Section - 3

Lesson - 1

Type of Railway Bridges and Their Construction

1. What Are The Bridges:

Any structure which allows more than one type of movement unobstructed is known as bridge. For example if our purpose is to allow river water flowing unobstructed, but simultaneously to cross the river also at safer level for passage of traffic, then we need a structure known as bridge. It should have efficient opening to pass the river water, provide decking arrangement for passage of traffic at desired level and also as a structure. It should have adequate strength to cater for the various loads and forces coming to it.

Similarly if objective is to pass rail traffic as well as road traffic unobstructed at the crossing point then these two traffics should be allowed at different level by means of a structure, here also known as bridge. It is a separate issue that this bridge is to be further categorized as road over bridge or road under bridge depending upon the situation whether road traffic is above the track or below the track respectively.

Basic parts of the bridge

Mainly the bridges are having two parts i.e. super structure and sub structure & foundation. The same are described below:

(a) Super Structure

The super structure is the part of a bridge structure which receives and supports highway, railway or other traffic and transfers the reactions to the bridge substructure. The main components of the superstructure are the deck and the main structural system. Structural system supports the deck and spans between the substructure units.

The deck, which carries traffic, is classified on the basis of method of construction and material such as concrete deck slab, steel girder, laminated timber deck, etc.

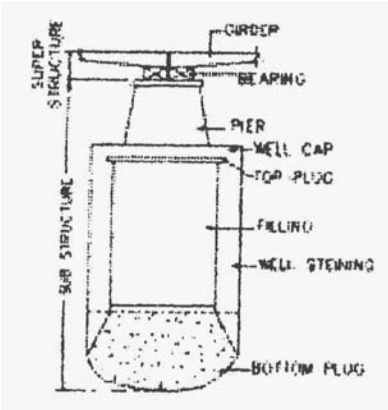
The deck is the floor system which distributes the dead loads and live loads to the main structural members or stringers.

(b) Sub Structure & Foundation

The substructure, the lower structural portion of a structure, transmits the total dead load, live loads and forces to the supporting rock or soil through foundation. The components of the substructure are abutments and piers. Also included as sub structural elements are foundations, including footings, piles and retaining walls etc.

Piers and abutments provide the connection between the superstructure and the supporting soil or rock. They are essentially blocks of concrete or stone masonry, built such that a large portion of their mass usually is below the ground or water level.

The piers are generally the intermediate substructure unit which supports the superstructure.



An abutment is a structure that carries one end of bridge span and at the same time, laterally supports the end of an embankment that serves as an approach to the bridge.

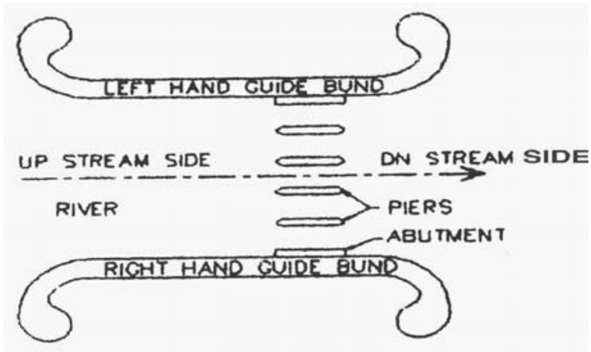
In this way, abutments function as a combination of pier and retaining wall. In the case of a stream crossing, an abutment often functions as protection for the embankment against scour of the stream Details of sub structure and super structure is shown in fig.1

Over and above, some of the bridges have some additional components, which are known as protective works. Some of protective works are described below:

Fig. 1 DETAILS OF SUBSTRUCTURE AND SUPERSTRUCTURE ON WELL FOUNDATION

- Guide bund
- Marginal bund
- Aprons
- Flooring, drop wall and curtain wall etc.

Details of guide bund as protective work is shown in fig. 1 (a) while that wing wall is shown in fig. 1 (b)



WING WALL

FIG. I (a) BRIDGE PLAN SHOWING GUIDE BUND AS A PROTECTION WORK

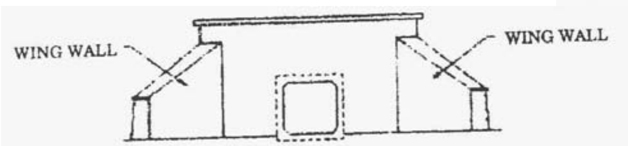


Fig 1(b) WIN WALL WHICH ALSO WORK AS PROTECTIVE WORK IN ADDITION TO EARTH RETAINER AND GUIDING THE FLOW OF WATER

1.1 Classification of Bridges

According to the Railway Bridges sub-structure code, the Railway Bridges are divided into following categories depending upon their water-way:

(a) **Important Bridges –** Those having a linear waterway of 300 m or more or a total waterway of 1000 sqm or more. Any other bridge can also be classified as 'important' by Chief Engineer or Chief Bridge Engineer depending on its maintenance problems.

(b) **Major Bridges –** Those having either a total waterway of 18 m or more or which have a clear opening of 12 m or more in any one span.

(c) **Minor Bridges –** Those having a total waterway of less than 18 m or clear opening of less than 12 m.

1.2. Types of Bridges

(According to materials of construction)

The bridges on the Railway can be divided into various types according to their material of construction. These are :

(a) **Masonry bridges:** consisting of masonry structure such as masonry pipes and masonry arch bridges etc.

