CHAP-1

BRIDGE ENGINEERING

INTRODUCTION

Bridge is a structure providing passage over an obstacle without closing the way beneath.

→ The passage may be for a road, pedestrians, railways, etc.

→ The obstacle may be a river, a road, railway etc.

COMPONENTS OF A BRIDGE

The bridge structure can be broadly divided into two parts:-

① Superstructure:- It is part of the bridge over which the traffic moves.

→ It consists of railing or parapet, roadway and girder, stresses or arches over which the roadway is supported.

② Substructure:- The substructure of a bridge is the structure designed to support the Super-Structure of the bridge.

The components of substructure are
(i) foundation
(ii) pier
(iii) Abutment
(iv) wing-walls
(v) Approaches

CLASSIFICATION OF BRIDGES

Bridges can be classified into various types according to:

① Purpose :- (a) Highway Bridge
(b) Railway Bridge
(c) Foot Bridge
(d) Aqueduct
(e) Viaduct

② Materials used for construction:
(a) Timber Bridge
(b) Masonary Bridge
(c) Steel Bridge
(d) R.C.C Bridge
(e) Prestressed Concrete Bridge

③ Life :- (a) Temporary Bridge
(b) permanent Bridge

④ Relative position of floor :-
(a) Deck Bridge
(b) Semi-through Bridge

(c) Through Bridge

(5) Type of Superstructure:
(a) Arch type Bridge
(b) Girder type Bridge
(c) Truss Bridge
(d) Suspension Bridge

(6) Alignment :- (a) Straight Bridge
(b) Skew Bridge

(7) Position of High Flood Level :-
(a) Submersible Bridge
(b) Non-submersible Bridge

REQUIREMENTS OF AN IDEAL BRIDGE

An ideal bridge must meet the following requirements :-
(a) It should be economical
(b) It should serve the intended functions with safety and convenience
(c) It should give aesthetic elegant look.

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BRIDGE SUBSTRUCTURE AND APPROACHES

PIER

A pier is an intermediate supporting structure of a bridge. Piers are intended to transfer the loads from the superstructure of the bridge to the foundation. These are generally constructed using Concrete although Steel is also used.

Piers help in (i) sustaining dead load and live load (ii) facilitating a long bridge to be converted into segments.

TYPES OF PIERS

Piers are of the following types:- (i) Solid pier
(ii) Abutment pier
(iii) Column pier
(iv) Cylindrical pier
(v) pile pier
(vi) Dumb-bell pier
(vii) Trestle pier
(viii) Cellular pier
(ix) Hammer pier

(i) Solid pier:- A solid pier can be made of concrete or stone masonary. These provide excellent resistance against floating bodies and can

be used for any type of superstructure of the bridge.

(ii) Abutment pier: For long arch bridges, it is desirable to provide some intermediate piers with heavier sections to bear the horizontal thrust.

→ These piers are very useful and save centering charges, because if no such pier is provided the centering for whole length of the bridge is to be done at one time

(iii) Column pier:- This type of piers are used when the girders of the superstructure of a bridge are very close together and is impossible to construct separate pier for each girder.

→ In this type of arrangement columns are constructed and a beam is provided at the top of columns on which all girders rest.

(iv) Cylindrical pier:- These are open pier constructed of mild steel or cast iron cylinders which are filled with concrete.

(v) Pile pier:- This type of pier is used in shallow water to support the main girder of a bridge directly over the pile cap. The piles are braced by using R.C.C or steel braces to give more lateral rigidity to them.

(vi) Dumb-bell pier:- Dumb-bell pier is a type of solid R.C.C. pier constructed by connecting two R.C.C. columns by means by means of a thin reinforced concrete web, provided all along the height in a direction transverse to the direction of the bridge.

(vii) Trestle pier:- This is a open pier constructed of framework of R.C.C. steel or timber.

→ Each trestle consists of two or more vertical posts, braced horizontally and diagonally, to support the bridge superstructure.

→ These piers are suitable for bridges, where river bed is sufficiently firm and water current is slow.

(viii) Cellular pier :- Cellular piers are used to receive prestressed superstructure.

⇒ It consists of two concentric R.C.C. cells connected by horizontal bands and radial ribs at suitable intervals.

⇒ The space between the cells is filled with sand.

ABUTMENTS

The end supports of the super-structure of a bridge are called abutments. The basic functions of abutments are :-

(i) Supporting the bridge deck at the ends,

(ii) Connecting the approach road embankment.

