LECTURE NOTE

On

RAILWAY & BRIDGE ENGINEERING

RAAJDHANI ENGINEERING COLLEGE

DEPARTMENT OF CIVIL ENGINEERING

DIPLOMA 5th SEM

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RAILWAY & BRIDGE ENGINEERING

BRIDGES

10. Bridge substructure and approaches

The components involved in substructure of bridges are:

1. Piers
2. Abutments
3. Wing Walls and the Returns
4. Foundation

Piers

The piers are vertical structures used to support deck or the bearings provided for load transmission to underground soil through foundation. These structures serve as supports for the bridge spans at intermediate points.

The pier structure has mainly two functions:

1. Load transmission to the Foundation
2. Resistance to the horizontal forces

Most of the cases, piers are designed to resist the vertical loads alone. In areas which lie in the seismic zone, it is recommended to design the pier for lateral loads also.
Most of the piers are constructed using concrete. Steel for the construction of pier is used in very few cases till now. Use of composite columns i.e. steel columns filled with concrete is used as new technology of pier construction.
The pier is a vertical member that resist the forces by means of shear mechanism. These forces are mainly lateral forces. The pier that consist of multiple columns are called as **bent**.

Types of Piers in Bridge Construction

There are different types of piers based on the structural connectivity, the shape of the section and the framing configuration.

- Based on the structural connectivity, the pier can be classified as **monolithic or cantilevered.**
- Based on the shape of the section pier can be classified as **solid or hollow, hexagonal, round or octagonal or rectangular.**
- Based on the framing configuration the pier can be classified as single or multiple column bent, hammerhead or pier wall type.

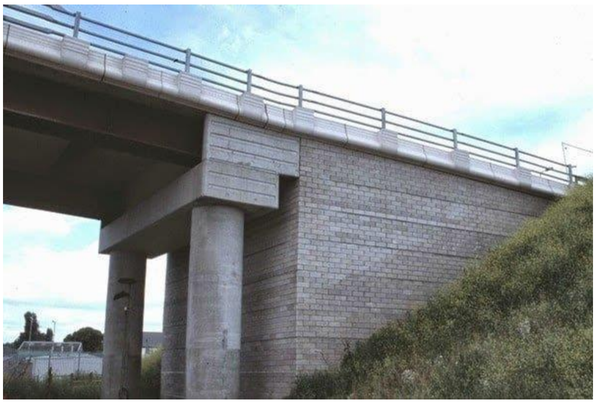
Abutments

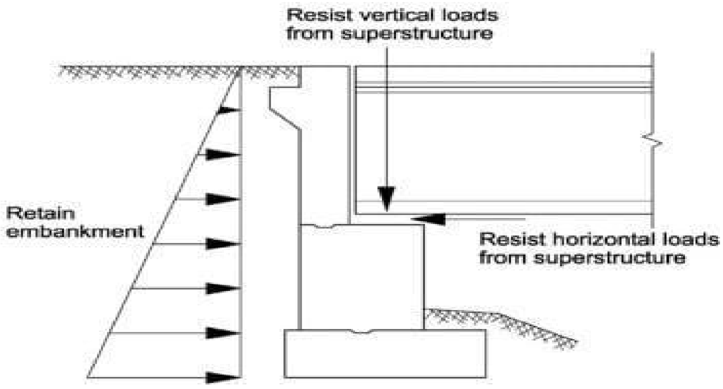
Abutments are vertical structures used to retain the earth behind the structure. The dead and the live loads from the bridge superstructure is supported by the bridge abutments.

The abutments are also subjected to lateral pressures mainly from the approach embankment. The design loads on the abutment is mainly dependent on the:

- Type of abutment selected
- The sequence of construction

The figure below shows the primary functions carried out by an abutment.





Abutments in Bridge Construction- Primary Functions

Wing Walls and Returns

Structures constructed as an extension of the abutments to retain the earth present in the approach bank are called wing walls. This portion will otherwise have a natural angle of repose. These are retaining walls constructed adjacent to the abutments. This wall can be constructed either integrally or independent with the abutment wall.

The rear of the wall must consider three design loads while designing. This includes:

- The earth pressure from the backfill
- The surcharge from the live loads or the compacting plant
- The hydraulic loads from the saturated soil conditions

The stability of the wing wall is mainly based on its resistance against the active earth pressures. The structural elements of the bridges are hereby designed and constructed to resist the earth pressures at rest.

Parapets and Handrails/ Guard Rails or Curbs

These components of bridges are not of structural importance, but provided for the safety concerns. These are provided above the decks. This will help in prevention of the vehicle from falling off the bridge into the water body below or as a means for the separation of traffic streams.

