available S.B.C. and a minimum grip length of 1/3rd of the maximum anticipated scour depth below HFL (i.e. 1/3rd of 2d) is ensured.

(iii) Shallow foundations in rock: A minimum embedment of 0.6 m in case of hard rocks having a crushing strength of 100 kg/cm2 or more may be provided considering the overall characteristics such as fissures, bedding planes, cavities etc. Higher embedment may be provided for softer varieties considering the above mentioned characteristics and strengthening measures, if any, proposed.

(iv) Deep foundations in rock: If hard rocky strata is met with at depths below the maximum scour level, and if deep foundations are resorted to, it shall be ensured that such foundations are evenly seated all along the periphery on sound rocky strata (devoid of fissures, cavities, weathered zones etc). On sloping rock surfaces, the foundations shall be properly seated by benching and the extent of seating and embedment in each case shall be decided by Engineer-in-charge/bridge designer/relevant IRC Code (IRC 78).

2.2.9.3. Substructure : Substructure include those portions of a bridge which are above the foundation which include piers, abutments, abutments and pier caps, dirt walls, returns, wing wall etc. but excludes bearings and superstructure. It can be built of brick/ stone masonry, plain/ reinforced/ pre-stressed concrete, steel. Selection of a particular type of substructure depends upon the span and type of superstructure, the height of substructure, availability of construction material and construction equipments, period and time of construction and above all on overall economy. The shape of piers and abutments in general, should be such as to cause minimum obstruction to flow of water.

Substructure shall be designed to withstand the loads and forces as specified in IRC: 6, the worst combination of forces and factors of safety shall be as specified in IRC: 78. For allowable stresses and other design requirements relevant IRC Codes depending upon the type of construction material shall be followed.

2.2.9.4. Bearings

(i) Bearings are vital components of a bridge which while allowing of longitudinal and/or transverse rotations and/ or movements of the superstructure with respect to the substructure (thus relieving stresses due to expansion and contraction), effectively transfer loads and forces from superstructure to substructure. Adequate care shall be exercised in selecting the right type of bearings based on the guidelines given below:

- For solid/voided slab superstructure resting on unyielding supports, no bearings are generally provided if the span length is less than 10m. The top of piers/abutments caps are however rubbed smooth with carborandum stone.
- For girder and slab spans more than 10m length and resting on unyielding supports, neoprene bearings may be considered. For spans larger than 25m roller and rocker bearings or PTFE bearings could be considered.
- For very large spans and where multidirectional freedom of movement and rotation are to be allowed provision of POT bearings may be considered.

(ii) The design of metallic bearings and neoprene bearings shall be in conformity with IRC: 83: Parts I & II respectively.

(iii) In case of roller-cum-rocker bearings only full circular rollers are to be provided.

(iv) In order to cater for any possible relative undue movement of bearings over the abutment resulting in girder ends jamming against the dirt wall preferably a larger gap may be provided between the girder end and the dirt wall.

(v) All bearings assemblies shall be installed in accordance with the instructions contained in the codes and specifications and on the approved drawings. In particular the following important points shall not be lost sight of.

- All bearings shall be set truly level so as to have full and even seating. Thin mortar pads (not exceeding 12mm) may be used to meet this requirement.
- The bottoms of girders resting on the bearing shall be plane and truly horizontal.
- In case of rockers and roller bearings, necessary adjustment for temperature at the time of placement, shrinkage, creep and elastic shortening shall be made, such that the line of bearing is as central as possible on the bearing plates at the normal temperature taken in design.
- For elastomeric bearing pads, the concrete surface shall be level such that the variation is not more than 1.5mm from a straight edge placed in any direction across the area.
- For spans in grade, the bearings shall be placed horizontal by using sole plates or suitably designed R.C.C. pedestals.
- Bearings of different sizes must not be placed next to each other to support a span.
- Installation of multiple bearings one behind the other on a single line of support is not permitted.
- The bearings shall be so protected while concreting the deck in situ that there is no flow of mortar or any other extraneous matter into the bearing assembly and particularly on to the bearing surfaces. The protection shall be such that it can be dismantled after the construction is over without disturbing the bearing assembly.

- Special attention should be given to the temporary fixtures to be provided for the bearings during the concreting of superstructure in order to ensure that they do not get displaced during the initial installation itself. The temporary fixtures should be removed as soon as the superstructure has attained its required strength

(vi) Bearings provided at any end of superstructure shall be along a single line of support and of identical dimensions.

(vii) Ministry of Road Transport and Highways, Govt. of India carries out pre qualification of the manufacturers of bearings from time to time. The pre qualification is valid for a certain period. It is advisable to procure bearings from such manufacturers only.

(viii) The regular inspection/maintenance of bearings shall be carried out as per the procedure laid down in relevant IRC Code, the details of same are provided in section 6 of this manual.

2.2.9.5. Superstructure

(i) It is the superstructure of a bridge that directly supports the traffic and facilitates its smooth uninterrupted passage over natural/ manmade barriers like rivers, creeks, railways, roads etc by transmitting the loads and forces coming over it to the foundation through the bearings and substructure.

(ii) The minimum functional requirement of superstructure is specified in IRC: 5 and IRC: 21. In case of box girder superstructure, the minimum clear height inside the box girders shall be 1.5 m to facilitate inspection.

(iii) Aesthetic aspects will be one of the major considerations while deciding on the type of superstructure of a bridge keeping in view the criteria mentioned therein.

(iv) Consistent with economy and local availability of the materials, labour and technology for a particular type of superstructure selection may have to be made out of the following material options:

- Masonry
- Reinforced cement concrete
- Pre stressed concrete
- Steel or
- Composite construction which is a combination, of the any of the above.

(i) Reinforced cement concrete superstructure: These are the most popular type of superstructures in the present day which may take the form of solid slab, voided slab. T-beam and slab, box girder, rigid frame, arch, balanced cantilever or bow-string girder.

(ii) Prestressed concrete superstructure: This may also take any of the above forms referred in the previous para.

(iii) Steel superstructure: With increasing availability of quality steel at international prices in recent years the use of steel for superstructure is becoming an attractive option. The forms, these may take are steel beam, plate girder, box girder, steel truss, arch, cantilever suspension bridges and cable stayed bridges.

(iv) Composite Superstructure: any combination of above materials considering their distinct advantages for particular elements may be adopted. Most common types of composite construction arc cast in situ or precast girder in prestressed concrete with R.C.C. deck or steel beam/plate girders with RCC deck or cable stayed bridges with RCC or PSC deck.

(v) Design: Relevant IRC Codes which have to be complied in the design of superstructure are IRC: 40, IRC: 21, IRC: 18, IRC: 24. IRC: 22 for Masonry, Reinforced Cement Concrete, Prestressed Concrete and Composite Superstructures respectively. Other codes applicable for all types of superstructures are IRC: 5 and IRC: 6. other major guidelines also include IRC: 85. In case IRC codes are silent about some design aspects, provisions, in the IS/International Codes may be followed.

(vi) Provision for future pre-stressing: In case of pre-stressed concrete superstructure, provision for future pre-stressing to the extent of 20 per cent of total pre-stress force may be made. For this purpose, dummy cables may be laid in the structure which can be used for further pre-stressing if the need arises afterwards.

(vii) Standard plans for highway bridges: Ministry of Road Transport & Highways gives preference to item rate contracts except in case of special problems, very large projects involving novel design/construction methods, and have brought out various standard plans which include standard plans for (i) RCC Solid Slab Superstructure, with and without footpaths for 3m to 10m spans with 12.00m overall width, (ii) T-Beam and Slab Superstructure of 12m to 24m spans of overall width 12.00 m, (iii) PSC Girder with RCC Deck Composite Superstructure for 30 m span with and without footpath, 35m span with footpaths and 40m span without footpaths and (iv) RCC Solid Slab Superstructures of 15, 22.5, 30 and 35° skew for span 4m to 10m with and without footpaths. These plans are published by MoRT&H / IRC.

2.2.9.6. Expansion joints: Expansion joints are provided at the end of deck and cater for movement of deck due to temperature, shrinkage, creep etc. Expansion joints make the deck joint leak proof, protect the edges of slab/girder and also allow smooth passage of loads from one span to other by bridging the gap. Depending upon the gap width to be bridged, there are various types of expansion joints in use at present as detailed below.

(i) Buried joints: Where the gap is 20mm or less, bituminous/asphalted surfacing is laid over a 12mm thick 200mm wide steel plate resting freely over the top surface of deck concrete. To keep the plate in position 8mm dia 100 mm long nails spaced at 300mm c/c along the center line of the plate are welded to the bottom surface of the plate and protrude into the gap.

(ii) Filler joint: This type of joint is suitable for fixed ends of simply supported spans with insignificant movements or simply supported spans not exceeding 10 meters. It can cater for horizontal movement upto 20mm.

(iii) Asphaltic plug joint: It is of asphaltic concrete made from polymer modified bitumen binder and selected single size aggregate. It rests over a 6mm thick and 200mm wide steel plate placed over the gap. The width of the plug varies from 500 to 750mm and its depth varies from 75 to 100mm. It caters for a horizontal movement upto 25mm and vertical movement upto 2mm.

(iv) Compression seal joint: It consists of steel armored nosing at two edges of the joint gap suitably anchored to the deck concrete and a joint sealer performed multi web cellular section of chloroprene elastomer compressed and fixed into the joint gap with special adhesive binder. The seal shall cater for a horizontal movement upto 40mm and vertical movement of 3mm.

(v) Elastomeric slab seal joint: It comprises of reinforced elastomeric seal fixed on either side to deck concrete of adjacent spans through bolts. It can cater to a maximum horizontal movement of 40mm.

(vi) Strip seal expansion joint: It comprises of an extruded section of chloroprene held in position by edge beams made of either expanded or hot rolled steel section or cold rolled cellular steel sections with suitable profile to mechanically lock the scaling element. The edge beams are anchored to deck by reinforcing bars, headed studs or bolts or anchor plates. The working movement range of the sealing element shall be 70mm.

(vii) Modular Strip Seal/Box Seal Joint: A modular expansion joint consists of two or more modules so as to cater to a horizontal movement in excess of 70mm. It allows movement in all the three directions and rotation about all the three axes as per design requirement. During all movement cycles of the joint, opening or closing of all modules are equal.

(viii) Special Joints: For bridges having wide deck or span length of more than 120m or/and involving complex movements/rotations in different directions/planes provision of special type of modular expansion joints such as swivel joints may be made.

(ix) Ministry of Road Transport & Highways, Govt. of India vide their letters No.RW/NH-34059/1/96 S&R dated 31.3.97 and 17.7.97 have issued interim specifications for expansion joints and subsequent modifications in the list of manufacturers / suppliers which may be followed. Supply of new type of expansion joints may be obtained on the basis of competitive bidding from amongst the manufacturers/suppliers listed at Annexure-II to the above referred letter. Further, a warranty of 10 years of trouble free performance may be insisted upon from the contractors/suppliers for all type of joints except for buried joints and filler joints.

2.2.9.7 Diaphragms and bracings

For steel bridges, general recommendations (as per IRC-24) for diaphragms and bracings are summarized below:

(i) Diaphragms in Members: In addition to diaphragms required for the proper functioning of the structure, diaphragms shall be provided as necessary for fabrication, transport and erection.

(ii) Lateral Bracings:

- ❖ Girders shall be provided with a lateral bracing system extending from endto-end of sufficient strength designed to transmit the effect of wind, seismic and centrifugal forces, if any to the bearings. Bracing system need not be provided if alternative system for lateral load transfer has been catered for e.g., by rigid deck.
- ❖ The bracing on the loaded chord shall be so designed as to transmit to the main girders the longitudinal loads due to tractive effort and/or braking effect in order to relieve the cross girders of horizontal bending stress.
- ❖ Where the depth permits, lateral diagonal bracings shall be fixed between the top chords of main girders of through span, of sufficient rigidity to maintain the chords in line and of sufficient strength to transmit the wind or seismic forces to the portal bracing between end posts. The floor system may be taken as part of the bracing system provided it is designed for that purpose.
- ❖ The lateral bracings between compression chords shall be designed to resist a transverse shear at any section equal to 2.5 percent of the total compressive force carried by both the chords at the section under consideration. This force should be considered in addition to the wind, and centrifugal forces.

(iii) Sway bracings: Wherever the depth of girder allows, the intermediate cross bracings or sway bracings between vertical web members shall be proportioned to transmit to the chord supported on bearings through the web members at least 50 percent of the panel lateral load and the vertical members shall be designed to resist the resulting bending moment. The sway bracing so provided shall not be taken as affording any relief to the lateral bracing system or portal system. IRC:24-2010.

(iv) Portal bracings: Through truss spans shall be provided with suitably designed portal system, as deep as the clearance will allow. The portal system shall be designed to take the full end reaction of the top chord lateral system and the end posts of the portal shall be designed to transfer this reaction to the bearings. In addition, the portal system shall be designed to resist a lateral shear equal to 1.25 percent of the total compressive force in the end posts or in the top chords in the end panel whichever is greater

For detailed analysis and design, IRC -24-2010 may be referred to. However, for curved bridges, rigorous analysis should be made and detailing must follow the needs of the curvature effects.

2.2.10. Corrosion protection measures:

Reinforced concrete has generally been considered to be a durable construction material. However, of late distress has been observed in several bridges primarily due to corrosion of embedded reinforcement. The cause of occurrence of corrosion is observed due to hot and aggressive environment, defective workmanship and presence of chloride both in ingredients and/or atmosphere.

It is generally agreed that corrosion does not occur when adequate cover is provided on rebars, aided by well compacted concrete, since both water and oxygen are required in free state to initiate corrosion which will not occur in dry concrete or totally submerged condition. It is, therefore, imperative to use design mix concrete as cited in the MoRT&H specification and strict quality control may be observed especially in severe marine conditions. Many approaches are available to inhibit or delay the onset of corrosion in rebars such as (i) usage of inhibitors in concrete, (ii) application of surface sealant (on concrete), (iii) metallurgical improvements in steel, (iv) cathodic protection, and (v) protective coatings on reinforcement. Ministry has brought out a circular vide No. RW/NH 34041/44/91-S&R dated 21.3.2000 giving detailed guidelines on use of fusion bonded epoxy coated reinforcement and other coatings for bridges on National Highways and other centrally sponsored bridges to be constructed in marine environment susceptible to severe corrosion which may be followed to reduce the chances of corrosion.

2.2.11. Design of river training and protective works

2.2.11.1 River training and protective works is required for ensuring the safety of bridges and their approaches on either side. The selection of the type of river training or protective work will depend upon terrain, overall behavior of the river, location of the bridge vis-à-vis the areas of attack of the river, span arrangement, nearness of the approaches from the influence zone of the river, etc. The types of river training and protective works generally being used are as follows:

- **(i)** Guide bunds
- **(ii)** Spurs or groynes
- **(iii)** River bank protection
- **(iv)** Approach road protection
- **(v)** River bed protection

The special features along with the broad design principles for each type are described in IRC:89-1987. "The Guidelines for Design and Construction of River Training and Protective Works for Road Bridges", which may be referred to for details.

2.2.12. Preliminary cost estimate

2.2.12.1 Preliminary cost estimate shall be a reasonably firm cost estimate on the basis of which administrative approval can be accorded. It shall be based on quantities worked out during preliminary design and current schedule of rates from which no major changes either in quantities or in rates shall normally occur except under totally unforeseen circumstances.

2.2.12.2 While preparing detailed project estimate, following additional points should also be kept in view:

(i) Structural elements like light posts and cable ducts for electrification of new bridges of lengths 300m or more on National Highways may be provided, if required, and the cost thereof included in the estimate for the bridge proper provided that the Municipal Board/ concerned local authority is prepared to meet the initial cost as well as subsequent maintenance charges of electrical installations including cost of wiring, lamps etc. and also to bear the electricity charges. Accordingly, the estimate should be accompanied by a clear certificate from the local authority that is prepared to meet the cost of electric installations and maintenance charges.

(ii) All proposals for reconstruction of existing weak bridges in National Highways should be accompanied with the rating of the bridges based on detailed provisions contained in IRC Special Publication No. 9 “Report on rating of bridges" for proper appreciation. Further', the inspection of existing structure should be done for collection of data in accordance with the provisions contained in Chapter R-3 of the aforesaid publication and the required information furnished.

2.3. Detailed Project Preparation

2.3.1 Survey:

Determining the relative positions of points on the surface of the earth (all desirable points of the projected area) is an essential part of project preparation for bridge construction. Final selection of site, type of structure, type of foundation, span arrangement and alignment of approaches would be governed by the relative positions of various point of the site.

After collecting the data, preliminary design is to be undertaken keeping in view the data collected. As the preliminary investigation results are analyzed, there might be need for more details in particular areas. A further topographic survey may be required along the final alignment to verify the changes levels etc. based on detailed provisions contained in IRC: SP:54-2000, a review of the available topographic data should reveal the addition details required. Efforts should be made to collect these through and accurate instrument survey. The data collected should be accurate, detailed and exhaustive enough for use in the detailed designed stage.

Ground surveys conducted at site help in preparations of site map and river cross sections. Keeping in view that these maps are to be used in the identification of alternative locations and alignments, the surveys should be planned to be sufficiently exhaustive.

Establishment of permanent bench marks at site linked to GIS levels which are to be used during detailed survey, construction and maintenance must precede such survey.

Based on IRC: SP:54-2000 clause 5.6.3, for bridge projects across any stream / river, a hydrological survey should be carried out. The basic purpose of collecting hydrological data is to study the rainfall pattern (like intensity, duration, frequency) and run off characteristics of the basin under consideration and thereby determine the likely discharged through the channel, decide the optimum waterway for the bridge and determine the scour depth.

Based on IRC: SP:54-2000 clause 5.6.4 traffic survey should be carried out in accordance with the relevant IRC code (IRC:SP:19-2001).Traffic required to be conducted in connection with the preparation of project are as under :

Classified traffic volume counts.

(i) Origin–destination surveys.

(ii) Speed and delay studies.

(iii) Traffic surveys for the design of road junction.

(iv) Traffic surveys for replacing railway level crossings with over bridges/subways

(v) Axle load surveys.

(vi) Accident records.

2.3.2 Hydraulic Designs

Hydraulic designs done at the preliminary project report stage may be considered adequate unless special circumstances warrant updation of the same.

2.3.3 Surface and Subsurface Geotechnical Investigations

2.3.3.1 General.

The topography of J&K has naturally been gifted with one of the most diverse geological formations ranging from Greater/Intermediate/Lower Himalayas (Mountainous reaches) to Sub-Mountainous (Submontane or Foot-Hill reaches) to Plateau (Upland reaches) to Qasi-Alluvial (Trough reaches) to Alluvium (Alluvial reaches). While the network of our roads, and associated bridges, run across all such geological disposition, it is important to emphasize that very concentrated efforts are required, by executing divisions, to evaluate the surface and subsurface conditions at project sites, by way of coherent geotechnical investigation and application of appropriate geo-technique for facilitating/providing apposite foundation system, thereof.

Surface condition assessment generally includes geomorphology studies, geological mapping, geophysical and photogrammetric methods, while Sub-Surface condition assessment includes shallow or deep soil/rock sounding with sampling and testing so that design, constructability, soundness, safety, longevity of a given bridge project is duly achieved, with rational economics. Such assessment may also, customarily, form a part of other Techno-Economic Feasibility studies, based on which final proposal of bridge may be conceived.

The professional expertise, under subject domain of Surface and Sub-Surface investigation, for bridges, shall include a Geo-Structural/Geotechnical engineer, an Engineering Geologist/Geophysicist and a Hydrologist/ Hydro geologist.

2.3.3.2 Indian Standards Applicable: The mandate of following BIS/IRC Codes shall apply;

IS: 1498, IS:1888, IS: 1892, IS: 2131, IS:2132, IS:2720, IS:4434, IS: 4968, IRC:78, IRC:75, MoRT&H, IS:7292, IS:7317, IS: 7746, IS: 5313, IS: 4464, IS: 4078, IS:10042.

Specification for Road & Bridge Works, MORT&H, under section 2400 covers the requirements of Surface and Sub-Surface Geotechnical Investigations, which have been used as main source of reference literature, in this sub-section of manual.

2.3.3.3 Objective/Scope of Geotechnical Investigations

The principal objectives, that a competent surface/sub-surface investigation shall serve, for comprehensive planning, design and construction of bridge, are summarized below. This information may get compiled and eventually completed during course of process for preliminary and detailed stages of investigation. However, it is very important to emphasize that construction stage conformation of characteristics of sub-surface geo-materials shall also form a critical part of geotechnical investigations. This is to rationally evaluate the design choices made and check if any requirement arises to make adaptive changes, particularly with regards to sub-structure/foundation support system.

(i) To assess and evaluate the nature of soil overburden or rock deposits, which includes Bore-Log for type of geo-material (soil/rock), thickness and spatial variation of various deposits of soil/rock, which are likely to support the foundations of bridge structure.

(ii) To determine location and extent of soft/compressible soil layers, presence of any potential localized gas bearing seams or gas pockets or cavities/hollows, which are critical to stability of foundations.

(iii) To determine the orientation (dip & strike) of founding rock beds, their fault patterns, location of fault and their activity, fissure/fracture frequency and their permeability.

(iv) Assessment of location of HFL/ subsoil water/ground-water and quality of water encountered in foundation zone. This shall include information about any potential artesian condition.

(v) In-situ engineering property assessment during Surface and Sub-surface exploration (SRM, ERM, GPR, SPT, DCPT, SCPT, Vane Shear Test, PMT, Drill advancement rate, RQD etc.,)

(vi) Assessment of Seismic Activity/Seismic disturbances based on past earthquakes and seismic-zoning of area. This may include liquefaction studies (As per IS: 1893-part 1: 2016), for major bridge projects and assessment of any reported potential liquefaction damages of proximate structures.

(vii) Evaluation of all pertinent indexes, physical and engineering properties of soil/rock, based on testing of representative disturbed and un-disturbed samples, retrieved during sub-surface exploration and correlation of same with geophysical data established during surface exploration.

(viii) To determine depth wise particle size distribution of representative samples of sub-soil, particularly for river banks/bed of active non-regime rivers, up to significant depth, to assess silt-factor and depth/extent of scour, thereof.

(ix) Clarity on stratum profiling and classification of soils/rocks, in particular, with details of density, frictional and pore structure properties, which can be prudent for determining sinking or driving or blasting efforts for foundation.

(x) Selection of foundation type and embedment depth, with assessment of load bearing capacity and settlement characteristics.

(xi) Assessment of stability aspects of riverbanks, potential identification of slope instabilities or landslides with may have direct repercussions on stability of major bridge components.

(xii) Assessment of potential subsidence of any part of bridge component due to mining in close proximity.

(xiii) Assessment of constructional difficulties.

2.3.3.4 Field Investigation Program: Field investigations of sub-surface have usually three phases:

2.3.3.4.1 Reconnaissance: includes a review of available topographic and geological information, aerial photographs and data from previous investigations and site examination.

2.3.3.4.2 Preliminary Explorations: shall include the study of existing geological information, previous site reports, geological maps, aerial photos, etc. and surface geological examination. For large and important structures the information may be supplemented by geophysical methods {like Seismic Reflection Method, Seismic Refraction Method, Cross-Hole Test, Down Hole Test & Up-Hole Test, Seismic Cone Penetration Test (SCPT), Spectral Analysis of Surface Wave (SASW), Multichannel Analysis of Surface Waves (MASW) and Ground Penetration Radar (GPR)}. In some cases where no previous sub-strata data are available, exploratory geophysical investigation may need to be supplemented by resorting to a few bore-holes. These will help to narrow down the number of sites under consideration and also to locate the most desirable location for detailed sub-surface investigation like bore or drill holes, sounding probes, etc.

2.3.3.4.3 Detailed Explorations: The scope of detailed investigation for bridges may be decided based on data obtained after preliminary investigation so that the bridge site, type of structure with span arrangement and the location and type of foundations, can be tentatively decided. Thereafter, the scope of detailed investigation including the extent of exploration, number of bore-holes, type of soundings, type of tests, number of tests, etc., shall be decided, so that adequate data considered to be necessary for the detailed design and execution, are obtained.

2.3.3.5 Field Work: Soil investigation for foundations shall contain a programme for boring/drilling and retrieval of samples. The field work shall consist of excavation, drilling of bore-holes for the purposes of collection of undisturbed and disturbed samples, standard penetration tests, in-situ vane tests, static and dynamic cone penetration tests, other field tests, as specified by the Engineer and preparation of bore-logs. Collection, preservation and testing of disturbed and undisturbed samples, from bore holes, borrow pits, etc., as specified by the Engineer, shall form a part of the above. All in-situ tests shall be supplemented by laboratory investigations. Relevant Indian Standards such as IS: 1498, IS:1888, IS:1892, IS:2131, IS:2720, IS:4434 and IS:4698 and Appendix I of RIC:78, IRC:75 etc., shall be followed for guidance. The soundings by dynamic method shall be carried out in bore-holes using a standard sampler as specified in IS: 2131.

2.3.3.5.1 Location, Extent and Number of Boreholes:

The Specification for Road & Bridge Works, MoRT&H, section 2402, shall apply under this section. The type and extend of exploration shall be divided into the following groups as per requirement of foundation design and likely method of data collection:

(i) Foundation requiring shallow depth of exploration

(ii) Foundation requiring large depth of exploration

(iii) Fill behind abutments and protection works

The exploration program shall cover the entire length of the bridge and also extend at either side for a distance about twice the depth below bed of the last main foundations. Bores shall be taken at the location of each pier and abutment of the bridge. In case of short-span bridges, it may be adequate if the boreholes are made at alternative pier positions. For long span of over 20m, it will be necessary to take bores at every pier and abutment location. For well and pile foundation, sometimes more than one bore at each pier location is desired, particularly if subsoil is rocky and un-even. For high value projects, it is desirable to have few representative bores in addition on the upstream and downstream of the alignment, to have an idea of the nature of change of strata along the river.

