CHAPTER-7

BRIDGE ENGINERRING

DEFINATION

The following definitions of certain important terms used in Bridge Engineering are given below:

1. **Bridge: -** A structure is facilitating a communication route for carrying road traffic or other moving loads over a depression or obstruction such as river, stream, channel, road or railway. The communication route may be a railway track, a tramway, a roadway, footpath, a cycle track or a combination of them.
2. **High Level Bridge or Non-submersible Bridge:** - The Bridge which does not allow the high flood waters to pass over them. All the flood water is allowed to pass through its vents. In other words it carries the roadway above the highest flood level of the channel.
3. **Submersible Bridge: -** A submersible bridge is a structure which allows fold water to pass over bridge submerging the communication route. Its formation level should be so fixed as not to cause interruption to traffic during floods for more than three days at a time nor for more than six times in a year.
4. **Causeway: -** It is a pucca submersible bridge which allows floods to pass over it. It is provided on less important routes in order to reduce the construction cost of cross drainage structures. It may have vents for low water flow.
5. **Foot Bridge: -** The foot bridge is a bridge exclusively used for carrying pedestrians. Cycles and animals.
6. **Culvert: -** When a small stream crosses a road with linear waterway less than about 6 meters. The cross drainage structure so provided is called culvert.
7. **Desk Bridge:** - These are the bridge whose floorings are supported at top of the superstructures.
8. Through Bridge. These are the bridges whose floorings are supported or suspended at the bottom of the superstructures.
9. **Semi-Through Bridges: -** These are the bridges whose floorings are supported at some intermediate level of the superstructure.
10. **Simple Bridges: -** They include all beam, girder or truss bridges whose flooring is supported at some intermediate level of superstructure.
11. **Cantilever Bridges:** - Bridges which are more or less fixed at one end and free at other. It can be used for spans varying from 8 meters to 20 meters.
12. **Continues Bridges: -** Bridges which continue over two or more spans. They are used for large spans and where unyielding foundations are available.

13. **Arch Bridge: -** These are the bridges which [produce inclined pressures on supports under vertical loads. These bridges can be economically used up to spans about 20 meters. The arches may be in the barrel from or in the form of ribs.
14. **Rigid Frame Bridges: -** In these bridges the horizontal deck slab is made monolithic with the vertical abutments walls. These bridges can be used up to span about 20 meters. Generally this type of bridge is not found economical for spans less than 10 meters.
15. **Square Bridge: -** These are the bridges at right angles to axis of the river.
16. **Square Bridge: -** These are the bridges not at right angles to axis of the river.
17. **Suspension Bridges: -** These are the bridges which are suspended on cables anchored at ends.
18. **Under-Bridges: -** It is a bridge constructed to enable a road to pass under another work or obstruction.
19. **Over-Bridges: -** it is a bridge constructed to enable one from of land communication over the other.
20. **Class AA Bridges: -** These are bridges designed for I.R.C. class AA loading and checked for class A loading. Hey are provided within certain municipal limits, in certain existing or contemplated industrial area, in other specified areas, and along certain specified highways.
21. **Class A Bridges: -** These are permanent bridges designed for I.R.C. class A loading.
22. **Class B Bridges: -** These are permanent bridges designed for I.R.C. class B loading.
23. **Viaduct: -** It is a long continues structure which carries a road or railways like Bridge over a dry valley composed of series of span over trestle bents instead of solid piers.
24. **Apron: -** It is a layer of concrete, masonry stone etc. placed like flooring at the entrance or out of a culvert to prevent scour.
25. **Piers: -** They are the intermediate supports of a bridge superstructure and may be solid of open type.
26. **Abutments: -** They are the end supports of the superstructure.
27. **Curtain Wall: -** It is a thin wall used as a protection against scouring action a stream.
28. **Effective Span: -** The centre to centre distance between any two adjacent supports is called as the effective span of a bridge.
29. **Clear Span: -** The clear distance between any two adjacent supports of a bridge is called clear Span.
30. **Economic Span: -** the span, for which the total cost of bridge structure is minimum is known as economic span.
31. **Afflux: -** due to construction of the Bridge there is a contraction in waterway. This results in rise of water level above its normal level while passing under the Bridge. This rise is known as afflux.
32. **Free Board: -** Free Board at any point is the difference between the highest flood level after allowing for afflux, if any, and the information level of road embankment on the approaches or top level of guide bunds at the points.
33. **Headroom: -** Headroom is the vertical distance between the highest points of a vehicle or vessel and the lowest points of any points of any protruding member of a Bridge.
34. **Length of the Bridge: -** The length of a Bridge structure will be taken as the overall length measure along the centre line of the Bridge from the end to end of the Bridge deck.

35. **Liner Waterway: -** The liner waterway of a Bridge shall be the length available in the bridge between extreme edges of water surface at the highest flood level, measures at right angles to the abutment faces.
36. **Low Water Level (L.W.L.): -** The low water level is the of water surface obtained generally in the dry season.
37. **Ordinary Flood Level (O.F.L.):-** It is average level of a high flood which is expected to occur normally every year.
38. **Highest Flood Level (H.F.L.):-** It is the level of highest flood every recorded or the calculated level for the highest possible flood.
39. **Effective Liner Waterway: -** Effective linear waterway is the total width of waterway of a bridge minus the effective width of obstruction. For calculating the effective linear waterways, the width of mean obstruction due to each pier shall be taken as mean submerged width of the pier at its foundation up to maximum scour level. The obstruction at ends due to abutments or pitched slopes should be ignored.

COMPONENTS OF A BRIDGE

The bridge structure is divided mainly into two components:

1) Substructure

- The function of substructure is similar to that of foundations, columns and walls etc. of a building. Thus the substructure supports the superstructure and distributes the load into the soil below through foundation.
- The substructure consists of foundation piers and abutment piers, foundation for the piers, abutments, wing walls, and approaches.
- The above all supports the superstructure of the bridge.

2) Superstructure

- The superstructure of a bridge is analogues to a single story building roof and substructure to that of walls, columns and foundations supporting it.
- Superstructure consists of structural members carrying a communication route
- It consists of handrails, parapets, roadways, girders, arches, wall trusses over which the road is support.
- It is that part of the bridge over which the traffic moves safely

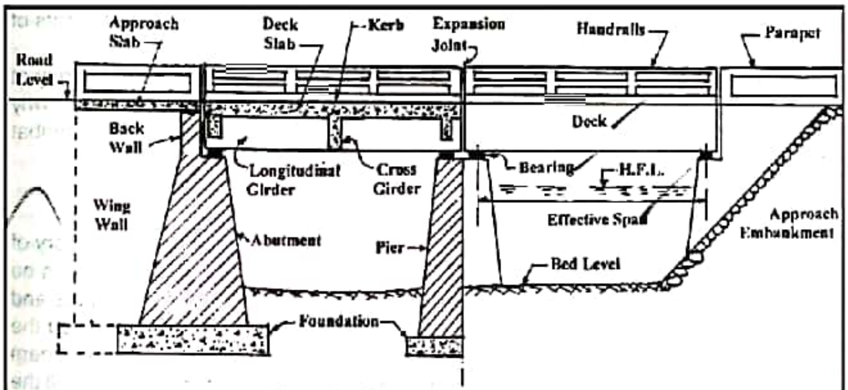


Figure 1 Components of a Typical Bridge.

Classification of a Bridge: -

The bridges may be classified depending upon the following factors:-

(a) Their functions or purpose as railway, highway Foot Bridge, aqueduct etc.

(b) Their material of construction used as timber masonry, R.C.C. Steel, prestresses concrete etc.

(c) Nature or life span such as temporary permanent bridge etc.

(d) Their relative position of floor such as deep bridge, through bridges etc.

(e) Type of super-structure such as arched girder, truss, suspension bridge etc.

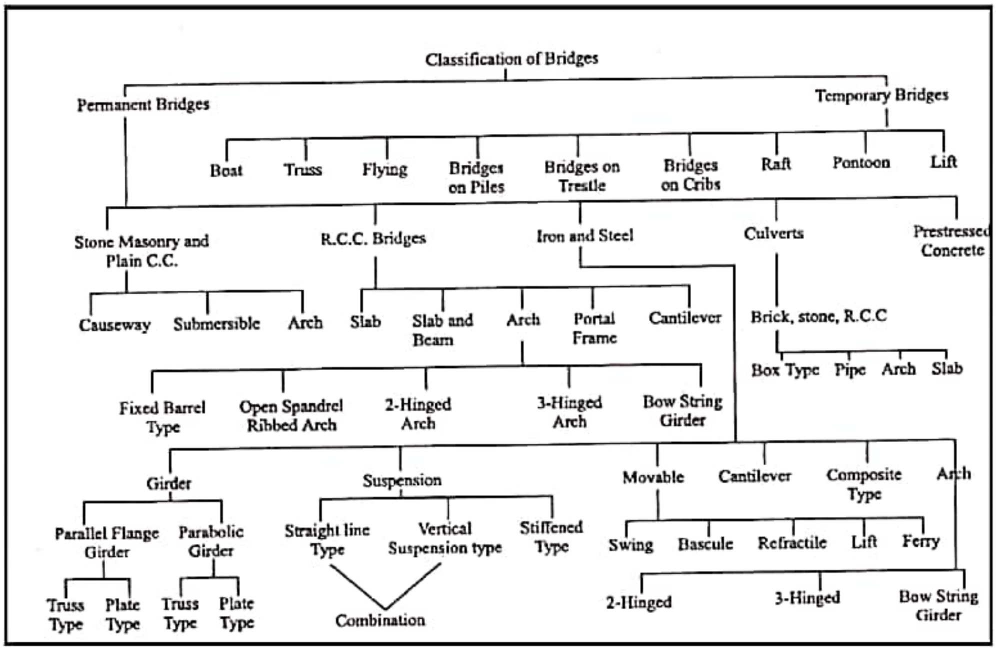
(f) Loadings: - Road Bridges and culverts have been classified by I.R.C. into class AA, Class A, Class B bridges according to the loadings they are designed to carry.