Foundation of Bridges
Foundation are structures constructed to transmit the load from the piers, abutments, wing walls and the returns evenly on the strata.

The foundation provided for bridge structures are deep in sufficient manner to avoid scouring due to the water movement or to reduce the chances of undermining.

11. Permanent bridges

11.1. Masonry bridges

A bridge whose 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 built the spandrel, which in turn supports the bridge roadway. The spandrel is made from a gravel or crushed stone backing held in by lateral (side) walls made of concrete masonry or stonework or in the form of an open structure of small arches resting on crosswalk.
The advantages of a masonry bridge are its architectural at-tractiveness and its durability. Masonry bridges are known thathave been in use for more than 1,000 years. The basic short comings that limit the use of masonry bridges are their complexityand labor-intensiveness of construction. A variation of a ma-sonry bridge is the concrete bridge, which has an arch made of cast concrete.

11.2. Steel bridges – classification with sketches

This article throws light upon the top four types of steel bridges.
The types are:
1. Rolled Steel Beam Bridges
2. Plated Beam Bridges
3. Plate Girder Bridges
4. Trussed Girder Bridges.

1. Rolled Steel Beam Bridges:
This is the simplest type steel bridge having RSJ as the girder and steel trough plate filled with concrete or reinforced concrete slab as the bridge. These bridges have very small spans and are constructed over canals or small channels where scour is negligible and shallow foundations are possible to reduce foundation cost. Since the load carrying capacity of these bridges is limited, these bridges are suitable for village roads where both the laden weight and frequency of the vehicular traffic are less.

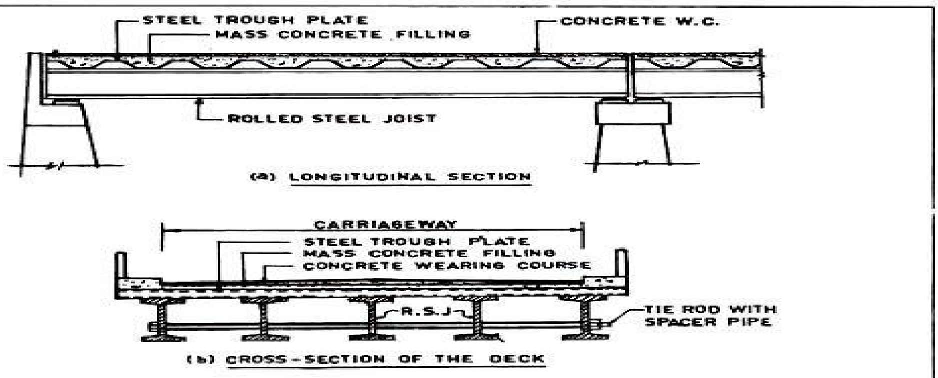


FIG.14·1 STEEL TROUGH PLATE WITH CONCRETE DECKING

2. Plated Beam Bridges

Plated beam bridges can cover comparatively larger spans than the RSJ bridges since their section modulus is increased by increasing the flange areas with additional plates fixed to the flanges by rivetting or welding

3. Plate Girder Bridges:

When the span of the bridge is beyond the spanning capacity of plated beam bridges, plate girder bridges are adopted. In such bridges, the depth of the girder from bending and deflection consideration is such that rolled steel joists are not suitable and therefore, the girders are fabricated with plates and angles either by rivetting or by welding. If the bridge is through type then only two girders can be used one on either side but in case of deck type bridges, any number of girders can be used depending upon the economic consideration.

The section modulus required for the plate girder at various sections such as mid-section, one-third section, one fourth sections etc. varies depending upon the moment at these sections and as such the flange plates may be curtailed at the point of less moments such as at the ends for simply supported girders.

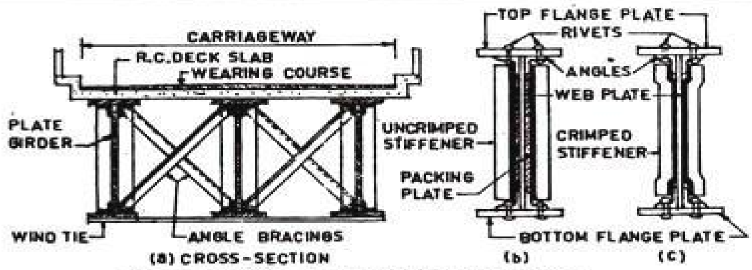


FIG. 14·3 DETAILS OF PLATE GIRDER BRIDGE

The components of a plate girder

1. Web plate
2. Flange plates
3. Flange angles
4. Rivets or welds connecting flange angles with the flange plates and web plate.
5. Vertical stiffeners fixed to the web plate at intervals along the length of the girder to guard against buckling of web plate.
6. Horizontal stiffeners fixed to the web plate depth wise, one or more in numbers, to prevent buckling of web plate.
7. Bearing stiffeners at the ends over the centre line of bearing and at intermediate points under the point loads.
8. Web splice-plates used to join the two web plates.
9. Flange splice-plates used to join the two flange plates.
10. Angle splice-plates used to join the two flange angles.
11. Bearing plates at the ends resting on the piers/abutments.