If there is any necessity for designing investigation for approaches particularly on soft soil or with high embankment or there is a possibility of considering alternatives between viaduct or earthen embankment, the extended length and location of the borings beyond the proposed location of abutment should be determined and executed, rationally. However, a minimum of two bores shall be taken in the approaches on either side, along the center line of the bridge alignment, at a distance of 50m and 120m behind the abutment positions. In case of viaducts in the approaches on either side of the bridge, bores shall be taken at the location of each foundation of the viaduct spans.

Wherever the data made available, by the detailed exploration, indicates appreciable variation or where variations in a particular foundation are likely to appreciably affect the construction (specially in case of bridge foundations resting on rock), it will be necessary to resort to additional bores/soundings, in transverse directions also, to establish complete profile of the underlying strata. The additional borings/soundings shall be decided depending upon the extent of variation at a particular foundation location and should cover the entire area of that particular foundation.

2.3.3.5.2 Depth of Bores:

The Specification for Road & Bridge Works, MoRT&H, section 2403, shall apply under this section.

Important Zones of Investigations:

The subsurface investigation for bridges shall be carried out on the following three zones:

(i) Between bed level and up to anticipated maximum scour depth (below HFL).

(ii) From the maximum scour depth to founding level.

(iii) From founding level to a significant depth below foundation, which is generally a factored value of width of foundation.

The depth of exploration should be at least 1½ times the width of foundation below the proposed foundation level. Where such investigation end in any unsuitable or questionable foundation material (or with doubtful bearing capacity) the exploration shall be extended to a sufficient depth into firm and stable soils or rock but not less than four times the width of foundation, below the earlier contemplated foundation level. In case of good sound rock with RQD of more than 75, the stipulation of minimum depth may be decreased based on difficulty to conduct core drilling and the minimum depth may be restricted to 3 meters.

2.3.3.5.2.1 Exploration for Embankments and Guide Bunds

For embankments and guide bunds, the depth of exploration should include all strata likely to affect stability of the embankment, guide bund and/or cause undesirable settlement. In general, the requirement of settlement governs the depth of exploration for high embankments in particular. Ordinarily, the depth of bore holes below the ground level may be taken up to 2.5 times the maximum height of embankment/guide bund. However, borings can be terminated at shallower depths when firm strata or bed rock is encountered. Where highly compressible strata are encountered, the boring may have to be taken deeper. In order to ensure that a firm stratum is sufficiently thick, the boring should extend 3 meter into the firm strata.

Detailed exploration for high embankments is to ascertain the average shear strength of each stratum and to ascertain the compressibility characteristics of the clayey strata. It is, therefore, necessary that detailed and well-illustrated description of the characteristics of stratification should be prepared. After the general shape and trend of the boundaries of the various soil deposits have been determined and rough assessment of their strength has been made by sub-surface sounding, with or without sampling in exploratory boring, the location of bore-hole(s) for undisturbed sampling shall be decided. At least one representative undisturbed sample should be collected from each strata. When the homogeneous strata is very thick, one representative sample shall be collected for each 3 m thickness of the strata. For guidance reference may be made to IRC 75.

Whenever a change in the sub-soil strata/rock profile is encountered during construction, further explorations shall be resorted to establish the correct data for further decisions and revisions of foundation designs, thereof.

Logging of bore-holes by radio-active methods shall be done for detailed investigations as specified in the contract or in special provisions.

2.3.3.6 Provisions for investigations for Bridge Foundations resting on Rock

The Specification for Road & Bridge Works, MoRT&H, section 2405, shall apply under this section. Investigation and interpretation of data for rock is a recognized as a specialized work, for which the services of an Engineering Geologist/Structural-Geologist, shall be necessarily availed. To arrive at the characteristic strength of rock mass, reliance shall be placed more on in-situ tests in comparison to laboratory tests.

Identification and classification of rock types for engineering purpose may, in general, be limited to broad, basic geological classes in accordance with accepted practice. Strength assessment shall be based on overall characteristics of rock formation like origin/nature of rocks, spacing and distribution of discontinuities of the rock mass, fracture/joint frequency, bedding planes, faults and presence of weathered seams. Another important factor affecting the behavior of the rock, as founding material, is the weathered zone at top. Assessment of foundations, resting over rock formations shall never be made based on strength of parent rock, alone.

Categorization of rocky subsurface shall also be explicitly made like; Sound Rock (≥85% core recovery), Medium Rock (≥50% core recovery), Intermediate Rock (≥35% core recovery) and Soft Rock (<35% core recovery but Standard Penetration Resistance value "N" is >50). For core recoveries less than 20%, the subsoil strata must be treated as soil, instead of rock.

2.3.3.6.1 Information required from exploration/investigation within rock/rock-mass

Following information shall be deemed mandatory:

(i) Identification and characterization of Geological System.

(ii) Depth of rock strata and its variation over the site, particularly over length of bridge.

(iii) Whether subsurface consists of an isolated boulder or a massive/continuous rock formation, particularly if met with at shallow or erratic depths in adjacent bores,

(iv) Extent/thickness and character of weathered zone,

(v) Structure of rock - including bedding planes, faults, fissures, solution cavities etc.,

(vi) Properties of rock material-strength, geological formation, etc,

(vii) Erodibility of rock to the extent possible, where relevant, particularly when met at shallow depths,

(viii) Color, quality and quantity of water coming out during drilling operation.

(ix) Seismicity of the area, based on macro/micro zonation.

2.3.3.6.2 Extent of Investigation within rock/rock-mass

If preliminary investigations have revealed presence of rock within levels where the foundation is to rest, it is essential to take up detailed investigation to collect necessary information mentioned, above. The exploratory bore-hole shall be drilled into the rock to a depth of about 3 meters to distinguish a boulder from a continuous rock formation.

The extent of exploration shall be adequate enough to cover the whole area of the bridge site for general characteristics and in particular, the foundation location, to obtain definite information regarding depth of rock and its variation over the foundation area. A complete picture of the rock profile both in depth and across the channel width is necessary to assess the constructional difficulties in reaching the foundation levels. The detailed programme of exploration will depend on the type and depth of over-burden, the size and importance of the structure, etc. To decide this, geophysical methods adopted at the preliminary investigation stage will be helpful, this data being supplemented by sounding, bore-holes and drill holes.

The depth of boring in rock depends primarily on local geology, erodibility of the rock, extent of structural loads to be transferred to foundation etc. Normally, it shall pass through the upper weathered or otherwise weak zone, well into the sound rock. Minimum depth of boring in sound rock shall be 3.0meters.

As stated earlier, the drilling through rock is a very specialized work and every care shall be taken to notice and record any small change during drilling. The time required to drill through a certain depth, amount of core recovery, physical condition, length of pieces of core, joints, color of water residue, weathering and evidence of disturbance and other effects shall be carefully noticed and entered in the drilling log. For guidance, IS: 5313 may be referred to. The data shall be presented in accordance with IS: 4464.The cores shall be stored properly in accordance with IS: 4078.

2.3.3.6.2.1 Testing of Rocks

The rock cores obtained shall be subjected to following tests:

(i) Visual identification for texture, structure, composition, color and grain size.

(ii) Laboratory tests shall be done for specific gravity, porosity and moisture content.

Use of in-situ tests for measuring strength and deformation characteristics shall be made. In-situ tests shall be made in accordance with IS: 7292; IS:7317; and IS:7746. Use of bore-hold photography will be desirable to evaluate the presence of faults, fissures or cavities, etc.

The quality of rock cores shall be classified according to Rock Quality Designation as presented in **Table: 2.3,** below;

TABLE-2.3 Classification of Rocks as per RQD

S.No	RQD Percent	Core Quality
1.	90-100	Excellent
2.	75-90	Good
3.	50-75	Fair
4.	25-50	Poor
5.	25	Very Poor

2.3.3.6.3 Gravel-Boulder Deposits

Investigation for foundation in Gravel-Boulder Deposits shall conform to specifications of IS: 10042.

2.3.3.6.4 Caution

The interpretation of laboratory results on rock samples depends upon the relationship of the specimens tested to the overall rock characteristics, enumerated in Appendix 1 of IRC: 78. For this purpose, care shall be exercised in the choice of specimen size and its orientation in relation to the joint pattern.

In some cases, the foundation behaviour will be dominated by a possible mode of failure involving movement along some joint surface, fissures or weak layer within a generally strong rock system and also by possible weathering. In-situ shear tests may be conducted wherever feasible, as such tests are likely to give more representative data than the shear tests conducted on core samples.

2.3.3.6.5 Presentation of Data

The data shall be given in diagrammatic form in 3 sheets giving the following details:

Sheet 1: Plan showing the position of bore-holes clearly marked so as to fix the position/location at a future date.

Sheet 2: This shall contain the bore-log chart and test results of the samples separately for each bore-hole/pit etc.

Sheet 3: This shall contain pictorial representation of the bore-log data to get an overall picture of the soil profile at the cross section of the river.

Schematics representation of typical subsoil profile, the actual bore-log and cross-sectional representation of the river, along the bridge, as per IRC: 78-2014, is reproduced at **Fig-2.3a to Fig-2.3c**, below.

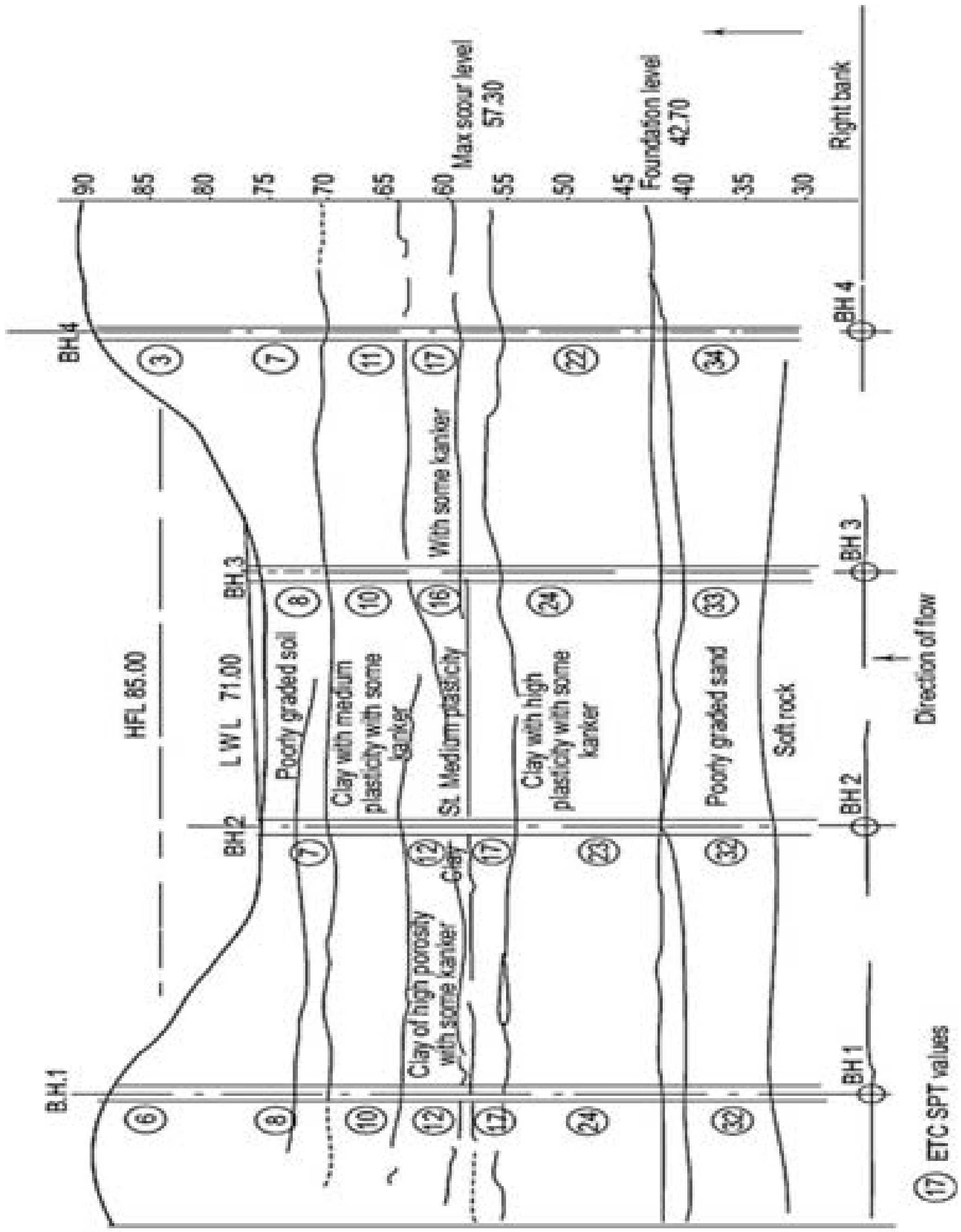


Fig-2.3a: Schematics of typical subsoil profile.

Fig-2.3b: Typical bore-log.

REFER TO IRC 78:2014

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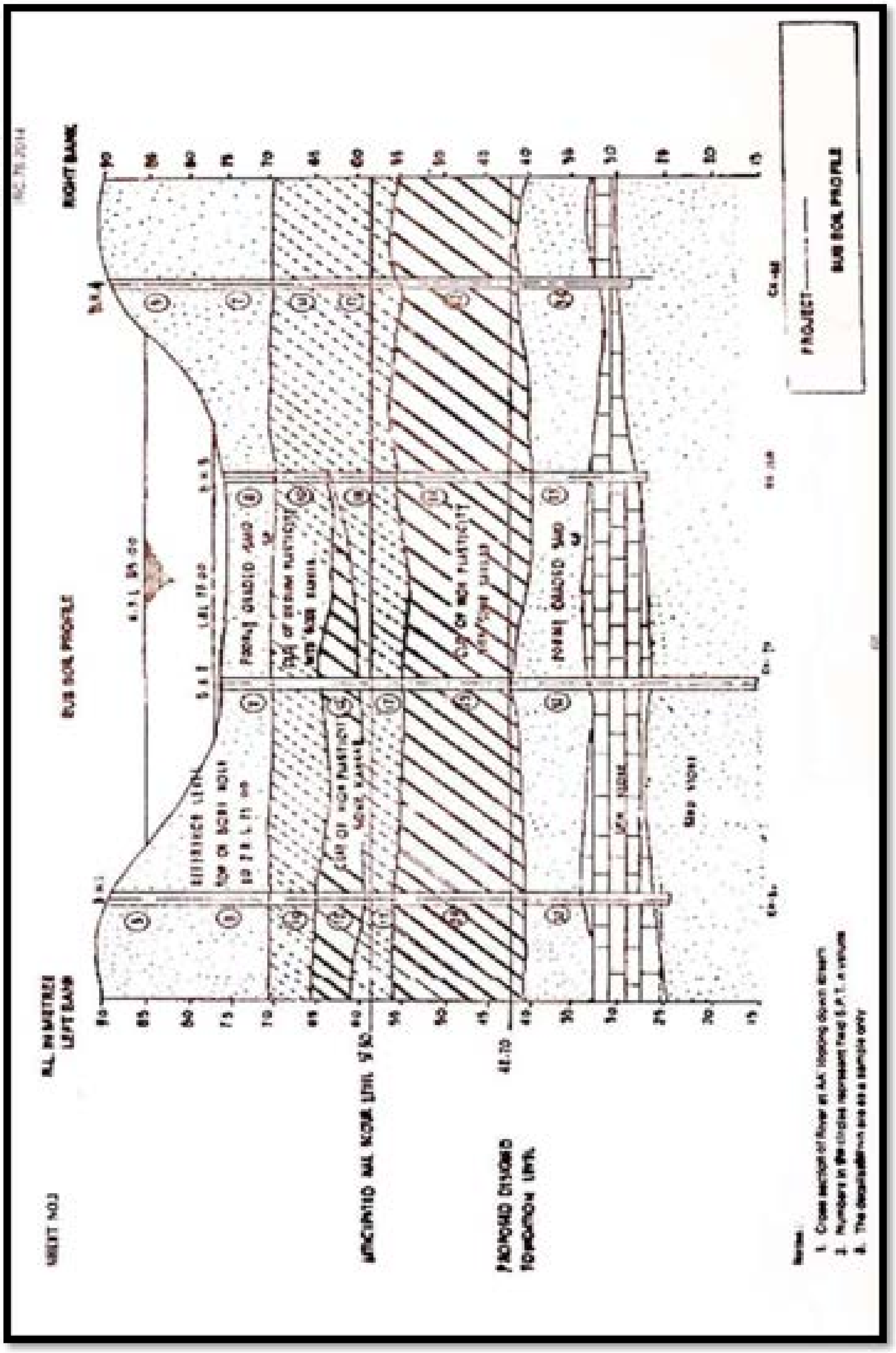

Fig-2.3c: Typical Cross-Section indicating subsoil profile.

2.3.3.7 Boring/Drilling Operation

The Specification for Road & Bridge Works, MoRT&H, section 2406, shall apply under this section. The exploratory boreholes in soils/rocks shall be executed by any of the following methods, depending on the soil/rock type and types of samples required for the investigation:

- ❖ Auger Boring
- ❖ Shell and Auger Boring
- ❖ Percussion Boring
- ❖ Wash Boring
- ❖ Rotary Boring/Drilling.

Details specifications as per IS: 1892, IS:2132 may be referred.

For preliminary and detailed sub-surface investigation only rotary drills shall be used, in case of rocks. The casing, in such cases, shall also be invariably provided with diameters not less than 150 mm up to the level of hard rock, if any. However, use of percussion or wash boring equipment shall be permitted only to penetrate through bouldery or gravelly strata for progressing the boring but not for the collection of samples. While conducting detailed borings, the resistance to the speed of drilling i.e. rate of penetration, core loss, etc., as already specified in Annexure of IRC: 78, shall be carefully recorded, to evaluate the different types of strata and to distinguish specially sand from sandstone, clay from shale, etc.

2.3.3.7.1 Records of Boring and Trial Pits

The Specification for Road & Bridge Works, MoRT&H, section 2407, shall apply under this section. The field records for the preliminary and detailed exploration shall contain the date when the boring was made, the location of the boring with reference to a permanent system of co-ordinates (Geo-tagging/GPS marking is desirable) and the elevation of the ground surface with respect to a permanent bench mark. They shall include elevation at which the water table and the upper boundary of each of the successive soil strata were encountered, the investigator's classification of the layer on the basis of general information obtained from field examination (refer to Appendix 2.1 of IRC:75) and the value of the resistance obtained by means of Standard Penetration Test. The type of tools used for borings shall be recorded. If the tools were changed, the depth at which the change was made and the reason thereof shall also be noted. Incomplete and abandoned borings shall be described with no less care than successfully completed drill holes. The notes shall contain everything of significance observed on the job such as the elevation at which wash water was lost from the hole.

2.3.3.7.2 Information in Boreholes/Trial pits.

For all borings and trial pits, necessary information as detailed below shall be given. A site plan showing the disposition of the bore holes shall also be attached:

- ❖ Name of Agency.
- ❖ Location with reference map.
- ❖ Pit/Bore-hole number.
- ❖ Reduced level (RL) of ground surface or other reference point.

- Dates of starting and completion.
- Name of supervisor.
- Scales of plans and sections.
- Description of methods of advancing exploration such as; by hand tools, blasting, boring, etc.
- General description of strata met with and RLs at which they are met.
- Position and altitude of contracts, faults, strong joint, slicken sides, etc.
- Inflow of water, methods of controlling the water, required capacity of pumps for dewatering
- The level at which the sub-soil water is met with.
- Dip and strike o bedding and of cleavage
- Visual description of strata
- Results of field tests e.g. SPT, in-situ vane shear test etc.
- Any other information and remarks.
- The length of the sample in the tube and the length between the top of the tube and the top of the sample, in the tube, shall be measured and recorded, upon removal of sampling tube.

2.3.3.8 Method of Sampling.

The Specification for Road & Bridge Works, MoRT&H, section 2408, shall apply under this section

2.3.3.8.1 Soil Sampling.

The details for method of sampling may be referred from IS:1892 & IS: 2132 and process of sampling shall conform to same. For proper identification of sub-surface material, sample should be recovered containing all the constituents of the materials in their proper proportion. In clayey deposits such samples could be collected by spilt spoon samplers. In the case of sandy deposits, sampling spoons shall be fitted with suitable devices for retaining samples. All data required for soil identification (Appendix 2.1 of IRC:75) should be collected from the samples so extracted when undisturbed samples, which are more desirable for collection of some of the data, are not available. Penetration test should be carried out with the standard split spoon sampler or penetrometers if the soil is coarse grained. When it is known in advance that the soil profile is fairly regular, preliminary and detailed investigation may be combined. Tube samplers can be used in place of split spoon samplers for collecting samples in clayey strata.

Generally there are two types of samples viz. (a) Disturbed sample (b) Undisturbed sample for both soils and rocks, as presented below in Table-2.4.

Table- 2.4 Type and method of sampling for various ground characteristics.

Nature of Ground	Type of Sample	Method of Sampling
Soil	Disturbed	Hand Samples Auger Samples Shell Samples
	Undisturbed	Hand Samples Tube Samples
Rock	Disturbed	Wash Samples from Percussion of rotary drilling
	Undisturbed	Cores

2.3.3.8.1.1 Disturbed Soil Samples

Disturbed samples of soil shall be obtained in the course of excavation and boring. For procuring samples from below the ground water level, where possible, special type of sampler shall be used. Where Standard Penetration Test is conducted, representative samples shall be obtained from the split spoon. While collecting disturbed samples from borrow areas it shall be ensured that the samples collected represent all types of borrow materials to be used in the construction of embankment and sub-grade. The size of sample generally required shall be as given in Table-2.5.

Table-2.5 Size/Magnitude of sample required for various Soil types.

S.No.	PURPOSE OF SAMPLES	SOIL TYPE	WEIGHT OF SAMPLE REQUIRED (Kg)
1	Soil identification, natural moisture content tests, mechanical analysis and index properties, chemical tests	Cohesive soils	1
		Sands and Gravels	3
2	Compression tests	Cohesive soils and sand	12.5
3	Comprehensive examination of construction material and borrow area soil including soil stabilization.	Cohesive soils and sands	25 - 50
		Gravelly soil	50 – 100

While taking out disturbed soil samples, Standard Penetration Test may also be conducted to find out the bearing capacity of the sub-soils at specified levels.

2.3.3.8.1.2 Undisturbed Soil Samples

For undisturbed sampling procedure, the samples shall be obtained in such a manner that their moisture content and structure do not get altered. This may be ensured by use of correctly designed sampler and by careful preservation, packing and transportation.

Standard Penetration Test may have to be conducted in each case to obtain additional data as directed by the Engineer. In soft clay, in-situ vane shear test as per IS: 4434 may have to be conducted. Where all the three operations have to be carried out in one layer, the sequence shall be undisturbed soil sampling followed by in-situ vane shear test, followed by Standard Penetration Test.

For compression test samples, a core of 40 mm diameter and about 150 to 200 mm length may be sufficient, but for other laboratory tests, a core of 100 mm diameter and 300 mm length shall be taken as far as possible, unless otherwise specified by the Engineer.The upper few millimeters of both types of sample shall be rejected as the soil at the bottom of the borehole usually gets disturbed by the boring tools.

2.3.3.8.2 Rock Sampling.

2.3.3.8.2.1 Disturbed samples: The sludge from percussion borings or from rotary borings which have failed to yield a core, shall be collected for a disturbed sample. It may be recovered from circulating water by settlement in a trough.

2.3.3.8.2.2 Undisturbed samples: Block samples taken from the rock formation shall be dressed to a size of about 90 x 75 x 50 mm.

For core samples within rocks, the cores of rock shall be taken by means of rotary drills fitted with a coring bit with core retainer, if warranted.

In case of rock at shallow depths which can be conveniently reached, test pits or trenches are the most dependable and valuable methods since they permit a direct examination of the surface, the weathered zone and presence of any discontinuities. It is also possible to take representative samples for tests. For guidance, IS: 4453 may be referred to.

2.3.3.8.3 Preservation, Handling and Labeling of samples.

The Specification for Road & Bridge Works, MoRT&H, section 2410, shall apply under this section. Care shall be taken in handling and labeling of samples so that they are received in a fit state for examination and testing and can be correctly identified as coming from a specified trial pit or boring.The disturbed material in the upper end of the tube shall be completely removed before applying was for sealing. The length and type of sample so removed should be recorded.

The soil at the lower end of the tube shall be renamed to a distance of about 20 mm. After cleaning, both ends shall be sealed with wax applied in a way that will prevent wax from entering the sample. Wax used for sealing should not be heated to more than a few degrees above its melting temperature. The empty space in the samplers, if any, should be filled with moist soil, saw dust, etc., and the ends covered with tight fitting caps.

Labels giving the following information should be affixed to the tubes.

- Job designation

- Sample location
- Boring number
- Tube number
- Sample number
- Depth
- Penetration
- Gross recovery ratio

The tube and boring numbers should be marked in duplicate. The duplicate markings of the boring number and sample number on a sheet which will not be affected by moisture should be enclosed inside the tube.