(b) **Concrete bridges:** consisting of reinforced cement concrete slab culverts, Pre-stressed concrete slab culverts and Pre-stressed concrete girders etc.

(c) **Steel bridges:** consisting of steel girders of various spans either of plate girder type or open web girder type.

1.3 Types of Bridges

(According to the load distribution)

(a) **Beam Bridges:** Two major types of beam bridges are the simple beam supported at its ends; and the cantilever beam bridge that overhang from its main supports. While beam bridge transfer vertical downward reaction on their substructure, the cantilever bridge produce additional vertical upward forces at its other end due to cantilever moments. A truss bridge is also considered a 'Beam Bridge'.

(b) **Arch Bridges:** Due to its shape, the arch withstands minor tensile and major compression forces through out. Its abutment sustains the outward horizontal component of its inclined thrust and vertical leads.

(c) **Suspension Bridges:** Most suspension bridges are supported by cables, which are on pier towers and tension anchored at its ends. Cable stayed bridges are a new design concept which is a combination of beam suspension bridges.

(d) **Movable Bridge:** Due to many site constraints, in some locations it is not possible to construct a bridge at sufficiently high level to pass the ship since in that case road/rail level will become very high. In such case, moveable bridge is provided. Moveable bridge is type of bridge whose location is permanent but not its level. By providing special arrangements, its movement can be ensured from time to give passage to the ships. It is further of two types as given below:

1. **Swing Bridge:** Such type of bridge is supported at the central pivots as well as at the end on abutments. In case of passing of ship, bridge swings to take alignment parallel to the flow of water and thus space is created for passing the ship.

2. **Lift Bridge:** Lift Bridge is further of two types, in one type, bridge as a whole is lifted at higher level with the arrangement of pulley for giving more clearance for passage of the ship. In another type, bridge is of cantilever type supported on either end with the help of hinged arrangement. In case of the need, two leaves of the bridge is rotated at 90 degree to make the cantilevering armed vertical for providing clearance to the passage of the ship.

1.4 Types of bridges: (According to Type of opening)

1.4.1 Box Culverts (Fig. 2)

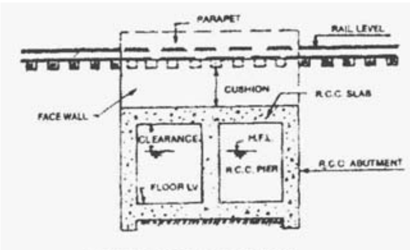


FIG. 2. BOX CULVERT

(i) Box culverts have one or more number of rectangular or square openings with their

floor and top slabs constructed monolithically with abutments and piers.

(ii) R.C.C. box culverts either cast in situ or precast. These culverts can be constructed by having comparatively lesser interference to traffic during construction.

(iii) The cushion above top slab should not be less than 300 mm (12"):

(iv) Box culverts are generally constructed in cement concrete M-25/ M-30.

1.4.2 RCC Slab Culverts (Fig 2 A)

(i) The slab in these culverts in generally precast reinforced cement concrete units. Cement concrete unit is controlled concrete and in the proportion of M-25/ M-30.

(ii) The slab directly spans over solid masonry piers or abutments and forms the super structure in simply supported construction.

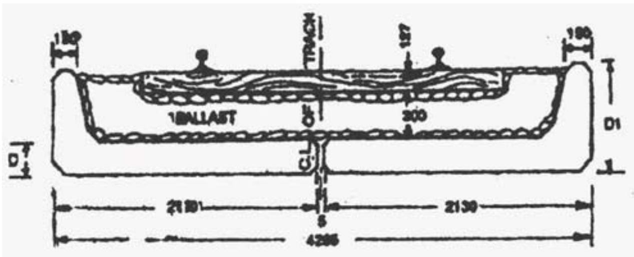


FIG. 2. (A) DETAILS OF RCC BRIDGE SLABS FOR BG LOADING

(iii) The ballast cushion above slab normally provided as 300mm (12") or above.

1.4.3 Hume Pipe Culverts (Fig.3)

(i) Reinforced concrete pipe used for Railway culverts are of I.R.S class only.

(ii) Minimum cushion prescribed for Hume pipe culverts is 400mm.

1.4.4 Solid Web Girder Bridges (Fig. 4 & 5)

(a) Super structure

(i) Girders in these bridges include R.S.J/plate girders.

(ii) The girder spacing is kept slightly more than the centre to centre distance of rails. The distance between centers of girders should be sufficient to prevent overturning by the specified lateral forces. In no case it should be less than 1/20th of span for open web girders and 1/16th of span of solid web girders.

(iii) The depth of truss should preferably be not less than 1/10th of span and that of plate girders and rolled beam not less than 1/12th of the span.