(g) Span Length:- Under this category the bridges can be classified as

- Culverts (Span Less than 8m) i.e. BOX Type, Hume Pipe Type,
- Minor Bridge (Span length = 8 to 30m) i.e. BOX type, Girder Type
- Major Bridge (Span Length =above than 30m)

(h) Degree of Redundancy: - Under this the bridges can be classified as indeterminate bridges

(i) Types of Connection:- Under this category the steel bridges can be classified as pinned connected , riveted or welded bridges.



Classification of Bridge

REQUIRMENTS OF AN IDEAL BRIDGE:-

An ideal bridge meets the following requirements to fulfil the three criteria of efficiency, effectiveness and equity

- It serves the intended function with utmost safety and convenience
- It is aesthetically sound
- It si economical

The site characteristic of an Ideal Bridge has been discussed below:

1. The stream at the bridge side should be well defined and as narrow as possible.
2. There should be a straight reach of stream at bridge site
3. The site should have firm, permanent, straight and high banks.
4. Te flow of water in the stream at the bridge site should be in steady regime condition. It should be free from whirls and cross-current
5. There should be no confluence of large tributaries in the vicinity of bridge site
6. It should be reliable to have straight approach roads and square alignment, i.e. right-angled crossing
7. There should be minimum obstruction of a natural waterway so as to have minimum afflux
8. In order to achieve economy there should be easy availability of labour, construction material and transport facility in the vicinity of bridge site.
9. In order to have minimum foundation cost, the bridge site should be such that no excessive work is to be carried inside the water
10. At bridge site it should be possible to provide secure and economical approaches.

11. In case of curved alignment the bridge should not be on the curve, but preferably on the tangent since otherwise there is a greater like hood of accident as well as an added centrifugal force which increases the load effect on the structure and will require modification of design.
12. There should be no adverse environmental input
13. The bridge site should be such that adequate vertical height and waterway is available
14. Underneath the bridge for navigational use.

In actual practice the determination of best possible site for any proposed bridge is truly an economic problem. The various factors which should be carefully examined before setting finally upon the layout of a bridge as follows:

i. Grade on alignment,
ii. Geographical Conditions,
iii. Government requirements,
iv. Commercial influences ,
v. Adjacent property consideration,
vi. General features of the bridge structure,
vii. Future trends for enlargement,
viii. Time Consideration,
ix. Foundation Considerations,
x. Construction facilities available,
xi. Erection Consideration,
xii. Aesthetics,
xiii. Maintenance and repairs,
xiv. Environment Impact

CHAPTER-8

Bridge Alignment:-

Depending upon the angle which the bridge makes with tee axis of the river, the aliment an me of two types:

a) Square Alignments: - In this the bridge is at right angle to the axis of the river.

b) Skew Alignments: - In this the bridge is at some angle to the axis of the river which is not a right angle.

Note: - As far as possible, it is always desirable to provide the square alignment. the skew alignments suffers from the following disadvantages:-

(i) A great skill is required for the construction of skew Bridges. Maintenance of such type of Bridges is also difficult.

(ii) The water-pressure on piers in case of skew alignment is also excessive because of non-uniform flow of water underneath the bridge superstructure.

(iii) The foundation of skew bridge is more susceptible to scour action.

Flood Discharge: -

One of the essential data for the bridge design is fair assessment of the maximum flow which could be expected to occur at the bridges site during the design period of the bridge. The conventional practice in India for determination of flood discharge is to use a few convenient formulae or past records.

Note: - This faulty determination of flood discharge which led to failure of many hydraulic structures.

As per I.R.C. recommendation the maximum discharge which a bridge on a natural stream should be designed to pass determined by the following methods:-

(a) From the rainfall and other characteristics of the catchment.

(i) By use of an empirical formula applied to that region, or

(ii) By a rational method, provided it is possible to evaluate for the region concerned the various factors employed in the method.

(b) From the hydraulic characteristics of the stream such as cross-sectional area, and slope of the stream allowing for velocity of flow.

(c) From the records available, if any, of discharges observed on the stream at the site of the bridge, or at any other site vicinity.

Empirical Methods for Estimation of Flood Discharge:-

In these methods are of basin or catchment is considered mainly. All other factors which influence peak flow are merged in a constant.

A general equation may be followed in the form:-

$$Q = C \cdot M^{n}$$

Here, Q= Peak Flow or rate of maximum discharge

C= a constant for the catchment

M= area of catchment, and '*n*' is an index

The constant for catchment is arrived at, after taking the following factors into account:

(A) Basin Characteristics

a) Area
b) Shape
c) Slope

(B) Strom Characteristics

a) Intensity
b) Duration
c) Distribution

Limitations

These methods do not take frequency of flood into consideration.

These methods cannot be applied universally

Fixing of constant is very difficult and exact theory cannot be put forth for its selection.

1) Dicken's Formula

$$Q = C. M^{3/4}$$

Here, Q= Discharge in cum/sec

C= a constant

M= area of catchment in sq .km.

2) Tyve's formula

$$Q = C.M^{2/3}$$

Here, Q= Discharge in cum/sec

C= 6.74 for area within 24 km from coast or,

C= 8.45 for areas within 24-161 km from coast or,

C= 10.1 for limited hilly areas

In worst case C goes up to 40.5

M= area of catchment in sq .km.

3) Inglis Formula

This formula used only Mahastra state and here three different cases are taken into consideration.

(a) For small areas only (It is also applicable for fan-shaped catchment)

$$Q = 123.2 \sqrt{M}$$

(b) For areas between 160 to 1000 square km.

$$Q = 123.2 \sqrt{M} - 2.62(M - 259)$$

(c) For all type of catchment

$$Q = 123.2 M / \sqrt{(M + 10.36)}$$

In all equations, M= area of catchment in sq .km.

4) Nawab Jang Bahadur's Formula :-

$$Q = C (M / 2.59) (a - b. \log A)$$

Here, a, b, and C are constant.

a= 0.993 and b= 1/14

C = 59.5 for North India or,

= 48.1 for South India

5) Creager's Formula :-

$$q = C.M\ n$$

Here, q=the peak flow per sq. km of a basin

M= area of catchment in sq. km. and '*n*' is some index

By multiplying both sides of the above equation are of the basin M, we get

$$Q = C.M^{n+1}$$

Where Q is peak value

Equation given by Creager , Justin and Hinds is

$$Q=46.\ CM^{(0.849M-0.048)}$$

6) **Khosla's Formula** :-

It is a rational formula, It si based on the equation **P= R + L**

Or **R= P - L**

Here, R is round off, P is rainfall and L is losses.

L=4.82 Tm, where L is in mm and Tm is in centigrade [in C.G.S. System]

R= P - 4.82Tm

7) **Besson's Formula :-**

This formula is very rational and can be used in any case:

$$Q_m = (P_m \times Q_r) / (P_r)$$

Here, Q_m = Peak flow expected

Q_r = Some observed peak flow

P_r = Observed rainfall

P_m= expected rainfall

Rational Methods for Estimation of Flood Discharge:-

This method is applicable for determination of flood discharge for small culverts only. In order to arrive at a rational approach, a relationship has been established between rainfall and runoff under various circumstances. The size of flood depends upon the following factors.

(i) Climate or Rainfall Factors. This includes

(a) Intensity (b) Distribution and (c) Duration of Rainfall

(ii) Catchment Area Factors. This includes:

(a) Catchment Area (b) its slope (c) its shape (d) porosity of soil

(e) Vegetable cover (f) initial state of wetness

WATERWAY

The area through which the water flows under a bridge superstructure is known as the waterway of the bridge. The linear measurement of this area along the bridge is known as the linear waterway. This linear waterway is equal to the sum of all the clear spas. This may be called as artificial linear waterway.

Due to the construction of a bridge the natural waterway gets contracted thereby increasing the velocity of flow under a bridge. This increased velocity results into heading up of water on the upstream of the river or stream, known as Afflux.

Economic Span: - the economic span of a bridge is the one which reduces the overall cost of a bridge to be minimum. The overall cost of a bridge depends upon the following factors

a. Cost of material and its nature.
b. Availability of skilled labour
c. Span Length.
d. Nature of stream to be bridged.
e. Climatic and other conditions.

Notes:-

It is not in the hand of engineers to bring down the cost of living index or price of the materials like cement, steel, timber, etc. but they can help in bringing down the cost of bridges by evolving economical designs.

Considering only variable items, the cost of superstructure increases and that of sub-structure decreases with an increase in the span length. Thus most economic span length is that which stultifies the following :-

i.e. The cost of Super Structure= The cost of the Sub-Structure

AFFLUX

When a bridge is constructed, the structure such as abutments and piers cause the reduction of natural waterway area. The contraction of stream is desirable because it leads to tangible saving in the cost specially for alluvial stream whose natural surface width is too large than required for stability. Therefore, to carry the maximum flood discharge, the velocity under a bridge increases. This increased velocity gives rise to sudden heading up of water on the upstream side of the stream. The phenomenon o0f heading up of water on the upstream side of the stream is known as **"AFFLUX"**

Greater the afflux greater will be the velocity under the downstream side of the bridge and greater will be the depth of scour and consequently greater will be depth of foundations required.