2.3.3.9 Exploration of Shallow Foundations of Bridges.

The Specification for Road & Bridge Works, MoRT&H, section 2412, shall apply under this section. Test pits or trenches are the most dependable and valuable methods of exploration since they permit direct visual examination and more reliably the type of soil and their stratification. This will also allow in-situ tests like plate bearing tests, shear tests and uni-axial jacking tests, etc.Tests shall be conducted on undisturbed samples, which may be obtained from open pits. The use of Plate Load Test (as per IS: 1888) is considered desirable to ascertain the safe bearing pressure and settlement characteristics. A few exploratory bore holes or soundings shall be made to safeguard against presence of weak strata underlying the foundation. This shall extend to a depth of about 1½ times the proposed width of foundation.

The laboratory results shall correlate with in-situ tests like Plate Load Tests and Penetration Test results.

2.3.3.10 Exploration of Deep Foundations of Bridges.

The Specification for Road & Bridge Works, MoRT&H, section 2412, shall apply under this section. The tests to be conducted at various locations for properties of soil, etc., are different for cohesive and cohesionless soils. These are enumerated below and shall be carried out, wherever practicable, according to soil type.

2.3.3.10.1 Tests for Cohesionless soil

a) Field tests
- Plate Load test as per IS: 1888
- Standard Penetration test as per IS: 2121.
- Dynamic Cone Penetration test as per IS: 4698 (Part 1 or Part 2)
- Static Cone Penetration test as per IS:4968 (Part 3)

b) Laboratory tests

- ❖ Classification test, index tests, grain size distribution, density/density index etc.
- ❖ Shear Strength by direct shear/triaxial shear test method.
- ❖ Permeability/hydraulic conductivity tests (Where dewatering is expected, IS: 2720 Part 17).

2.3.3.10.2 Tests for Cohesive soil

c) Field tests

- ❖ Plate Load test as per IS: 1888.
- ❖ Standard Penetration test as per IS: 2121.
- ❖ Dynamic Cone Penetration test as per IS: 4698 (Part 1 or Part 2)
- ❖ Static Cone Penetration test as per IS:4968 (Part 3)
- ❖ Vane Shear test as per IS:4434.

d) Laboratory tests

- ❖ Classification test, index tests, grain size distribution, density/density index etc.
- ❖ Shear Strength by direct shear/triaxial shear test method.
- ❖ Unconfined Compression test as per IS:2720 Part-10.
- ❖ Consolidation test as per IS: 2720 Part-5.
- ❖ Permeability/hydraulic conductivity tests (Where dewatering is expected, IS: 2720 Part 17).

2.3.3.10.3 Tests for Subsoil Water

The sub-soil water shall be tested for chemical properties to ascertain the hazard of deterioration to foundations.

2.3.3.11 Testing of material for foundation of guide bund and High Embankments.

The Specification for Road & Bridge Works, MoRT&H, section 2413, shall apply under this section.

The soil properties for the embankment foundation shall be as specified in particular specifications and shall be got verified prior to construction operation. In case the actual soil properties do not match the particular specification, then embankment design shall be revised. Field investigation for the embankment material should be carried out to collect general information as indicated in IRC: 75.

Field investigations for sub-soil strata shall consist of taking minimum two bore holes for each approach to a bridge along center line of the alignment at a distance of 50 m and 120 m behind the abutment positions on both sides. The depth of bore holes below the ground level may ordinarily be 2.5 times the maximum height of the embankment subject to minimum depth of 20 m. Thin walled sampling tubes of 100 mm internal diameter and 450 mm minimum length conforming to IS: 2132 shall be used for collecting undisturbed samples from bore-holes at an interval of 2.5 to 3.5 m. Standard penetration test should be conducted immediately after undisturbed sample is collected.

In addition to the relevant identification tests, mentioned in IRC:75, it shall be necessary to conduct some of the following tests (Table-2.6) on the undisturbed samples collected from the sub-strata for stability analysis of embankment. The choice of test is primarily determined by the type of soil, type of stability analysis, availability of apparatus and cost of investigation.

Table-2.6 Shear Strength Tests for Stability Analysis of Embankments

S.No.	Stage in Life of Embankment	Strength Parameters	Shear Test	Type of Analysis
1.	(a)During construction or immediate post-construction	Cuu, ϕuu	Unconsolidated undrained triaxial shear test on undisturbed samples and on compacted embankment material	Total stress analysis
	(b) - do -	Su	Unconfined compression test in laboratory or vane shear test	- do -
	(c) During construction or immediate post-construction	C'ϕ'	Consolidated undrained test with pore-pressure measurement on as compacted soil samples of embankment materials and on undisturbed samples	Effective stress analysis
2.	Long term stability	C'ϕ'	- do -	- do -

While compiling a geotechnical report for embankment, results of reconnaissance, filed investigations, location map, sub-soil profile, pertinent geological information, boring logs, subsoil properties, graphs, tables related to laboratory investigations, results of borrow area investiagtions, as per recommendations of IRC: 75 must be adhered.

2.3.3.12 Subsurface investigation for Piles.

The Specification for Road & Bridge Works, MoRT&H, section 1102, shall apply under this section. The complete sub-surface investigation of strata in which pile foundations are proposed shall be carried out in advance and by in-situ pile tests. At least one bore-hole for every foundation of the bridge shall be executed. Boring should be carried upto sufficient depths so as to ascertain the nature of strata around the pile shaft and below the pile tip. However, depth of boring shall not be less than following:

a) 1.5 times estimated length of pile in soil but not less than 15 m beyond the probable length of pile.
b) 15 times diameter of pile in weak/jointed rock but minimum 15 m in such rock.
c) 4 times diameter of pile in sound, hard rock but minimum 3 m in such rock.

The sub-surface investigation shall define adequately stratification of sub-strata including the nature and type of strata, its variation and extent and specific properties of the same. The investigation shall be adequate for the purpose of selection of appropriate piling system and for estimating design capacities for different diameters and length of piles.

Pressure meter tests may be used in the case of rock, gravel of soil for direct evaluation of strength and compressibility characteristics. Though these tests are of specialized nature they are most appropriate for difficult/uncertain sub-strata especially for important projects.

For piles socketed into rocks, it is necessary to determine the uniaxial compressive strength of the rock and its quality. The investigation shall also include location of ground water table and other parameters including results of chemical tests showing sulphate and chloride content and any other deleterious chemical content in soil and/or ground water, likely to affect durability.

2.3.3.13 Presentation of Surface, Sub-Surface Investigation.

Preliminary or Detailed surface or subsurface investigation shall be compiled and presented in the form of a Competent Geotechnical Investigation Report, with following minimum typical contents, as per Table-2.7.

Table-2.7 Typical Content of a Geotechnical Investigation Report

S.No	Content Description
1	**General** 1.1 Introduction. 1.2 Project Description & Scope of Investigation Work. 1.3 Previous preliminary investigation inputs/reports.
2	**Geologic Condition & General Reconnaissance** 2.1 Regional/Local Geologic Assessment. 2.2 Seismicity/Anticipated Geological Hazard. 2.3 Climatic Conditions. 2.4 Site Accessibility. 2.5 Reported Highest Flood Level & History of Scour from Water Courses.
3	**Field/ Reconnaissance Exploration Protocol.** 3.1 Site Selection and Extent of Investigation. 3.2 Exploration Methodology (Boring/Open Excavation/Drilling). 3.3 Sampling Practice (UDS/RD/DS/). 3.4 Sub-Soil Water/Seepage Conditions. 3.5 Field Bore Logs & General Stratification/ Stratum Profiling.

4	**Laboratory Investigations/Testing Protocol.** 4.1 Soil/Rock Identification/Classification Tests (Index Properties). 4.2 Soil/Rock Strength Characterization. 4.3 Soil/Rock Compressibility/Compaction Characterization. 4.4 Ground /Soil-Water Characterization. 4.5 Chemical Analysis.
5	**Foundation Analysis Criterion & Design Parameters.** 5.1 Analysis Criterion (BIS-Code of Practice). 5.2 Geometrical Parameters & Assumptions for Analysis Criterion. 5.3 Liquefaction Potential & Probable Ground Damage. 5.4 Silt-Factor and Scour Depth (if applicable).
6	**Analysis of Results & Recommendations.** 6.1 Bearing Capacity Analysis & Results. 6.2 Pile Capacity Analysis & Results. 6.3 Design inputs for Well-Foundations. 6.4 Design inputs for Retaining Fronts. 6.5 Design inputs for Excavated Material and its suitability of use. 6.6 Design inputs for Approach Embankments. 6.7 Recommendations for Bearing Capacity.
7	**Critical Comments/Discussions & All Technical Recommendations.**
8	**Appendix** Appendix-A (Field Bore Logs with location GPS coordinates). Appendix-B (Laboratory Test Results). Appendix-C (Nomenclature). Appendix-D (References: Codal Specifications, Literature/Internet citations) Appendix-E (Geo-tagged Site Photo Manifestations)

2.3.3.14 Measurement for Payment and Rate.

The Specification for Road & Bridge Works, MoRT&H, section 2414, shall apply under this section.

In case of bridge and road structures, the work of boring and trial pits shall be considered as incidental to the foundation works and nothing extra shall be paid unless otherwise specified in the contract. In cases where it is specified to be paid separately, like contract for soil investigation, the work shall be measured in running meters for boring, in cubic meters for trial pits, in number of samples for collection of disturbed and undisturbed samples and in number of tests for each type of test.

The contract unit rate shall include the cost of all labour, materials, tools and plant and equipment required for doing the boring or making pits as per these specifications, taking out and packing the samples, sending and getting them tested in approved laboratories and making available the test report as specified or directed by the Engineer inclusive of all incidental costs to complete the work as per the specifications.

2.3.4. Detailed Structural Design

2.3.4.1. Preferably detailed design should be done top downwards, i.e. Superstructure to be finalized first, bearings next and so on, though it is started from foundation onwards in design and build contracts.

2.3.4.2. Superstructure

(i) Detailed design and detailing of each of the elements of the superstructure have to be done during this phase.

(ii) In case computer programmers' are used for the analysis and/or detailing, it has to be ensured that the programmer has been adequately validated.

Also listing of input data and input values needs to be thoroughly checked and indicated for verification by approving authority.

2.3.4.3. Bearings: Detailed design of bearings shall conform to IRC: 83 Parts I & II for metallic and neoprene bearings and in case of special type of bearings like POT/PTFE bearings, specialized literature and codes and MoRT&H Specifications for Roads & Bridge Works Section 2000 clause 2006 may be referred and complied with.

2.3.4.4. Substructures: Unlike the typical design in preliminary stage, while preparing detailed design all individual piers, abutments, return walls etc. which have any difference with regard to the forces acting, height of substructure etc. have to be separately analyzed and designed individually if economy/safety demands so.

2.3.4.5. Foundation: In the case of foundations also each individual foundation has to be designed separately during the detailed design stage taking into account difference in founding levels and the subsoil data as obtained at each of the individual foundation locations during detailed subsurface investigations.

2.3.4.6. Secondary elements: Detailed design of secondary elements like railings/crash barriers, expansion joints, kerbs, footpaths, approach slab etc. have also to be included in the D.P.R.

2.3.5 Detailed estimate

2.3.5.1. Detailed Estimate shall be based on detailed items of work constituting the construction of proposed bridge with an unerring precision which shall not deviate the final bill unless under unforeseen circumstances. The items of the estimate may be arranged systematically in the following order.

(i) Preparatory works

(ii) Foundation

(iii) Substructure

(iv) Superstructure

(v) Protection Works/ River training works

(vi) Miscellaneous items

(vii) Sub-estimate for approaches

(viii) Centage charges like quality control contingencies work charged establishment and agency charges.

(ix) Clearance of accumulated debris during and after foundation works which may constrict / obstruct the water way.

2.3.5.2. The bill of quantities have to be based on detailed quantity estimates which again have to be based on detailed design and dimensions so arrived at for all the elements of the bridge on SSR latest.

2.3.5.3. The rates adopted shall be the current schedule of rates applicable for the region and wherever same items are not covered by the schedule, the rate for the same shall be based on detailed analysis of rates in vogue.

2.3.5.4. The abstract of cost estimate containing the complete nomenclature of each item of works, final quantities as worked out in the detailed estimate, rates as in Para 2.3.5.3 cost of each item and remarks, if any, shall invariably form part of the detailed estimate.

2.3.6 Detailed project report:

Detailed Project Report should contain the following live volumes namely:

1) Final Report
2) Detailed Designs
3) Detailed Estimate
4) Detailed Bill of Quantities and Specifications
5) Detailed Drawings.

2.3.6.1. Final report: The final Report should contain:

(i) Introductory report indicating the location of the bridge, the need for the same, the population and economic activities likely to be served by the bridge, alternative sites considered and the aspects in favor of the site finally selected.

(ii) Design data for the bridge including survey data, hydraulic data and subsoil data.

(iii) Detailed information on the general arrangement selected for the bridge and the factors favoring the choice.

(iv) Report on the environmental impact assessment as per the format laid in JKPWD Manual 2020 appendix 100.2.

(v) A schedule of construction including a CPM chart in case of major projects; and at least a Bar chart indicating important mile stones in other cases.

(vi) After analyzing various economical options in preliminary designs, the final most economical design should be adopted in detailed project report.

2.3.6.2. Detailed designs: Detailed design sheets of all components of the bridge have to be included in this volume.

2.3.6.3. Detailed estimate: This volume should contain all the items covered under Para 2.3.5.

2.3.6.4 Detailed bill of quantities and specifications: The detailed bill of quantities should contain the reasonably firm quantities of each item of work forming part of the project worked out on the basis of detailed drawings. The detailed specifications of each of the items of the project.

2.3.6.5 Detailed drawings: This volume should contain the following:-

(i) Index plan

(ii) Site plan

(iii) At least three cross sections of the river.

(iv) A longitudinal section connecting the cross section points.

(v) A contour survey plan

(vi) Bore log data

(vii) A general arrangement drawing of the bridge superimposed on the cross section of the river al at the proposed site also indicating the bore details

(viii) Detailed drawings of all the components of the bridge

(ix) Complete details of existing bridges, if any

(x) Plan and L section of approaches

(xi) Cross section of approaches

(xii) Detailed drawings of CD. Works

(xiii) Miscellaneous drawings

2.3.6.6 Bridge Utilities: -Bridges don't just help people and vehicles move from place to place, although that is their most visible function. Bridges in fact serve as a supporting structure for lots of utilities. Everything from water supply pipe lines, electric cables to fiber optic cables runs through the space running throughout the bridge.

Without bridges, pipeline would need to be buried or suspended in the air. Bridges protect these utilities from threats like weather, animals and other accidents. Bridge – attached utilities are far easier to access and maintain than utilities installed underground.

Here are few reasons why bridge attached utilities should be installed by experts in conjunction with the construction of a new bridge, not after the job.

(i) Holistic design always creates a higher performing product. When utility pipelines are considered during construction, the entire structure can be designed and built with pipelines, joints and maintenance access points in mind.

(ii) Integrated design reduces the risk of unforeseen consequences of a new utility installation such as weakening of bridge component or stress on the structural support.

(iii) When designed specifically for a place and time rather than implemented ad-hoc, utility components can be matched specifically to the bridge including its materials and aesthetics.

2.3.6.6.1 Provision for Utilities as specified in IRC: 5-2015

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

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

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

3. CONSTRUCTION

3.1 General

3.1.1 The construction of a bridge involves building of its various components such as foundation, substructure, superstructure and other ancillary works which include construction of approaches, finishing works and protective works for the bridge.

3.1.2 The execution of a bridge may be taken up departmental or through a contracting agency. Before start of construction work, care must be taken to ensure that the following documents are available:

- **(i)** Sanction letter and technical note, if any.
- **(ii)** Bill of quantities.
- **(iii)** Copy of contract document along with any special conditions thereof.
- **(iv)** Copy of approved set of plans and detailed working drawings.
- **(v)** Survey, investigation and sub-soil test reports.
- **(vi)** Standards, specifications, guidelines, codes of practices etc., according to which the work must be executed as per contract.

All the above documents shall be as per the format already laid down in JKPWD Manual 2020.

3.1.3 Finalize the site and decide location of site office, storage sheds, batching plant, casting yard, labour camp etc. to be checked w.r.t HFL, flood plains etc.

3.1.4 Identify sources of construction materials like sand, coarse aggregate and boulders etc. and supply of cement and steel including the time required in transportation of these materials to the site of work.

3.1.5 Draw a detailed work program (CPM) on the basis of availability of plant, equipment, material, manpower etc. Refer IRC Special Publication No. 14 - A manual for application of the critical path method.

3.1.6 Identify major milestones to serve as important dates for reviewing the progress of work.

3.1.7 After having cleared the site, transfer the alignment of the bridge and ground with the help of reference pillars fixed at site during the location survey. Fix up permanent bench marks, reference pillars. Use Auto levels, accurate theodolite, total station and other precision electronic instrument.

3.1.8 The construction of various components of bridge works, protective works shall conform to MoRT&H Specification for Road and Bridge Works and relevant IRC Bridge Codes/Standards.

3.2 Formwork and Staging

Formwork shall include all the temporary and permanent forms required for forming the concrete of the shape, dimensions and surface finish as shown on the drawing or as directed by the

Engineer, together with all props, staging, centering, scaffolding and temporary construction required for their support.

Materials and components used for formwork shall be examined for damage or excessive deterioration before use/re-use and shall be used only if found suitable after necessary repairs. The formwork shall be constructed with timber or metal. In case of timber formwork, the material shall also be examined for signs of attacks by decay, rot or insect attack or development of splits apart from any other physical damage. The metals used for forms shall be of such thickness that the forms remain true to shape. All bolts should be counter sunk. The structural steel tubes used as support for forms shall have a minimum thickness of 4mm.

All the materials, the designs, erection and removal of formwork shall conform to IRC 87-2018 “Guidelines for Formwork, False-work and Temporary Structures for Road Bridges”.

3.3 Placing of Reinforcement

Reinforcing steel shall conform to the dimensions and shapes given in the approved Bar Bending Schedules. Reinforcement bars shall be placed accurately in position as shown on the drawings. The bars, crossing one another shall be tied together at every intersection with binding wire (annealed) conforming to IS-280: 2006: Mild Steel Wire for General Engineering Purposes” to make the skeleton of the reinforcement rigid such that the reinforcement does not get displaced during placing of concrete, or any other operation. The diameter of binding wire shall not be less than 1 mm. Layers of reinforcement shall be separated by spacer bars at approximately one meter intervals. The minimum diameter of spacer bars shall be 12 mm or equal to maximum size of main reinforcement or maximum size of coarse aggregate, whichever is greater. No person shall be allowed to walk directly over the reinforcement placed in position.

Necessary stays, concrete/polymer cover blocks, metal chairs, metal hangers, supporting wires etc or other subsidiary reinforcement shall be provided to fix the reinforcement firmly in its correct position. Use of pebbles, broken stones, metal pipes, bricks, mortar or wooden blocks etc as devices for positioning reinforcement shall not be permitted. Placing and fixing of reinforcement shall be inspected and approved by the Engineer before concrete is deposited.

3.4 Foundations

3.4.1 Open foundation:

Excavation for laying the foundation shall be carried out in accordance with Section 300 of MoRT&H Specifications. Any depth excavated below the specified level shall be made good with M 15 concrete in case of foundation resting on soil and foundation grade concrete for foundations in rock. Open foundation shall be constructed in dry conditions. When the bearing surface is earth, a layer of M 15 concrete shall be provided below foundation concrete. The thickness of this layer shall be 100mm minimum unless otherwise specified. Where water is met with an excavation, adequate measures such as bailing out, pumping, constructing diversion channels etc shall be taken to keep the foundation trenches dry and to protect the green concrete against damage. All spaces excavated and not occupied by the foundation, shall be refilled with earth upto surface of surrounding ground. In ease of excavation in rock, the annular space around foundation shall be filled with M 15 concrete upto the top of rock.

3.4.2 Well foundations:

3.4.2.1. The construction procedure shall conform to the provisions contained in Section 1200 of MoRT&H Specifications.

Well sinking: Sinking of well can be accomplished by the following methods:-

- **(i)** Open grabbing with / without kentledge
- **(ii)** Jackdown methods
- **(iii)** Pneumatic sinking of wells
- **(iv)** Blasting

3.4.2.2 Blasting: Blasting may be employed with prior approval of competent authority to help sinking of well for breaking obstacles such as bounders or for leveling the rock layers for square setting of wells. Blasting may be resorted to only when methods are found ineffective.

3.4.3 Pile Foundation:

The piles may be either pre-cast concrete piles or cast in situ driven or bored piles. The detailed procedure for construction of pile foundation shall conform to the specification given in section 1100 of m RT&H's specifications and Clause 711 of IRC: 78.

3.5 Substructure

3.5.1 Materials shall conform to section 1000 of MoRT&H Specifications.

3.5.2 Piers and abutments: Masonry form work concrete and reinforcement for piers and abutment shall conform to Section 2200 of MoRT&H Specification.

3.5.3 Pier cap and abutment cap: The surface of cap shall be finished smooth and shall have a slope for draining of water. For short span slab bridges with continuous support on pier caps the surface shall be cast horizontal. The top surface of the pedestal on which bearing are to be placed shall also be cast horizontally.

The surface on which elastomeric bearings are to placed shall be wood float finished to a level plane which shall not vary more than 1.5 mm from straight edge placed in any direction across the area. The surface on which other bearings (steel bearings, pot bearings) are to be placed shall be cast about 25 mm below the bottom level of bearings.

3.5.4 Dirt/ballast wall, return wall and wing wall: In case of cantilever walls, no construction joint shall be permitted. Wherever, feasible, the concreting in cantilever walls shall be carried out in continuation of the ballast wall.

No horizontal construction joint shall be provided. If shown on drawings or directed by the engineers, vertical construction joints may be provided. Vertical expansion gap of 20 mm shall be provided in return wall/wing wall at every 10 m intervals. Weep holes shall be provided as prescribed for abutments.

The finish of the surface on the earth side shall be rough while the front face shall be smooth finished.

Architectural coping for wing wall/return wall in brick masonry shall conform to Section 1300 of MoRT&H specifications.

3.5.5 Tolerances in concrete elements shall conform to Section 2208 of MoRT&H specifications.

3.6 Superstructure

3.6.1 Concreting:

Concreting shall be done as per Section 2300 of MoRT&H specifications.

3.6.2 Prestressing:

Before commencement of the prestressing, it shall be ensured that all the tendons are free to move between the jacking points.

The tendons shall be stressed at a gradual and steady rate and the extension recorded at each increment of jack pressure.

The extension of the tendons at the agreed pre-specified total force shall be within 5 per cent of the agreed calculated extension. Any appreciable variation between the calculated extension and actual extension should be notified and settled in consultation with the Engineer-in-charge before proceeding with further tensioning.

Stressing shall be done from both ends unless one end prestressing is specified in the drawings.

Prestressing record of all the cables shall be maintained in the format given in Appendix 1800/II of MoRT&H Specifications for roads & bridge works (third revision).

Efficiency of prestressing jack should be found before hand and catered for in the extension of cables.

3.6.3 Grouting:

Grouting of cable ducts shall be carried out as per Appendix 1800/III of MoRT&H Specifications.

Grouting shall be carried out as early as possible as but not later than 2 weeks of stressing in tendon.

Before grouting, ducts shall be flushed with water for cleaning as well as for wetting the surfaces of the ducts walls. Water used for flushing should be of same quality as used for grouting. It may, however, contain about 1 per cent of slaked lime of quick line. All water should be drained through the lowest vent pipe or by blowing compressed air through the duct.

Water/cement ratio of grout mix should be as low as possible, consistent with workability. This ratio should not normally exceed 0.45. Mixing time depends upon the type of the mixer, but will normally be between 2 and 3 minutes. However, mixing should be for such duration as to obtain uniform and thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixtures. The grout should be continuously agitated until it is injected.

It is essential that the grout is maintained in a homogeneous state and of uniform consistency so that there is no separation of cement. Use of grout mixers to obtain a colloidal grout is essential.

The pump should be a positive displacement type and should be capable of ejecting the grout in a continuous operation and not by way of pulses. The grout pump must be fitted with a pressure gauge to enable pressure of injection to be controlled. The minimum pressure at which the grout should be pumped shall be 0.3 MPa and the grout pump must have a relief arrangement for bypass of the grout in case of build-up of pressure beyond 1 MPa. The capacity of the grout pump should be such as to achieve forward speed of grout of around 5 to 10m per minute. The slow rates are preferable as they reduce the possibility of occurrence of voids.

Pumping of grout should continue till the mix coming out at the other end is of the same consistency.

Grouting record should be maintained in the format given at Appendix 1800/IV of MoRT&H Specifications (Third revision) – 1995.

3.7 Bearings:

Bearings shall conform to the provisions contained under Section 200 of MoRT&H specifications for Road & Bridge Works published in April 1995 and IRC: 83 – Part I & Part II.

3.8 Expansion Joints:

The fabrication and fixing of expansion joints shall be as per approved drawings and in accordance with Section 2600 of MoRT&H Specifications and with manufacturers' recommendations and MoRT&H interim specifications issued vide letter no. RW/NH/34059/1/96 dated 31/03/97 with amendment issued from time to time.

3.9 Materials for Structures

3.9.1 General

Material to be used in the work shall strictly conform to the specifications mentioned on the drawings and other specifications as may be mentioned in other design document, including BOQ. Material, not covered in this section, which may be required to be used in the work, shall conform to relevant Indian Standards, if there are any, or to the requirements specified by the Engineer.

The Contractor shall notify the Engineer of his proposed sources of materials prior to delivery and same shall be duly approved by the engineer. If it is found after trial that sources of supply previously approved do not produce uniform and satisfactory products, or if the product from any other source proves unacceptable at any time, the Contractor shall furnish acceptable material from other sources at his own expense.