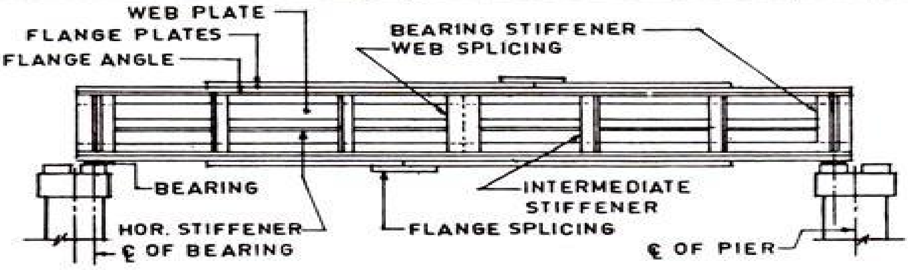


FIG. 14.4 COMPONENTS OF A PLATE GIRDER

Full length of plates and angles for the fabrication of the plate girder may not be available for which splicing is necessary. The flange plates are normally spliced near the ends for simply supported spans while the web plate is spliced at or near the centre.
To guard against buckling of the web plate, vertical and horizontal stiffeners are provided by use of m.s. angles. At each end and also at the point of concentrated heavy loads, bearing stiffeners are necessary for transmission of loads. The bearing stiffeners are un-crimped and packing plate is used in between the web and the stiffening angle but intermediate angle stiffeners are usually crimped.

The design of a plate girder involves the following steps:
1. Computation of B.M. and S.F. at various sections say one-fourth, one-third and one-half span.
2. Estimation of required section moduli at various sections.
3. Design of web from shear consideration.
4. Design of flange angles and flange plates to obtain the required section moduli at various sections.
5. Curtailment of flange plates and flange angles in consideration of reduced values of required section moduli near the end sections.
6. Design of rivets or welds connecting various members such as flange angles with web plate and flange angles with flange plates.
7. Design of splices such as flange splice and web splice.
8. Design of stiffeners.
9. Design of bearing plates.

4. Trussed Girder Bridges:
Trussed girder or truss bridges have an upper or top chord, lower or bottom chord and web members which are vertical and diagonals. For a simply supported truss bridge, the upper chord is subjected to compression and the lower chord is subjected to tension.
The web members may be only diagonals as in Warren Truss (Fig. 14.6a) or a combination of verticals and diagonals as in modified Warren Truss (Fig. 14.6b) or Pratt Truss (Fig. 14.6c & 14.6d) or Howe Truss (Fig. 14.6e) or Parker Truss (Fig. 14.6g).For larger spans, the panels are again subdivided from structural considerations as in truss with diamond bracing (Fig. 14.6f), Pettit Truss (Fig. 14.6h) or K-truss (Fig. 14.6i). The span range for a simply supported truss bridge is 100 to 150 metres.