Afflux is calculated by one of the following formula

(A) Marriman's Formula

$$h_a = (V^2 / 2g)\ \{(A/Ca)^2 - (A/A_1)\}$$

Here, h_a = Afflux in meters

V= Velocity of approach in meters per second

A= Natural Waterway area at the site

a=Contracted area in square meters

A_1= The enlarged area upstream of the bridge square meters

C= Coefficient of Discharge = $0.75+0.35\,(a/A)-0.1(a/A)^2$ approximately

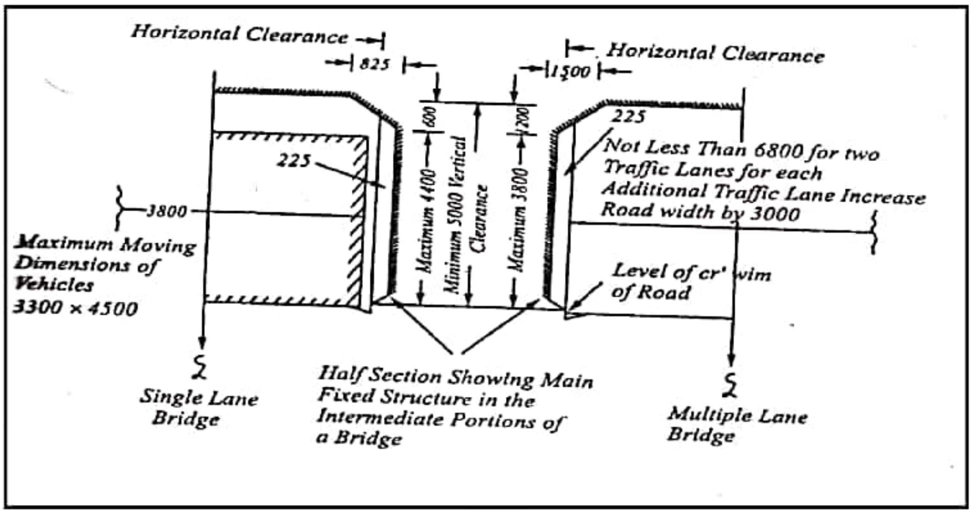
(A) Molesworth's Formula

$$h_a = \left(\frac{V^2}{17.9} + 0.015\right)\{(A/a)^2 - 1\}$$

Here, V, A and a have the same meaning as in the Marriman's Formula

CLEARANCE

To avoid any possibility of traffic striking any structural part clearance diagram are specified. The horizontal clearance should be the clear width and vertical clearance of the clear height, available for the passage of vehicular traffic as shown in the clearance diagram in the figure below.



Clearance Diagram for Road Bridges

Note : *- For a bridge constructed on a horizontal curve with superelevated road surfaces, the horizontal clearance should be increased on the side of inner kerb by an amount equal to 5m multiplied by the superelevation. The minimum vertical clearance should be measured from the super elevated level of roadway.*

FREE BOARD

Free board is the vertical distance between the designed high flood level, allowing for the afflux, if any, and level of the crown of the bridge at its lowest point.

It is essential to provide the free board in all types of bridges for the following reasons:-

- Free Board is required to allow floating debris, fallen tree trunks and approaches waves top pass under the bridge.
- Free board is also required to allow for the afflux during the maximum flood discharge due to contraction of waterway.
- Free board is required to allow the vessels to cross the bridges in case of navigable rivers. The value of free-broad depends upon the types of the bridge.

Collection of Bridge Design Data: -

For a complete and proper appreciation of the bridge project the engineer in charge of the investigation should carry out studies regarding its financial, economic, social and physical feasibility. The detailed information to be collected may cover loading to be used for design based on the present and anticipated future traffic, hydraulic data based on stream characteristics, geological data, subsoil data, climatic data, alternative sites, aesthetics, cost etc.

The following drawings containing information as indicated should be prepared

1. INDEX MAP
2. CONTURE SURVEY PLAN
3. SITE PLAN
4. CROSS-SECTION
5. LONGITUDINAL SECTION
6. CATCHEMENT AREA MAP
7. SOIL PROFILE

Design data for major bridge:-

A- General data:-

(i) Name of the road and its classification.

(ii) Name of the stream.

(iii) Location of nearest G.T.S. bench mark and its reduced level.

(iv) Chainage at centre line of the stream.

(v) Existing arrangement for crossing the stream.

a) During Monsoon b) During dry season

(vi) Liability of the site to earthquake disturbance

B- Catchment Area and Run Off Data:-

(i) Catchment Area

(a) Hilly Area b) In plains

(ii) Maximum recorded intensity and frequency of rainfall in catchment.

(iii) Rainfall in cementer per year in a reason

(iv) Length of catchment in kilometres.

(v) Width of catchment in kilometres.

(vi) Longitudinal slope of catchment.

(vii) Cross slope of catchment.

(viii) The nature of catchment and its shape.

C- Data Regarding Nature of Stream

Sub-Surface Investigation:-

Sub-Surface investigation is essential for to know the properties of the bridge site soil. The field and laboratory investigations required to obtain the necessary soil data for the design are called soil exploration.

The principal requirements of a complete investigation can be summarized as follows:-

1. Nature of the soil deposits up to sufficient depth.
2. Depth, thickness and composition of each soil stratum.
3. The location of ground water.
4. Depth to rock and composition of rock.
5. The engineering properties of soil and rock strata that affect the design of the structure.

In exploration programme the extent of distribution of different soils both in the horizontal and vertical directions can be determined by the following methods:

1. By use of open pits.
2. By making bore holes and taking out samples.
3. By Soundings.
4. By use of geophysical methods.

Equipments for laboratory Work:-

The disturbed soil sample as taken from bed level to scour level at every one meter interval or at depths wherever strata changes ate tested to determine the following properties:-

1. Liquid Limit, Plastic ,Limit and Plasticity Index
2. Organic Content
3. Harmful Salts
4. Sieve Analysis
5. Silt Factor

The undisturbed soil samples as taken below the scour level to a level where the pressure is about 5% of the pressure at the base are tested to determine

1. Particle size analysis.
2. Values of cohesion and angle of internal friction by shear test.
3. Compression index and pre-consolidation pressure by consolidation test.
4. Density specific gravity and moisture content.

Advantage of Sub-Surface Investigation:-

There are manifold advantages of carefully planned investigation programme. These can be summarized as below:-

1. A suitable and economical solution can be worked out.
2. The construction schedule can be properly planned.
3. The extent and nature of difficulties likely to be met with can be determined.
4. The rate and amount of settlements can be determined.
5. The variation in the water –table, of the presence of artesian pressures can be found out.

CHAPTER 9

9.1 Depth of Scour:-

DEPTH OF SCOUR (D) is the depth of the eroded bed of the river, measured from the water level for the discharge considered. Well-laid foundation is mostly provided in road and railway bridges in India over large and medium-sized rivers. The age-old Lacey–Inglis method issued for estimation of the design scour depth around bridge elements such as pier, abutment, guide bank, spur and groyene. Codal provisions are seen to produce too large a scour depth around bridge elements resulting in bridge sub-structures that lead to increased construction costs. Limitations that exist in the codes of practice are illustrated in this paper using examples. The methods recently developed for estimation of the scour are described. New railway and road bridges are required to be built in large numbers in the near future across several rivers to strengthen such infrastructure in the country. It is strongly felt that provisions in the existing codes of practice for determination of design scour depth require immediate review. The present paper provides a critical note on the practices followed in India for estimating the design scour depth.

Indian practices on estimation of design scour depth

1. Lacey–Inglis method
2. Comments on Lacey's method

- The probable maximum depth of scour for design of foundations and training and protection works shall be estimated considering local conditions.
- Wherever possible and especially for flashy rivers and those with beds of gravel or boulders, sounding for purpose of determining the depth of scour shall be taken in the vicinity of the site proposed for the bridge. Such soundings are best taken during or immediately after a flood before the scour holes have had time to silt up appreciably. In calculating design depth of scour, allowance shall be made in the observed depth for increased scour resulting from:

(i) The design discharge being greater than the flood discharge observed.

(ii) The increase in velocity due to the constriction of waterway caused by construction of the bridge.

(iii) The increase in scour in the proximity of piers and abutments.

- 4.6.3 In the case of natural channels flowing in alluvial beds where the width of waterway provided is not less than Lacey's regime width, the normal depth or Scour (D) below the foundation design discharge (Qf) level may be estimated from Lacey's formula as indicated below

$$D = 0.473 (Q^f / f)^{1/3}$$

Where D is depth in metres Qf is in cumecs and 'f' is Lacey's silt factor for representative sample of bed material obtained from scour zone.

- Where due to constriction of waterway, the width is less than Lacey's regime width for Qf or where it is narrow and deep as in the case of incised rivers and has sandy bed, the normal depth of scour may be estimated by the following formula:

$$D = 1.338 (Q_f^2 / f)^{1/2}$$

Where 'Q_f ' is the discharge intensity in cubic metre per second per metre width and f is silt factor
The silt factor 'f' shall be determined for representative samples of bed material collected from scour zone using the formula : $f = 1.76 \sqrt{m}$ where m is weighted mean diameter of the bed material particles in mm. Values of 'f' for different types of bed material commonly met with are given below :

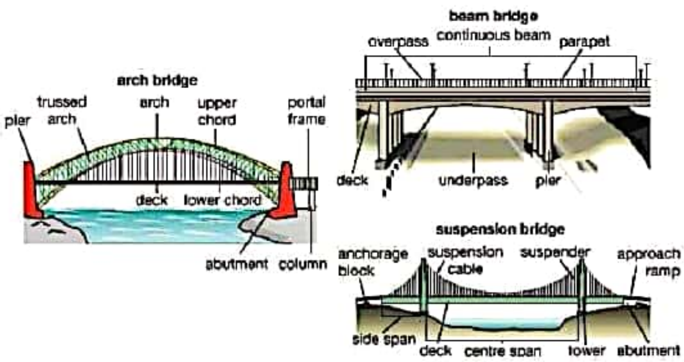
Type of bed	Material Weighted mean dia of particle(mm)	Value of 'f'
(i)Coarse silt	0.04	0.35
(ii) Fine sand	0.08 0.15	0.50 0.68
(iii) Medium sand	0.3 0.5	0.96 1.24
(iv) Coarse sand	0.7 1.0 2.0	1.47 1.76 2.49

The depth calculated (vide clause 4.6.3 and 4.6.4 above) shall be increased as indicated below, to obtain maximum depth of scour for design of foundations, protection works and training works:-

Nature of the river	**Depth of scour**
In a straight reach	1.25D
At the moderate bend conditions e.g. along apron of guide bund	1.5D
At a severe bend	1.75D
At a right angle bend or at nose of piers	2.0D
In severe swirls e.g. against mole head of a guide bund.	2.5 to 2.75D

In case of clayey beds, wherever possible, maximum depth of scour shall be assessed from actual observations.