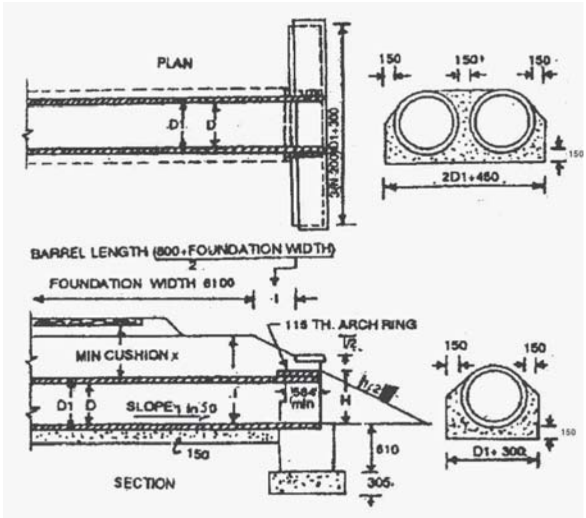


FIG. 3. DETAILS OF HUME PIPE CULVERTS

(iv) For plate girders, which are normally provided up to 100ft clear spans, sliding bearings on both supports are provided. For through girders, which are normally provided above 100ft. spans, fixed bearing (rocker type) are provided on one end and expansion bearings (roller type) are provided on the other end.

(v) The two girders are suitably braced with cross frames, top and bottom lateral bracings to make the girders act together for both vertical and horizontal loads.

(vi) Special bridge timbers or steel channel

sleepers are used for sleepers directly resting over girders.

(b) Substructure

(i) RCC bed blocks should be provided under girder seats for transferring the load to greater area over abutment/pier masonry.

(ii) Length of abutment should normally be equal to the formation width.

(iii) Important dimensions of typical abutment and pier sections are shown in Fig. 4 & 5 respectively. The final dimensions are, however, subject to checking for various loads and forces coming on the abutment and pier.

(iv) Masonry piers are provided at both ends with suitably shaped cut waters to requisite height, cut waters are normally provided upto the height of 1 meter (3ft.) above H.F.L. taking afflux into consideration.

(v) Open foundations should normally be protected by pucca flooring to guard against scour. Drop and curtain walls up to adequate depth are also provided for protecting the flooring.

(vi) Weep holes of size 50 mm dia or 60 mm x 50 mm are provided at 1.5 meters intervals horizontally and one meter vertically for the entire height of abutment above low water level to provide drainage and ease the earth pressure on the abutments.

1.4.5 Open Web girder bridges

(i) Open web girder bridges include only those bridges, which have truss - girders to carry the flooring system to support the track.

(ii) The track is supported over stringers; stringers are supported over cross-girders and cross-girders are supported over the main trusses.

(iii) Cross-girders are provided at every intersection point of bottom boom with web members of truss girders and stringers provided between cross-girders.

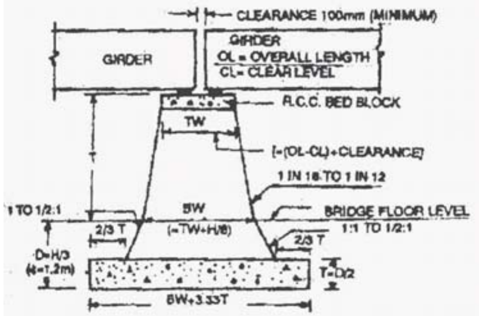


FIG. 4. TYPICAL PIER SECTION
(CASE-II)

(iv) Open web can be provided in all the three types of bridges viz. Deck bridges, Semi-through bridge and through bridge.

(v) Well foundation is normally provided for these types of bridges. Details of open web girder bridge, both through as well as, deck type are shown in fig. 6 & 7.

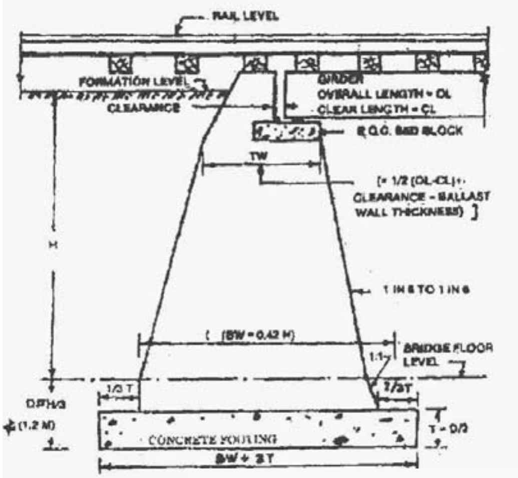


FIG. 4. TYPI
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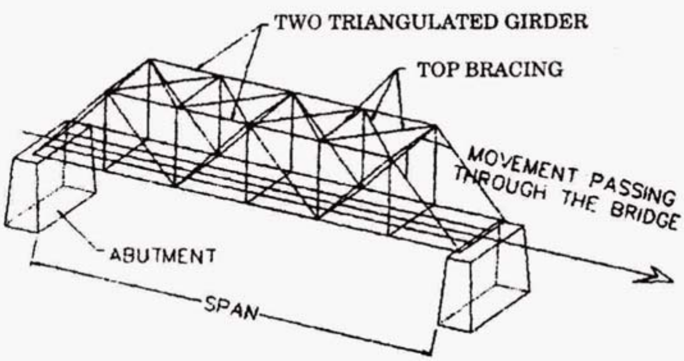

FIG. 6. THROUGH TYPE OPEN WEB GIRDER BRIDGE

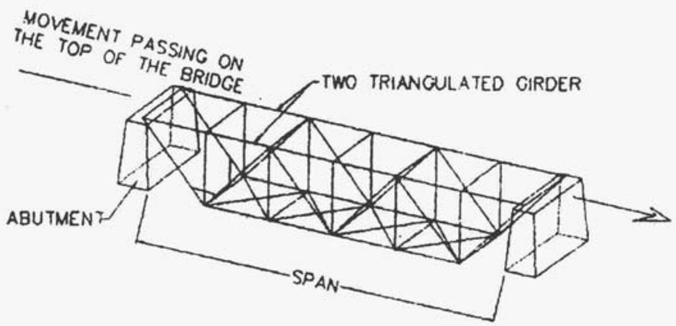

FIG. 7. DECK TYPE OF OPEN WEB GIRDER BRIDGE

2.0 Bridge Terminology

(i) ***Afflux:*** Afflux is the rise in the flood level of the river, up stream of a bridge, as a result of the obstruction to natural flow caused by the construction of the bridge. Afflux is normally measured as difference in water level between up stream and down stream of the bridge.