Samples of material from the approved source shall be tested for all relevant parameters for conformity to applicable specifications. For manufactured items like cement, steel reinforcement, structural steel, admixtures and pre-stressing strands etc., the contractor shall intimate the Engineer the details of the source, testing facilities available with the manufacturer and arrangements for transport and storage of material at site. At the demand of an engineer, the contractor shall be able to furnish samples and test results of recently received batch of material. The engineer, at his discretion, in case of observing and inconsistency, may require the contractor to test the material in an independent laboratory, duly approved by the engineer, as part of third party evaluation. The cost of such additional tests shall be borne by the contractor.

If any proprietary items are proposed to be used in the works, they shall be governed by the provisions of Specification for Road & Bridge Works, MoRT&H (Clause 115.4).

3.9.2 Bricks & Stones.

Burnt clay bricks shall conform to the requirements of IS:1077, except that the minimum compressive strength when tested flat shall not be less than 8.4 Mpa for individual bricks and 10.5 Mpa for average of 5 specimens. They shall be free from cracks and flaws and nodules of free lime. The brick shall have smooth rectangular faces with sharp corners and emit a clear ringing sound when struck. The size may be according to local practice with a tolerance of ± 5 per cent.

Stones shall be of the type specified. It shall be hard, sound, free from cracks, decay and weathering and shall be freshly quarried from an approved quarry. Stone with round surface shall not be used. The stones, when immersed in water for 24 hours, shall not absorb water by more than 5 per cent of their dry weight when tested in accordance with IS: 1124.The length of stones shall not exceed 3 times its height nor shall they be less than twice its height plus one joint. No stone shall be less in width than the height and width on the base shall not be greater than three-fourth of the thickness of the wall nor less than 150 mm.

3.9.3 Cast Iron.

Cast iron shall conform to IS: 210. The grade number of the material shall not be less than 14.

3.9.4 Cement.

Cement to be used in the works shall be any of the following types with the prior approval of the Engineer:

(i) Ordinary Portland Cement, 33 Grade, conforming to IS: 269.
(ii) Ordinary Portland Cement, 43 Grade, conforming to IS: 8112.
(iii) Ordinary Portland Cement, 53 Grade, conforming to IS: 12269.
(iv) Sulphate Resistant Portland Cement, conforming to IS: 12330.
(v) Portland Pozzolana Cement, conforming to IS: 12330.
(vi) Rapid Hardening Portland Cement, conforming to IS: 8041.
(vii) Portland Slag Cement, conforming to IS:455.
(viii) Low Heat Portland Cement, conforming to IS:12600.

Manufacturers test certificate shall be submitted to the engineer by the contractor for every consignment of cement. The certificate shall cover all the tests for chemical requirements, physical requirements and chloride content as per relevant codes/specifications.

Independent tests of samples drawn from the consignment, shall be carried out at the site laboratory or in an independent laboratory, as may be approved by an engineer. The tests like Setting time, Compressive Strength must be mandatory. Any cement still in storage, in bags, for more than 3months, from the date of last test, may be got re-tested.

Cement conforming to IS:269 (33-Grade) shall be used only after ensuring that the minimum required design strength can be achieved without exceeding the maximum permissible cement content of 450 kg/cum of concrete, without use of mineral admixtures.

Cement conforming to IS: 8112 and IS: 12269 (43 & 53 Grade) may be used provided the minimum cement content mentioned elsewhere from durability considerations is not reduced.

Details on use of other types of cement and limitations may be referred from Specification for Road & Bridge Works, MoRT&H, Section: 1006.

3.9.5 Aggregates (Mineral Aggregates).

3.9.5.1 Coarse Aggregates.

For plain and reinforced cement concrete (PCC and RCC) or pre-stressed concrete (PSC) works, coarse aggregate shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone, crushed gravel, natural gravel or a suitable combination thereof or other approved inert material. They shall not consist pieces of disintegrated stones, soft, flaky, elongated particles, salt, alkali, vegetable matter or other deleterious materials in such quantities as to reduce the strength and durability of the concrete, or to attack the steel reinforcement. Coarse aggregate having positive alkali-silica reaction shall not be used. All coarse aggregates shall conform to IS: 383 and tests for conformity shall be carried out as per IS: 2386, Parts I to VIII.

The contractor shall submit for the approval of the Engineer, the entire information, indicated in Appendix A of IS: 383.

Maximum nominal size of coarse aggregate for various structural components in PCC, RCC or PSC, shall conform to Section 1700 of Specification for Road & Bridge Works, MoRT&H. The maximum value for flakiness index for coarse aggregate shall not exceed 35 per cent. The coarse aggregate shall satisfy the following requirements of grading (Table-3.1).

IS Sieve size	Per cent by Weight Passing the Sieve		
	40 mm	20 mm	12.5 mm
63 mm	-	–	–
40 mm	95-100	100	–
20 mm	30-70	95-100	100
12.5 mm	–	–	90-100
10 mm	10-35	25-55	40-85
4.75 mm	0-5	0-10	0-10

Table-3.1 Grading Requirements of Coarse Aggregates

3.9.5.2 Fine Aggregates.

For plain and reinforced cement concrete (PCC and RCC) or prestressed concrete (PSC) works, fine aggregate shall consist of clean, hard, strong, dense and durable pieces (<4.75mm) of crushed stone, crushed gravel, which must be free of veins and adherent coating or other deleterious substances. Suitable combination of natural sand, crushed stone sand, crushed gravel sand may also be adopted. They shall not contain dust, lumps, soft or flaky, materials, mica or other deleterious materials in such quantities as to reduce the strength and durability of the concrete, or to attack the embedded steel.

Motorized/Mechanized sand washing machines should be used to remove impurities from sand. Fine aggregate having positive alkali-silica reaction shall not be used. All fine aggregates shall conform to IS:383, with test conformity to IS: 2386, (Parts 1 to VIII). The Contractor shall submit to the Engineer the entire information indicated in Appendix A of IS: 383. The fitness modulus of fine aggregate shall neither be less than 2.0 nor greater than 3.5.

Sand/fine aggregate for structural concrete shall conform to the following grading requirements (Table-3.2):

IS Sieve size	Per cent by Weight Passing the Sieve		
	Zone I	Zone II	None III
10 mm	100	100	100
4.75 mm	90-100	90-100	90-100
2.36 mm	60-95	75-100	85-100
1.18 mm	30-70	55-90	75-100
600 micron	15-34	35-59	60-79
300 micron	5-20	8-30	12-40
150 micron	0-10	0-10	0-10

Table-3.2 Grading Requirements of Fine Aggregates

Note: *When the grading falls outside the limits of any particular grading zone (other than 600micron IS-sieve) by total amount not exceeding 5%, it shall be regarded as falling within that zone. However, for crushed stone sand, the permissible limit on 150-micron IS sieve is increased to 20% (Ref: IS: 383, Clause:4.3)*

3.9.6 Structural Concrete

Materials of structural concrete shall conform to ingredient material requirements under Specification for Road & Bridge Works, MoRT&H, Section: 1000. The detailed specification on Structural Concrete shall be referred from Section 1700 of Specification for Road & Bridge Works, MoRT&H.

The specifications under Section 1700 of Specification for Road & Bridge Works, MoRT&H shall cover following;

3.9.6.1 Grades of Concrete, for Nominal, Standard and High Performance Concrete.

The grades of concrete shall be designated by the characteristic strength as given in Table-3.3 below, where the characteristic strength is defined as the strength of concrete below which not more than 5 percent of the test results are expected to fall.

Table-3.3 Grades of Concrete				
S.No	Types of Concrete/Grade Designation			Characteristic Strength in MPa
	Nominal Mix	Standard Designed Mix Concrete	High Performance Designed Mix Concrete	
1.	M15	M15		15
2.	M20	M20		20
3.		M25		25
4.		M30	M30	30
5.		-	M35	35
6.		M40	M40	40
7.		M45	M45	45
8.		M50	M50	50
9.			M55	55
10			M60	60
11			M65	65
12			M70	70
13			M75	75
14			M80	80
15			M85	85
16			M90	90

Note:

a) *Definition of Nominal, Standard & High Performance Concrete may be referred from MoRT&H, Section 17030.1.*

b) *Requirements of High Performance Concrete shall be referred to Section 1715 of Specification for Road & Bridge Works, MoRT&H.*

The minimum grades of concrete and corresponding minimum cement content and maximum water/cement ratios for different exposure conditions shall be as per Table-3.4, below

Table-3.4 Requirements of Concrete for different exposure conditions			
Exposure Condition	Maximum W/C Ratio	Minimum Cement Content, kg/cm^3	Minimum Grade of Concrete
Moderate	0.45	340	M25
Severe	0.45	360	M30
Very Severe	0.40	380	M40

Note:

1) Above table is applicable for 20mm mineral aggregates.

2) Cement content shown above shall be increased by 40kg/m^3 for use of 12.50mm nominal maximum size of aggregate (NMSA) and decreased by 30kg/m^3 for use of 40mm NMSA.

3) The maximum cement content excluding any mineral admixtures (Portland Cement Content alone) shall not exceed 450 kg/m^3.

4) Use of Design Mix Concrete shall invariably be preferred. Nominal mix shall however be permitted only for minor bridges and culverts or other incidental construction where requirement is up to M20 only.

For concrete subject to Sulphate attack, the requirements may be referred from Table-1700-3 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.2 Proportioning of Concrete.

Proportioning of concrete shall be as per requirements of section 1704 of Specification for Road & Bridge Works, MoRT&H-2013. Contractor shall design the mix in case of "Design Mix Concrete" or propose nominal mix in case of "Nominal Mix Concrete", and submit same to the Engineer for approval of the proportions of materials, including admixtures to be used. Water-reducing admixtures (including plasticisers or super-plasticisers) may be used at the Contractor's option, subject to the approval of the Engineer. However, if design mix specifically has been recommended with any admixtures, same shall be binding on contractor. Other types of admixtures shall be prohibited, unless specifically permitted by the Engineer. Design Mix shall be encouraged from an Authorized/NABL accredited laboratory.

The optimum consistency of various types of structures shall be as per Table-3.5, below.

Table-3.5 Requirements of Consistency

S.No	Type	Slump (mm) at the time of Placing
1	(a) Structures with exposed inclined surface requiring low slump concrete to allow proper compaction. (b) Plain cement concrete.	25 25
2	RCC structures with widely spaced reinforcements; e.g. solid columns, piers, abutments, footings, well steining	40 – 50
3	RCC structures with fair degree of congestion of reinforcement; e.g. pier and abutment caps, box culverts well curb, well cap, walls with thickness greater than 300 mm.	50 – 75
4	RCC and PSC structures with highly congested reinforcements e.g. deck slab girders, box girders, walls with thickness less than 300 mm	75 – 125
5	Underwater concreting through tremie e.g. bottom plug, cast-in-situ piling	150 – 200
Note: *Refer Section 1704.1 of Specification for Road & Bridge Works, MoRT&H, for additional requirements of optimum consistency*		

3.9.6.2.1 Requirements of Design Mixes

For specific requirements under design mixes, section 1704.2 of Specification for Road & Bridge Works, MoRT&H, shall be adhered.

The target mean strength of specimen shall exceed the specified characteristic compressive strength by at least the “current margin”.

1) The current margin for a concrete mix shall be determined by the Contractor and shall be taken as 1.64 times the standard deviation of sample test results taken from at least 40 separate batches of concrete of nominally similar proportions produced at site by the same plant under similar supervision over a period exceeding 5 days, but not exceeding 6 months.
2) Where there is insufficient data to satisfy the above, the current margin for the initial design mix shall be taken as given in Table-3.6 below, till sufficient data is available to determine the current margin.

Table-3.6 Current Margin for Initial Design Mix

Concrete Grade	Current Margin (MPa)	Target Mean Strength (MPa)
M 15	10	25
M 20	10	30
M 25	11	36
M 30	12	42
M 35	12	47
M 40	12	52
M 45	13	58
M 50	13	63
M 55	14	69
M 60	14	74
M 65	15	80
M 70	15	85
M 75	15	90
M 80	15	95
M 85	16	101
M 90	16	106

The requirements of Trial Mixes and Control of Strength of Design Mixes shall be adhered as per section 1704.2.2 & section 1704.2.3 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.2.2 Requirements of Nominal Mixes

Requirements for nominal mix concrete unless otherwise specified, shall be as detailed in Table-3.7, below.

Table-3.7 Requirements of Nominal Mix Concrete

Concrete Grade	Total Quantity of dry aggregate by mass per 50 kg of cement to be taken as the sum of individual masses of fine and coarse aggregates (kg)	Proportion of fine to Coarse aggregate (by mass)	Maximum Quantity of Water for 50kg of Cement	
			PCC	RCC
M 15	350	Generally 1:2, subject to upper limit 1:1:5 and lower limit of 1:2:5	25	-
M20	250		25	22

3.9.6.2.3 Additional Requirements.

Concrete shall meet with any other requirements as specified on the drawing or as directed by the Engineer. Additional requirements shall also consist of the following overall limits of deleterious substances in concrete:

a) The total chloride content of all constituents of concrete as a percentage of mass of cement in mix shall be limited to values given below:

Prestressed Concrete : 0.1 percent

Reinforced concrete exposed to chlorides in service (e.g. structures located near sea coast) : 0.2 percent

b) Other reinforced concrete construction : 0.3 percent

c) The total water soluble sulphate content of the concrete mix expressed as (SO_3), shall not exceed : 4 percent by mass in the mix.

Proper checks shall be exercised on Suitability of proposed Mix Proportions, Mix Proportioning process and Water/Cement Ratio as per guidelines of section 1704.5 & 1704.6 of Specification for Road & Bridge Works, MoRT&H.

Grading of aggregates for pumped concrete shall be adhered as per section 1704.7 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.3 Admixtures

Use of admixtures such as Superplasticizers, or air entraining, water reducing, accelerating and retarding agents for concrete, may be used with the approval of the Engineer.

As the selection of an appropriate concrete admixture is an integral part of the mix design, the manufacturers shall recommend the use of any one of his products only after obtaining complete knowledge of all the actual constituents of concrete as well as methodologies of manufacture, transportation and compaction of concrete proposed to be used in the project work. Admixtures/additives shall be used conforming to IS: 910, subjected to approval of the Engineer.

The general requirements of admixtures shall be as per section 1007 of Specification for Road & Bridge Works, MoRT&H. However, use of mineral admixtures shall be used as per clause 1714.1 and 1715.2 of Specification for Road & Bridge Works, MoRT&H.

Some of the requirements of Admixtures have been discussed in following Section 3.10, of this chapter,

3.9.6.4 Size of Coarse Aggregates

The size (maximum nominal) of coarse aggregates for concrete to be used in various components shall be given as Table-3.8, below.

Table-3.8 Requirements of Maximum Nominal Size of Coarse Aggregates

Components	Maximum Nominal size of coarse Aggregate(mm)
1) RCC well curb	20
2) RCC/PCC Well Steining	40
3) Well cap or Pile cap, Solid type piers and abutments	40
4) RCC work in girders, slabs, wearing coat, kerb, approach slab hollow piers and abutments, pier / abutment caps, piles	20
5) PSC work	20
6) Any other item.	As specified by Engineer

Maximum nominal size of aggregates shall also be restricted to the smaller of the following values:

- ❖ 10 mm less than the minimum lateral clear distance between individual reinforcements.
- ❖ 10 mm less than the minimum clear cover to the reinforcements.
- ❖ One quarter of minimum thickness of member.

The proportions of the various individual size of aggregates shall be so adjusted that the grading produces densest mix and the grading curve corresponds to the maximum nominal size adopted for the concrete mix.

3.9.6.5 Equipment for Batching, Mixing, Transportation, Placing and Compaction

The various requirements of various Equipment, including that used for Batching, Mixing, Transportation, Placing and Compaction shall be as per Section 1707 and 1708 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.6 Concreting Under Water & Extreme Weather

The various requirements of concreting under water and other extreme weather conditions shall be as per Section 1710 & Section 1711 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.7 Protection and Curing

Concreting operations shall not commence until adequate arrangements for concrete curing have been made by the contractor. Curing and protection of concrete shall start immediately after compaction of the concrete to protect it from:

- Premature drying out particularly by solar radiation and wind
- High internal thermal gradients
- Leaching out by rain and flowing water.
- Rapid cooling during the first few days after placing.
- Low temperature or frost
- Vibration and impact which may disrupt the concrete and interfere with its bond to the reinforcement.

Where members are of considerable size and length, with high cement content, accelerated curing methods may be applied, as approved by the Engineer. The additional requirements under Curing using Water Curing, Steam Curing and use of Curing Compound may be referred under section 1712 of Specification for Road & Bridge Works, MoRT&H.

3.9.6.8 Finishing

Immediately after the removal of forms, exposed bars or bolts, if any, shall be cut inside the concrete member to a depth of at least 50 mm below the surface of the concrete and the resulting holes filled with cement mortar.

All fins caused by form joints, all cavities produced by the removal of form ties and all other holes and depressions, honey comb spots, broken edges or corners, and other defects, shall be thoroughly cleaned, saturated with water, and carefully pointed and rendered true with mortar of cement and fine aggregate mixed in the proportions used in the grade of concrete that is being finished and of as dry a consistency as is possible to use.

Considerable pressure shall be applied in filling and pointing to ensure thorough filling in all voids. Surfaces which have been pointed shall be kept moist for a period of twenty thousand four hours. Special pre-packaged proprietary mortars shall be used where appropriate or where specified in the drawing.

All construction and expansion joints in the completed work shall be left carefully tooled and free from any mortar and concrete. Expansion joint filler shall be left exposed for its full length with clean and true edges.

Immediately on removal of forms, the concrete work shall be examined by the engineer before any defects are made good.

- The work that has sagged or contains honeycombing to an extent detrimental to structural safety or architectural appearance shall be rejected.

- Surface defect of a minor nature may be accepted. On acceptance of such work by the Engineer, the same shall be rectified as directed by the Engineer.

3.9.7 Steel (Other than Structural Steel)

3.9.7.1 Cast Steel

The use of cast shall be limited to bearings and other similar parts. Steel for casting shall conform to Grade 280-520 N of IS: 1030. In case where subsequent welding is unavoidable in the relevant cast steel components, the letter N at the end of the grade designation of the steel casting shall be replaced by letter W. Generally, 0.3% to .0.5% copper may be added to increase the corrosion resistance properties.

3.9.7.2 Steel for Prestressing

The prestressing steel shall conform to either of the following:

(i) Plain hard drawn steel wire conforming to IS: 1785 (Part I) and IS: 1785 (Part II).

(ii) Cold drawn indented wire conforming to IS: 6003.

(iii) High tensile steel bar conforming to IS: 2090.

(iv) Uncoated stress relieved strands conforming to IS: 6006.

(v) Uncoated stress relieved low relaxation seven ply strand, conforming to IS: 14268.

3.9.7.3 Reinforcement/Un-tensioned Steel

For plain and reinforced cement concrete (PCC and RCC) or prestressed concrete (PSC) works, the reinforcement/un-tensioned steel, as the case may be shall consist of the following grades of reinforcing bars.

Grade Designation	Bar Type conforming to governing IS Specification	Characteristic Strength f_yMPa	Elastic Modulus GPa
Fe 240	IS: 432 Part I Mild Steel Bar	240	200
Fe 415	IS: 1786 High Yield Strength Deformed Bars (HSD)	415	200
Fe 500 or Fe 500D	IS: 1786 High Yield Strength Deformed Bars (HSD)	500	200
Fe 550 or Fe 550D	IS: 1786 High Yield Strength Deformed Bars (HSD)	550	200
Fe 600	IS: 1786 High Yield Strength Deformed Bars (HSD)	600	200

Table-3.9 Grading Requirements of Reinforcement Steel

Note: *If any grade of steel, above, is not commercially available, steel of next higher grade may be used. Other grades of bars conforming to IS: 432 and IS: 1786 shall not be permitted.*

All steel shall be procured from original producers, no re-rolled steel shall be incorporated in the work. Only new steel shall be delivered to the site. Every bar shall be inspected before assembling on the work and defective, brittle or burnt bar shall be discarded. Cracked ends of bars shall be discarded.

Purchase of steel, as far as possible must be made from Original Manufacturer and as per Specifications conforming IS:1786. Engineer may allow the procurement of steel from other suppliers, provided same is conforming IS:1786. Further, is such case, apart from having the manufacturer's test certificate, the steel shall be got tested by third party test facility, which must be NABL accredited laboratory, ensuring conformity to IS: 1786. However, regular third party evaluation of lots of steel may carried out, at the discretion of engineer.

3.9.7.4. Fusion Bonded Epoxy Coated Reinforcement/Un-tensioned Steel

Fusion-bonded epoxy coated reinforcing bars shall meet the requirements of IS: 13620. Additional requirements for the use of such reinforcement bars may be referred to Specification for Road & Bridge Works, MoRT&H, Section:1009.3.2. Coating of Hot dipped galvanized reinforcing steel shall be provided, wherever required, and as per IS: 12594-1988.

3.9.7.5 Grey Iron Castings

Grey Iron castings to be used for bearings shall have the following minimum properties and shall conform to testing as per IS: 210:

(i)	Minimum ultimate tensile strength	370 MPa
(ii)	Modulus of Elasticity	147000 MPa
(iii)	Brinell Hardness	230 MPa
(iv)	Shear Strength	370 MPa
(v)	Compressive Strength	1370 MPa

3.9.7.6 Steel Forgings

Forged steel pins shall comply with clause 3, 3A or 4 of IS: 1875 and steel forgings shall comply with clause 3, 3A or 4 of IS: 2004. Raw materials of the forging will be taken as per IS: 1875 with minimum reduction ratio of 1.8:1. Alternatively, if forging is made from ingot, a minimum reduction ratio between the ingot and forging will be 4:1. Forging shall be normalized.

3.9.8 Structural Steel

Unless otherwise permitted herein, all structural steel shall before fabrication comply with the requirements of the following Indian Standards:

IS: 226 : Structural Steel (Standard Quality).

IS: 961 : Structural Steel (High Tensile).

IS: 2062 : Wieldable Structural Steel.

IS: 8500 : Wieldable Structural Steel (medium & high strength qualities).

IS: 1148 : Hot rolled rivet bars (upto 40 mm dia) for structural purposes.

IS: 1149 : High tensile rivet bars for structural purposes.

IS: 1161 : Steel tubes for structural purposes.

IS: 4923 : Hollow Steel sections for structural use.

IS: 11587: Structural weather resistant steel.

IS: 808 : Specifications for Rolled Steel Beam, Channel and Angle Sections.

IS: 1239 : Mild Steel Tubes.

IS: 1730 : Dimension for Steel Plate, sheet and strip for structural and general engineering purposes.

IS: 1731 : Dimension for Steel flats for structural and general engineering purposes

IS: 1732 : Dimension for round and square steel bars for structural and general engineering purposes

IS: 1852 : Rolling and cutting tolerances for hot rolled steel products

The use of structural steel not covered by the above standards may be permitted with the specific approval of the authority. Detailed description on use of Structural Steel may be referred under Specification for Road & Bridge Works, MoRT&H, Section-1900. This covers following in particular;

(i) Assorted materials including casting & forging, fastners, welding consumables, welds and paints.

(ii) Detailed fabrication requirements.

(iii) Erection & testing.

(iv) Test and standards of acceptance.

3.9.9 Stainless Steel

Stainless steel shall be austenitic chromium-nickel steel, possessing rust, acid and heat resistant properties conforming to IS: 6603 and IS: 6911. Mechanical properties/grade for such stainless steel shall be as specified by the accepting authority, but in no case be inferior to mild steel. Generally, stainless steel is available as per AISI grades. AISI 304 which I equivalent to grade 04Cr18Ni110 of IS: 6911 satisfies the requirements of mechanical properties of structural steel. Other grades of stainless steel for specific purposes may be provided as per specific requirements. For application in adverse/corrosive environment, stainless steel shall conform to AISI 316L or O2G17NiMo2 of IS: 6911.

3.9.10 Water

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water is generally considered satisfactory for mixing concrete. Mixing and curing with sea water shall not be permitted. pH value of water shall not be less than 6.

In case of any doubt about the quality of water, test samples may be casted, with same water, to ascertain critical test parameters like compressive strength and initial/final setting time of cement. Sample of water referred for testing shall represent the water proposed to be used for concreting.

Average 28 days compressive strength of at least three 150mm concrete cubes, prepared with proposed water, shall not be less than 90% of average strength of other three samples of concrete, prepared with distilled water. Guidelines and conformity of IS: 516, shall apply.

Maximum permissible values for concentrations within water, shall be referred from Specification for Road & Bridge Works, MoRT&H, Section: 1010.

3.9.11 Timber

The timber used for structural purposes shall conform to IS: 883.

3.9.12 Concrete Admixtures

Admixtures are materials added to the concrete before or during mixing with a view to modify one or more of the properties of concrete in the plastic or hardened state. Concrete admixtures are proprietary items of manufacture and shall be obtained only from established manufacturers with proven track record, quality assurance and full-fledged laboratory facilities for the manufacture and testing of concrete.

3.9.12.1 Mineral Admixtures

Mineral admixtures, as part of replacement of Portland Cement, with approval of engineer, shall include Fly-Ash (conforming IS:3812-3), Granulated slag (conforming IS:12089), and Silca fumes (conforming IS:15388).

3.9.12.2 Chemical admixtures

Chemical admixtures shall be used when contractor/supplier can provide following information concerning each admixture, after obtaining the same from the manufacturer:

- **(i)** Compatibility of admixture with cement.
- **(ii)** Normal dosage and detrimental effects, if any, of under dosage and over dosage.
- **(iii)** The chemical names of the main ingredients in the admixtures.
- **(iv)** The chloride content, if any, expressed as a percentage by the weight of the admixture.
- **(v)** Values of dry material content, ash content and relative density of the admixture which can be used for Uniformity Tests.
- **(vi)** Whether or not the admixture leads to the entertainment of air when used as per the manufacturer's recommended dosage, and if so to what extent.