9.2 Types of Bridge



Types of Bridge

Arch bridge	
Arch bridge (concrete)	
Through arch bridge	
Beam bridge	
Log bridge (beam bridge)	
Cavity wall Viaduct	
Bowstring arch	
Box girder bridge	

Cable-stayed bridge	
Cantilever bridge	
Cantilever spar cable-stayed bridge	
Clapper bridge	
Covered bridge	
Girder bridge	
Continuous span girder bridge	
Moon bridge	
Movable bridge	

Pigtail bridge	
Plate girder bridge	
Pontoon bridge	
Roving bridge	
Segmental bridge	
Self-anchored suspension bridge	
Side-spar cable-stayed bridge	
Simple suspension bridge (Inca rope bridge))	
Step-stone bridge	
Stressed ribbon bridge	
Suspension bridge	

Transporter bridge	
Trestle	
Truss arch bridge	
Truss bridge	
Vierendeel bridge	
Brown truss	
Covered bridge	
Lattice truss bridge (Town lattice truss	
Tubular bridge	

Bridge Foundation:-

Definition:- A foundation is the part of the structure which is in direct contact with the ground. It transfers the load of the structure to the soil below. Before deciding upon its size, we must ensure that:

(i) The bearing pressure at the base does not exceed the allowable soil pressure.

(ii) The settlement of foundation is within reasonable limits

(iii) Differential settlement is to limited as not to cause any damage to the structure.

Broadly, foundation may be classified under two categories i.e.

1. Shallow foundation
2. Deep Foundation

Shallow Foundation:-According to Trezaghi, a foundation is said to be shallow if its depth is equal or less than its width.

Deep Foundation:- According to Trezaghi, a foundation is said to be deep , the depth is greater than its width and it cannot be prepared by open excavation.

Types of Bridge Foundation:-

The selection of foundation type suitable for a particular site depends on the following considerations:-

1) Nature of Subsoil

2) Nature and extent of difficulties, e.g. presence of boulder, buried tree trunks, etc. Likely to be met with, and

3) Availability of expertise and equipment.

Depending upon their nature and depth, bridge foundation can be categories as follows:

i. **Open Foundation,**
ii. **Raft Foundation,**
iii. **Pile Foundation,**
iv. **Well foundation,**

(i)Open Foundation in Bridges:-

1. An open foundation or spread foundation is a type of foundation and can be laid using open excavation by allowing natural slopes on all sides.
2. This type of foundation is practicable for a depth of about 5m and is normally convenient above the water table.
3. The base of the pier or abutment is enlarged or spread to provide individual support.
4. Since spread foundations are constructed in open excavation, therefore, they are termed as open foundation.
5. This type of foundation is provided for bridges of moderate height built on sufficiently form day ground.
6. The piers in such cases are usually made with slight batter and provided with footings widened at bottom. Where the ground is not stiff the bearing surface is further extended by a wide layer of concreter at bottom (see the figure).

(ii) Raft Foundation:-

1. A raft foundation or mat is a combined footing that covers the entire area beneath a bridge and supports all the piers and abutments.
2. When the allowable soil pressure is low, or bridge loads are heavy, the use of spread footing would cover more one-half of the area, and it may prove more economical to use raft foundation
3. They are also used where the soil mass contains compressible lenses so that the differential settlement would be difficult to control.
4. The raft tends to bridge over the erratic deposits and eliminates the differential settlement.

5. Raft foundation is also used to reduce the settlement above highly compressible soils by making the weight of bridge and raft may undergo large settlement without causing harmful differential settlement. For this reason, almost double settlement of that permitted for footings is acceptable for rafts.
6. Usually when hard soil is not available within 1.5 to 2.5 m a raft foundation is adopted.
7. The raft is composed of reinforced concrete beams a relatively thin slab underneath, figure

(iii)Pile foundation in Bridges:

1. The pile foundation is constructions for the foundation of abridge pier or abutment supported on piers.
2. A pile is an element of construction composed of timber, concrete or steel or combination of them.
3. Pile foundation may be defined as a column support type of foundation which may be cast-in-situ or precast.
4. The piles may be place separately or they may be placed in form of a cluster throughout the length of the pier or abutment.
5. This type of construction is adopted when the loose soil extends to great depth.
6. The load of the bridge is transmitted by the piles to hard stratum below or it is resisted by the friction developed on the sides of piles.

Classification of piles:-

Piles are broadly classified into two categories:-.

i- Classification based on the function

ii- Classification based on the materials and composition

Classification based on the function

- Bearing Pile.
- Friction Pile.
- Screw Pile.
- Compaction Pile.
- Uplift Pile.
- Batter Pile.
- Sheet Pile.

Classification based on the function

- Cement concrete piles.
- Timber Piles.
- Steel Piles.
- Sand Piles.
- Composite Piles.

(iv)Well Foundation in bridges

a) Well foundations are commonly used for transferring heavy loads to deep strata in river or sea bed for bridges, transmission towers and harbour structures. The situation where well foundations are resorted are as below as) Wherever consideration of scour or bearing capacity require foundation to be taken to depth of more than 5 M below ground level open foundation becomes uneconomical. Heavy excavation and dewatering problem coupled with effort involve in retaining the soil makes the open foundation costlier in comparison to other type of foundation.

b) Soil becomes loose due to excavation around the open foundation and hence susceptible to scouring. This is avoided in well foundation which is sunk by dredging inside of the well.

c) From bearing pressure considerations, a well foundation can always be left hollow thereby considerably reducing bearing pressure transmitted to the foundation material. This is very important in soils of poor bearing capacity, particularly in clayey soils. In other type of foundation, the soil displaced is occupied by solid masonry/concrete which are heavier than the soil displaced and hence this does not give any relief in respect of adjusting bearing capacity. However in case of well foundation this is easily achieved because of cellular space left inside the well.

Caisson:-

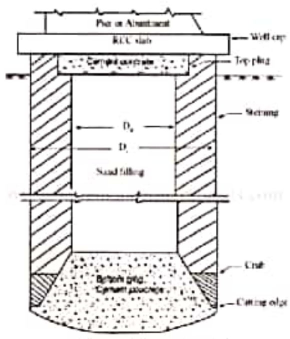


Fig 1 Parts of a Well Foundation

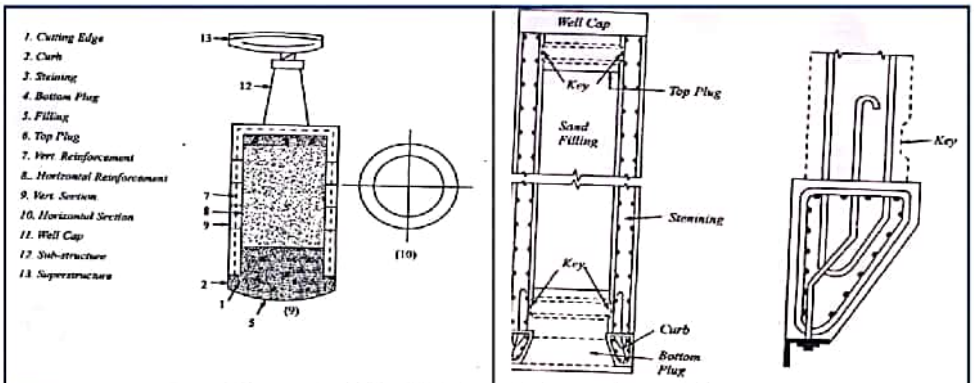


Figure :- DETAILS OF WELL FOUNDATION

Caisson: - The caisson is a structure used for the purpose of placing as foundation in correct position under water. The term caisson is derived from the French word 'caisse' meaning a box. It is a member with hollow portion, which after installing in palace by any means is filled with concrete or other material. Caissons are prepared in sandy soils the caissons can be divided in the following three groups

a. Box Caissons
b. Open Caissons or Wells
c. Pneumatic Caissons

Well components and their functions:

- ***Cutting edge:*** - It provides a comparatively sharp edge to cut the soil below during sinking operation. It is usually consists of a mild steel equal angle of side 150mm.
- ***Curb: -*** It has a two-fold purpose. During sinking it acts as an extension of cutting edge and also provided support to the well steining and bottom plug while after sinking it transfers the load to the soil below. It is made up of reinforced concrete using controlled concrete of grade M200.
- ***Steining:***- It is the main body of the well. It is serves dual purpose. It acts as a cofferdam during sinking and structural member to transfer the load to the soil below afterwards. The steining may consist of brick masonry or reinforced concrete. The thickness of steining should not be less than 4.5 cm not less than that given by equation.

$$t= K [(H/100) + (D/10)]$$

Here, t= minimum concrete steining thickness.
H= well depth below bed
D= External diameter of Well
K= a constant which is 1.0 for sandy strata.

- Bottom Plug: - Its main function is to transfers load from the steining to the soil below.
- Sand Plug: - Its utility is doubtful. It is supposed to afford some relief to the steining by transforming directly a portion of load from well cap to bottom plug.
- Top Plug: - The opinion is divided about the top plug. It, at least, serves as a shuttering for laying well cap.
- Reinforcement: – It provides requisite strength to the structure during sinking and service.

- Well Cap: - It is needed to transfer the loads and moments from the pier to the well or wells below. The shape of well cap is similar to that of the well with a cantilevering of about 15cm. Whenever 2 or 3 wells of small diameter are needed to support the sub-structure , the well cap designed as a slab resting over the well or wells with partial fixity at the edges of the wells.
- Depth of Well Foundation:- As per I.R.C. Bridge Code (Part-III), the depth of well foundation is to be decided on the following consideration
    1. The minimum depth of foundation below the H.F.L. should be 1.33D, Where D is the anticipated max. Depth of scour below H.F.L. Depth should provided proper grip according to some rational formula.
    2. The max bearing pressure on the subsoil under the foundation resulting form any combination of the loads and forces except wind and seismic forces should not exceed the safe bearing capacity of the subsoil, after taking into account the effect of scour.