(ii) ***Cause Way:*** A cause way or Irish bridge is a dip in the railway track which allows flood water to pass over it.

(iii) ***Viaduct:*** When the railway crosses a deep valley without perennial water, it is called a via-duct.

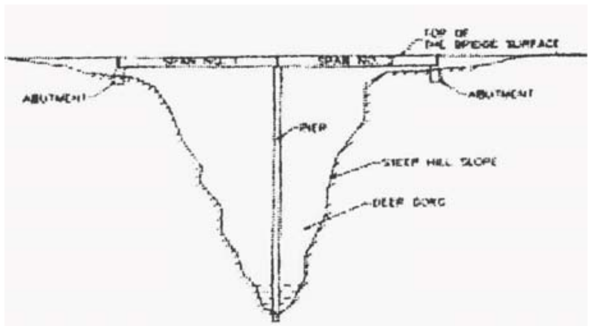

FIG. 8. TYPICAL DIAGRAM SHOWING VIADUCT BRIDGING A DEEP GORGE

Details of Viaduct Bridge are shown in fig.8.

(iv) ***Grade separation:*** When railway crosses another route of communication viz. road or

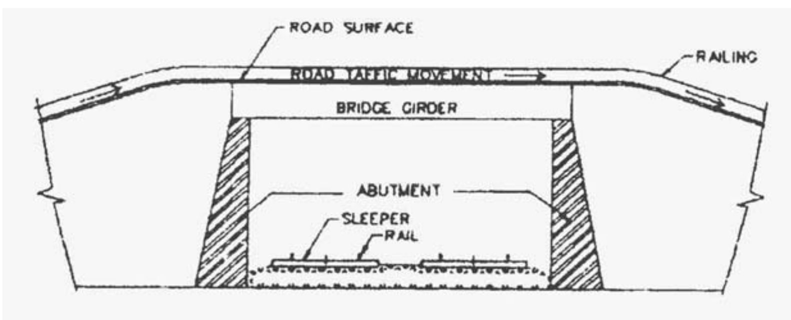

FIG. 9. TYPICAL CROSS SECTIONAL DIAGRAM OF ROAD OVER BRIDGE

rail way at higher or lower level, it is called grade separation

(v) ***Road-over bridge and road under-bridge:***

When railway line crosses road way below it (at lower level) the bridge is called as Road-under Bridge. When railway crosses road way above it (at higher level), the bridge is called Road-over bridge. Details of ROB and RUB are given in fig. 9 & 10.

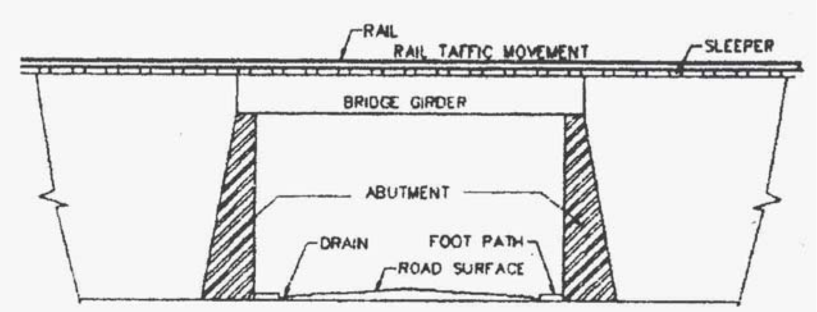

FIG. 10. TYPICAL CROSS SECTIONAL DIAGRAM OF ROAD UNDER BRIDGE

(vi) ***Skew bridge:*** When the bridge is not at right angle to the axis of the river or any other such opening/obstruction, it is called a skew bridge.

As per Bridge Manual, angle of skew should not be more than 30 degree.

(vii) ***Deck bridge:*** The bridge having its track supported on the top of the structure is called a 'Deck bridge'. This type of bridge is provided where H.F.L. is sufficiently below rail/ formation level to accommodate girder depth with adequate clearances between H.F.L. and bottom of girders. No cross girders and stringers etc. are provided in such bridges and the flooring system consists of track directly supported over main girders.