(vii) Where two or more admixtures are proposed to be used in any one mix, confirmation as to their compatibility.

(viii) Whether there is any increased risk of corrosion of the reinforcement or other embedments, as a result of using the admixture.

(ix) Adverse effects on Durability of concrete

3.9.12.3 Physical and Chemical Requirements

Admixtures shall confirm to the requirements of IS: 9103. In addition, other conditions as mentioned in Specification for Road & Bridge Works, MoRT&H, Section: 1012, for physical and chemical requirements, shall be satisfied:

3.9.13 Reinforced and Prestressed Concrete Pipes

Reinforced concrete pipes for highway structures shall be of NP4 type conforming to the requirements of IS:458. Prestressed concrete pipes (NP4), conforming to IS: 784, can also be used.

3.9.14 Storage of Material

All material may be stored at proper places so as to prevent their deterioration or intrusion by foreign matter and to ensure their satisfactory quality and fitness for the work. The storage space must also permit easy inspection, removal and re-storage of the materials. All such materials even though stored in approved godowns/places, must be subjected to acceptance test prior to their immediate use.

The guidelines for storage of Bricks, Aggregates, Cement, Reinforcement/Un-tensioned Steel, Prestressing Material, Water etc, may be referred from Specification for Road & Bridge Works, MoRT&H, Section: 1014.

3.10 Tests & Standards of Acceptance

All materials, even though stored in an approved manner shall be subjected to an acceptance test, prior to their immediate use, as per applicable standard. Independent testing of cement for every consignment shall be subjected to an acceptance test prior to their immediate use.

Independent testing of cement for every consignment shall be done by the Contractor at site in the laboratory approved by the Engineer before use. Any cement with lower quality than those shown in manufacturer's certificate shall be debarred from use. In case of imported cement, the same series of tests shall be carried out before acceptance.

3.10.1 Testing and Approval of Material

The Contractor shall furnish test certificates from the manufacturer/supplier of materials along with each batch of materials, finished products used in the construction as per requirements of conditions of contract and the relevant specifications. The contractor shall set up a field laboratory with necessary equipment for testing of all materials. The testing of all the materials shall be carried out by the Engineer or his representative for which the Contractor shall make all the necessary arrangements and bear the entire cost.

Tests which cannot be carried out in the field laboratory have to be got done at the Contractor's cost at any recognized laboratory/testing establishments approved by the Engineer.

3.10.2 Sampling of Materials

Samples provided to the Engineer or his representative for their inspection/retention are to be in labeled boxes suitable for storage. Samples required for approval and testing must be supplied well in advance by at least 48 hours or minimum period required for carrying out relevant tests to allow for testing and approval. Delay to works arising from the late submission of samples will not be acceptable as a reason for delay in the completion of the works. If materials are brought from abroad, the cost of sampling/testing whether in India or abroad shall be borne by the Contractor.

3.10.3 Rejection of Materials not conforming to the Specifications

Any stack or batch of materials(s) of which samples(s) does not conform to the prescribed tests and quality shall be rejected by the Engineer, or his representative, and such materials shall be removed from site by the Contractor, at his own cost. Such rejected materials shall not be made acceptable by any modifications/rectification.

3.10.4 Testing and Approval of Plant and Equipment

All plants and equipment used for preparing, testing and production of materials for incorporation into the permanent works shall be in accordance with manufacturer's specifications and shall be got approved by the Engineer before use.

3.11 Concrete in Piles

The basic materials and the specifications for steel reinforcement, structural concrete, prestressed concrete and structural steel to be used in pile foundations shall be as given in the relevant sections above or as per Specification for Road & Bridge Works, MoRT&H, Section: 1000, 1700,1800 & 1900.

3.11.1 Concrete in Piles

Requirements of concrete to be used in cast-in-situ and precast piles shall be as per following Table-3.10 below;

	Cast in-situ Concrete by Tremie	Precast Concrete
Grade Designation	M35	M35
Minimum Cement Content	400kg/m^3	400kg/m^3
Minimum w/c ratio	0.40	0.40
Slump (mm) at placement	150-200	50-75

Table-3.10 Requirement of Concrete in Piles

***Note**: minimum cement content and minimum w/c ratio are to be based on total cementious material, including mineral admixtures.*

Concrete mix should have homogeneous mixture with required workability for the system of piling adopted. Suitable and approved admixtures (mineral/chemical) may be used in concrete mix where necessary, as cement reducing agents or water reducing agents/plasticizers/super plasticizers.

Where piles are exposed to action of harmful chemicals or severe conditions of exposure due to presence of sulphate, chloride etc, it may be preferable to opt for higher grades of concrete restricting water cement ratio to 0.45. For improving resistance against the penetration of chlorides and sulphates from surrounding soils or water, mineral admixtures such as fly ash, silica fumes, GGBFS conforming to BIS/International Standards and as per IRC:112, may be used.

3.12 Geosynthetics as Special Material

Geosynthetic is a general classification for all synthetic materials used in geotechnical/geo-structural engineering application. It includes geo-textiles, geo-grids, geo-nets, geo-membranes, geo-cells, geo-mats, natural geotextiles, paving fabric/glass grids and geo-composites.

Such material generally have quite a wide range of applicability for bridge construction like slope protection, reinforcement, drainage, separation, erosion control, capillary cut-off, water barrier etc. Specification for Road & Bridge Works, MoRT&H, Section: 700, covers the various applications of Geosynthetic materials in road and bridge works including supplying and laying as per special provisions.

3.13 Sampling and Testing Frequency of Testing Material

3.13.1 Sampling

The testing of material shall be conducted based on samples collected from field or quarries or batching plants as per relevant standards codes / prescribed procedures. The minimum weight of sample shall be adequate to conduct test for which it has been sampled. For sampling, random numbering statistical method shall be used. The random sampling procedure to be followed as given in IRC/IS/ASTM/AASHTO codes etc.

3.13.2 Testing

The Contractor and the Executing Departments/Agency's Quality Control Engineer shall ensure that any test is carried out as per relevant code mentioned therein and the record of testing is maintained in laboratory. Tests which could not be conducted in field / lab shall be conducted in an independent laboratory.

The tests shall be conducted on unbiased samples, taken from field as per relevant Specification for Road & Bridge Works, MoRT&H or the relevant Indian Road Congress (IRC). Where the said specifications are silent in regard to the specifications in question, in that case, the specifications under the Bureau of Indian Standards (BIS)/ AASHTO/ ASTM and BS code shall apply in that order. All tests shall be conducted in Engineering Testing Laboratory established by Contractor under the supervision of qualified Quality Control Engineer, from the Executing Department/Agency.

All test results shall be properly maintained in laboratory. Any substandard material in the work shall be identified immediately and Contractor shall be informed in writing for removing as per concession agreement.

3.13.3 Frequency of Testing

The type and frequencies of various quality control tests conducted on unbiased samples collected form field/quarry/source, shall be deemed mandatory. The Contractor's QC Engineer/Material Engineer and Executing Department/Agencies Field Engineer/QC Engineer shall ensure that frequencies of test are maintained as per relevant specifications. Confirmatory test if desired shall be carried out in Independent Laboratory. Any sub-standard material incorporated in work should be identified immediately and the Executing Department/Agencies shall informs the Contractor, in writing, for the removal, of same, from the site. The frequencies of various tests to be conducted shall be as per relevant code and MoRT&H specification

The brief account of various Tests & their Frequency, which is required to be maintained as per relevant provisions of codes/specifications, is presented as per Table-3.11 below or same may be referred as per well documented Contract Agreement:

Table- 3.11 Brief Requirement of various Tests & Frequency

Sr. No.	Description of Work / Tests	Ref. Codes	Frequency	Acceptance Standards
NOTE: Most latest mandate of BIS/IRC/MoRT&H code/specifications shall apply, wherever applicable				
1. Coarse Aggregate for Structures (MORTH Specification clause 1007 & I.S 383- 1970)				
i.	Grading	IS:2386 (Part 1)	Before starting of work	As per Table 1000-1 of MORTH Specifications & As per Table -1 of IS 383.
ii.	Estimation of deleterious materials and organic impurities	IS:2386 (Part 2)	Once for source approval	Table -1 of IS 383.

Sr. No.	Description of Work / Tests	Ref. Codes	Frequency	Acceptance Standards
NOTE: Most latest mandate of BIS/IRC/MoRT&H code/specifications shall apply, wherever applicable				
a.	Coal and Lignite	-	One test per source	Max. 1%
b.	Clay Lumps	-	One test per source	Max. 1%
c.	Material finer than 75 micron.	-	One test per source & one test per day	Max. 3%
d.	Total of all Deleterious Matters	-	One test per source	Max. 5% As per table- 2 of IS: 383
iii.	Specific gravity, density, voids, water absorption and bulking	IS:2386 (Part 3)	One test per source	Water absorption max-2%
iv.	Mechanical properties (Aggregate Impact Value-AIV or Loss Angeles Abrasion Value-LAAV)	IS:2386 (Part 4)	One each source of supply and when called for by the Engineer In charge	AIV - 45% max for concrete LAAV - 50% max for concrete
v.	Soundness in Sodium Sulphate and Magnesium Sulphate	IS:2386 (Part 5)	One test per source	Max. 12% and Max. 18% respectively.
vi.	Alkali aggregate reactivity	IS:2386 (Part 7) & IS: 383	One test per source	Innocuous aggregate
vii.	Petrography examination	IS: 2386 (Part 8) & IS:383	One test per source	Information required for approval of source
viii.	Flakiness Index	IS: 2386 (Part 1)	Before starting of work	Not greater than 35%
Maximum Nominal Size of Coarse Aggregates Shall be referred from MoRT&H Table 1700-7				
2. Sand/ Fine Aggregate for Structures (MORTH Specifications Clause 1008 & IS: 383-1970)				
i.	Fineness modulus of fine aggregate	IS: 383	One test for 15 m^3	Min. 2.0 and Max. 3.5
ii.	Soundness in Sodium Sulphate and Magnesium Sulphate	IS: 2386 (Part 5)	One test per source	Max. 10% and Max. 15% respectively.
iii.	Deleterious Constituents	IS: 2386 (Part 2)	One test for 15 m^3	
a.	Coal and Lignite	-	One test for 15 m^3	Max. 1%
b.	Clay Lumps	-	One test for 15 m^3	Max. 1%
c.	Shale	-	One test for 15 m^3	Max. 1%
d.	Total of all Deleterious Matters	-	One test for 15 m^3	Max. 5%
v.	Material Passing 75 micron	IS: 2386 (Part 1)	Before starting of work	Max. 3% for natural sand and 15% for crushed aggregate (As per IS 383- 1970)
vi.	Specific Gravity	IS: 2386 (Part 3)	One test per source	Min 2.5
vii.	Water Absorption	IS: 2386 (Part 3)	One test per source	Max. 2%
viii.	Surface Moisture Content (Free moisture)	IS: 2386 (Part 3)	When required	Max. 5%

Sr. No.	Description of Work / Tests	Ref. Codes	Frequency	Acceptance Standards
NOTE: Most latest mandate of BIS/IRC/MoRT&H code/specifications shall apply, wherever applicable				
ix.	Alkali – Aggregate Reactivity	IS: 2386 (Part 7)	One test per source	Innocuous aggregate
x.	Grading Requirement	IS: 2386 (Part 1)	Before starting of work	As per Table 1000-2 of MORTH Specifications
xi	Bulking	IS: 2386	One test per source	
3. Admixture				
i	Chemical Tests	As per IS: 9103	Once per source	As per IS: 9103
4. Construction Water				
i	Alkalinity and Acidity	MORT&H clause 1010	Once per source	MORT&H clause 1010
ii	Solids	As per IS: 3025	One test per source	As per IS 3025
5. Steel				
i	Physical & Chemical test	As per IS:1786	As per IS 1786	As per IS 1786
6. Size Stones				
i	Water absorption	As per relevant IS:1124	One each source of supply and when called by the Engineer In charge	Not more than 5% of its dry weight
ii	Dimension check	-	As directed by Engineer	-
Iii	Type of rock	As per IS: 2386	As directed by Engineer	-
7. Cement				
i	Fineness	As per IS: 4031	One each source of supply and when called by the Engineer In charge	Limit as per IS 269: 2015
ii	Initial/ Final setting time	As per IS: 4031	One each source of supply and when called by the Engineer In charge	Limit as per IS 269: 2015
iii	Compressive strength (3days,7days,28days)	As per IS: 4031	One each source of supply and when called by the Engineer In charge	Limit as per IS 269: 2015
8. Mortar				
i	Compressive strength	As per IS: 2250	One sample for every 2 m^3 of mortar subject to a minimum of three samples for a day work	As per IS 2250
9. Lime				
i	Chemical properties	as per IS: 6932, 1514	Three final test sample for a lot size up to 100 tones as per table 3 in IS 712- 1984	as per IS 6932, 1514
ii	Physical properties	As per IS: 6932	Three final test sample for a lot size up to 100 tones as per table 3 in IS 712- 1984	as per IS 6932

10. Structural Concrete (MoRT&H Specifications Section 1700)

Requirements of Structural Concrete shall be as described in Section 3.9.6, above, with following requirements for quality assurance of concrete.

<table>
<tr><th>Sr. No.</th><th>Description of Work / Tests</th><th>Ref. Codes</th><th colspan="2">Frequency</th><th>Acceptance Standards</th></tr>
<tr><td colspan="6">Note:
a) Random sampling and lot by lot acceptance inspection shall be made for the 28 days Cube Strength.
b) Concrete shall be tested in lots with no individual lot more than 30 cu.m in volume.
c) Different grades of mixes of concrete shall be divided into separate lots.
d) Concrete of a given lot shall be used in the same identifiable component of the Bridge.
e) A sample of concrete shall be the average of</td></tr>
<tr><td>i</td><td>Sampling of 150mm size cube specimen of each mix.</td><td>-</td><td colspan="2">3 cubes for 7 days & 6 cubes for 28 days Compressive strength test</td><td>IS:1199</td></tr>
<tr><td>ii</td><td>Cube strength (At least 3 cubes on 7 days &6 cubes on 28 days)

Note: A sample shall be understood as average of strength of 3-cubes.</td><td>IS:516</td><td colspan="2">Each trial mix</td><td>a) 7days strength: for preliminary assessment only.
b) 28 days cubes strength shall achieved Target mean strength

Individual variation in test of cubes should not be more than ± 15% of Average.</td></tr>
<tr><td rowspan="2">iii</td><td rowspan="2">Sampling of concrete for each grade at site and compressive strength
(At least one sample shall be taken from each shift of work)</td><td rowspan="2">IS: 1199</td><td>Qty of concrete (m3)</td><td>No. of Samples</td><td rowspan="2">MORTH Specifications Clause 1717.7

The mean strength determined from any group of four consecutive non-overlapping samples should exceed the specified characteristic compressive strength by 3Mpa.
a) Strength of any sample is not less than the specified characteristic compressive strength minus 3 MPa.
b) When Concrete does not satisfy the above conditions, representative cores shall be extracted from hardened concrete for compression test in accordance with IS:1199 & IS:516.</td></tr>
<tr><td>1 – 5
6 – 15
16 – 30
31 – 50
51 and above</td><td>1
2
3
4
4 plus one additional sample for each additional 50 m3or part thereof</td></tr>
</table>

3.14 Calibration of Instruments of Material Testing & Manufacturing:

All measuring instruments and testing equipment (field and laboratory) shall be uniquely numbered, properly stored, suitably handled in a manner appropriate to its sensitivity & calibration. Each equipment shall be maintained in a known state of calibration. If any instrument is repaired, steps shall be taken.

4. QUALITY SYSTEMS FOR ROAD BRIDGES

4.1 To ensure building of safe, serviceable, durable and economically viable bridges, it is necessary to have a strategy for management of human skills by way of quality system defining quality policy, quality assurance and quality audit. Guidelines on quality systems for road bridges have been evolved by IRC vide SP: 47 - 1998 “to facilitate preparation of appropriate quality systems for new bridge projects and application of these guidelines will inculcate in all those involved in this building activity that provide the product or services expected of them consistently. These guidelines cover quality system for activities of bridge structure using concrete elements and include project preparation, design and drawing, construction and supervision, contract management, quality of materials and equipments used in construction and workmanship. The guideline also stipulate organizational requirement for adoption of quality system by suppliers, purchasers, owners, approving authorities and consultants. These guidelines have been made applicable for all the bridge structures on National Highways and centrally financed schemes by the Ministry vide Circular No. RW/NH 34066/5/S&R dated 20th Dec. 1999.

5. PROJECT SCHEDULING AND MONITORING OF WORKS

5.1 Scheduling

In construction project it is very important to identify the risk factors affecting the project at the early stage in order to control and monitor the progress at every stage of the construction work to avoid the time and cost overruns of the project. This can be achieved by proper project management process.

For all important bridge projects, it is essential to have a CPM/ PERT chart for the entire project. Reference may be made to Special Publication No. SP-14 of IRC Construction agency should submit the chart preferably along with the tender, and in any case before commencement of work. For minor bridges, bar charts fixing the targets for the major activities along with the construction schedule may be submitted.

The various activities involved in the completion of the project right from the award of work to its completion shall be identified both in terms of time and money as also the resources like manpower, T&P and materials etc., required for the completion of the activity, the entire purpose being to streamline the construction procedures and take advance action in respect of those activities which affect the subsequent activities and in particular, the activities in critical path, so as to avoid any delay arising in the completion of the project. The inter-dependency of different activities should be correctly shown and the activity durations considered shall be realistic. The CPM chart should be updated regularly as the work progresses.

Availability of resources, viz, manpower, material, plant and machinery and funds shall be clearly identified to enable their mobilization / procurement well in time.

5.2 Monitoring

It is important to monitor the progress of work during execution so that time frame already set for completion of the work is not exceeded. So to complete the project on time the site Supervisor shall maintain progress of the work on daily, weekly and monthly basis and same shall be forwarded to higher authorities.

5.2.1 To monitor the progress of the work at various stages, necessary data must be maintained at site showing the position of each activity, targets to be achieved, bottlenecks, if any, expenditure and position of funds, etc.

5.2.2 Monthly/quarterly progress reports may be prepared in the Performa prescribed by the department and submitted regularly to the concerned officers for their information and for keeping a close watch on the progress of the work and the problems encountered in the field with a view to sort them out.

5.2.3 It is necessary to ensure simultaneous completion of a bridge work and its approaches. Accordingly, progress made on the approaches may also be indicated.

5.3 Record Keeping and Documentation.

It is important to record an activity or conversation in writing and not leave these events to memory. It is extremely difficult to recall events that have occurred five or six years in the past. If an activity or event is not recorded in writing and there is a conflict in those positions, then the arbitrator or judge is left in a difficult position of determining which witness is more credible.

Good record keeping is based on a fair and unbiased recording of actual facts and not speculation or denigration of personalities. Written factual records of any event will always be preferred over oral recollections or reconstruction of the event.

If a claim or dispute appears to arise this should be recorded with the other parties. Relevant photographs of change in work and circumstances forming the basis of a claim often lead to a quick resolution of the dispute.

Record of design and drawings as approved for construction and completion of drawings as per actual construction should be maintained meticulously at the division / circle office or at Chief Engineer's office. To save storage space micro filming system may be introduced.

6. BRIDGE INSPECTION AND MAINTENANCE

6.1 Bridge Inspection

6.1.1 Introduction

Bridges are key elements of the Road or Railway network because of their strategic location and the dangerous consequences when they fail or when their capacity is impaired. The fundamental justification for a bridge inspection programme lies in the assurance of safety. Timely and economic planning and programming of remedial and preventive maintenance and repair work, or even bridge replacement with the minimum interruption to traffic are dependent upon detailed bridge inspection. It is particularly necessary in case of old bridges not designed to modern loading standards and also whose materials of construction have deteriorated as a result of weathering.

Inspection is aimed at identifying and quantifying deterioration, which may be caused by applied loads and factors such as dead load, live load, wind load and physical/chemical influences exerted by the environment. Apart from inspection of bridge damage caused by unpredictable natural phenomena or collision by vehicles or vessels, inspection is also needed to identify or follow up the effect of any built-in imperfections. Inspection can also help to increase life of older bridges. For example, there are certain types of deterioration which appear early in the life of a bridge and which, if not recorded and repaired promptly, can lead to considerable reduction in the length of service life of the bridge.

6.1.2 Purpose of Bridge Inspection

Specific purposes of bridge inspection can be identified as detailed below:

- To know whether the bridge is structurally safe, and to decide the course of action to make it safe.
- To identify actual and potential sources of trouble at the earliest possible stage.
- To record systematically and periodically the state of the structure.
- To impose speed restriction on the bridge if the condition/ situation warrants the same till the repair/ rehabilitation of the bridge is carried out.
- To determine and report whether major rehabilitation of the bridge is necessary to cope with the natural environment and the traffic passing over the bridge.
- To provide a feedback of information to designers and construction engineers on those features which give maintenance problems.

6.1.3 Planning the Inspection

Careful planning is essential for a well-organized, complete and efficient inspection. The bridges over water are inspected at times of low water, generally after the monsoon. Bridges requiring high climbing should be inspected during seasons when winds or extreme temperatures are not prevalent. Bridges suspected of having trouble on account of thermal movement should be inspected during temperature extremes. The bridges are inspected starting from foundations and ending with superstructures. Planning for inspection must include the following essential steps:

- Decide the number of bridges to be inspected on a particular day.
- Go through the previous inspection reports of those bridges before starting the inspection.
- Try to have plans and other details of important bridges.
- Plan any special inspection equipments, staging etc. required in advance.
- Don't rush through the inspection just for completion sake. Remember that you are inspecting the bridge only once in a year.

6.1.4 Preliminary Study

While going for bridge inspection one should be familiar with the historical data of the bridges i.e.

- Completion plans, where available
- Pile and well foundation details
- Earlier inspection reports
- Reports regarding the repairs/strengthening carried out in the past.
- For major girder bridges, stress sheets are useful.

6.1.5 Inspection Equipments

The following equipments are required for thorough inspection of the various elements of bridges:

- Pocket tape (3 or 5 m long)
- Chipping hammer
- Plumb bob
- Straight edge (at least 2 m long)
- 30 metre steel tape
- A set of feeler gauges (0.1 to 5 mm)
- Log line with 20 kg lead ball (to be kept at bridge site)
- Thermometer
- Elcometer
- Wire brush
- Mirror (10x15 cm)
- Magnifying glass (100 mm dia.)
- Crackmeter

- Chalk, Waterproof pencil, pen or paint for marking on concrete or steel
- Centre punch
- Calipers (inside and outside)
- Torch light (5 cell)
- Screw drivers
- Paint and paint brush for repainting areas damaged during inspection
- Gauge-cum-level
- Piano wire or leveling instrument for camber measurement
- 15 cm steel scale
- Inspection hammer (350-450 gm)
- Rivet testing hammer (110 gm)
- Schmidt hammer
- Concrete cover meter
- Binoculars (Optional where required)
- Camera (Optional where required)

Depending on the bridge site and the need envisaged during inspection, some additional equipments that may become necessary are listed below:

- Ladders
- Scaffolding
- Boats or barges
- Echo sounders to assess the depth of water/ scour depth
- Levelling equipment (to assess camber)
- Hand held laser distance/range meter.
- Dye penetration test equipment (to detect cracks specially in welds)

6.1.6 Safety Precautions

While inspecting bridges, one should adopt certain safety measures which are listed below:

- Wear suitable dress so that loose ends do not get caught; too-tight-a-dress may hamper your free movements.
- If you normally wear glasses for improving your eye sight, wear them when climbing up or down the sub- structures or superstructures.
- Keep clothing and shoes free of grease.
- Scaffolding or platforms should be free from grease or other slippery substances.
- Scaffolding and working platforms should be of adequate strength and must be secured against slipping or over turning.

- Line block or power block shall be taken as and when necessary.
- No short cuts, at any cost, should be adopted.

A Proforma for inspection report for road bridges (extracted from IRC SP 35 Guidelines for inspection and maintenance 1990) is given below.

INSPECTION PROFORMA
(for Routine Inspection)

1. General
   - 1.1. Name of bridge/No. of bridge/Name of river
   - 1.2. Name of Highway/Location of Bridge
   - 1.3. Type of Bridge High level/submersible
2. Last Routine Inspection on by
3. Traffic Intensity PCU/T per day
   (latest census)
4. Condition of
   - (a) Approaches
   - (b) Protective works
     (Pitching, apron, toes, floor, guidebunds)
5. State
   - (a) H.F.L. Yes/No
   - (b) Inadequacy of waterway Yes/No
   - (c) Erosion of banks as evident Yes/No
6. Foundation and substructure
   (State whether any abnormal scour, settlement/tilting/ cracks/cavitation/damages/growth of vegetation)
7. Bearings
   (State condition/movements/deformation/cleanliness/ condition of grease)
8. Superstructure
   - (a) *Concrete* (RCC and PSC)
     (State whether leaching/stains/cracks/spalling/ scaling/excessive deflection condition of articulation and inside box)
   - (b) *Steel*
     (State condition of protective system/corrosion/ deformations/rivet and weld condition/buckling and kinking/waviness/fracture/cleanlines)
   - (c) *Masonry Arches*
     (State condition of joints/cracks/vegetation growth/ bulging of spandrel walls and parapets/ deformation).
9. Miscellaneous
   - (a) Wearing course (Surface condition and drainage)
   - (b. Drainage (Spouts/Ventholes/clogging/cleanliness)

(c) Parapets and Handrails, etc.,
(condition and profile)
(d) Footpath (condition and drainage)
(e) Expansion joints
(Cleanliness/Wearing out and alignment/ gap width/hump/drainage/deformation/ corrosion/cracks)
(f) Utilities (State condition)

10. Have actions been taken on the observations and recommendations from the last Routine/Principal inspection ? Yes/No

11. Recommended corrective measures
(Attach separate sheet if space is insufficient)

Name, designation and dated signature of reviewing officer (Next higher Authority of the Inspecting Officer)	Name, designation and dated signature of Inspecting Officer

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INSPECTION PROFORMA
Check List for Inspection Report

1. **GENERAL**

1.1. Name of bridge/No. of the bridge/Name of the River.
1.2. Name of the Highway, Bridge Location
2. **Type of Bridge — High level/Submersible**
3 (A) Date of last such Inspection by
(B) Date of last routine Inspection by
(C) Traffic Intensity PCU/T per day (The latest census)

4. **APPROACHES**

4.1. Condition of pavement surface (check unevenness settlement, cracking, pot noles, etc.)
4.2. Side slopes/(Check pitched or unpitched, condition of pitching/turfing, any signs of slope failure etc.)
4.3. Erosion of embankment by rain cuts or any other damage to embankment.
4.4. Approach slab (check settlement, cracks movement etc.)
4.5. Retaining walls: (Checks, subsidence, tilting, condition of weepholes guardstone and railing)
4.6. Accumulation of silt and debris on submersible, approaches in cutting and embankment.
4.7. Approach geometrics (check whether it satisfies the standards in force).