       With wind and seismic forces in addition, the max. Bearing pressure should not exceed the safe bearing capacity of the subsoil by more than 25%.
    3. While calculating max. Baring pressure on the foundation bearing layer resulting from the worst combination of direct forces and overturning moments, the effect of a passive resistance of the earth on sides of the foundation structure may be taken into account below the max, depth of the scour only.
    4. The effect of skin friction may be allowed on the portions below the max, depth of scour. Accordingly for deciding the depth of well foundation, we require correct estimation of the following.
        1. Max. Sour depth.
        2. Safe bearing capacity.
        3. Skin friction.
        4. Lateral earth support below max. Scour level.

It is always desirable to fix the level of a well foundation on a sandy strata with adequate bearing capacity. Whenever a thin stratum of clay occurring between two layers of sand is met with, in that case well must be pierced through the clayey strata. If at all foundation has to be laid on clayey layer it should be ensured that the clay is stiff.

Design loads and Forces. The forces acting o n a bridge structure, to be considered fo the design of a well foundation, are as follows:

Vertical

(i) Dead load,

(ii) Live load,

(iii) Buoyancy.

Horizontal

(i) Wind force.

(ii) Force due to water currents.

(iii) Longitudinal forces caused by the tractive effort of vehicle or by braking effect of vehicles.

(iv) Longitudinal force on account of resistance of the bearing against movement due to variations of temperature.

(v) Seismic force.

(vi) Earth pressure.

(vii) Centrifugal force.

The I.R.C. Bridge code II stipulates the magnitude of above loads and forces. The magnitude, direction and point of application of all the above forces can be resolved into two horizontal forces, P and Q and a single vertical force W under the worst possible combinations.

Chapter 10

10.1 Piers:-

Piers provide vertical supports for spans at intermediate points and perform two main functions: transferring superstructure vertical loads to the foundations and resisting horizontal forces acting on the bridge. Although piers are traditionally designed to resist vertical loads, it is becoming more and more common to design piers to resist high lateral loads caused by seismic events. Even in some low seismic areas, designers are paying more attention to the ductility aspect of the design. Piers are predominantly constructed using reinforced concrete. Steel, to a lesser degree, is also used for piers. Steel tubes filled with concrete (composite) columns have gained more attention recently.

FIGURE: 1 : Typical cross-section shapes of piers for overcrossings or viaducts on land.

Pier is usually used as a general term for any type of substructure located between horizontal spans and foundations. However, from time to time, it is also used particularly for a solid wall in order to distinguish it from columns or bents. From a structural point of view, a column is a member that resists the lateral force mainly by flexure action whereas a pier is a member that resists the lateral force mainly by a shear mechanism. A pier that consists of multiple columns is often called a bent.

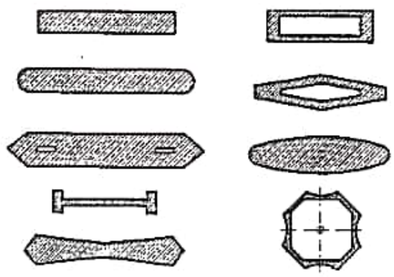


FIGURE:-2 Typical cross-section shapes of piers for river and waterway crossings.

There are several ways of defining pier types. One is by its structural connectivity to the superstructure: monolithic or cantilevered. Another is by its sectional shape: solid or hollow; round, octagonal, hexagonal, or rectangular. It can also be distinguished by its framing configuration: single or multiple columns bent; hammerhead or pier wall. Selection of the type of piers for a bridge should be based on functional, structural, and geometric requirements. Aesthetics is also a very important factor of selection since modern highway bridges are part of a city's landscape. Figure-1 shows a collection of typical cross section shapes for overcrossings and viaducts on land and Figure-2 shows some typical cross section shapes for piers of river and waterway crossings. Often, pier types are mandated by government agencies or owners. Many state departments of transportation in the United States have their own standard column shapes.

Broadly piers are classified under following two categories:-

I. Solid Piers.

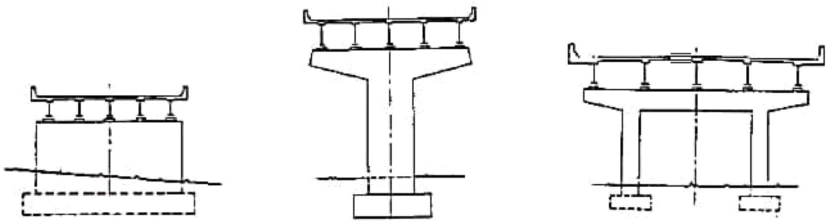
II. Open Piers.

Solid wall piers, as shown in Figures 3-a and 4, are often used at water crossings since they can be constructed to proportions that are both slender and streamlined. These features lend themselves well for providing minimal resistance to flood flows.

Hammerhead piers, as shown in Figure 3-b, are often found in urban areas where space limitation is a concern. They are used to support steel girder or precast prestressed concrete superstructures. They are aesthetically appealing. They generally occupy less space, thereby providing more room for the traffic underneath. Standards for the use of hammerhead piers are often maintained by individual transportation departments. A column bent pier consists of a cap beam and supporting columns forming a frame.

Column bent piers, as shown in Figure 3-c and Figure 27.5, can either be used to support a steel girder superstructure or be used as an integral pier where the cast-in-place construction technique is used. The columns can be either circular or rectangular in cross section. They are by far the most popular forms of piers in the modern highway system.

A pile extension pier consists of a drilled shaft as the foundation and the circular column extended from the shaft to form the substructure. An obvious advantage of this type of pier is that it occupies minimal amount of space. Widening an existing bridge in some instances may require pile extensions because limited space precludes the use of other types of foundations.



(a) Solid wall pier (b) Hammerhead pier (c) Rigid frame pier

FIGURE-3

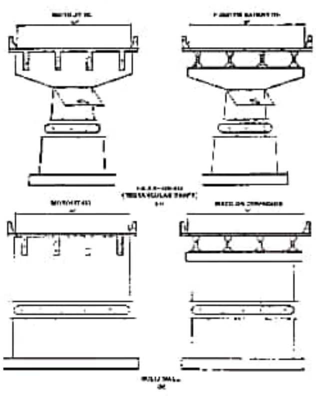
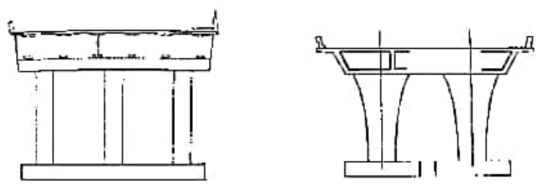


FIGURE-4



(a) Bent for precast girders (b) Bent for cast-in-place girders

10.2 Abutments:-

They are the end supports of the superstructure, retaining earth on their back. They are built either with masonry, stone or brick work or ordinary mass concrete or reinforced concrete. The top surface of the abutment is made flat when the superstructure is of trusses or girders or semi-circular arch. In case of segmental or elliptical arch type of superstructure, the abutment top is made skew. Weep holes are provided at different levels through the body of the abutment to drain of the retained earth.

The salient features of bridge abutments are listed below.

(a) Height. The height of the abutments is kept equal to that of the piers.

(b) Abutment batter. The water face of the abutment is usually kept vertical or could be given a batter of 1 in 12 to 1 in 24 as of piers. The face retaining earth is given a batter of 1 in 6 or may be stepped down.

(c) Abutment Width. The top width of the abutment should provide enough space for the bridge seat and for the construction of a dwarf wall to retain earth up to the approach level.

(d) Length of Abutment. The length of abutment is kept at least equal to the width of the bridge.

(e) Abutment cap. The design is similar to that of pier cap.

Abutments can be spill-through or closed. The spill through abutment generally has a substantial berm to help restrain embankment settlement at the approach of the structure.

Approach embankment settlement can also be accommodated by approach slabs to eliminate bumps at the bridge ends, closed abutments partially or completely retain the approach embankments from spilling under the span, and Bridges of several spans require expansion at the abutments. Therefore they are no usually required to resist the longitudinal forces that develop.

Broadly, abutments are classified under the following categories.

1. Abutments with wing walls
2. Abutments without wing walls

<u>Abutments with wing walls</u>

(a) Straight Wing walls

(b) Splayed Wing walls

(c) Return Wing Walls

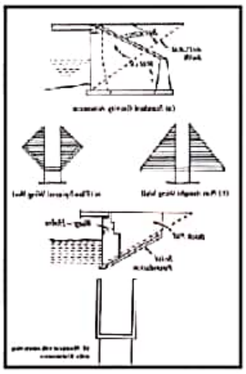
<u>Abutments without wing walls</u>

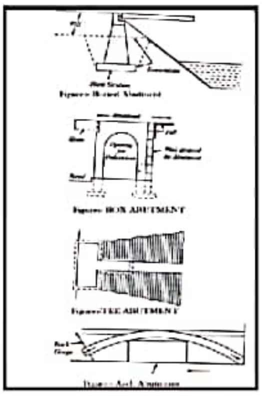
(a) Buried Abutments

(b) Box Abutments

(c) Tee Abutments

(d) Arch Abutments





FIGURES: - ABUTMENTS

Buried Abutments: - This type of abutments is generally built prior to the placing of the fill. Since it is filled on both sides the earth pressure is low. Superstructure erection can be begin before placement of fill .

Box Abutments: - This employs a short span of bridge built integral with columns to act as a frame and resist earth pressure of the approaches. It is most often used overpass work where the short span may be employed for pedestrian passage (see figure).