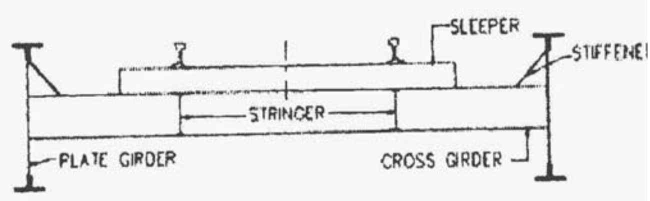

FIG. 11. CROSS SECTION OF SEMI THROUGH TYPE OF BRIDGE

(viii) ***Semi-Through bridge:*** The bridge having the floor supported at some intermediate level of super structure is called a 'semi-through bridge'. In this bridge, girders partially overlap the rolling stock. Flooring system consists of girders and stringers to support the track at a level, which is lower than the top of girder. Details of semi through bridges are shown in fig. 11

(ix) ***Through Bridge:*** The bridge having its floor supported or suspended at the bottom of the super structure is known as 'Through Bridge' Flooring system consist of cross girders and stringers to support the track. Top lateral bracings are provided between two girders for lateral support. (Refer fig no. 6)

(x) ***Span :***(a) **Clear span:** It is clear distance between any two supports.

(b) **Effective span:** It is distance between centre to centre of bearings of girders on adjacent supports.

(c) **Overall span:** It is overall length of a girder. Details of various types of span are given in fig. 12.

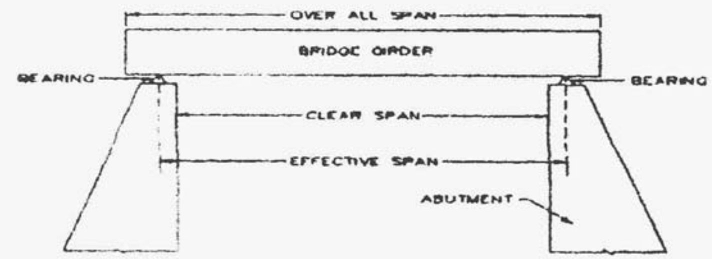

FIG. 12. DIFFERENT TYPES OF SPANS IN A BRIDGE

(xi) ***Waterway:*** The area of total clear opening of a bridge below girder through which water flows is called 'water-way'.

(xii) ***Linear water way:*** The total clear opening between piers and abutments of the bridge across its total length measured at right angles to the abutment faces is called linear water-way.

(xiii) ***Total waterway:*** Total water way is the waterway in square meter i.e. with area concept in which water is flowing. For calculating the total waterway, cross sectional profile of the river is to be arrived at HFL.

(xiv) ***Highest Flood level (H.F.L):*** This is the level of the highest water level known to have occurred.

(xv) ***Low Water Level (L.W.L.):*** This is the level of the highest water level known in dry weather.

(xvi) ***Scour Depth:*** This is the depth of eroded river bed of the river measured from the water level for the discharge considered.

(xvii) ***Free board:*** This is the vertical distance between the water level corresponding to the design discharge including afflux and the formation level of the approach banks or the top level of the guide bund.

(xviii) ***Design flood Discharge:*** This is estimated maximum flood discharged for the purpose of design of water way for bridges. For design of the sub-structure, design flood discharge is further enhanced by 10% to 30% depending upon catchment area.

Numbering of pier and abutment (Fig. 13)

Numbering of pier and abutment is being done based on the direction of increasing kilometer. Accordingly abutment No.1 will be designated to that abutment which is having lesser kilometer.

Details of the designation of piers, abutments and girders are explained in the figure given below:

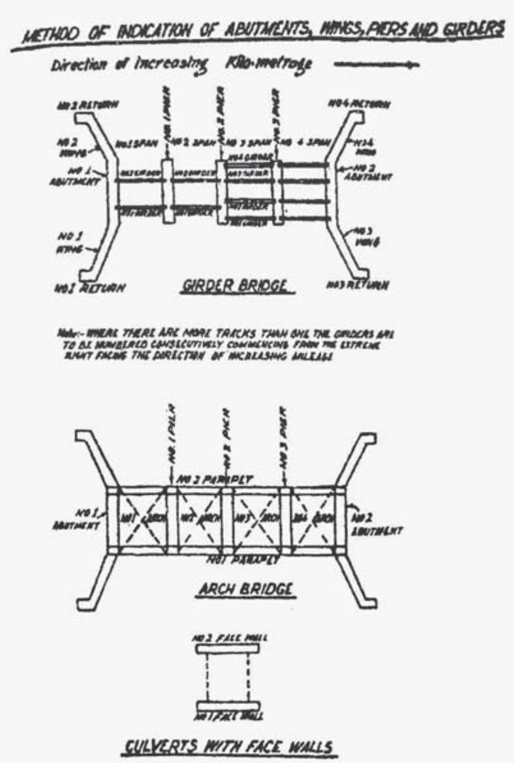

FIG. 13. NUMBERING OF PIER & ABUTMENT OF A CULVERT

3.0 Design Of A Bridge

The construction of a bridge is normally undertaken for new lines, gauge conversion works and for augmentation of the capacity of a bridge, etc. For new lines, the bridges can be constructed without interference of Railway traffic, but construction of bridge or modification of an existing bridge on a running track, has to be done either by providing a diversion or by providing temporary arrangements. Each of these methods has different procedures and precautions to be taken during their construction.

3.1 Design Load for Bridges

Before the construction of a bridge is undertaken, whether for railway or for the roads, it should be specified as to what design load is proposed to be carried on the bridge. The 'Indian Road Congress' has specified various loads for standardized classes of road bridges and similarly, 'Bridge rules' have been issued for the Railway bridges by the Research Design & Standard Organisation. The various loads for the purpose of computing stresses in the members of the bridges to be constructed are given below:

3.2 Loads

For the purpose of computing stresses, the following forces shall, where applicable, be taken into account:

(a) Dead Load.