5. **PROTECTIVE WORKS**

5.1. Type (mention whether guidebund or protection around abutments or spurs).
5.2. Check damage to the layout, cross section profile (check whether the layout and the general cross sections are in order).
5.3. Check condition of slope pitching, apron and toe walls indicating the nature of damage if any (check for proper slope, thickness of pitching in the slopes, width and thickness of appron, erosion of toe walls, etc.)
5.4. Check condition of floor protection works, indicate nature of damage if any, (Condition of impervious floor, flexible appron, curtain walls, etc.)
5.5. Check any abnormal scour noticed.
5.6. Reserve store material (check against specified quality).

6. **WATERWAY**

6.1. Check presence of obstruction, island formation, vegetation, undergrowth etc.
6.2. Check any abnormal change in flow pattern

6.3. Check maximum flood level observed during the year and mark the same on the pier/abutment both on the U/S and D/S (Local enquiry if necessary)
6.4. Check signs of abnormal aflux from U/S & D/S watermarks on piers if any
6.5. Check adequacy of waterway
6.6. Check of erosion of bank

7. **FOUNDATION**

7.1. Check settlement, abnormal scour, tilting, if any
7.2. Check cracking, disintegration, decay, erosion, cavitation etc.
7.3. Check damage due to impact of floating bodies, boulders, etc.
7.4. For sub-ways report seepage, vehicle impact, if any, damage to the foundations, etc.

8. **SUBSTRUCTURE** : (piers, abutments, return walls and wing walls).

8.1. Check efficacy of drainage of the backfill behind abutments (check functioning of weep holes, evidence of moisture on abutment faces, etc.)
8.2. Check tilting, cracking, disintegration decay and other damages, etc.
8.3. Check conditions of side retaining walls like cracking, disintegration and seepage, if any (For subways)
8.4. Check large excavations done in the road below in the vicinity of flyover or road over bridge of viaduct
8.5. Check damages to protective measures to pier and abutments (for viaducts, flyover and R.O. Bs.)
8.6. Check damages to protective coating or paint

9. **BEARINGS**

9.1. Metallic bearings (State types/Sliding plate/Rocker Roller/PTFE/Pot bearings
9.1.1. Check general condition (check rusting, cleanliness, seizing of plates), silting, accumulation of dirt in case of submersible bridges
9.1.2. Functioning (check excessive movement, tilting, jumping off guides)
9.1.3. Greasing (check date of last greasing/oil bath and whether to be redone or not)
9.1.4. Effectiveness of anchor bolts (check whether they are in position and tightened)
9.2. Elastomeric bearings (State numbers)
9.2.1. Check condition: of pads (oxidation, creep, flattening, bulging, splitting, displacements, if any)
9.2.2. Check general cleanliness
9.3. Concrete bearings
9.3.1. Check any signs of distress (cracking, spalling, disintegrating staining, dishing etc.)
9.3.2. Check any excessive shifting
9.3.3. Check loss of shape
9.3.4. Check general cleanliness

9.4. Check cracks if any in supporting member (abutment cap, pier cap, pedestal)
9.5. Condition of d/s stoppers (for submersible bridges)

10. **SUPERSTRUCTURE**

10.1. Reinforced concrete and prestressed concrete members
10.1.1. Check spalling, disintegration or honey combing, (special attention; to be given at points of bearings)
10.1.2. Check cracking (pattern, location, explain preferably by photograph and plotting on sketch. A map of the cracking should be produced. The size and distribution of cracks and their penetration should be noted)
10.1.3. Check exposed reinforcement, if any
10.1.4. Check wear of deck surface
10.1.5. Check scaling (This is gradual and continuous loss of surface mortar and aggregate over irregular areas)
10.1.6. Check surface stains and rust stains along with the locations
10.1.7. Check Leaching (Effects are most usually evident on the soffits of decks)
10.1.8. Check corrosion of reinforcements, sheathing and tendons if visible
10.1.9. Check leakage (Leakages of water can take place through concrete decks, construction joints or thin component sections of the deck viz., kerbs, etc.)
10.1.10. Check damages if any due to moving vehicles
10.1.11. Check condition of drainage system (spouts, collection pits, grating, etc.)
10.1.12. Check condition of articulation (cracks, exposed reinforcement if any)
10.1.13. Check excessive vibrations, if any
10.1.14. Check excessive deflections (sag) or loss of camber if any at same point each time
10.1.15. Check cracks, if any, around anchorage zone for prestressed concrete members
10.1.16. Check excessive deflection (sag) at central hinge, tip, of cantilever for cantilever bridge
10.1.17. In box girders, the interior faces of flangers and webs need to be examined for signs of cracking and report excessive accumulation of water or debris. Interior diaphragms will also require examination, particularly for any signs of cracking at their junction to the webs
10.1.18. Check accumulation of silt and debris on surface of deck (for submersible bridges)
10.1.19. Check peeling off of protective coat or paint
10.2. Check Steel Members
10.2.1. Check condition of protective system
10.2.2. Check corrosion, if any
10.2.3. Check excessive vibrations, if any
10.2.4. Check alignment of members
10.2.5. Check condition of connection (adequacy, looseness of rivets, bolts or wornout welds, specially on connection of stringers to cross girders, cross

girders to main girders, gussets or splices, condition of hinges, splices, etc.)

10.2.6. Check excessive loss of camber and excessive deflections and deformations, if any

10.2.7. Check buckling, kinking, warping and waviness

10.2.8. Check on the cleanliness of members and joints (check choking of drainage holes provided in the bottom booms).

10.2.9. Check apparent fracture if any

10.2.10. Check excessive wear (such as in pins in joints of truss) and their locations requiring close monitoring

10.2.11. Check conditions inside the closed members

10.3. Check masonry arches

10.3.1. Check condition of joints mortar, pointing, masonry, etc.

10.3.2. Check Profile, report flattening by observing rise of the arch at centre and quarter points

10.3.3. Check cracks, if any, (indicate location, pattern, extent, depth; explain by sketches)

10.3.4. Check drainage of spandrel fillings (check bulging of spandrel walls, if any)

10.3.5. Check growth of vegetation

10.4. Check all Cast Iron/Wrought Iron Components

10.4.1. These materials occur in older bridges and the defects which they exhibit are in general very similar to those described above for steel. It should be recognised that the homogeneity and purity of the material will not be upto the present day standards of steel, as such the inspection process has to take into account the variability of materials. (Blow holes and cracking are probably the main defects that occur during the casting of the metal and its cooling.)

11. EXPANSION JOINTS

11.1. Functioning (cracks in wearing course, existence of normal gap, excessive noise, etc.)

11.2. Check condition of sealing material (for neoprene sealing material, check for splitting, oxidation, creep, flattening, bulging and for bitumen filler., check for hardening, cracking, etc.)

11.3. Check secureness of the joints

11.4. Top sliding plate (check corrosion, damage to welds, etc.)

11.5. Locking of joints (Check locking of joints especially for finger type expansion joints).

11.6. Check for debris in joints

11.7. Report rattling, if any

11.8. Check drainage for expansion joint

11.9. Check alignment and clearance

12. WEARING COAT (CONCRETE/BITUMEN)

12.1. Check surface condition (cracks, spalling, disintegration, pot holes, etc.)

12.2. Check evidence of wear (Tell-Tale rings, check for thickness as against actual thickness, check data of last inspection)

12.3. Compare additional thickness with design thickness, with reference to kerb height

13. **DRAINAGE SPOUTS AND VENT HOLES**

13.1. Check clogging, deterioration and damage, if any
13.2. Check the projection of the spout on the underside (see whether structural members are being affected)
13.3. Check adequacy thereof
13.4. For subways report about adequacy of drainage and pumping arrangements, etc.
13.5. For submersible bridges, report on functioning.

14. **HANDRAILS, PARAPETS**

14.1. Check general condition (check expansion gaps, missing parts if any etc.)
14.2. Check damage due to collision
14.3. Check alignment (report any abruptness in profile)

15. **FOOTPATHS**

15.1. Check general condition (damage due to mounting of vehicles)
15.2. Check missing footpaths slabs
15.3. Cleanliness of ducts along footpaths

16. **UTILITIES**

16.1. Check leakage of water and sewage pipes
16.2. Check any damage by telephone and electric cables
16.3. Check condition of lighting facilities
16.4. Check damages due to any other utilities

17. **BRIDGE NUMBER**

17.1. Check condition of painting

18. **ENVIRONMENT**

Check for signs of aggressiveness

19. **AESTHETICS**

19.1. Check any visual intrusion, hoardings, vegetation on structural members, etc.
19.2. Check whether all actions for maintenance and repairs recommended during last inspection have been done or not (give details)

20. **MAINTENANCE AND IMPROVEMENT RECOMMENDATION**

S.No.	Item needing attention	Action recommended	Time by which to be completed	Remarks

21. Certificate to be accorded by the inspecting official
Certified that I have personally inspected this bridge.

Signature of the Inspecting Officer

Date :
Duration of Inspection

From AM/PM
to AM/PM
Method of inspection

POSSIBLE ASSESSMENT METHODS (ONLY INDICATIVE)

Assessment of	Possible method (s)
Concrete	
Strength	"Schmidt-hammer"
Quality	Ultra-sonic;
Lamination	Sounding
cover	Profometer
Steel	
Cracks	Ultra-sonic;
Cable/wire failure	radiographic;
corrosion	electrical halfcell potential; electrical resistivity meter;
Global behaviour movements	Surveying instruments; dial gauges (straining gauges)
extensometric measurement	Strain gauges and extensometers;
pressures, Forces	Pressure transducers or load cells
Miscellaneous	
thickness of coatings	Paint film gauge (digital elecometer)
waterproofing membranes	electrical resistance;
vibrations	Accelerometer
widening of cracks	Glass tell-tales

6.2 Maintenance of Bridges

6.2.1 Introduction

Bridges represent a considerable capital asset not only because of the heavy investment required in constructing or replacing them but also because some of them form part of the historic and cultural heritage of a country. None of the bridges is endowed with an eternal life. Lack of maintenance generally results in reduced life and deterioration in the bridge structure. The adage "Prevention is better than cure" and "A stitch in time saves nine" are eminently true for bridges, where defects can rapidly lead to serious consequences if action is not taken in time. Demands made on bridges as also problems in attending to them have increased over the years. Therefore, it is essential to prolong the life of structures and rehabilitate them wherever necessary and possible.

The maintenance of bridge involves the up-keeping of the bridge components in good and serviceable condition so as to ensure a longer life of the bridge as envisaged at the time of its design and construction. Even if the bridges are well designed and properly constructed, periodic maintenance, if needed, is very essential to keep them in good serviceable condition. Therefore the bridges should be inspected and properly maintained.

6.2.2 Symptoms and Remedial Measures

Some of the common symptoms and remedial measures thereof are listed below:

Nature of the Problem	**Remedial Measures**
a) Foundation	
i) Settlement:	
Moderate	- Packing under superstructure
Severe	- Stabilize by piles around foundation
	- Do micro pilling or root piling or rebuild
ii) Scour:	
Moderate	- Protect by flooring
	- Dump boulders around piers in scoured portion.
Severe	- Protect by piles around the foundation.
b) Substructure	
i) Weathering of masonry :	
Joints - Superficial	- Pointing
Deep	- Grouting with cement or epoxy
	- Plaster the masonry
Leaching of lime mortar	- Cement grouting
Leaching of masonry	- Guniting

ii) Vertical cracks	- Grouting with cement or epoxy - Jacketing
iii) Horizontal cracks	- Increase the section by jacketing
iv) Leaning/bulging	- Backfill drain - Weep holes - Soil Anchoring/rock anchoring - Jacketing - Rebuilding
v) Hollow left in masonry due to defective workmanship	- Cement grouting
vi)Reduction of gap at end of girder.	- Check the bearing - Pull back the girder after checking the verticality of piers.

c) Training and Protection Works

i) Damaged pitching	- Repair with stone and point them.
ii) Toe wall damaged	- Rebuild them
iii) Damaged apron or washed away	- Repair or rebuild them
iv) Reduction in section of guide bund/spur etc.	- Repair before monsoon

d) Bed Blocks

i) Crushing of bed blocks bed plates	- Repair them with epoxy mortar after removing all loose under material
ii) Shaken/loose bed blocks	- Pointing around the bed blocks - Epoxy grouting - Provide through bed blocks
iii) Cracked bed block	- Recast bed blocks either cast-in-situ or precast
iv) Cracks in masonry below bed block	- Repair the crushed masonry with epoxy mortar

e) Bearings

i) Corroded but not seized	- Clean and Grease it
ii) Corroded and seized	- Replace it
iii) Shearing of strips, anchor bolts	- Check the movement of girder. - Strengthen the approaches. - Repair the sheared parts.
iv) Impact at bearing	- Check the levels of bed blocks.

	- Provide a layer of epoxy mortar in the gaps.
v) Flattening of rollers or cracked rollers	- Replace the rollers
vi) Tearing/cracking/ bulging of elastomeric Bearings	- Replace the bearing with good quality bearing.

f) Superstructure

1. Arches

i) Weathering	- Pointing - Grouting with cement or epoxy - Guniting
ii) Visible distortion	- Jacketing intrados or extrados in profile
iii) Cracks in arch	- Grouting with cement or epoxy. - Jacketing intrados or extrados
iv) Cracks/bulges in parapet/spandrel wall	- Draining the back fill - Providing Ties - Rebuilding

2. Steel Girders (Riveted and welded)

Plate Girder / Open Web Girder

i) Early steel	- Replace the girder - Check with reduced stresses
ii) Weathered paint surface	- Painting
iii) Flaking & peeling of steel	- Provide cover plates
iv) Distortion of bracings	- Change the bracings. Also check for its adequacy.
v) Distortion of stiffeners	- May be due to over load. - Redesign and provide a heavier section
vi) Loose rivets at floor system joint	- Replace the rivets.
vii) Cracks in steel works	

a. Whenever a crack is detected in the steel work, its cause should be established and further propagation, if any, monitored. If the crack is propagating in a direction perpendicular to the stress in member, holes 20 or 22 mm dia may be drilled at crack ends to arrest the crack propagation. The edge of holes should be placed at visible ends of the crack. After holes are drilled it should be checked that crack tips have been removed and turned bolts of 20 or 22 mm dia as the case may be should be provided in the holes and fully tightened. Any reduction in strength of girder due to the crack and drill of holes should be given due consideration.

b. The method of repair of crack should be decided based on the location and severity of the crack.

As a long term solution the cracked member may be strengthened by cover plate (s), adequately riveted. If this is not feasible, the defective member may have to be taken out and repaired/replaced.

c. Permanent measures may consist of the cracked member being retrofitted with riveted or bolted splice or where feasible the entire member may be replaced.

d. Field welding should not be undertaken for repair of cracks.

viii) Rust mark over metalized - same as above (vii)
surface Possibility of crack/ loose rivet at joint

ix) Progressive loss of camber - May be due to overload or bad riveting. Check for stresses and strengthen it.
- Regirder the bridge
- Lift the panel joints and re-rivet the girder joints.

3. Pipes

i) Distortion of section/cracks - Change the pipe by rebuilding

ii) Sag - Strengthen sagged portion.

4. RC/PSC Slabs

i) Map pattern surface cracks (not progressive) - Keep under observation

ii) Structural cracks - Grouting with epoxy

iii) Spalling of concrete - Guniting

5. RC/PSC Girders

i) Cracks in anchorage zone - Epoxy grouting
- Replace the girder.

ii) Spalling/crushing	- Guniting
iii) Shear cracks, Flexural cracks	- Epoxy grouting.

6. Composite girders

i) Seperation of the concrete or Crack in Concrete	**a**. If separation of the concrete deck slab Slab from the steel girder is noticed, the location and length should be marked distinctly with paint for easy identification. Repair and retrofit scheme should be prepared after fully investigating the cause of the problem. Epoxy grouting may be done to bind the deck slab and the girder where the defect is noticed and the girder should be kept under close observation. If the epoxy grouting is not found effective, vertical prestressing or strapping may be necessary for which holes should be drilled in the deck slab near the girder in the affected location and vertical prestressing/ strapping provided. **b.** The drainage system of the deck slab should be thoroughly cleaned and repaired as necessary before the onset of monsoon. **c.** Wearing coat where provided, should be maintained.
ii) Defects in steel portion	- Similar action as mentioned under heading of steel girders.

7. BRIDGE NUMBERING IN LIGHT OF IRC 7:2017

7.1 Introduction

A uniform system of numbering of all the structures is essential for proper asset management. All culverts, minor bridges, major bridges, underpasses, flyovers, grade separators and tunnels on road shall be assigned separate numbers. This is a means for their easy identification of location and type of structure for the personnel for inspection and maintenance.

7.2 Scope

7.2.1 This document covers structures on all roads in the country.

7.2.2 Structures shall include

- **(i)** All culverts, including slab, box, hume pipes etc.
- **(ii)** All bridges
- **(iii)** All underpasses
- **(iv)** All overpasses, pedestrian bridges etc.
- **(v)** ROB's, flyovers and grade separator etc.
- **(vi)** Tunnels
- **(vii)** Any other structure

7.3 Numbering of Structures

7.3.1 All structures on a road shall be numbered in serial order, in each kilometer separately.

7.3.2 The number shall be in the form of a fraction, the numerator denoting the number of kilometer in which the structure is situated and the denominator the km wise serial number of the structure. For instance, the 5th structure in the 4th km (i.e. between km stones 3 and 4) shall be designated as 4/5, and the 8th structure in 25th km as 25/8.

7.3.3 For multi-lane carriageways, there should be either one combined structure or separate bridge structures. In case of one combined structure, the structure number shall be designated as in Sub-Clause 7.3.2 above. In case of separate bridge structures, the structure number shall be indicated as mentioned hereinafter. As the section progresses, the left hand side structure will have a suffix 'L ' and the right hand side structure will have a suffix 'R Similarly, the structures on service roads will have additional suffix For example (Table 7.1):

S. No.	**Location of Structures**	**Structure No.**
	2^{nd} structure between km 280 and 281	
1	Left side structure on service road	281/2 L S

2	Right side structure on service road	281/2 R S
3	Left side structure on main carriageway	281/2L
4	Right side structure on main carriageway	281/2R

Table 7.1 Numbering of Bridge

7.3.4 If any new culvert bridge or structures are built subsequently, say between the 3rd and 4th structure in km 375, the same shall be designated as 375/3/1, 375/3/2, etc.

7.4 Salient Information

For inspection and maintenance, it is useful to have mention of following salient information about structures:

- Year of construction
- Name of Channel / River / Crossing
- Length
- Span arrangement
- HFL
- Roadway
- Type of structure e.g. RCC/PSC, T-Beam and slab, Box girder, RCC/Stone Slab, Box culvert, tunnel feature, Arch, HP, Steel, Cable stayed, Extra-dosed.

These shall be provided on separate plate on the right hand side of the carriageway or the road.

7.5 Inscription of Structure Number

7.5.1 The structure number shall be inscribed near the top left hand side parapet wall railing posts for end of crash barrier as seen by traffic in the end elevation when approaching the structure from each direction. These are illustrated in Figs.1, 2 and 3.

7.5.2 In situations where instead of parapet walls, the structure is provided with railings, but having no end supporting pillars on which the number etc. could be inscribed, the number of the structure shall be indicated by means of a separate numbering plate of the size300 mm x 300 mm. There shall be two such numbering plates, one for each direction. The plates shall be welded or fixed securely on the left hand side facing the carriageway as close to entrance to the structure as possible.

7.5.3 In case of structures, such as pipe culverts, where there are usually no parapet walls or railings at the roadway level, two stone or R.C.C. marker posts, having a cross section of 150 mm x 150 mm and exposed height of at least 300 mm, shall be set up on the left side, one in each direction. Care shall be taken to locate the marker posts fully outside the prescribed roadway width. The culvert number shall be either engraved or painted. Alternatively, the number might also be inscribed at a suitable location on the head wall of the structure above the highest flood level.

NOTE: Deck Level shall indicate the level of bridge deck at the starting point of bridge as the section progresses, as under:

- *For 2-lane bridge - Deck Level at the road kerb (right side)*
- *For multi-lane carriageway - Deck Level at median*

7.6 Information Plate

7.6.1 The information of the structure shall be inscribed on two information plates one in each direction and fixed in the end elevation on a plate size near the top right hand side parapet wall / railing parts or end post of crash barrier etc. in the end elevation when approaching the structure. Information plate shall be of size 300 mm x 500 mm (for minor bridge and culverts) and 500 mm X 1000 m (for major bridges and other structures) Illustration is given in Fig. 4. The plate shall be fixed near the top right hand side.

7.6.2 In situation where instead of parapet walls, the structure is provided with railings, but having no end supporting pillars on which information could be inscribed, the same shall be indicated on a separate information plate of size 300 x 500 m. There shall be two such information plates, one in each direction. The plates shall be welded or fixed securely on the right hand side facing the carriageway as close to the entrance to the structure as possible.

7.6.3 In case of structures, such as pipe culverts where there are usually no parapet walls or railings, at the roadway level, two stone or R.C.C. posts having a cross section of 150 x 1 50 mm and exposed height of at least 500 mm, shall be set up on right side, one in each direction, on which an information plate of size 300 x 500 mm shall be fixed or welded securely. Care shall be taken to locate the posts and the plates fully outside the prescribed roadway width.

7.7 Numerals and Details

The numerals used shall be 100 mm high and of international form conforming to IRC: 30-1968 Standard Letters and Numerals of Different Height for use on Highway Signs. These shall be painted on smooth panels as prescribed. In case of right hand panel the height shall be suitably adjusted so that it does not obstruct the visibility. The colour of the background shall be canary yellow, ISI Shade 309.

7.8. Maintenance

The structure numbers and information plate shall be updated whenever any change takes place affecting the existing position. They shall be kept clean well maintained and regularly painted.