TYPES OF ABUTMENTS

Following are the major type of abutments currently in use :

(i) Gravity abutment

(ii) Stub abutment

(iii) U - abutment

(iv) Counterfort abutment

(i) Gravity Abutment :- A gravity abutment resists horizontal earth pressure from rear with its own weight.
→ Hence gravity abutment is a massive sized abutment, constructed by using mass concrete or stone masonary.

(ii) Stub Abutment :- A stub abutment is a relatively short abutment which is placed on top of the embankment or slope.

(iii) U-abutment :- When the wing walls of a gravity abutment are placed right angles to the back wall, the abutment is known as U-abutment.

(iv) Counterfort abutment :- It is very much similar to a counterfort retaining wall. This type of abutments are used when high abutments are required.

WING-WALLS

Wing-walls are the walls constructed at both ends of the abutment to retain the earth banks of the river or of the bridge

approaches.

→ The materials used in the construction of these walls are the same as that of abutments.

→ The design of these walls depends on the nature of banks.

Types of wing-walls

Wing-walls are of the following types:-

(i) Straight wing-walls
(ii) Splayed wing-walls
(iii) Curved wing-walls
(iv) Return wing-walls

(i) Straight wing-walls :- Straight wing-walls are constructed parallel to the abutment at both their ends.

→ These walls are constructed across small streams with low banks.

(ii) Splayed wing-walls :- Splayed wing-walls are constructed at an acute angle (at 45° with the abutment at both their ends.

→ It is provided when the road width is to be decreased on the bridge

across a river or stream.
→ These are best suitable for small as well as big bridges.

(iii) Curved wing-walls :- This type of wing-walls is generally used in bridges of irrigation channels or canals, as they provide smooth entry of water under the bridge.

(iv) Return wing-walls :- Return wing-walls are constructed at right angles to the abutments at both of their ends.
→ This type of wing-walls are suitable when the embankments is very high and banks are firm.

APPROACHES

Approaches are the lengths of the communication route affected by the layout and construction of the bridges, at its both ends.

→ These are constructed in embankment for high level bridges and culverts.

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CHAP-3 # BRIDGE FOUNDATION

Bridge foundation is the structure which transfer the entire load coming to it to the hard soil below

Types of foundation

The foundations used in bridge structures may be broadly classified as :- (a) Shallow foundations
(b) Deep foundations

(a) Shallow Foundation :- Shallow foundations are used in places where stable foundation ~~strata~~ strata are available at lower depths.

→ Shallow foundations used in bridges are :- (i) Spread foundation
(ii) Raft foundation

(i) Spread foundation :- This type of foundation is suitable for bridges of moderate height.

→ This type of foundation is best suited at such places where scouring is minimum.

→ It is suited in situations where hard soil is available within

2.0 to 3m below the bed level of the river.

(ii) Raft foundation:- This type of foundation is suitable when the bed of river consists of weak soils like silt, soft clay and hard soil is not available within reasonable depth

(b) Deep foundation:- Deep foundation is provided at places where a good stratum is available only at greater depth.

→ Deep foundations used for bridges are of two types:-

(i) Well foundation:- Well foundations from the most common type of deep foundations for bridges in india.

→ Well foundations are identified under three categories:-

(A) Box caission:- A box caission is open at top and closed at bottom and is made of timber, steel or reinforced concrete.
→ It is suitable for shallow depth & where loads are not very heavy.

(B) Open Caission:- An open caission is a box of timber, metal, reinforced concrete or masonary which is open both at the top and at the bottom.

→ It is used for building & bridge foundations

→ Open Caission are also called wells.

(C) Pneumatic Caission:- When it is required to go to greather depths for want of suitable hard strata, pneumatic caissions are used.

→ These are wells with open bottom and closed tops.

(ii) Pile foundations:- Piles are slender structural elements placed in the ground for :-

(i) receiving load from the super-structure and transferring it to ground by friction or bearing,

(ii) increasing the bearing capacity of the soil.

→ These may be wooden, steel or

Concrete piles depending on location and need.

→ Precast concrete piles are made in the workshop and transported to the site.

MCQ

(1) Slab culverts are suitable for maximum span of 3m.

(2) Which of the followings is not the component of substructure of a bridge :- Roadway.

(3) A pier is an intermediate supporting structure of a bridge which transfers the load directly to foundation.

(4) When the wing-walls are constructed at right angles to the abutment then it is called :- Return wing-walls.

(5) Spread foundation is a type of :- shallow foundation.

(6) Pneumatic caission is a type of :- well foundation.

Caission foundation

The term caission has been derived from the french word caisse, meaning box.

→ It can be round or rectangular, which is sunk from the surface of either land or water to the desired depth.