(b) Live Load.

(c) Dynamic effect.

(d) Forces due to curvature or eccentricity of track.

(e) Forces and effect due to temperature.

(f) Forces due to wind

(g) Forces and effects due to earthquake

(h) Frictional resistance of expansion bearings.

(i) Longitudinal forces etc. (Tractive efforts, braking force etc.)

3.2.1 Dead Load

Dead lead is the weight of the structure itself together with the permanent loads carried thereon.

3.2.2 Live Load

Railway bridges including combined Rail and Road bridges shall be designed for one of the following standards of railway loading.

(a) For Broad gauge 1676 mm:

(i) 25t loading-2008 with a maximum axle load of 245.25 KN (25 tonnes for the locomotive) and a train load of 91.53 KN/m (9.33 t/m) on both sides of locomotive.

(ii) DFC loading (32.5t load) with a maximum axle load of 245.25 KN (25 tonnes for the locomotive) and a train load of 118.99 KN/m (12.13 t/m) on both sides of locomotive.

(b) ***Modified Meter Gauge Loading:*** 1988 with maximum axle load of 156.91KN (16.0 tonnes for locomotive and a train load of 53.9 KN (5.5 tonnes) per meter on both sides of locomotive with maximum axle load of 137.29 KN (14.0 tonnes) for the train load.

(c) ***For Narrow Gauge 762 m:***

(i) H (heavy) class loading with a maximum axle load of 95.1KN (9.7 tonnes) and a train load of 27.8KN (2.83 tonnes) per meter behind the locomotive.

(iii) 'A' class main line loading with a maximum axle load of 79.4 (8.1 tonnes) and a train load of 27.8 (2.83 tonnes) per meter behind the locomotive.

(iv) 'B' class branch line loading with a maximum axle load of 59.8 KN (6.1 tonnes) and a train load of 27.8 KN (2.83 t) per meter behind the engines.

3.2.3 Dynamic Effect

Railway Bridges (Steel): For Broad and Meter Gauge Railway.

The augmentation in load due to dynamic effect should be considered by adding a load equivalent to a coefficient of dynamic augment (CDA) multiplied by the live load giving the maximum stress in the member under consideration.

3.2.4 Forces Due to Curvature or Eccentricity of Track

Where a track (or tracks) on a bridge is curved, allowance for centrifugal action of the moving load shall be made in designing the member, all tracks on the structure being considered as occupied.

3.2.5 Forces and Effect due to Temperature

Where any portion of the structure is not free to expand or contract under variation of temperature, allowance shall be made for the stress resulting from this condition and temperature limits shall be specified.

3.2.6 Forces and Effects due to Earthquake

Bridge as a whole and every part of it shall be designed and constructed to resist forces due to earthquake as specified in Indian Railway Standard Bridge Rule & IRC Codes. Stresses shall be calculated as the effects of forces applied vertically or horizontally at the centre of mass of the elements of the structure.

Slab, box and pipe culverts need not be designed for seismic forces.

For the purpose of determining the seismic (earthquake) force the country is classified into five zones i.e. zone I to V. (In the latest revision, zone I has been omitted. Now revised zones are zone II to Zone V i.e. there is now no zone I). For the zones II to zone III these forces for the design of bridges are not to be considered. Severe seismic areas of the country are covered by zone IV & V. In important structures, model analysis shall be necessary in zone IV & V.

Few main items required for seismic design are, centre of mass, centre of rigidity, critical damping, epicenter, focus, mode shape coefficient, basic horizontal seismic coefficient, importance factor, soil foundation factor, design horizontal seismic coefficient etc.

Seismic forces to be resisted shall be computed, taking complete weight of mass under consideration ignoring reduction due to buoyancy. Horizontal seismic force due to live load on the bridge shall be ignored when acting in the direction perpendicular to traffic this is to be considred for 50% of the design live load without impact (dynamic effect).

3.2.7 Frictional Resistance of Expansion Bearings

Where the frictional resistance of the expansion bearings has to be taken into account, the following coefficients shall be assumed in calculating the amount of friction on bearings:

(i)	For roller bearings	0.03
(ii)	For sliding bearings of steel on cast iron or steel bearing.	0.25
(iii)	For sliding bearings of steel on ferro-asbestos.	0.20
(iv)	For sliding bearings of steel on hard copper alloy bearings.	0.15
(v)	For sliding bearing of PTFE/Elastomeric type.	0.10

3.2.8 Longitudinal Forces

Where a structure carries a railway track, provision as under shall be made for longitudinal forces arising from any one or more of the following causes:

(i) The tractive effort of the driving wheels of locomotives. –

(ii) The braking force resulting from the application of the brakes of all braking wheels.

(iii) Resistance to the movement of the bearing due to change of temperature.

Note-

1. *No increase for dynamic effect shall be made for longitudinal forces.*
2. *Tractive effort of the coupled locomotive as per MBG loading is 100 tonnes.*
3. *Braking force coming on the bridge depends upon the length of the bridge. For a smaller bridge, tractive effort is more, while for larger bridge, braking force will become more.*

4.0 Loads for Road Bridges

Road bridges and culverts shall be divided into classes according to the loading they are designed to carry as per Indian Road Congress:

(a) I.R.C. Class AA Loading:

This loading is to be adopted within certain municipal limits, in certain existing or contemplated industrial area, in other specified areas, and along certain specified highways. Bridges designed for Class AA. Loading should be checked for class A. Loading also as under certain conditions, heavier stresses may be obtained under Class 'A' loading.