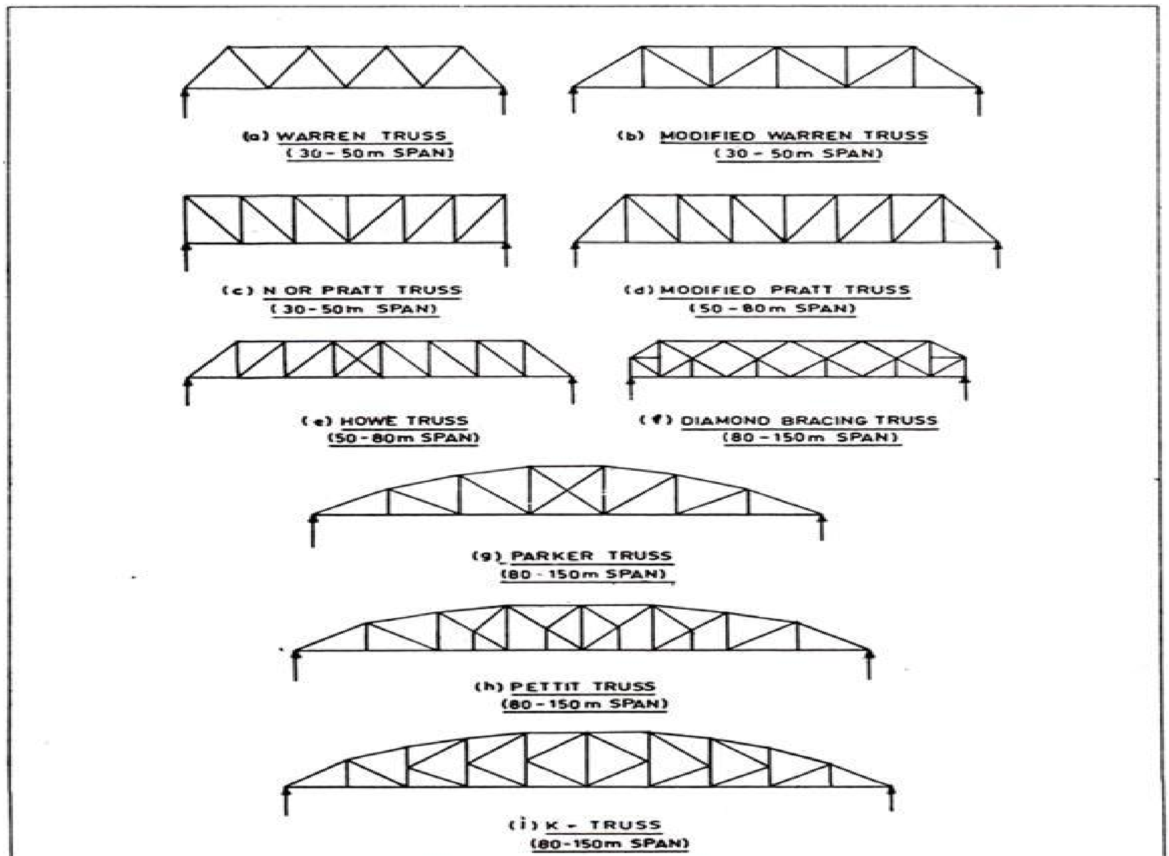


FIG.14'6 VARIOUS TYPES OF BRIDGE TRUSSES

The truss bridges may be either of deck type or of through type (Fig: 14.7) i.e. the bridge deck will be near the top chord in the former type and near the bottom chord in the latter type.

It is, therefore, needless to say that parallel chord trusses which are shown in Fig. 14.6a to 14.6c may be either of deck type or through type as in Fig. 14.7a and 14.7b but trusses with curved lop chord as shown in Fig. 14.6g to 14.6i are invariably of through type

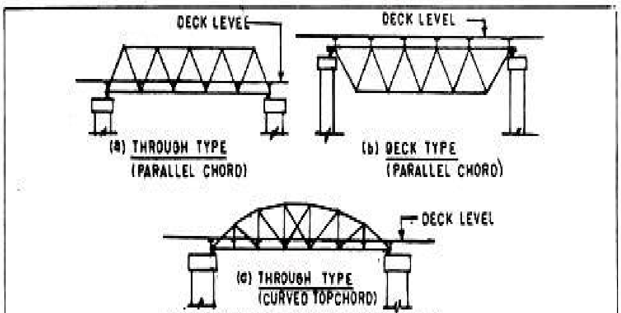


FIG.14'7 THROUGH OR DECK TYPE BRIDGE

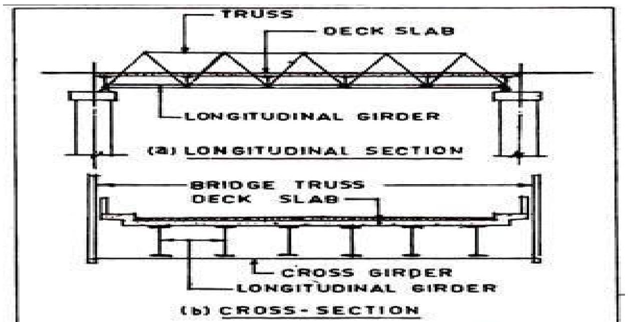


FIG. 14'8 DETAILS OF TRUSS BRIDGE

The bridge deck is on longitudinal girders resting on cross-girders which transfer the loads to the trusses at each panel joints. Details of a truss bridge are shown in Fig. 14.8. Since no load comes on the truss members except at panel joints, the truss members are subjected to direct stress only, either tensile or compressive, and no bending moment or shear force occurs in the truss members.The panel joints where members meet are assumed as hinged and therefore, no bending moment in the truss members is developed even due to the deflection of the truss.