Cofferdams

A cofferdam is a temporary dike built across a body of water, and constructed to allow the water to be pumped out of the enclosed area.

CHAP-4 CULVERT & CAUSEWAYS

CULVERT

A Culvert is a small bridge having its total length of 6 meters or less between the faces of abutments.

→ These are permanent drainages structures, constructed to carry roadway or railway track over small streams or canals.

Types of Culverts

Culverts are of following types:-

(i) Arch Culverts
(ii) Slab Culverts
(iii) Box Culverts
(iv) Pipe Culverts

(i) Arch Culverts:- Arch culverts are culverts having its superstructure consisting of one or two arches.

→ These are suitable where the approaches are to be constructed in cutting.

(ii) Slab Culverts:- In this type of Culvert R.C.C slab is simply supported over abutments made of brick masonary or any other masonary.

→ These culverts are provided upto

maximum span of 3m and are suitable where bed of streams or canal is sufficiently firm.

(iii) Box Culverts :- A box culvert consists of an R.C.C box of square or rectangular opening with span generally restricted to 4m.

→ Box culverts are suitable if the bearing capacity of the soil is low and the discharge in a channel or drain crossing a road is small.

(iv) Pipe Culverts :- A pipe culvert consists essentially of a pipe barrel under the embankment with protection works at the entry and exit.

→ It is suitable when cross drainage flows on a relatively flat terrain and if the discharge is limited.

CAUSEWAYS

It is a submersible bridge having no span for passing water below it.

→ In other words, it can be said that it is one type of bridge which allows flood water to pass over

it.

⇒ It is adopted on streams which are dry for almost all part of the year, water only flows in them for about 10 to 15 days in a year in rainy season.

Types of Causeways

Causeways may be classified as follows :- ① Fresh causeway
② Low level causeway
③ High level causeway

① Fresh causeway :- Fresh causeways usually are provided in hilly roads if the maximum depth of flood water does not exceed about 1.75 m and the road does not remain interrupted for more than 10 to 15 days in a year.

② Low level causeway :- When the streams or water courses remain dry for the major part of the year or the depth of water is very small then Low level causeway may be provided with vents.

③ High level causeway :- It is also known as submersible bridge.

→ According to Indian Road Congress, the Submersible bridge should not remain submerged under water for a maximum period of 72 hours at a time and such occurances should not occur more than 10-12 times a year.

Difference between a causeway & a bridge

Generally following differences are there between a causeway and a bridge :-

(a) Causeway does not have foundation, pier or abutment.

(b) Usually water flows over the top surface of the causeway.

(c) These are cheap as they are constructed of a R.C.C. slab over foundation with approaches on both sides.

BRIDGE SITE INVESTIGATION, HYDROLOGY & PLANNING

CHAP-5

Introduction

Before constructing a bridge at a particular site, it is essential to consider the factors such as need of the bridge, present and future traffic volume, characteristics of the stream, sub soil conditions, cost of the project, alternative sites available and their relative merits and aesthetic etc.

The aim of the investigation is to select a suitable site for the construction of the bridge. The site for a bridge is governed by engineering, factors economics, demands of traffic, condition of stream and aesthetics etc.

Selection of bridge site

An ideal site for a bridge across a river should have following characteristics:-

→ At bridge site the reach of stream should be straight.

→ The site should be geologically sound i.e. it should be away from fault zone and should have unyielding, non erodible foundation for abutments and piers.

→ At the site, the stream should be narrow with well defined and firm banks.

→ At site the river flow should be without whirls and cross currents.

→ At the site there should be suitable high banks above high flood levels on each side

→ The approaches should be economical.

→ The site should be at reasonable proximity to a direct alignment of the road to be connected.

→ There should be no sharp curves in the approaches.

→ Absence of costly river training works, where they are unavoidable they should be executed in dry as far as possible.

→ Avoidance of excessive cofferdam water construction work.

Waterway

The waterway may be defined as the area of opening, under the bridge which should be sufficient to pass the maximum flood discharge that would ever pass under the

bridge without increasing the velocity of flow beyond permissible limit

Economic span

It may be defined as the economic span is that span for which the cost of super structure for one span is equal to the cost of sub-structure of the span.

Afflux

It is the rise in water level near the bridge or difference in water level immediately above and below the bridge due to the obstruction caused by the construction of the bridge.

Clearance

To avoid any possibility of striking normal traffic against any part of the super structure, clearances are provided.

Free board

It is the vertical distance between the H.F.L of the river and the bottom level of the girder or springing level in case of arch bridges.