Note – Where Class 70-R is specified, it shall be used in place of IRC AA Loading.

(b) I.R.C. Class A loading.

This loading is to be normally adopted on all roads on which permanent bridges and culverts are constructed.

(c) I.R.C. Class B loading.

This loading is to be normally adopted for temporary structures and for bridges in specified areas. Structures with timber spans are to be regarded as temporary structure for the purpose of this clause.

Existing bridges which were not originally constructed for these loading or are later strengthened to take one of the above specified I.R.C. loading will be classified by highest standard load class whose effects it can safely withstand.

5.0 Construction of Bridge with Temporary Arrangements.

It is proposed to give a brief description of the step by step procedure of construction of a typical bridge with temporary arrangements. This will cover all the constituents of the construction of a new bridge and this will give an idea to the reader about the most difficult construction that is undertaken is under running traffic conditions.

5.1. Preliminary Arrangements

Green notice for imposition of speed restriction is issued after obtaining necessary sanction from the 'Commissioner of Railway Safety'. Precautions of putting up speed restriction board with lighting arrangements (at night) and posting necessary men for stopping the train at site are taken during preliminary arrangements.

5.2 Sleeper Cribs

Sleeper cribs are introduced in the track for the construction work. Over the sleeper cribs service girders are placed.

5.3 Service Girders (for temporary arrangements)

These are normally of 45', 60' or 87' over all length of span used for such works. These are duplicate girders of smaller depth than the normal depth of the girders of same span, to allow more working space under the girder.

5.4 Putting Service Girder in Track

After the main and intermediate cribs have been introduced in track, the service girder duly assembled along with bridge timbers and rails, is installed in the track. Before this necessary precautions of traffic block are taken well in time.

5.5. Bridge Foundations

Bridge foundations generally consist of deep or shallow well, Piles or open foundations. Deep wells are normally constructed only on diversions. Open/Piles foundations as well shallow wells may be constructed under running traffic with such temporary arrangements.

After the sinking of well foundations is completed up to the desired level, bottom plug and the top plug of the well is cast with cement concrete. Vertical rails 6-8 nos are also embedded into the top plug to provide lateral bond with the superstructure.

5.6 Sub Structure

It is constructed at the top of well cap (above the well top plug) either with Brick, stone masonary or cement concrete in the shape of pier or abutment. Adequate numbers of weep holes are kept in the abutment above the high water level. No weep holes are kept in the piers.

5.7 Back Filling

Back filling of the abutment is then done in layers with necessary watering and ramming, leaving at least 2' wide space immediately behind the abutment for brick-bats-filling. The earth filling can be done up to the bottom of the service girder only. The rest of the filling will have to be done during the traffic block when the service girder is removed. Required quantity of earth is collected by the side of the abutment for this purpose before the traffic block for removal of service girder is asked for.

5.8 Bed Blocks

The bed blocks on the abutment are then cast keeping necessary holes for the holding down bolts at the correct location. Space under the service girder should be able to accommodate the whole of the bed block + about 3" working space for casting. If necessary, the track along with the service girder can be raised by the required amount at the time of putting the service girder in track so that bed block can be cast under the girder at the required level.

5.9 Permanent Girder

The permanent girder is then brought to site and can be kept along the side of the track at its correct position. The permanent girder is provided with timbers and hook bolts along with bearing plates and fixtures and rails. The block for putting in the permanent girder should be asked for only after bed blocks are fully cured on the abutment and the permanent girder is fully ready with required insulation for putting in the track circuited areas.

5.10 Removal of Temporary Arrangements

The scheme for removal of temporary girders from the track and putting in the permanent girder on the bridge is decided as per the circumstances and space available on either side on the girder. Traffic blocks are then asked for as per the time required in the approved scheme and the temporary girder slewed out from the track and the permanent girder slewed in and lowered on the bearings resting on the bed blocks.

The girder is adjusted for alignment and level and the block is then released. Commissioner of Railway safety is then informed of the work having been carried out, mentioning the number of first train which has passed over the bridges. The main cribs are subsequently removed during traffic blocks salvaging as many sleeper as possible and filling the hole with earth and packing the track with ballast. After the track is fully consolidated, the speed restriction at the site of bridge is removed in stages.

6.0 Regirdering

Sometimes girders of a bridge need replacement on account of the following:

- Due to serious defect in the girder.
- Old girder being of early steel girder, requiring replacement.

If sub-structure of the bridge is found to be in sound condition then only replacement of girder is needed. Such bridge work, where only replacement of girder to be done, is known as regirdering.

The girder to be changed may be either on single line or on a double line bridge. In the case of single line the usual method is to roll out old girders and cross-roll in new girders. This is, however, not possible when there is a double line track, which interferes with the rolling out of the old girders. In such a situation it is usual to lift up small girders by cranes and the new girder is rolled in cross-wise. The rolling is however possible only when the bed of the river or stream is dry and shallow staging or piers can be formed in the bed. However in case of bridges across deep gorges or on high piers cross-rolling of girder is not economical as the cost is abnormally high. In such situations, service span method of regirdering is adopted.