Determination of Forces in Statically Determinate Trusses:
The forces in the truss members are determined by the following methods when the trusses are statically determinate:

1. Graphical Method by Stressor Force Diagrams.
2. Method of Sections.
3. Method of Resolutions.

11.3 Concrete bridges – classification, brief description with sketches

Types of Concrete Bridges

1. **Arch Bridges**
2. **Reinforced Slab Bridges**
3. **Beam and Slab Bridge**
4. **Box Girder Bridge**
5. **Integral Bridges**
6. **Cable-Stayed Bridges**
7. **Suspension Bridges**

1. 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. The Romans knew all about this.

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.

Modern concrete arch bridges utilise prestressing or reinforcing to resist the tensile stresses which can develop in slender arch rings.

The shape attracted the attention of many of the early pioneers of concrete construction. In 1930, Freyssinet was responsible for a spectacular arched bridge at Plougastel in France and three years later, Swiss engineer, Robert Maillart created the famously elegant Schwandbach bridge in which slender cross-walls tie the arch to the horizontally curved roadway.

2. 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 falsework 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.

3. 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.

4. Box Girder Bridge

For spans greater than around 45 metres, prestressed concrete box girders are the most common method of concrete bridge construction. The main spans are hollow and the shape of the 'box' will vary from bridge to bridge and along the span, being deeper in cross-section at the abutments and piers and shallower at midspan.

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

- *incrementally launched*
- *span-by-span*
- *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 falsework 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 falsework 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 are 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.

5. **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

6. **Cable-Stayed Bridges**

For really large spans, one solution is the cable-stayed bridge. As typified by the Dee Crossing 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.

7. **Suspension Bridges**

Concrete plays an important part in the construction of a suspension bridge. There will be massive foundations, usually embedded in the ground, that support the weight and cable anchorages. 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.

11.4. IRC bridge loading

Various types of loads are considered for design of bridge structures. These loads and their combinations decides the safety of the bridge construction during its use under all circumstances. The design loads should be considered properly for perfect design of bridge. Different design loads acting on bridges are explained below

Types of Loads

1. Dead load
2. Live load

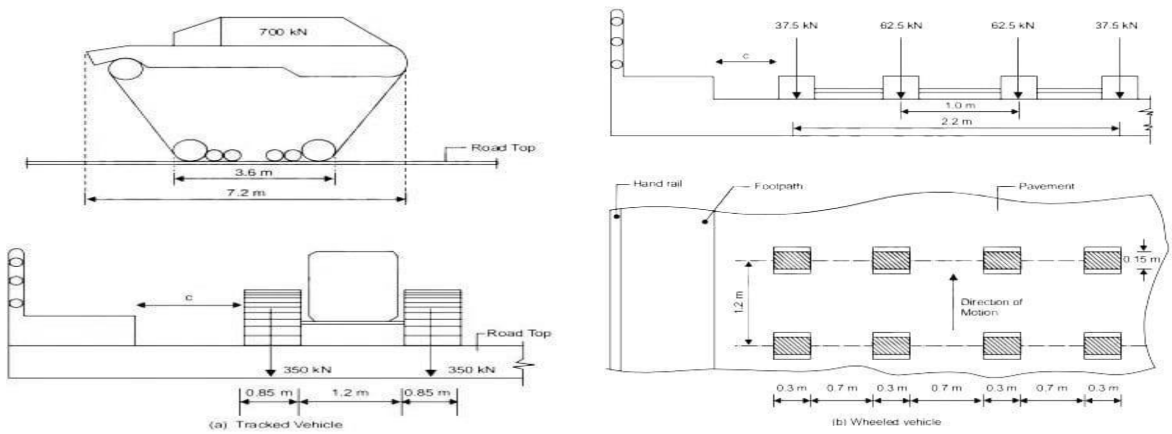
3. Impact load
4. Wind load
5. Longitudinal forces
6. Centrifugal forces
7. Buoyancy effect
8. Effect of water current
9. Thermal effects
10. Deformation and horizontal effects
11. Erection stresses
12. Seismic loads

1. Dead Load

The dead load is nothing but a self-weight of the bridge elements. The different elements of bridge are deck slab, wearing coat, railings, parapet, stiffeners and other utilities. It is the first design load to be calculated in the design of bridge.

2. Live Load

The live load on the bridge, is moving load on the bridge throughout its length. The moving loads are vehicles, Pedestrians etc. but it is difficult to select one vehicle or a group of vehicles to design a safe bridge.