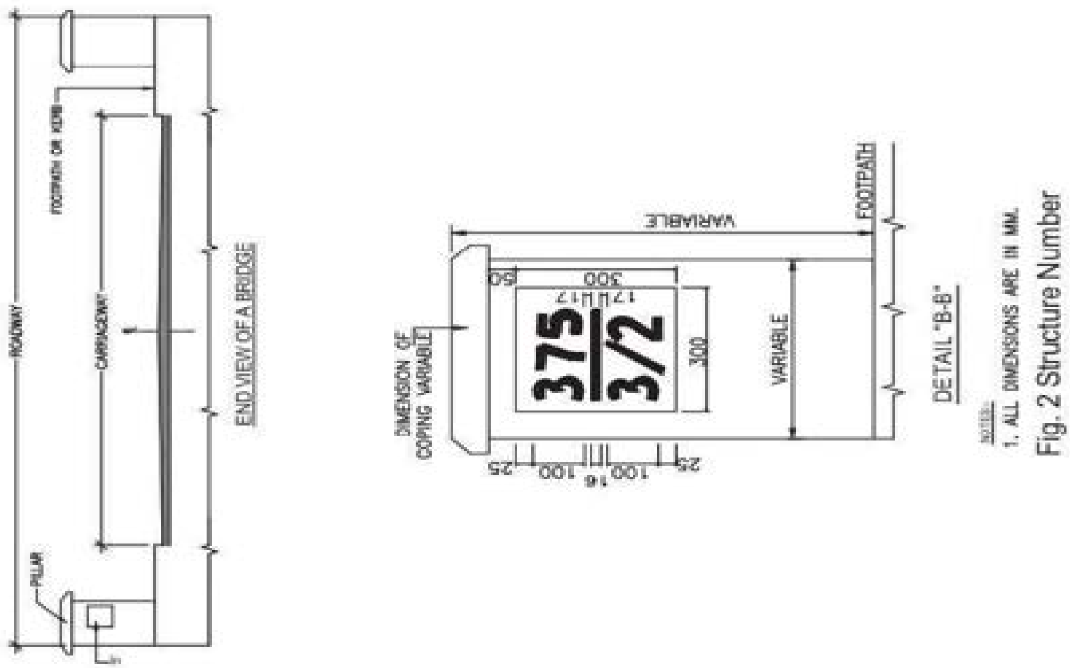


Fig. 2 Structure Number

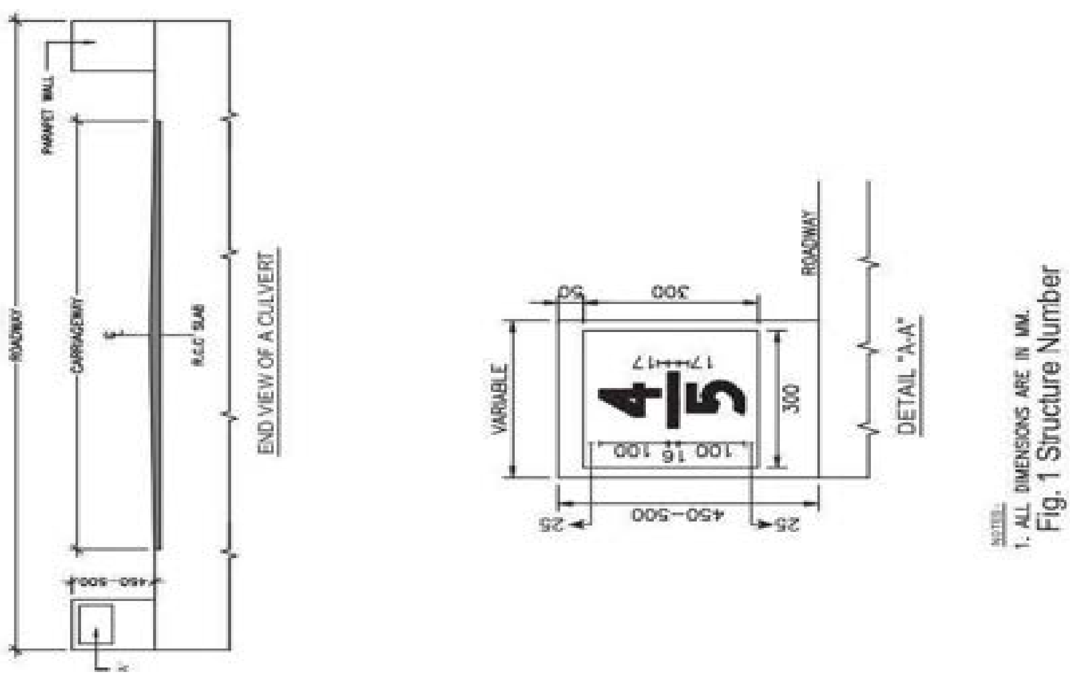
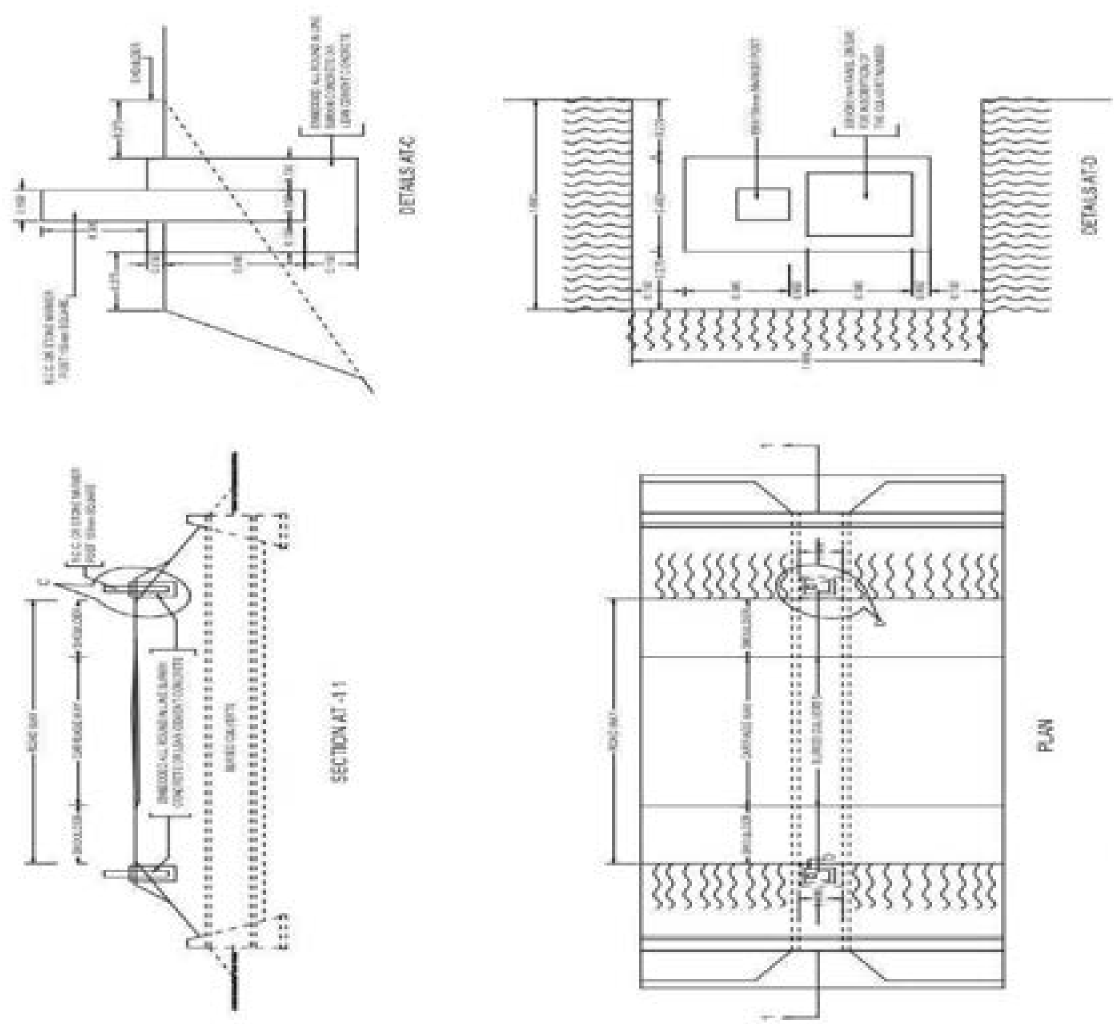


Fig. 1 Structure Number



ALL DIMENSION IN mm

Fig. 3 Structure number for Pipe Culverts and other Structures without end Pillars

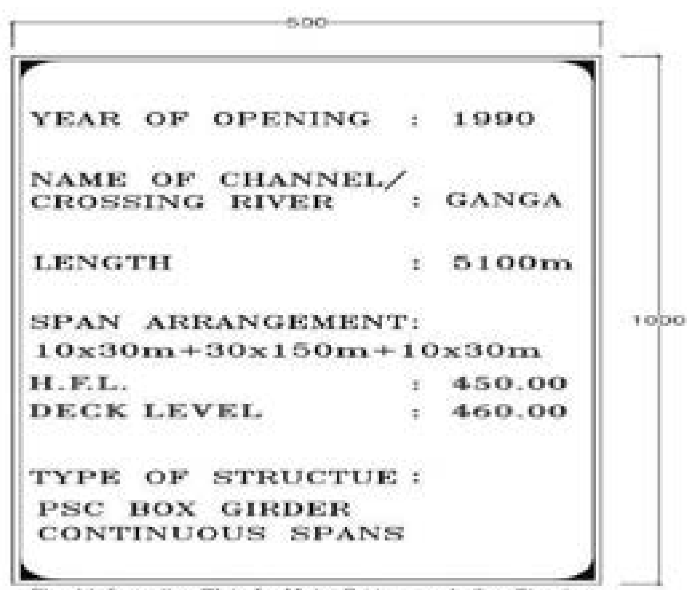


Fig. 4 Information Plate for Major Bridges and other Structures

8. STRUCTURAL HEALTH MONITORING (SHM) OF BRIDGES

8.1 Introduction

Structural Health Monitoring (SHM) involves the observation and analysis of a system over time using periodically sampled response measurements to monitor changes to the material and geometric properties of engineering structures such as bridges and buildings.

For long term SHM, the output of this process is periodically updated information regarding the ability of the structure to perform its intended function in light of the inevitable aging and degradation resulting from operational environments. After extreme events, such as earthquakes or blast loading, SHM is used for rapid condition screening and aims to provide, in near real time, reliable information regarding the integrity of the structure.

The SHM process involves selecting the excitation methods, the sensor types, number and locations, and the data acquisition/storage/transmittal hardware commonly called health and usage monitoring systems. Measurements may be taken to either directly detect any degradation or damage that may occur to a system or indirectly by measuring the size and frequency of loads experienced to allow the state of the system to be predicted.

SHM system implemented on bridges includes five operations of acquisition, validation, analysis, prognosis, and management of the system. The system and the sensors were developed to cover the parameters for the most important deterioration mechanisms: corrosion of reinforcement in bridges, carbonation of concrete, freeze-thaw cycles, alkali-silica reaction and mechanical damage, as well as the changes in the structures behavior and safety: static deformation, strains; crack widths and vibrations (frequencies, amplitudes, accelerations and vibration modes).

A SHM system can contribute to damage assessment in main five levels

- **Level I** - Damage detection when identifies that damage has occurred
- **Level II** - Damage location, when identifies that damage has occurred and determines the location of damage
- **Level III** - Damage typification, where identifies that damage has occurred, location of damage, and estimates the type of damage
- **Level IV** - Damage extent, where identifies that damage has occurred, location of damage, estimates the type of damage and evaluates the severity of damage
- **Level V** - Damage extent, where identifies that damage has occurred, location of damage, the type of damage, the severity of damage, and evaluates the remaining useful life of the bridge or viability state

It is recommended that SHM should be applied in case of exceptionally important bridges only due to its cost, skill and highly refined analysis involved.

8.2 Types of Monitoring

Health Monitoring can be subdivided into multiple types of categories. Both the time frame of monitoring and the scale of monitoring are necessary considerations that need to be addressed before choosing a type of monitoring system. A bridge owner may want to monitor the bridge health for a period of a year or a few months, while in other cases only a one-time short-term solution may be necessary. Conversely, a new structure may have an expected lifetime of 50 years and the owner would like a monitoring system that would last an extended period of time as well. Regarding the scale of monitoring, a specific joint or member in a bridge that has been problematic in the past may be the focus of the monitoring. On the other hand, an overall assessment of bridge response to loading may be the goal. The following definitions have been established to address the issues above.

8.2.1 Time Frame

Short-term – Monitoring to obtain bridge response information for a short-term objective. Examples include, but are not limited to load rating, tracking short-term fatigue growth, extending the life of a bridge for a year or less, or monitoring the response of a bridge for a permit vehicle.

Long-term – Monitoring of a new, retrofitted, or structurally deficient bridge to track response over an extended period of time, usually more than one year.

Inspection – Monitoring to assess the condition of the bridge or its components (e.g., the deck) as part of a regularly scheduled program (e.g., once every year or two).

Early Warning – Monitoring that offers alarm features which will provide notification automatically when certain pre-determined parameters are exceeded.

Collapse Warning – Monitoring that will close the bridge and warn motorists in the event of a bridge collapse.

8.2.2 Scale

Local – Monitoring that focuses on a specific location in the bridge; examples include monitoring to assess growth of a known crack, local buckling, corrosion at specific locations, and strain measurements.

Member – Monitoring that focuses on a specific member or member-sized region of a bridge; e.g., strain distributions in or deflections of a particular member.

Global – Monitoring that focuses on the overall health of the entire bridge; examples include natural frequencies and mode shapes, bridge deflection distributions, acoustic emissions, temperature distributions, and wind profiles.

8.3 Monitoring Metrics

Monitoring metrics are a system of parameters intended to measure bridge condition and performance. Depending on the type of bridge and the needs of the bridge owner, different measurements should be taken in order to properly monitor bridge health. Some metrics can be measured for any type of bridge; however, there are some measurements specific to concrete and steel bridges. It is important to know how each metric applies to the bridge of interest and what will be useful in monitoring the health of the bridge.

8.3.1 General Metrics

8.3.1.1 Acceleration - The instantaneous rate at which the velocity of a point in a vibrating bridge is changing with time. Acceleration is the most common measure taken to characterize vibrations. It is possible to define the frequencies and shapes of the different modes of vibration from a single acceleration trace. The frequencies and modes can be compared to values obtained from previous acceleration measurements to determine if the bridge has deteriorated or has been damaged.

8.3.1.2 Climatic Conditions - Pertains to the environmental conditions in the area of the bridge that may relate to bridge performance. Parameters that can be measured include: air temperature, wind speed, wind direction, relative humidity, and solar radiation.

8.3.1.3 Curvature - The rate of change of slope along the length of a flexural member and produced by transverse loading (i.e., normal to the longitudinal axis). From principles of structural mechanics, curvature is known to be directly proportional to bending moment in the member.

8.3.1.4 Displacements - The overall linear movement (i.e., translation) of a bridge either in relation to its original position or on a global scale. It is possible to measure the displacement in one, two or three independent directions.

8.3.1.5 Load - The total load of objects passing over a particular area of a bridge. This measure can be useful to enforce weight restrictions, as well as to define the range (i.e., spectrum) of typical traffic loads.

8.3.1.6 Tilt/Slope -The angular change of components in a bridge. This is useful in determining distortion in bridge geometry. Slope is the rate of change of deflection of a flexural member with respect to length. Angle changes with respect to a vertical plane are also useful to assess ‘out-of-plumb’ elements. It is useful to know if there has been a large change in angle on an element.

8.3.1.7 Scour - The removal of soil around the piers of bridges due to fast moving water currents during flooding. Removal of soil can lead to instability of piers.

8.3.2 Concrete Metrics

8.3.2.1 Corrosion - It is possible to determine whether or not the steel reinforcement embedded in concrete is at risk of depletion from attack of chloride or carbon dioxide. Some corrosion monitoring techniques determine the probability of corrosion occurring, while others determine the approximate corrosion rate. Different sensors and/or procedures may be required to monitor the corrosion of epoxy coated and non-epoxy coated rebar.

8.3.2.2 Cracking – The separation of concrete surfaces at the location of fractures is typically characterized by the width, length and number of cracks. Small-scale cracking (i.e., few, short, narrow cracks) is expected to take place in all concrete; however wider, longer and/or more numerous cracks are not expected. It is possible to detect the formation of these cracks through acoustic emission sensors. It is also possible to monitor known cracks using strain gauges placed over the area of interest.

8.3.2.3 Location of rebar/delaminations – The location of reinforcement in concrete can be determined using several non-destructive methods. These or similar techniques can be used to determine if the concrete above and below the reinforcement has begun to delaminate.

8.3.2.4 Strain – The relative elongation or shortening present in the concrete in specific locations of a bridge. In the service load range, the concrete behaves in a linear manner allowing the estimation of the stresses present at the particular location in the bridge.

8.3.2.5 Strength – The strength of concrete is typically characterized from tests of cylinder or cubes that are cast at the same time and from the same mix as the bridge member or component. For determining the initial in-situ strength of the concrete, measurements of concrete temperature can be taken while the member or component is curing and compared to previously obtained temperature-strength correlations for the particular concrete mix. This can be useful for quality control of the concrete during construction.

8.3.2.6 Tension (in rebar/tendons) – In post-tensioned systems, the tension in the cables is important to the overall strength of the concrete member. Also, if delamination occurs in reinforced concrete, the concrete cannot transfer forces to the rebar causing a reduction in stress. Thus, tension measurements can be used to assess the overall health of the structure.

8.3.3 Steel Metrics

8.3.3.1 Corrosion – The chemical reaction whereby steel loses electrons to water and oxygen and other corrosive materials (e.g., road salts). Monitoring is useful in order to determine extent and rates of corrosion within the structure.

8.3.3.2 Crack Growth – The elongation and/or widening of a known crack. Fatigue cracks may grow or remain static, with the former posing larger concerns than the latter regarding potential failure. Therefore, it is useful to a bridge owner to know if a fatigue crack is growing under the current loading conditions.

8.3.3.3 Cracking – The number, width and length of cracks in a steel member or component at locations of stress concentrations or fatigue loading. Such information is useful for predicting the remaining life in a steel bridge or for averting a sudden failure. Quantification of cracking is important because extensive cracking at a critical location or member in a steel bridge can cause large changes in stresses at other bridge locations.

8.3.3.4 Strain – The relative elongation or shortening present in the steel in specific locations of a bridge. In the service load range, the steel behaves in a linear manner allowing the estimation of the stresses present at the particular location in the bridge.

8.3.3.5 Tension (in cables) – Cables in suspension bridges are designed to handle tensile forces. Monitoring the magnitude of these forces is of interest, especially in cases where bridge loads have increased beyond design levels, or if deterioration of the cables is suspected or known.

8.4 Methods Used in Bridge SHM

8.4.1 Non-destructive testing methods

Testing can be an effective tool in the inspection and condition assessment of bridge structures. According to the degree of their invasiveness, testing methods can be divided into destructive, semi-destructive and non-destructive testing (NDT) methods. The destructive methods comprise tests normally performed in laboratory under more or less controlled conditions that may not mirror actual conditions experienced in the field. Additionally, these tests can be rather expensive as it is often necessary to damage the component or load it to failure. The NDT methods comprise a wide group of analysis techniques used to evaluate the properties of a material, component or system without causing damage. This advantage is particularly useful for evaluating in-service bridges, since the bridges can remain intact and open to traffic under the evaluation period minimizing the impact to the community and the travelling public. Table 8.1 lists some of the most well-known traditional NDT techniques used for damage detection.

Table 8.1 Non-destructive testing methods

Audio-visual methods	Visual inspection Chain drag Coin tap test
Stress-wave methods	Acoustic emission Impact echo testing Sonic testing Ultrasonic NDT

	Impulse response (IR)
Electro-magnetic methods	Ground penetrating radar (GPR) Conductivity Half-cell potential Electrical resistivity measurement
Deterministic methods	Proof load test Coring
Miscellaneous tests	Dynamic/vibration testing Infrared thermography Radiography

8.4.2. Vibration-based damage identification methods

For a global assessment of the structure's integrity vibration-based damage identification (VBDI) methods can be used. Natural frequencies are the most fundamental vibration parameter and methods directly measuring shifts in natural frequency (or eigenvalue) can be used for identifying damage. Traditional VBDI techniques have been widely researched in the past decades and Cawley & Adams are likely to be the first researchers to give formulation for damage detection from frequency changes before and after damage is introduced. Since frequencies and mode shapes of the structure under vibration are a function of its mass and stiffness and, as mass generally remains constant, any changes in the dynamic behavior will be associated with stiffness variations, which implicitly point to the presence of damage in the structure. Thus, VBDI methods consist of measuring and evaluating the dynamic behavior of the structure often by comparing it to the behaviour simulated by numerical models, for instance by finite element (FE) models. Other times that comparison is based on times series data but in that case a large number of sensors need to be placed accurately in order to record the required data.

8.4.3. Model-based and data-based methods

The methods for assessment of structures can be split into two main classes, according to their approach. For a full understanding of the behavior of a particular structure, physics-based models are usually the most appropriate. As the name itself indicates, a physics-based approach typically presupposes a finite element (FE) model of the target structure. These models are often of gradually increasing complexity during the development stage, so as to make sure that the measured responses can be reproduced as much as accurate by the FE model. As such, the models evolve from simple conceptual system representations to physics-based high-fidelity models, which accurately represent the actual physical asset. Since many algorithms of damage detection are based on the difference between the modified models before and after occurrence of damage, problems such as parameter identification and damage detection are closely related to model updating. The models can be updated in the presence of new collected data, provide feedback into the physical twin and simulate plausible scenarios for assessing risks and predicting structural performance. The data-based approach is free of geometrical and material information, allowing to circumvent the burden of having to develop a detailed FE model of the monitored structure, mostly by using Artificial Intelligence (AI) techniques. With this approach time series analysis or signal processing techniques are employed to extract damage-sensitive features from the measured signals. In these regards, choosing proper damage features is crucial for successful damage detection as these features are used to establish baseline statistics and to monitor change in structural behavior.

8.5 Review of Case Studies of SHM of Bridges

8.5.1 Russia-Monitoring of Vintage Bridge –

This bridge was constructed in 1936-37 over Moskova river in Moscow next to Kremlin. It is a Reinforced Concrete arched box girder bridge. It was declared a heritage building as it is more than 70 years old. Total length of bridge is 250m with 3 spans (43+92+43), 3 parallel arches. The SHM was started in 2003. Types of sensors used were 16 standard SOFO sensors in central arch plus 6 thermo couples. Numbers of sensors used were 22. Instrumentation was designed by SMARTEC SA, Switzerland and ZAO Triada holdings, Russia.

Purpose- To continuously monitor temperature and average strain along horizontal and vertical directions.

Results- Settlement of an abutment producing cracking of the stone lining and structural element. Another was chloride penetration into the structure leading to reinforcement corrosion.

8.5.2 Japan - Monitoring of Suspension Bridge

Hakucho bridge which is located at windy and seismically active area in northern part of Muroran, Hokkaido, Japan was opened on April 17, 1998. The main span of the bridge is 720 m installed with sensors placed at locations Z1 to Z19.

Purpose- The purpose of the monitoring is to understand the actual dynamic behavior and loading conditions, and to develop a health monitoring scheme using ambient vibration measurement which is readily available under service conditions

8.5.3 India- SHM of Naini Bridge (2001-2004)

Naini Bridge is 1510 meter long bridge for four lane traffic and with a footpath and a cycle track on each side of the traffic lanes. For crossing the deep channel of the river a 490 meter long cable stayed bridge is provided having a main span of 260 meter and side spans of 115 meter. On both sides of the cable stayed part approach bridges have been provided, one 365 meter long with typical spans of 25 meter and the other 515 meter long with typical spans of 60 meter.

The Structural Health Monitoring System (SHMS) for Naini Bridge was designed as a modern advanced monitoring system with the provisions for design verification, user safety support and optimization of maintenance planning. Also the system was designed to operate by a distributed data acquisition network based on standard data acquisition units and standard data acquisition software from US based National Instruments, in order to keep costs low.

Purpose- Building a high channel count SHM system to continuously scan the response of a large cable stayed bridge due to various changes in climate and operations.

So for the SHMS has through advanced GPS and Weigh in Motion monitoring proven able to detect the frequency of overloaded vehicles passing the bridge and to verify some design parameters concerning temperature movements.

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APPENDIX – I

CHECKLIST FOR PREPARATION OF GAD

A. GENERAL

1 Title block, scales names etc. correctly written

2 Key plan indicated

3 North Line indicated

4 Chainage indicated

5 In notes, units of dimensions, levels and chainages indicated

6 In notes, Type of superstructure indicated

7 In notes, Type of substructure indicated

8 In notes, Type of foundation indicated

9 In notes, Type of expansion joints indicated

10 In notes, Type of bearings indicated

11 In notes, Type of wearing coat indicated

12 Grades of concrete for superstructure, substructure, foundation, approach slab, abutment, wing wall / return wall, toe walls, PCC below foundations etc. indicated

13 Details for arrangements at dirt wall given

14 Details for arrangements at expansion joints given

15 Section of abutments given clearly

16 Section of return wall along with fly wings given

17 Section of piers and foundations given clearly

18 All section marks and details numbering are tallying with the actual sections / details

19 No detail / section numbering is repeated / missed

B. PLAN

1 Directions “to___” in both sides indicated

2 Span arrangements with embankment lengths, viaduct lengths etc indicated

3 Expansion joints indicated

4 Crash barrier location shown

5 Handrails location shown

6 Piers, abutment, return walls / wing walls shown

7 Toe walls shown

8 Length of return wall / wing walls shown

9 Skew angles indicated and skew / square dimensions indicated

10 Centre line of bridge axis and piers / abutments indicated along with setout dimensions.

11 Median indicated and shaded

12 Median wall and connectivity / dry joint to existing structure shown

13 Drainage spouts indicated

14 Tapering of carriageways at approaches indicated

15 Approach embankment revetment, side slope pitching and bed pitching with toe walls indicated

16 Indicated the profile of river bed / railway tracks / roads

17 U /s and D / s sides indicated

18 Web lines indicated in dotted

19 Chainages indicated

20 Approach slab indicated

21 Hand rails / Crash barrier lines indicated

22 Railway chainage indicated and railway directions indicated

C. ELEVATION

1 Span arrangements with embankment lengths, viaduct lengths etc indicated

2 Directions "To___" in both sides indicated

3 Expansion Joints indicated

4 Crash barrier location shown

5 Handrails location shown

6 Piers, abutment, return wall / wing walls shown

7 Toe walls shown

8 Length of return wall / wing wall shown

9 Dimensions in square / skew indicated

10 Centre line of bridge axis and piers / abutments indicated along with setout dimensions.

11 HFL indicated

12 Chainages and FRL at deck level indicated

13 Bed level indicated

14 Approach embankment revetment, side slope pitching and bed pitching with toe walls indicated.

15 Foundations shown and levels indicated

16 Indicated the clearance from HFL / tracks / highest road level to soffit

D. SECTION

1 Title block, scales names etc. Correctly written

2 Crash barrier location shown

3 Handrails location shown

4 Piers, abutment, return walls / wing walls shown

5 Toe walls shown

6 Centre line of bridge deck with respect to existing bridge indicated

7 Drainage spouts indicated

8 HFL indicated

9 FRL at deck level indicated

10 Bed level indicated

11 Approach embankment revetment, side slope pitching and bed pitching with toe walls indicated

12 Section of piers indicated

13 Section of abutment indicated

14 Foundations shown and levels indicated

15 Indicated the clearance from HFL / tracks / highest road level to soffit

16 U /s and D / s indicated

17 Wearing coat indicated

Appendix – II

CHECKLIST FOR SUBMISSION OF GAD TO RAILWAY DEPARTMENT FOR ROBs

(i) Railway Boundary marked on GAD.

(ii) Railway track existing and tracks proposed in future marked on GAD.

(iii) A railway signal detail (if at point) is marked. LC no if level crossing is present marked.

(iv) Railway chainage marked on drawings.