7.0 General Precautions During Erection Works of Girders :

1. Erection method should be combination of safety, economy and rapidity.
2. See that equipments are not ever loaded.
3. See that bolts and splice material have correctly been inserted in the steel derrick.
4. Use timber to pack chains, wire ropes, slings on sharp edges on the steel.
5. Check all guys and anchorages for safety.
6. See that timber used for derrick foot block for packing is sound.
7. Derricks and cranes should not be used when any of their part of member is found damaged.
8. See that the scaffolding is sound in strength.
9. Ropes, chains, slings, shackles must be tested before use.
10. First aid facilities should be made available at site.
11. Right workman on right job to be deputed.
12. When working on running line, track should be protected.
13. When load is in lifted position, no body should be allowed to go under the load without permission.
14. If welding or gas cutting is going on at the site, necessary precautions should be taken against fire and injury to eyes.
15. Do not mishandle the erection-tackle.
16. Soundness of the false-work should be checked.
17. Never lift the jack beyond their safe lift.
18. When two or more jacks are used to lift one load, see that each jack takes its share of load. Packing should be used simultaneously during the lifting, lowering loads by jacks.
20. Regularly inspect all your equipments.
21. All the wire ropes clamps, clips etc. should be fully tightened to ensure safety.

8.0 The Connections Between Steel Members

The various members of steel beam, columns, truss etc. are connected together in a proper geometrical shape so that all the loads and forces acting on the structure are safely transferred to the final supporting medium, i.e. the foundations. The steel to steel connections are usually accomplished by

(i) Hinged or pinned joints.

(ii) Rivets and bolts.

(iii) Welding.

In a roof truss of framed structure, some of the members are in direct tension only and the remainders are in direct compression only, provided that the loads are applied at the joints.

As the members are welded/riveted/bolted together, there is certain stiffness introduced and consequently some bending stresses. These secondary stresses are neglected in small span trusses, while in large span bridge trusses; these have to be catered for in designing compression and tension members.

8.1 Rivets and Bolts

Steel members are connected together by rivets or bolts, to build up a structure of the required shape and size. Normally riveted connections are fabricated in the workshop while bolted connections are used for site work. The bolts are made of mild steel and are following different kinds.

(i) Black bolts- These are manufactured from steel bars rolled in the steel mills. Their dimensions are not precise and holes for these bolts are drilled 2 millimeters larger in diameter than the size of the bolt. Thus there is always a small amount of play between the bolt and the holes and the bolted connection does not function as efficiently as the riveted one. The permitted stress in the bolted connection is therefore lesser than those permitted for the riveted connection.

(ii) Turned bolts- These are more accurate than the required size and diameter from rolled steel bars of larger diameters. They fit the holes much better and the connection has permitted stress almost equal to those of riveted connection.

Normally all bolts have to take shear stresses although sometimes compressive and tensile stresses have also to be resisted by bolt connection. Permissible shear stress for shop rivets 1OON/Sqmm and for turned bolts is approximately the same. So if the connection has four turned bolts for 22 mm dia (Area = 380 Sq.mm) the safe load for the connection of four rivets in shear is 4x380x1OO=152KN.

8.2 HSFG Bolts

These are bolts made of high tensile steel and are called High strength Friction Grip bolts. These are used with high tensile nuts and hardened washers. Special torque wrenches are required to tighten these bolts to a pre calculated torque so as to give it a definite clamping force, to compress the connected member together. The load in connected members is therefore transmitted through friction and not by shear or bearing strength of the bolts.

8.3 Welding

It is technique to join various structural members to fabricate a structure to required shape and size.

Uses and advantages of Welding:

(a) Welding requires much less time (which gives rapid production) than riveting and is more economical.

(b) Entire cross section of tension members is utilized as there are no rivet holes to be deducted and can thus take more loads.

(c) There is saving of material for end connections, as no gussets etc. are required.

(d) Reduction in weight of the structure.

(e) In certain works welded fabrication is the most practical solution.

8.3.1 Different Processes of Welding

There are two principal types of the various processes

(i) Welding with pressure, which includes Forge-Welding and Thermit Welding and

(ii) Fusion Welding without pressure which includes Gas –Welding, Arc-Welding and Thermit welding (without pressure).

The Metal Arc Welding of the fusion Welding process is the most important and is most extensively used.

8.4 Forms of Weld

The two types of welds (i) butt welds and (ii) fillet welds. There are many forms of butt welds. Allowable stresses in welds.

(i) Butt welds: The throat thickness of the butt weld is taken as the required thickness for stress calculations while the working stress is taken as the same as for the parent metal.

(ii) Fillet welds: In these welds the throat thickness is taken as the effective thickness while the allowable stress varies with the grade of steel used.

9.0. Opening of the Bridge for Traffic

At the time of opening of new railway lines all the bridges on the new line are inspected by Commissioner of Railway Safety. The speed at which the traffic is to be passed over the bridges on the new line is also specified by him. However in case of steel girder bridges, a Performa has to be filled up giving the general data and specifications of the bridge and mentioning the deflection of the girder at the mid point as well as at the ends under various incremental speeds. This standard Performa is required to be filled up after conducting a Load deflection test.

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