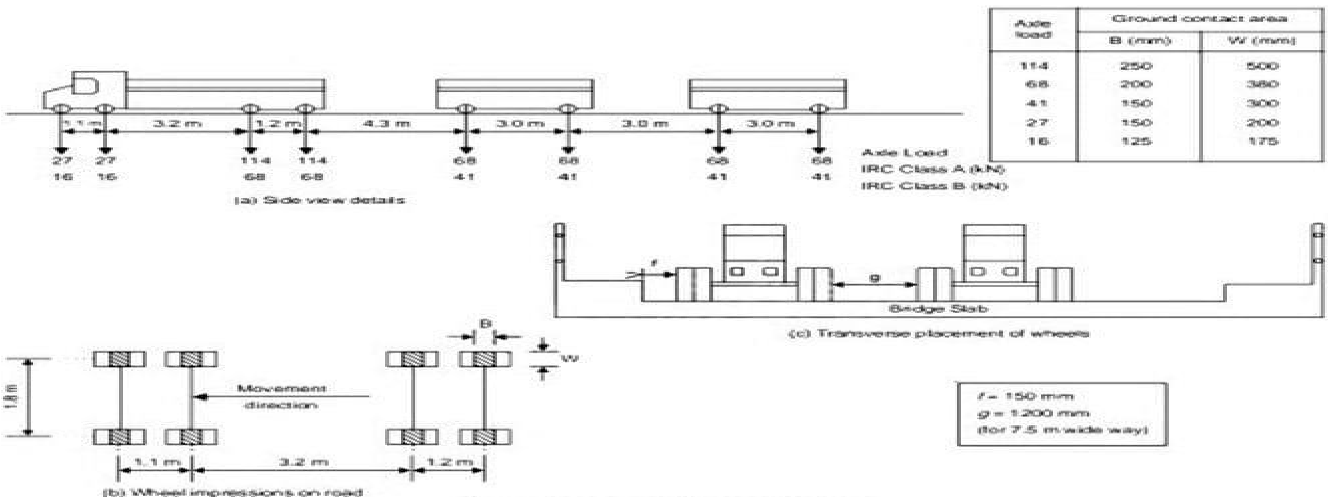
So, IRC recommended some imaginary vehicles as live loads which will give safe results against the any type of vehicle moving on the bridge. The vehicle loadings are categorized in to three types and they are

- IRC class AA loading
- IRC class A loading
- IRC class B loading

IRC Class AA Loading

This type of loading is considered for the design of new bridge especially heavy loading bridges like bridges on highways, in cities, industrial areas etc. In class AA loading generally two types of vehicles considered, and they are

- Tracked type
- Wheeled type
- **IRC Class A Loading**
- This type of loading is used in the design of all permanent bridges. It is considered as standard live load of bridge. When we design a bridge using class AA type loading, then it must be checked for class A loading also.
- **IRC Class B Loading**
- This type of loading is used to design temporary bridges like Timber Bridge etc. It is considered as light loading. Both IRC class A and Class B are shown in below figure.



3. Impact Loads

The Impact load on bridge is due to sudden loads which are caused when the vehicle is moving on the bridge. When the wheel is in movement, the live load will change periodically from one wheel to another which results the impact load on bridge.

To consider impact loads on bridges, an impact factor is used. Impact factor is a multiplying factor which depends upon many factors such as weight of vehicle, span of bridge, velocity of vehicle etc. The impact factors for different IRC loadings are given below.

For IRC Class AA Loading and 70R Loading

Span	**Vehicle type**	**Impact factor**
Less than 9 meters	Tracked vehicle	25% up to 5m and linearly reducing to 10% from 5 m to 9 m.
	Wheeled vehicle	25% up to 9 m
Greater than 9 meters	Tracked vehicle (RCC bridge)	10% up to 40 m
	Wheeled vehicle (RCC bridge)	25% up to 12m
	Tracked vehicle (steel bridge)	10% for all spans
	Wheeled vehicle (steel bridge)	25% up to 23 m

For IRC class A and class B loadings

Impact factor $I_f = A/(B+L)$

Where L = span in meters

A and B are constants

Apart from the super structure impact factor is also considered for substructures

- For bed blocks, $I_f = 0.5$
- For substructure up to the depth of 3 meters $I_f = 0.5$ to 0
- For substructure greater than 3 m depth $I_f = 0$

Bridge type	**A**	**B**
RCC	4.5	6.0
Steel	9.0	13.50

4. Wind Loads

Wind load also an important factor in the bridge design. For short span bridges, wind load can be negligible. But for medium span bridges, wind load should be considered for substructure design. For long span bridges, wind load is considered in the design of super structure.