(v) Minimum distance of Pile Cap / Pier Shaft / Abutment shall be minimum of 2360mm from the central line of track.

(vi) For the distance between top of railway track and soffit level shall be

a. The minimum height is 6550mm for ROB (Road Over Bridge).
b. Where double Decker trains are likely to run height is 7300.

Appendix – III

Order Copy of Ministry of Shipping, Road Transport and Highways Govt. of India

Government of India
Ministry of Shipping, Road Transport & Highways
(Department of Road Transport & Highways)

Transport Bhawan,
1, Parliament Street,
New Delhi – 110 001.

No. RW/NH/33044/2/88-S&R(B)

24th March, 2009

To

1. Secretaries of all State Governments /UTs dealing with National Highways.
2. Engineer-in-Chief / Chief Engineer of all States Governments/ UTs dealing with National Highways.
3. Secretary, Transport of all State Governments and UTs.
4. Chairman, National Highways Authority of India.
5. Director General (Border Roads).
6. All ROs/ELO

Subject: Width of Bridges on 2-lane National Highways (with and without footpath).

Sir,

Instructions were issued vide this Ministry's letter of even number dated 9th May, 2000 regarding width of bridges to be provided on National Highways. The matter has been reconsidered in the light of concern for safety of vehicles/pedestrians using the bridges. The following revised guidelines are now issued in supersession of the earlier instructions for bridges on 2-lane NHs. These guidelines are applicable essentially to future cases.

2. **GENERAL**

The basic approach is that the width of carriageway of all bridges irrespective of their lengths or location / terrain (rural, urban, plain) shall be that:-

a) for free flow of traffic from approaches to bridge, width of carriageway on bridge shall be equal to the carriageway width of immediate approaches plus paved shoulders even if presently not provided. For bridges on 2-lane NHs the carriageway width shall be 10.50m (paved shoulder and kerb shyness on either side taken as 1.50m and 0.25m respectively).

b) Overall width of bridges will vary depending upon width of carriageway, footpath, safety kerbs, crash barriers, railings and provision for kerb shyness. Overall width of bridges for 2-lane NHs without footpath and with footpath are given in table in Annexure.

c) Formation width of the immediate approaches shall be equal to overall width between outermost faces of the railing / crash barrier of the bridge. In case the formation width of approaches is different than the overall width of the bridge as stipulated in (b) above,

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formation shall be increased to the overall width of bridge in at least for 90 m on either side of bridge followed by a transition of 1: 20.

3. Existing Narrow bridges on NHs:

3.1 Narrow Bridges having width of deck less than the width of approaches are potential source of accidents. It is necessary to provide positive guidance so that the drivers have sufficient information to safely negotiate the narrow bridges. For this purpose, the safety measures shall be adopted as per site requirement as spelt out in circular No. RW/NH/33044/2/88-S&R(B dated 31.10.2008 .

4. FOOTPATHS

4.1 Footpath to bridges located in urban and rural areas may be decided on the basis of expect pedestrian traffic. In case the pedestrian traffic is heavy, the width of the footpath can be suitably increased or a separate pedestrian bridge can be considered depending on site condition. However minimum width of footpath shall be 1.5m.

4.2 Provision of footpath for bridges in rural areas particularly for very long bridges shall be considered on case to case basis.

4.3 Typical cross section of bridges on 2-lane NHs without footpath and with footpath of 1.5 m width are at Figure.1 and 2 respectively.

4.4 In case provision for ducts for taking telephone wires, gas pipeline and electric cable is to be provided, then the shoulder shall be raised otherwise the footpath shall be at the same level as that of the carriageway on the bridge.

4.5 At the entrance to the footpath on either end of the bridge suitable barrier shall be provid' so that two and three wheelers can't enter the footpath.

5. CRASH BARRIERS

5.1 Crash barriers shall be provided on all the bridges on National Highways to safeguard against the errant vehicles. The type & design for the concrete crash barrier may be adopted as per IRC: 5-1998 & IRC: 6: 2000.

5.2 For bridges without footpath, crash barriers shall be provided at the riverside.

5.3 For bridges with footpath, crash barrier shall be provided between footpath and carriageway as shown in Figure 2.

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5.4 For bridges with footpath, having length more than 100m, half metre (0.5 m) wide opening in the crash barrier shall be provided at 50 m interval.

6. EXTRA WIDTH ON BRIDGES LOCATED ON CURVES:

Extra carriageway width of bridge located on curves shall be provided as per IRC codal provisions applicable for road section on curves.

7. Road over bridges on National Highways

The above provisions shall also generally apply to all road over bridges except where any deviations have to be made due to specific site constraints.

It is requested that the contents of this circular be brought to the notice of all officers in your department concerned with National Highways and other centrally sponsored schemes.

Yours faithfully,

Sharma.

(Arun Kumar Sharma)
Chief Engineer (S & R) B
For Director General (Road Development) & S,S
Telephone: 011-23719850

Annexure : Width of bridge on two lane National Highway with and without footpath

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ANNEXURE

Width of bridge on two lane National Highway without and with footpath
(Reference para 2 and fig. 1, 2 & 3)

Dimensions in meters

Description	Bridge without footpath	Bridge with footpath (1.5 footpath
Carriageway Kerb shyness	10.00 0.50(2x 0.25)	10.00 0.50(2x 0.25)
Footpath	-	3.00 (2 x 1.50)
Safety Kerbs	1.50 (2 x 0.75)	-
Crash Barrier	0.90 (2 x 0.45)	0.90 (2 x 0.45)
Railings	-	0.40 (2 x 20)
Overall width	12.90	14.80

Note:

(a) Carriageway width of 10.50m on bridges is planned to account for paved shoulders on approaches if provided later. Thus to arrive at the width of carriageway on bridges, the allowance for paved shoulders and kerb shyness has been made.

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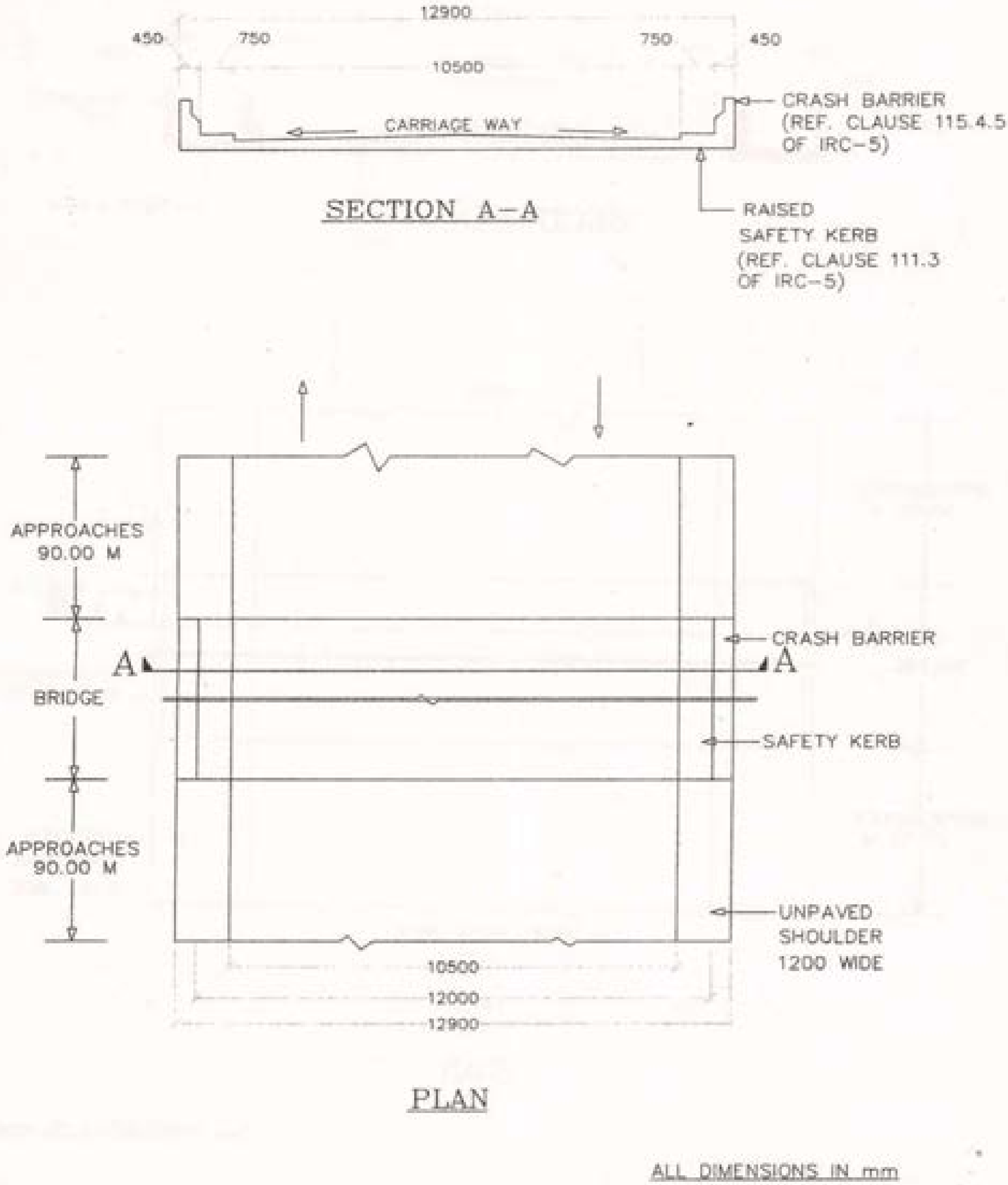

FIG.1:—TWO LANE HIGHWAY BRIDGE WITHOUT FOOTPATHS HAVING CRASH BARRIER AT THE EDGES

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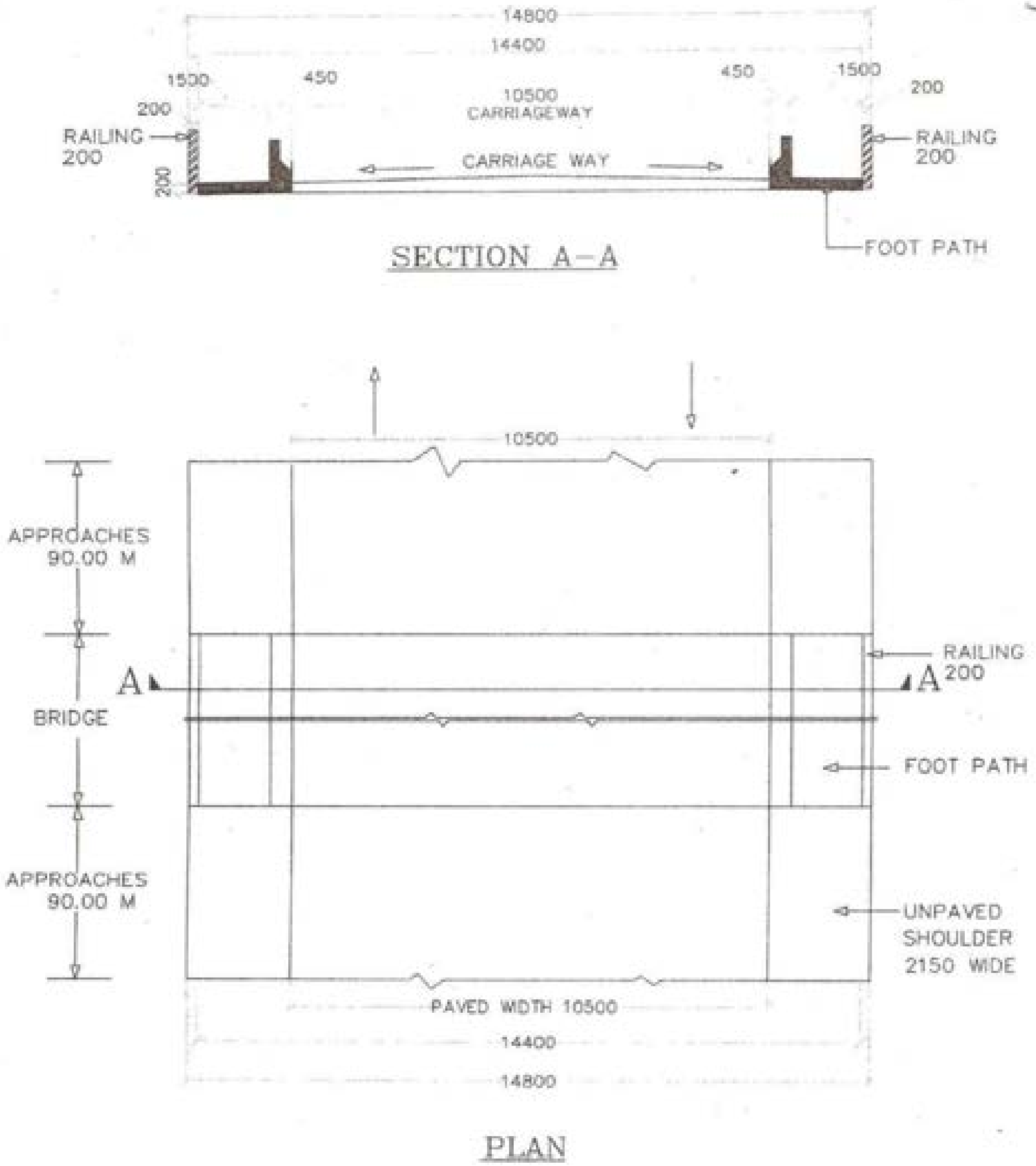

ALL DIMENSIONS IN mm

FIG.2:-TWO LANE HIGHWAY BRIDGE WITH FOOTPATHS HAVING CRASH BARRIER BETWEEN FOOTPATH AND CARRIAGEWAY

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APPENDIX-IV

LIST OF IRC CODES AND SPECIAL PUBLICATIONS

S. No.	Code/ Document No.	Title of the Publication
1	IRC:2-1968	Route Marker Signs for National Highways (First Revision)
2	IRC:3-1983	Dimensions & Weights of Road Design Vehicles (First Revision)
3	IRC:5-2015	Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design (Eighth Revision)
4	IRC:6-2017	Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Load Combinations (Seventh Revision)
5	IRC:7-2017	Recommended Practice for Numbering Culverts, Bridges and Tunnels (Second Revision)
6	IRC:8-1980	Type Designs for Highway Kilometre Stones (Second Revision)
7	IRC:9-1972	Traffic Census on Non-Urban Roads (First Revision)
8	IRC:11-2015	Recommended Practice for the Design and Layout of Cycle Tracks (First Revision)
9	IRC:12-2016	Unified Guidelines for Access Permission to Fuel Stations, Private Properties, Rest Area Complexes and Such Other Facilities Along National Highways (Fourth Revision)
10	IRC:14-2004	Recommended Practice for Open Graded Premix Carpets (Third Revision)
11	IRC:15-2017	Code of Practice for Construction of Jointed Plain Concrete Pavements (Fifth Revision)
12	IRC:16-2008	Standard Specifications and Code of Practice for Prime and Tack Coat (Second Revision)
13	IRC:19-2005	Standard Specifications and Code of Practice for Water Bound Macadam (Third Revision)
14	IRC:20-1966	Recommended Practice for Bituminous Penetration Macadam (Full Grout)
15	IRC:22-2015	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit States Design) (Third Revision)
16	IRC:24-2010	Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method) (Third Revision)
17	IRC:25-1967	Type Designs for Boundary Stones
18	IRC:26-1967	Type Design for 200-Metre Stones
19	IRC:27-2009	Specifications for Bituminous Macadam (First Revision)

20	IRC:28-1967	Tentative Specifications for the Construction of Stabilized Soil Roads with Soft Aggregate in Areas of Moderate and High Rainfall
21	IRC:30-1968	Standard Letters and Numerals of Different Heights for Use on Highway Signs
22	IRC:32-1969	Standard for Vertical and Horizontal Clearances of Overhead Electric Power and Telecommunication Lines as Related to Roads
23	IRC:33-1969	Standard Procedure for Evaluation and Condition Surveys of Stabilised Soil Roads
24	IRC:34-2011	Recommendations for Road Construction in Areas Affected by Water Logging,Flooding and/or Salts Infestation (First Revision)
25	IRC:35-2015	Code of Practice for Road Markings (Second Revision)
26	IRC:36-2010	Recommended Practice for Construction of Earth Embankments and Sub-Grade for Road Works (First Revision)
27	IRC:37-2018	Guidelines for the Design of Flexible Pavements" (Fourth Revision)
28	IRC:38-1988	Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision)
29	IRC:39-1986	Standards for Road-Rail Level Crossings (First Revision)
30	IRC:40-2002	Standard Specifications and Code of Practice for Road Bridges, Section IV – (Brick, Stone and Cement Concrete Block Masonry) (Second Revision)
31	IRC:41-1997	Guideline for Type Designs for Check Barriers (First Revision)
32	IRC:42-1972	Proforma for Record of Test Values of Locally Available Pavement Construction Materials
33	IRC:43-2015	Recommended Practice for Plants, Tools and Equipment Required for Construction and Maintenance of Concrete Roads (First Revision)
34	IRC:44-2017	Guidelines for Cement Concrete Mix Design for Pavements (Third Revision)
35	IRC:45-1972	Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well Foundations of Bridges
36	IRC:46-1972	A Policy on Roadside Advertisements (First Revision)
37	IRC:47-1972	Tentative Specification for Built-up Spray Grout
38	IRC:50-1973	Recommended Design Criteria for the Use of Cement Modified Soil in Road Construction
39	IRC:52-2019	Guidelines for the Alignment Survey and Geometric Design of Hill Roads (Third Revision)
40	IRC:53-2012	Road Accident Recording Forms A-1 and 4 (Second Revision)
41	IRC:54-1974	Lateral and Vertical Clearances at Underpasses for Vehicular Traffic
42	IRC:55-1974	Recommended Practice for Sand-Bitumen Base Courses
43	IRC:56-2011	Recommended Practices for Treatment of Embankment and Roadside Slopes for Erosion Control (First Revision)

44	IRC:57-2018	Recommended Practice for Sealing of Joints in Concrete Pavements (Second Revision)
45	IRC:58-2015	Guidelines for the Design of Plain Jointed Rigid Pavements for Highways (Fourth Revision)
46	IRC:60-1976	Tentative Guidelines for the Use of Lime- Fly Ash Concrete as Pavement Base or Sub-Base
47	IRC:62-1976	Guidelines for Control of Access of Highways
48	IRC:63-1976	Tentative Guidelines for the Use of Low Grade Aggregates and Soil Aggregates Mixtures in Road Pavement Construction
49	IRC:64-1990	Guidelines for Capacity of Roads in Rural Areas (First Revision)
50	IRC:65-2017	Guidelines for Planning and Design of Roundabouts (First Revision)
51	IRC:66-1976	Recommended Practice for Sight Distance on Rural Highways (First Revision)
52	IRC:67-2012	Code of Practice for Road Signs (Third Revision)
53	IRC:69-1977	Space Standards for Roads in Urban Areas
54	IRC:70-2017	Guidelines on Regulation and Control of Mixed Traffic in Urban Areas (First Revision)
55	IRC:71-1977	Recommended Practice for Preparation of Notations
56	IRC:72-1978	Recommended Practice for Use and Upkeep of Equipment, Tools and Appliances for Bituminous Pavement Construction
57	IRC:73-1980	Geometric Design Standards for Rural (Non- Urban) Highways
58	IRC:74-1979	Tentative Guidelines for Lean-Cement Concrete and Lean- Cement Fly Ash Concrete as a Pavement Base or Sub-Base
59	IRC:75-2015	Guidelines for the Design of High Embankments (First Revision)
60	IRC:76-1979	Tentative Guidelines for Structural Strength Evaluation of Rigid Airfield Pavements
61	IRC:78-2014	Standard Specifications and Code of Practice for Road Bridges, Section VII- Foundations and Substructure (Revised Edition)
62	IRC:79-2019	Recommended Practice for Road Delineators (First Revision)
63	IRC:80-1981	Type Designs for Pick-up Bus Stops on Rural (i.e., Non-Urban) Highways
64	IRC:81-1997	Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique (First Revision)
65	IRC:82-2015	Code of Practice for Maintenance of Bituminous Road Surfaces (First Revision)
66	IRC:83-2015 (Part-I)	Standard Specifications and Code of Practice for Road Bridges, Section IX Bearings, Part I : Roller & Rocker Bearings (Second Revision)
67	IRC:83-2018 (Part II)	Standard Specifications and Code of Practice for Road Bridges, Section : IX – Bearings (Elastomeric Bearings),Part II (Second Revision)

68	IRC:83-2018 (Part III)	Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearings, Part III: POT, PIN, Metallic Guide and Plane Sliding Bearings (First Revision)
69	IRC:83-2014 (Part IV)	Standard Specifications and Code of Practice for Road Bridges, (Section IX) – Bearings (Spherical and Cylindrical)
70	IRC:85-2015	Recommended Practice for Accelerated Strength Testing & Evaluation of Concrete (First Revision)
71	IRC:86-2018	Geometric Design Standards for Urban Roads and Streets (First Revision)
72	IRC:87-2018	Guidelines for Formwork, Falsework and Temporary Structures for Road Bridges (Second Revision)
73	IRC:88-1984	Recommended Practice for Lime Flyash Stabilised Soil Base/Sub-Base in Pavement Construction
74	IRC:89-2019	Guidelines for Design and Construction of River Training & Control Works for Road Bridges (Second Revision)
75	IRC:90-2010	Guidelines of Selection, Operation and Maintenance of Bituminous Hot Mix Plant (First Revision)
76	IRC:92-2017	Guidelines for the Design of Interchanges in Urban Areas (First Revision)
77	IRC:93-1985	Guidelines on Design and Installation of Road Traffic Signals
78	IRC:98-2011	Guidelines on Accommodation of Utility Services on Roads in Urban Areas (Second Revision)
79	IRC:99-2018	Guidelines for Traffic Calming Measures in Urban and Rural Areas (First Revision)
80	IRC:101-1988	Guidelines for Design of Continuously Reinforced Concrete Pavement with Elastic Joints
81	IRC:102-1988	Traffic Studies for Planning Bypasses Around Towns
82	IRC:103-2012	Guidelines for Pedestrian Facilities (First Revision)
83	IRC:104-1988	Guidelines for Environmental Impact Assessment of Highway Projects
84	IRC:105-2019	Specifications forDense Bituminous Macadam and Bituminous Concrete for Airfield Pavements (First Revision)
85	IRC:106-1990	Guidelines for Capacity of Urban Roads in Plain Areas
86	IRC:107-2013	Specifications for Bitumen Mastic Wearing Courses (First Revision)
87	IRC:108-2015	Guidelines for Traffic Forecast on Highways (First Revision)
88	IRC:109-2015	Guidelines for Wet Mix Macadam (First Revision)
89	IRC:110-2005	Standard Specifications and Code of Practice for Design and Construction of Surface Dressing
90	IRC:111-2009	Specifications for Dense Graded Bituminous Mixes

91	IRC:112-2019	Code of Practice for Concrete Road Bridges (First Revision)
92	IRC:113-2013	Guidelines for the Design and Construction of Geosynthetic Reinforced Embankments on Soft Subsoils
93	IRC:114-2013	Guidelines for use of Silica Fume in Rigid Pavement
94	IRC:115-2014	Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements Using Falling Weight Deflectometer (FWD) Technique”
95	IRC:116-2014	Specifications for Readymade Bituminous Pothole Paching Mix using Cut-Back Bitumen
96	IRC:117-2015	Guidelines for the Structural Evaluation of Rigid Pavement by Falling Weight Deflectometer
97	IRC:118-2015	Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement (CRCP)
98	IRC:119-2015	Guidelines for Traffic Safety Barriers
99	IRC:120-2015	Recommended Practice for Recycling of Bituminous Pavements
100	IRC:121-2017	Guidelines for Use of Construction and Demolition Waste in Road Sector
101	IRC:122-2017	Guidelines for Construction of Precast Concrete Segmental Box Culverts
102	IRC:123-2017	Guidelines on Geophysical Investigation for Bridges
103	IRC:124-2017	Bus Rapid Transit (BRT) Design Guidelines for Indian Cities
104	IRC:125-2017	Guidelines on Dozers for Highway Works
105	IRC:126-2017	Guidelines on Wet Mix Plant
106	IRC-127-2018	Guidelines on Skill Development of Workmen in Road Sector
107	IRC-128-2019	Guidelines on Training of Highway Professionals
108	IRC-129-2019	Specifications for Open-Graded Friction Course
109	IRC:SP:4-1966	Bridge Loading Round the World
110	IRC:SP:12 -2015	Guidelines for Parking Facilities in Urban Roads” (First Revision)
111	IRC:SP:13-2004	Guidelines for the Design of Small Bridges and Culverts (First Revision)
112	IRC:SP:14-1973	A Manual for the Application of the Critical Path Method to Highway Projects in India
113	IRC:SP:15-1996	Ribbon Development Along Highways and Its Prevention
114	IRC:SP:16-2019	Guidelines on Measuring Road Roughness and Norms (Second Revision)
115	IRC:SP:18-1978	Manual for Highway Bridge Maintenance Inspection
116	IRC:SP:19-2001	Manual for Survey, Investigation and Preparation of Road Projects (Second Revision)
117	IRC:SP:20-2002	Rural Roads Manual
118	IRC:SP:21-2009	Guidelines on Landscaping and Tree Plantation
119	IRC:SP:22-1986	Recommendation for the Sizes for each Type of Road Making Machinery to Cater to the General Demand of Road Works

120	IRC:SP:23-1983	Vertical Curves for Highways
121	IRC:SP:24-1984	Guidelines on the Choice and Planning of Appropriate Technology in Road Construction
122	IRC:SP:25-1984	Gopi and his Road Roller-Guidelines on Maintenance of Road Rollers
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