Tee Abutments: - This type looks like T in plan and has now become absolute (see figure)

Arch Abutments: - This type of abutment is used where arches are employed because of their economy in certain conditions. The high inclined skewback thrusts are difficult to handle unless the abutment can be seated in rock. Therefore, they are often used for span over gorges. (see figure)

10.3 WING WALLS:

In a bridge, the wing walls are adjacent to the abutments and act as retaining_walls. They are generally constructed of the same material as those of abutments. The wing walls can either be attached to the abutment or be independent of it. Wing walls are provided at both ends of the abutments to retain the earth filling of the approaches. Their design period depends upon the nature of the embankment and does not depend upon the type or parts of the bridge.[1]

The soil and fill supporting the roadway and approach embankment are retained by the wing walls, which can be at a right angle to the abutment or splayed at different angles. The wing walls are generally constructed at the same time and of the same materials as the abutments.

Classification of wing walls

Wing walls can be classified according to their position in plan with respect to banks and abutments. The classification is as follows:

1. Straight Wing walls: They are used for small bridges, on drains with low banks and for railway bridges in cities (weep holes are provided).

2. Splayed Wing walls: These are used for bridges across rivers. They provide smooth entry and exit to the water. The splay is usually 45°. Their top width is 0.5 m, face batter 1 in 12 and back batter 1 in 6, weep holes are provided.

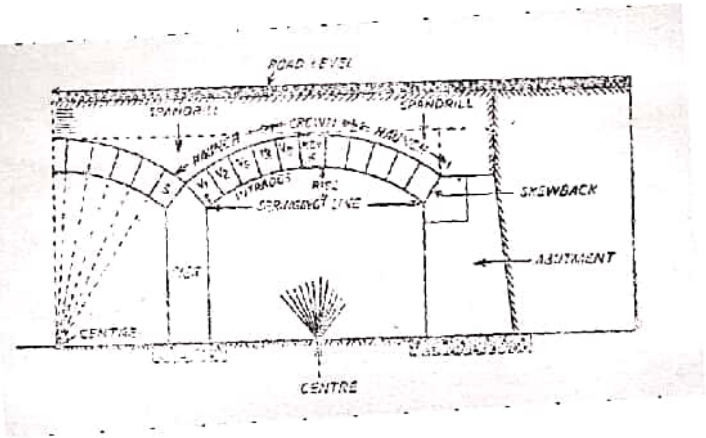
3. Return Wing walls: They are used where banks are high and hard or firm. Their top width is 1.5 m and face is vertical and back battered 1 in 4. Scour can be a problem for wing walls and abutments both, as the water in the stream erodes the supporting soil.[1]

CHAPTER-11

PERMANENT BRIDGES

Masonry Bridges:-

Bridge unit the spandrel, which supports the bridge roadway. The spandrel is made from gravel or crushed stone backing held in by lateral (side) walls made of concrete masonry or stonework or in the form of an open main load-bearing structures are made of natural stone, brick, or concrete blocks. Such a bridge is always arched, with massive supports. The main load-bearing element of a masonry bridge is the arch, over which is structure of small arches resting on crosswalk. The advantages of a masonry bridge are its architectural attractiveness and its durability. Masonry bridges are known that have been in use for more than 1,000 years. The basic short comings that limit the use of masonry bridges are their complexity and labor intensiveness of construction.. Their simplicity, economy and ease with which pleasing appearance can be obtained make them suitable for this purpose.



Classification of steel bridges

Steel bridges are classified according to

- the type of traffic carried
- the type of main structural system
- the position of the carriage way relative to the main structural system

These are briefly discussed in this section.

Classification based on type of traffic carried

Bridges are classified as

- Highway or road bridges
- Railway or rail bridges
- Road - cum - rail bridges

Classification based on the main structural system

Many different types of structural systems are used in bridges depending upon the span, carriageway width and types of traffic. Classification, according to makeup of main load carrying system, is as follows:

(i) Girder bridges - Flexure or bending between vertical supports is the main structural action in this type. Girder bridges may be either solid web girders or truss girders or box girders. Plate girder bridges are adopted for simply supported spans less than 50 m and box girders for continuous spans up to 250 m. Cross sections of a typical plate girder and box girder bridges are shown in Fig.7.2 (a) and Fig. 7.2(b) respectively. Truss bridges [See Fig.7. 2(c)] are suitable for the span range of 30 m to 375 m. Cantilever bridges have been built with success with main spans of 300 m to 550 m. . They may be further, sub-divided into simple spans, continuous spans and suspended-and-cantilevered spans, as illustrated in Fig.7. 3.

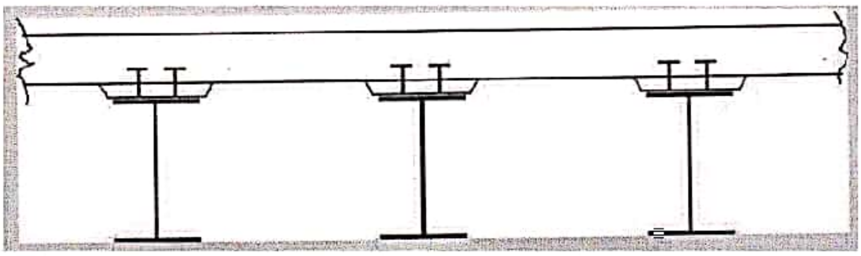


Fig.7.2 (a) Plate girder bridge section

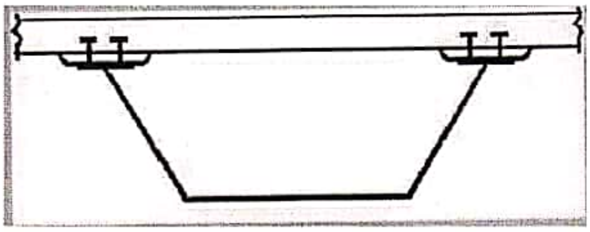


Fig.7.2 (b) Box girder bridge section

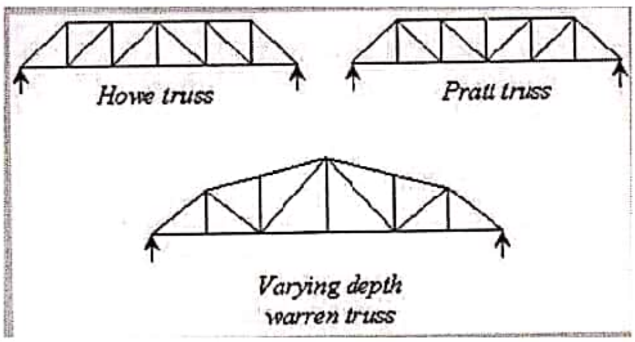


Fig.7.2 (c) Some of the trusses used in steel bridges

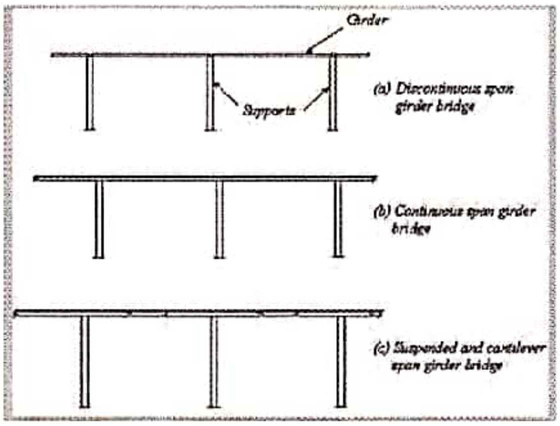


Fig.7.3 Typical girder bridges

(ii) Rigid frame bridges - In this type, the longitudinal girders are made structurally continuous with the vertical or inclined supporting member by means of moment carrying joints [Fig.7.4]. Flexure with some axial force is the main forces in the members in this type. Rigid frame bridges are suitable in the span range of 25 m to 200 m.

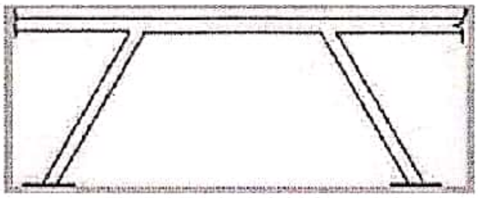
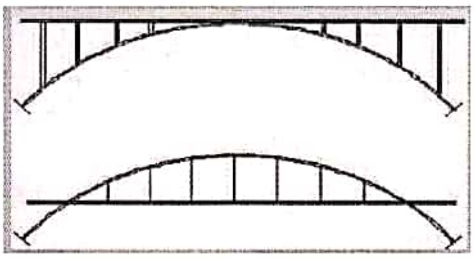


Fig.7.4 Typical rigid frame bridge

(iii) Arch bridges

The loads are transferred to the foundations by arches acting as the main structural element. Axial compression in arch rib is the main force, combined with some bending. Arch bridges are competitive in span range of 200 m to 500 m.



(iv) Cable stayed bridges - Cables in the vertical or near vertical planes support the main longitudinal girders. These cables are hung from one or more tall towers, and are usually anchored at the bottom to the girders. Cable stayed bridges are economical when the span is about 150 m to 700 m. Layout of cable stayed bridges are shown in Fig. 7.6.

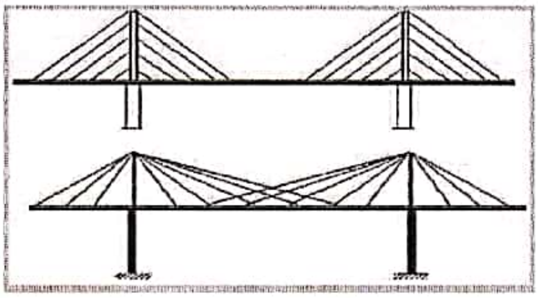


Fig.7.6 Layout of cable stayed bridges

(v) Suspension bridges - The bridge deck is suspended from cables stretched over the gap to be bridged, anchored to the ground at two ends and passing over tall towers erected at or near the two edges of the gap. Currently, the suspension bridge is best solution for long span bridges. Fig. shows a typical suspension bridge. Fig. 7.8 shows normal span range of different bridge types.