5. Longitudinal Forces
The longitudinal forces are caused by braking or accelerating of vehicle on the bridge. When the vehicle stops suddenly or accelerates suddenly it induces longitudinal forces on the bridge structure especially on the substructure. So, IRC recommends 20% of live load should be considered as longitudinal force on the bridges.

6. Centrifugal Forces
If bridge is to be built on horizontal curves, then the movement of vehicle along curves will cause centrifugal force on to the super structure. Hence, in this case design should be done for centrifugal forces also. Centrifugal force can be calculated by C (kN/m) = $(WV^2)/(12.7R)$

Where
W = live load (kN)
V = Design speed (kmph)
R = Radius of curve (m

7. Buoyancy Effect
Buoyancy effect is considered for substructures of large bridges submerged under deep water bodies. Is the depth of submergence is less it can be negligible.

8. Forces by Water Current
When the bridge is to be constructed across a river, some part of the substructure is under submergence of water. The water current induces horizontal forces on submerged portion. The forces caused by water currents are maximum at the top of water level and zero at the bottom water level or at the bed level.
The pressure by water current is $P = KW [V^2/2g]$
Where P = pressure (kN/m^2)
K = constant (value depending upon shape of pier)
W = unit weight of water
V = water current velocity (m/s)
G = acceleration due to gravity (m/s^2)

9. Thermal Stresses
Thermal stresses are caused due to temperature. When the temperature is very high or very low they induce stresses in the bridge elements especially at bearings and deck joints. These stresses are tensile in nature so, concrete cannot withstand against this and cracks are formed.

To resist this, additional steel reinforcement perpendicular to main reinforcement should be provided. Expansion joints are also provided.

10. Seismic Loads
When the bridge is to be built in seismic zone or earthquake zone, earthquake loads must be considered. They induce both vertical and horizontal forces during earthquake. The amount of forces exerted is mainly depends on the self-weight of the structure. If weight of structure is more, larger forces will be exerted.

11. Deformation and Horizontal Effects
Deformation stresses are occurred due to change is material properties either internally or externally. The change may be creep, shrinkage of concrete etc. similarly horizontal forces will develop due to temperature changes, braking of vehicles, earthquakes etc. Hence, these are also be considered as design loads in bridge design.

12. Erection Stresses
Erection stress are induced by the construction equipment during the bridge construction. These can be resisted by providing suitable supports for the members.

12.0. Culvert & cause ways

Culvert is a tunnel carrying a stream under a road or railway. A culvert may act as a bridge for traffic to pass on it. They are typically found in a natural flow of water and serves the purpose of a bridge or a current flow controller. Culverts are available in many and shape like round, elliptical, flat-bottomed, pear-shaped, and box-like constructions. Culverts are by their load and water flow capacities, lifespan and installation of bedding and backfill. The type is based on a number of factors including hydraulic, upstream elevation, and roadway height and other conditions.

12.1 Types of culverts - brief description
Following are the different types of Culvert:

- Pipe culvert (single or multiple)
- Pipe-Arch culvert (single or multiple)
- Box culvert (single or multiple)
- Arch culvert
- Bridge culvert
- Metal box culvert

Pipe Culvert
Pipe culverts are the most common types of culverts due to competitive price and easy installation. They are found in different shapes such as circular, elliptical and pipe arch. Generally, their shapes depend on site conditions and constraints. Pipe culverts on a small scale represent normal pipes like concrete pipes.
Advantages of Pipe Culvert
The main features of pipe culverts are:

- It can be constructed of any desired strength by proper mix design, thickness, and reinforcement.
- They are economical.
- These pipes can withhold any tensile stresses and compressive stresses.
- The crossing of water is under the structure.

Disadvantages of Pipe Culvert
The main disadvantage of pipe culvert is that it can be easily corroded at the crown because of bacteria's organic matter and release of harmful gas, which is known as Crown corrosion.
Pipe-Arch Culvert (Single or Multiple)
Arch culverts are suitable for large waterway opening where fishes can be provided with a greater hydraulic advantage. Moreover, they provide low clearance and are definitely, much artistic. Pipe arches are particularly useful for sites where headroom is limited and also have a hydraulic advantage at low flows.
Advantages of Pipe-Arch Culvert
The features of pipe arch culverts are:

- Limited headroom condition
- Improved hydraulic capacity at a low flow
- Aesthetic shape and appearance
- Lightweight
- Easy to install

Box Culvert
Box culverts are made up of concrete and especially, RCC (Reinforced Concrete). The most challenging part in constructing a box culvert is that dry surface is needed for installing it. However, due to the strength of the concrete floor, water direction can be changed when a large amount of water is expected. This feature makes box culverts, one of the most commonly found types of the culvert.
Advantages of Box Culvert
Box Culverts are economical for the reasons mentioned below:

- The box culvert is a rigid frame structure and very simple in construction
- It is Suitable for non-perennial streams where scrub depth is not significant but the soil is weak.
- The bottom slab of the box culvert reduces pressure on the soil.
- Box culverts are economical due to their rigidity and monolithic action and separate foundations are not required.
- It is used in special cases, weak foundation.