Determination of flood discharge

For the safe and stable design of a bridge, the correct estimation of the discharge to be passed through the bridge is very essential.

Generally two methods may be adopted for calculating the maximum flood discharge of a river.

(1) Direct method
(2) Indirect method

(1) **Direct Method**:- In this method the area is obtained by direct measurement and the velocity can be obtained by any of the following formula:-

(1) By Chazy's formula

$$V = C\sqrt{mi}$$

(2) By Manning's formula

$$V = \frac{1}{N} m^{2/3} i^{1/2}$$

where,

C = a constant

$$C = \frac{157.6}{1.81 + \frac{K}{\sqrt{m}}}$$

Kutter's formula for C,

$$C = \frac{23 + \frac{0.00155}{i} + \frac{1}{N}}{1 + \left(23 + \frac{0.00155}{i}\right)\frac{N}{\sqrt{m}}}$$

N = A constant which depends upon the roughness of the surface

m = Hydraulic mean depth

i = slope per km length

(2) INDIRECT METHODS

For estimating maximum flood discharge following methods may be used:

(1) Empirical formula: For calculating the maximum flood discharge in India many empirical formulae have been developed. Only a few are given below:

(a) Dicken's formula,

$$Q = CA^{3/4}$$

(b) Ryve's formula,

$$Q = CA^{2/3}$$

(c) Inglis formula, $Q = \frac{123.2A}{\sqrt{A + 10.4}}$

where,

Q = max. flood discharge in m^3/s

A = Area of catchment in km^2

C = A constant

Bessel's formula, $Q_m = \frac{p_m \times Q_n}{p_n}$

where,

Q_m = peak flow expected

p_n = observed rain fall

Q_n = Some observed peak flow

p_m = expected rainfall

This formula is very rational and can be used in any type of case.

(1) What is ballast ?

Ans The ballast is a layer of broken stones, gravel, moorum, or any other granular material placed and packed below and around sleepers for distributing load from the sleepers to the ballast. It helps in providing elasticity to the track.

(2) Define sleeper density?

Ans Sleeper density represents the number of sleeper per rail length in meters.

(3) Distinguish between bridge and Culvert?

Ans A culvert is a small bridge of carrying water a road or railway It is used when linear waterway does not exceed 12m.

(4) Define gauge with neat sketch?

Ans Gauge is defined as the minimum distance between two rails. The gauge is measured as the clear minimum distance between the running faces of the two rails

(5) Write the type of rail section used in our country?

Ans The type of rail section used in our country are:

(i) Double headed rail

(ii) Bull headed rail

(iii) Flat-footed rail

(6) What is ballast Crib?

Ans The loose ballast between the two adjacent sleepers is known as ballast Crib.

(7) What is the maximum value of Super-elevation provided in a track as per railway board?

Ans The maximum value of Super-elevation provided in a track as per railway board is 1/10th of gauge.

(8) Write the causes of failure of embankment?

Ans A railway embankment may fail due to these causes.

→ Failure of the natural ground
→ Failure of the fill material in the embankment.
→ Failure of the formation top.

(9) Write the different types of Crossing?

Ans The different types of Crossings are :- (i) Acute angle Crossing
(ii) Obtuse or dimond Crossing
(iii) Square Crossing
(iv) Spring or movable Crossing
(v) Ramped Crossing

(10) What do you mean by Super elevation or Cant?

Ans On Counteract the effect of Centrifugal force, the level of outer rail is raised above the inner rail by a certain amount. This rising of outer rail over the inner rail is called Super

elevation or cost.

(11) What is Wing Walls?

Ans 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.

(12) Define Cross drainage?

Ans Whenever streams or water courses have to cross the track facility for cross drainage has to be provided.

The water from the side drain is taken across drains in order to divert the waterway from the track.

Generally the cross drainage structures consists of drain pipes, culverts or the bridges.

(13) Define Creep of rails?

Ans Creep in rails is defined as the longitudinal movement of the rails in the track in the direction of motion of locomotives.

→ Creep is common to all railways and its values varies from almost nothing to about 6 inches or 15cm.

(14) Define buckling of track?

Ans The buckling of the track is a matter of grave concern as it may lead to derailments and even serious accidents.

(15) Describe the different types of bridge foundation?

Ans The foundations used in bridge structure may be broadly classified as: (i) shallow foundation
(ii) Deep foundation.

(i) shallow foundation: A shallow foundation is sometimes defined as one whose depth is smaller than its width.

(ii) Deep foundation: A deep foundation is defined as one whose depth is greater than its width.