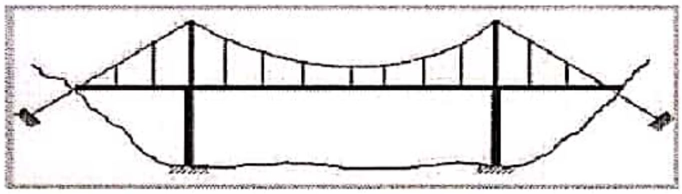


Fig.7.7 Suspension bridge

Classification based on the position of carriageway

The bridges may be of the "deck type", "through type" or "semi-through type". These are described below with respect to truss bridges:

(i) Deck type bridge -The carriageway rests on the top of the main load carrying members. In the deck type plate girder bridge, the roadway or railway is placed on the top flanges. In the deck type truss girder bridge, the roadway or railway is placed at the top chord level as shown in Fig. 7.9(a).

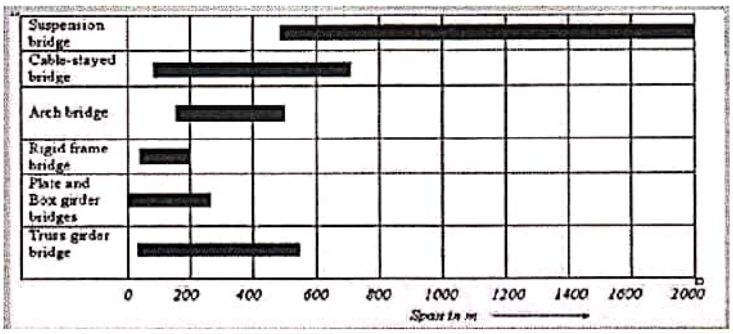
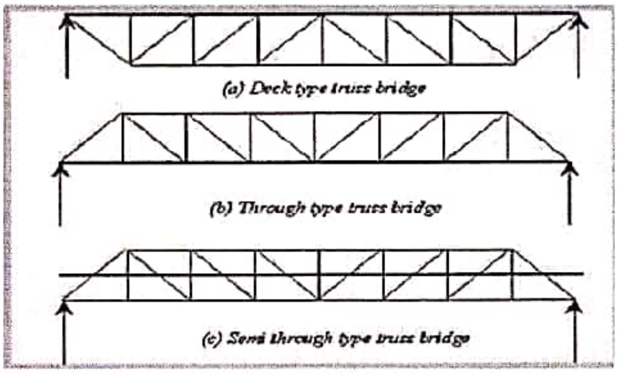


Fig.7.8 Normal span ranges of bridge system



TYPES OF CONCRETE BRIDGES

Arch Bridges

Arch bridges derive their strength from the fact that vertical loads on the arch generate compressive forces in the arch ring, which is constructed of materials well able to withstand these forces. The compressive forces in the arch ring result in inclined thrusts at the abutments, and it is essential that arch abutments are well founded or buttressed to resist the vertical and horizontal components of these thrusts. If the supports spread apart the arch falls down. Traditionally, arch bridges were constructed of stone, brick or mass concrete since these materials are very strong in compression and the arch could be configured so that tensile stresses did not develop. Modem concrete arch bridges utilize prestressing or reinforcing to resist the tensile stresses which can develop in slender arch rings.

Reinforced Slab Bridges

For short spans, a solid reinforced concrete slab, generally cast in-situ rather than precast, is the simplest design. It is also cost-effective, since the flat, level soffit means that false work and formwork are also simple. Reinforcement, too, is uncomplicated. With larger spans, the reinforced slab has to be thicker to carry the extra stresses under load. This extra weight of the slab itself then becomes a problem, which can be solved in one of two ways. The first is to use prestressing techniques and the second is to reduce the deadweight of the slab by including 'voids', often expanded polystyrene cylinders. Up to about 25m span, such voided slabs are more economical than prestressed slabs.

Beam and Slab Bridge

Beam and slab bridges are probably the most common form of concrete bridge in the UK today, thanks to the success of standard precast prestressed concrete beams developed originally by the Prestressed Concrete Development Group (Cement & Concrete Association) supplemented later by alternative designs by others, culminating in the Y-beam introduced by the Prestressed Concrete Association in the late 1980s.

They have the virtue of simplicity, economy, wide availability of the standard sections, and speed of erection.The precast beams are placed on the supporting piers or abutments, usually on rubber bearings which are maintenance free. An in-situ reinforced concrete deck slab is then cast on permanent shuttering which spans between the beams.

The precast beams can be joined together at the supports to form continuous beams which are structurally more efficient. However, this is not normally done because the costs involved are not justified by the increased efficiency.

Simply supported concrete beams and slab bridges are now giving way to integral bridges which offer the advantages of less cost and lower maintenance due to the elimination of expansion joints and bearings.

Techniques of construction vary according to the actual design and situation of the bridge, there being three main types:

1. Incrementally launched
2. Span-by-span
3. Balanced cantilever

Incrementally launched

As the name suggests, the incrementally launched technique creates the bridge section by section, pushing the structure outwards from the abutment towards the pier. The practical limit on span for the technique is around 75m.

Span-by-span

The span-by-span method is used for multi-span viaducts, where the individual span can be up to 60m.

These bridges are usually constructed in-situ with the false work moved forward span by span, but can be built of precast sections, put together as single spans and dropped into place, span by span.

Balanced cantilever

In the early 1950's, the German engineer Ulrich Finsterwalder developed a way of erecting prestressed concrete cantilevers segment by segment with each additional unit being prestressed to those already in position. This avoids the need for false work and the system has since been developed.

Whether created in-situ or using precast segments, the balanced cantilever is one of the most dramatic ways of building a bridge. Work starts with the construction of the abutments and piers. Then, from each pier, the bridge is constructed in both directions simultaneously. In this way, each pier remains stable - hence 'balanced' - until finally the individual structural elements meet and is connected together. In every case, the segments are progressively tied back to the piers by means of prestressing tendons or bars threaded through each unit.

Integral Bridges

One of the difficulties in designing any structure is deciding where to put the joints. These are necessary to allow movement as the structure expands under the heat of the summer sun and contracts during the cold of winter. Expansion joints in bridges are notoriously prone to leakage. Water laden with road salts can then reach the tops of the piers and the abutments, and this can result in corrosion of all reinforcement. The expansive effects of rust can split concrete apart. In addition, expansion joints and bearings are an additional cost so more and more bridges are being built without either. Such structures, called 'integral bridges', can be constructed with all types of concrete deck. They are constructed with their decks connected directly to the supporting piers and abutments and with no provision in the form of bearings or expansion joints for thermal movement. Thermal movement of the deck is accommodated by flexure of the supporting piers and horizontal movements of the abutments, with elastic compression of the surrounding soil.

Already used for lengths up to 60m, the integral bridge is becoming increasingly popular as engineers and designers find other ways of dealing with thermal movement.

Cable-Stayed Bridges

For really large spans, one solution is the cable-stayed bridge. These types of bridges first developed in west Germany. They consists of cables provided above the deck and are connected to the towers. The deck is either supported by a number cables meeting in a bunch at the tower or by joining at different levels on the tower. The multiple cables would facilitate smaller distance between points of supports for the deck girders. This results in reduction of structure depth. The cables can arrange in one plane or two planes. The two plane system requires additional widths to accommodate the towers and deck anchorages. Singly plane system requires less width of deck. Where all elements are concrete, the design consists of supporting towers carrying cables which support the bridge from both sides of the tower. Most cable-stayed bridges are built using a form of cantilever construction which can be either in-situ or precast.

The cable stayed bridges are similar to suspension bridges except that there are no suspenders in the cable stayed bridges and the cables are directly stretched from the towers to connect with decking. No special anchorage is required for the cables as incase of suspension bridges because the anchorage at one end is done in the girder and at the other on top of tower. The cable-stayed bridges have been found economical for up to span 300m. However due to cantilever effect their deflection is rather high and hence they are not preferred for very long span in railways.

Suspension Bridges

Concrete plays an important part in the construction of a suspension bridge suspension bridgs are ideal solution for bridging gaps in hilly areas because of their construction technology and capacity of spanning large gaps. There will be massive foundations, usually embedded in the ground, that support the weight and cable anchorages .The cable takes shape of catenary between two points of suspension. The flooring of bridge supported by the cable by virtue of tension developed in its cross section. The vertical members are known as **suspenders** are provided to transfer load from bridge floor to suspension cable. There will also be the abutments, again probably in mass concrete, providing the vital strength and ability to resist the enormous forces, and in addition, the slender superstructures carrying the upper ends of the supporting cables are also generally made from reinforced concrete.

Typical deck, through and semi-through type truss bridges

(ii) Through Type Bridge - The carriageway rests at the bottom level of the main load carrying members. In the through type plate girder bridge, the roadway or railway is placed at the level of bottom flanges. In the through type truss girder bridge, the roadway or railway is placed at the bottom chord level. The bracing of the top flange or lateral support of the top chord under compression is also required.

(iii) Semi through Type Bridge - The deck lies in between the top and the bottom of the main load carrying members. The bracing of the top flange or top chord under compression is not done and part of the load carrying system project above the floor level The lateral restraint in the system is obtained usually by the U-frame action of the verticals and cross beam acting together.

Concrete bridges-

They can be divided into the following main classes

(1)Unstiffened suspension Bridges.

(2)Stiffened suspension Bridges.

Un-stiffened suspension Bridges:-Incase of Un-stiffened suspension Bridges the moving load is transferred direct to the cables by each suspender. These are used for light construction such as foot bridges forest train structures, etc where the moving load is negligible and deflection requirements are not controlling. Also the places where span is very long and the ratio dead to moving load intensity is so great to render stiffening unnecessary.

Stiffened suspension Bridges:-In stiffened type suspension Bridges moving loads are transformed to the cables through medium of trusses called **stiffening girders** .The stiffening girder assists the cable to become more rigid and prevent change in shape and gradient of roadway platform. It is therefore adopted for heavy traffic .