Arch Culvert
An arch culvert is made up of metal, stone masonry, concrete, RCC etc. Construction does not take a lot of time and unlike box culvert, water diversion is not necessary, as it can be installed without disturbing the water current. Thus, it can be termed as a Low Profile Culvert. This type of culvert maintains the natural integrity of the wash bed.
Advantages of Arch Culvert
The advantages of using arch culverts over traditional box culverts and pipe culverts are as follows:

- Cost savings
- Accelerated construction schedule
- Greater hydraulic efficiency
- Pleasing aesthetics
- Design-build advantage

Bridge Culvert

Bridge culverts serve a dual purpose. It acts both as a bridge and a culvert. Generally, rectangular in shape, bridge culverts are constructed on rivers and canals. A foundation is laid under the ground level and pavement surface is laid on top of the series of culverts. Generally, we can term it as a Multi-Purpose culvert.

Advantages of Bridge Culvert

Following are the main features of bridge culvert:

- Extension of the network by acting as a repeater
- Very strong
- Allows traffic to pass on it
- Highly strong foundation
- Most expensive river crossings

Metal Box Culvert

The metal box culvert is the economic alternative of the bridge. These bridges are manufactured from a standard structural plate or deep-corrugated structural plate. They are the perfect bridge replacement maintaining the same road grade level.

Advantages of Metal Box Culvert

The advantages are as follows:

- Durability
- Shorter construction period and easy installation
- Deformation ability
- Long service life
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12.2 Types of causeway - brief description

OBJECTIVES

After you have learned this element you should be able to:
- explain what a causeway is;
- describe which specific design points are particular to a causeway;
- comment on how to locate a causeway;
- describe how a typical small causeway is constructed.

In engineering textbooks a water crossing having a number of culverts to receive regular waterflows and which is submersed during floods is described with a great number of names; culverts drift, causeway, submersible bridge or vented drift. In this learning element the structure is described as a causeway.

A causeway can be defined as a structure which has a double function:

(a) it allows the normal dry weather flow of a river/stream to pass through the culverts below the roadway; and

(b) the occasional floods pass both through the culverts and over the roadway.

Because they have this dual function causeways present hydraulic problems which are peculiar to this type of structure and great care should be taken with their construction. Many causeways have failed because of a wrong location or a wrong design.

Design

If the culverts are concentrated in the centre of the causeway, the high speed water jets coming out of these culverts will cause heavy scour at the sides of the culverts.

This implies that in designing causeways the culverts should be distributed evenly throughout the length of the structure .

When the water flows over the causeway it moves. The forward roller shown on the right moves the sand forward. The back roller makes the sand surface on the left side steeper and steeper until it collapses. This effect causes the foundation to be exposed very quickly unless effective protective measures are taken.

When roadside markers are provided to show the edges of the causeway and to indicate the stream level, care should be taken that these offer as little resistance as possible to the flow. This means that such markers should be streamlined to the greatest possible extent.

Location

The location of a causeway is - as with all structures - extremely important. Efforts should be made to locate the most stable portion of the river bed, so that a better foundation can be provided to the structure.

Also, avoid locating a drift, bridge or causeway near or in a river/stream bend. During floods the water will tend to cling to the concave bend of the river and cause continuous erosion at that side. At the convex bank silting will take place.

When a lot of debris (tree trunks or branches, etc.) floats in the river there will be a danger that the culverts get blocked. If this happens, usually a transverse flow will occur along the upstream side of the culverts creating a deep trench which can undermine the structure. To avoid this, debris diverting or collecting structures, such as debris deflectors or racks, may be necessary.

Construction

Two trenches are dug at the up and downstream edges of the causeway. The trench at the downstream side should be at least 1.50 metres deep if an overflow of 50 cm over the roadway is expected.
Between these trenches a suitable bed for the culverts is prepared of a well-graded gravel material. The provision of a 7.5 cm concrete floor is recommended. This floor should be indented to accommodate the shape of the culvert, so that the culvert is evenly supported. After the culverts are laid the head walls are constructed up to the road level and the area between the head walls is backfilled with a well-graded stony/gravelly material. Lean concrete may be used also as a backfilling material, although the costs of the structure will be considerably higher in this case.