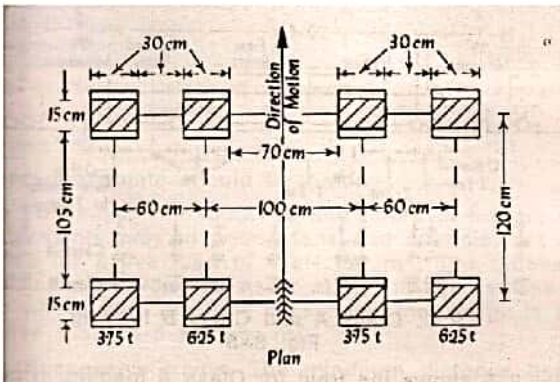
IRC Bridge loading:-

The public roads in India are managed and controlled by the Government and hence bridges to be constructed for roads to be designed as per standards set up by standard authorities. For highway bridges standard specifications are contained in the Indian Road Congress (I.R.C) Bridge code. 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,

(a) IRC class AA loading,
(b) IRC class A loading
(c) IRC class B loading.

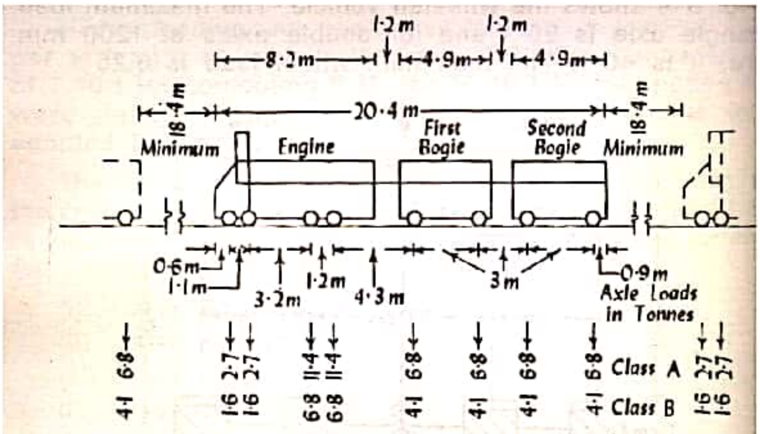
IRC class AA loading:-

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. 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 70 Rloading is not discussed further here.



I.R.C. Class *AA* loading—wheeled vehicle

IRC class A loading:-Class A loading is based on heaviest type commercial vehicle 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.



I.R.C. Class *A* and Class *B* loading

. **IRC class B loading**:-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.

CHAPTER-12

CULVERTS AND CAUSE WAYS

Culvert- A culvert is defined as a small bridge constructed over a stream which remains dry most part of the year. It is across drainage work having total length not exceeding 6m between faces of abutment.

Types of Culverts;-

The following are six different type culvert.

1.Arch culvert

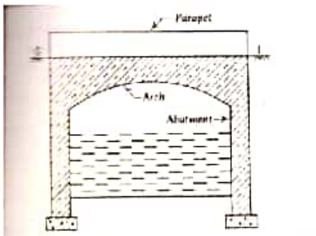
2.Box culvert

3.Pipe Culvert

4.Slab Culvert

Arch culvert:-

An arch culvert consists of abutments wing walls, arch, parapets and the foundation. The construction materials commonly used are brick work or concrete. Floor and curtain wall may or may not be provided depending upon the nature of foundation soil and velocity of flow. A typical arch culvert is shown in figure.



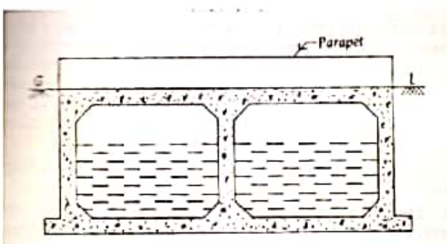
Arch culvert
Fig. 6-1

Box culvert:-

In case of box culvert the rectangular boxes are formed of masonry, R.C.C or steel. The R.C.C box culverts are very common and they consist of the following two component

(i)The barrel or box section of sufficient length to accommodate the roadway and the Krebs.

(ii)The wing walls splayed at 45 for retaining the embankment and also guiding the flow of water into and out of the barrel.



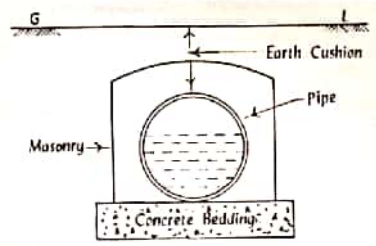
An R.C.C. box culvert
Fig. 6-2

Fig. 6-2 shows an R.C.C box culvert with two openings. Following points should be noted.

(i)Foundation: The box culverts prove to be safe where good foundations are easily available.
(ii)Height: The clear vent height i.e. the vertical distance between top and bottom of the culvert rarely exceeds 3 meters.
(iii) Sap: The box culverts are provided singly or in multiple units with individual span exceed about 6 m or so, it requires thick section which will make the construction uneconomical.
(iv)Top: Depending upon the site conditions, the top level of box may be at the road level or it can even be at a depth below road level with filling of suitable material.

Pipe Culvert:

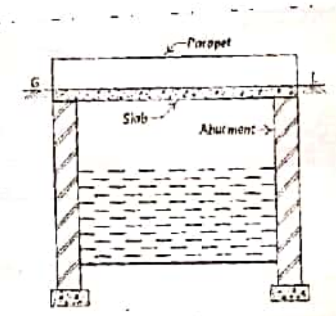
They are provided when discharge of stream is small or when sufficient headway is not available. Usually one or more pipes of diameter not less than 60cm are placed side by side. Their exact number and diameter depend upon the discharge and height of bank. For easy approach of water splayed type wing walls are provided in fig. 6.3 shows a Hume pipes culvert of single pipe. The pipes can be built of masonry. Stone ware, cement concrete, cast iron or steel. Concrete bedding should also be given below the pipes and earth cushion of sufficient thickness on the top to protect the pipes and their joints. For Economic reason road culverts should have non-pressure heavy duty pipes of type ISI class NP3 conforming to IS:458-1961. As far possible the gradient of the pipe should not be less than 1000.



Pipe culvert
FIG. 6-3

Slab Culvert:

A slab culvert consists of stone slabs or R.C.C slab, suitably support on masonry walls on either side. As shown in fig 6-4. The slab culverts of simply type are suitable up to a maximum span of 2.50 m or so. However the R.C.C culverts of deck slab type can economically be adopted up to spans of about 8 m. However, the thickness of slab and dead weight may sometimes prove to be the limiting factors for deciding the economical span of this type of culverts.



Slab culvert
Fig. 6-4

The construction of slab culverts is relatively simple as the frame work can easily be arranged, reinforcement can be suitably placed and concreting can be done easily. This type of culvert can be used for highway as well as Railway Bridge. Depending upon the span of culvert and site conditions the abutment and wing walls of suitable dimensions may be provided. The parapet or hand rail of at least 750 mm height should be provided on the slab to define the width of culvert.

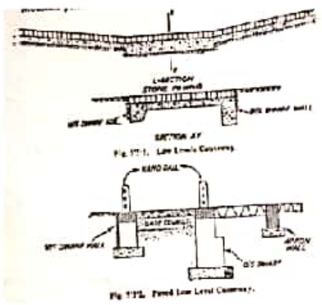
CAUSEWAYS :

A road causeway is a pucca dip which allows floods to pass over it. It may or may not have opening or vents for low water to flow. If it has vents for low water to flow then it is known as high level causeway or submersible bridge ; otherwise a low level causeway.

TYPES OF CAUSEWAY:

A) **Low level causeway:**

It is also known as Irish Bridge. The beds of small rivers or streams, which remain dry for most part of the year, are generally passable without a bridge. This involves heavy earth works in cutting for bridge approaches .Banks of such types of streams are cut down at an easy slope. For streams of rivers in plains having sandy beds, it is often sufficient to lay bundles of grass over and across the sandy track. The bundles may be of 20 to 25cm in diameter whose ends are secured by longitudinal fascines pegged down by stakes.



For crossings important from traffic point of view it is essential to lay a metal or pucca paving of stone or brick set in lime mortar on a substantial bed of concrete. To prevent against possible scour and undermining a cut off or dwarf wall usually 60cm deep on the upstream side and 120 to 150cm on downstream side is provided. Fig. 5.3.1 below shows the details of a typical Irish bridge.

The low level causeway could be provided with openings formed by concrete Hume pipes if there is a continuous flow stream during the monsoon periods.

B) High level Causeway:

A high level causeway is submersible road bridge designed to be overtopped in floods. Its formation level is fixed in such a way as not to cause interruption to traffic during floods for more than three days at a time not for more than six times in a year. A sufficient numbers of openings are provided to allow the normal flood discharge to pass through them with the required clearance. They are provided with abutments and piers, floors and slabs or arches to form the required number of openings. The slope of the approaches is kept as 1 in 20.When the velocity is high and stream bed is soft the aprons could be of concrete or harder masonry upto a certain distance. Similarly, the road can be formed of a cement concrete slab or stone blocks set in cement mortar. A typical type of high level causeway is shown in Fig.5.3.3.If railing are provided in the bridge, they should be of collapsible type.Temporary causeways used for an emergency military operations are formed either by using timber stringers and planking over cribs used as piers or by constructing a culvert using pipes.

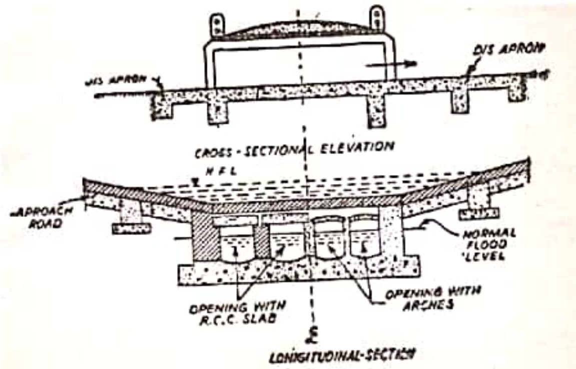


Fig. 5·3·3. High Level Causeway.