43 STEEL BRIDGES - I

1.0 INTRODUCTION

As discussed in earlier chapters the main advantages of structural steel over other construction materials are its strength and ductility. It has a higher strength to cost ratio in tension and a slightly lower strength to cost ratio in compression when compared with concrete. The stiffness to weight ratio of steel is much higher than that of concrete. Thus, structural steel is an efficient and economic material in bridges. Structural steel has been the natural solution for long span bridges since 1890, when the Firth of Forth cantilever bridge, the world's major steel bridge at that time was completed. Steel is indeed suitable for most span ranges, but particularly for longer spans. Howrah Bridge, also known as Rabindra Setu, is to be looked at as an early classical steel bridge in India. This cantilever bridge was built in 1943. It is *97 m* high and *705 m* long. This engineering marvel is still serving the nation, deriding all the myths that people have about steel. [See Fig. 1]

Fig. 1 Howrah bridge

The following are some of the advantages of steel bridges that have contributed to their popularity in Europe and in many other developed countries.

- They could carry heavier loads over longer spans with minimum dead weight, leading to smaller foundations.
- Steel has the advantage where speed of construction is vital, as many elements can be prefabricated and erected at site.

- In urban environment with traffic congestion and limited working space, steel bridges can be constructed with minimum disruption to the community.
- Greater efficiency than concrete structures is invariably achieved in resisting seismic forces and blast loading.
- The life of steel bridges is longer than that of concrete bridges.
- Due to shallow construction depth, steel bridges offer slender appearance, which make them aesthetically attractive. The reduced depth also contributes to the reduced cost of embankments.
- All these frequently leads to low life cycle costs in steel bridges

In India there are many engineers who feel that corrosion is a problem in steel bridges, but in reality it is not so. Corrosion in steel bridges can be effectively minimised by employing newly developed paints and special types of steel. These techniques are followed in Europe and other developed countries. These have been discussed in chapter 2.

2.0 STEEL USED IN BRIDGES

Steel used for bridges may be grouped into the following three categories:

(i) *Carbon Steel:* This is the cheapest steel available for structural users where stiffness is more important than the strength. Indian steels have yield stress values up to 250 N/mm^2 and can be easily welded. The steel conforming to IS: 2062 - 1969, the American ASTM A36, the British grades 40 and Euronorm 25 grades 235 and 275 steels belong to this category.

(ii) *High strength steels:* They derive their higher strength and other required properties from the addition of alloying elements. The steel conforming to IS: 961 - 1975, British grade 50, American ASTM A572 and Euronorm 155 grade 360 steels belong to this category. Another variety of steel in this category is produced with enhanced resistance to atmospheric corrosion. These are called '*weathering*' steels in Europe, in America they conform to ASTM A588 and have various trade names like *' cor-ten'*.

(iii) *Heat-treated carbon steels:* These are steels with the highest strength. They derive their enhanced strength from some form of heat-treatment after rolling namely normalisation or quenching and tempering.

The physical properties of structural steel such as strength, ductility, brittle fracture, weldability, weather resistance etc., are important factors for its use in bridge construction. These properties depend on the alloying elements, the amount of carbon, cooling rate of the steel and the mechanical deformation of the steel. The detailed discussion of physical properties of structural steel is presented in earlier chapter.

3.0 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.

3.1 Classification based on type of traffic carried

Bridges are classified as

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

3.2 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 make up 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 upto *250 m*. Cross sections of a typical plate girder and box girder bridges are shown in Fig. 2(*a*) and Fig. 2(*b*) respectively. Truss bridges [See Fig. 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*. In the next chapter girder bridges are discussed in detail. They may be further, sub-divided into simple spans, continuous spans and suspended-and-cantilevered spans, as illustrated in Fig. 3.

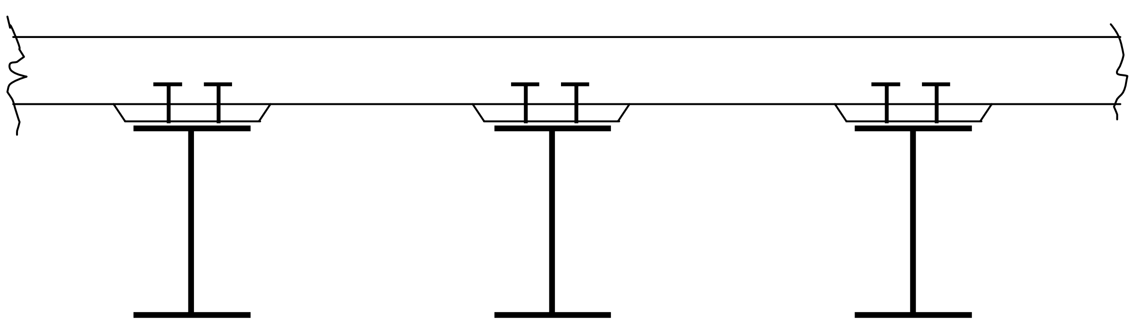


Fig. 2(a) Plate girder bridge section

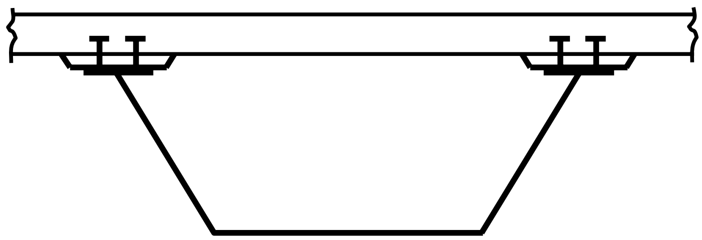


Fig. 2(b) Box girder Bridge section

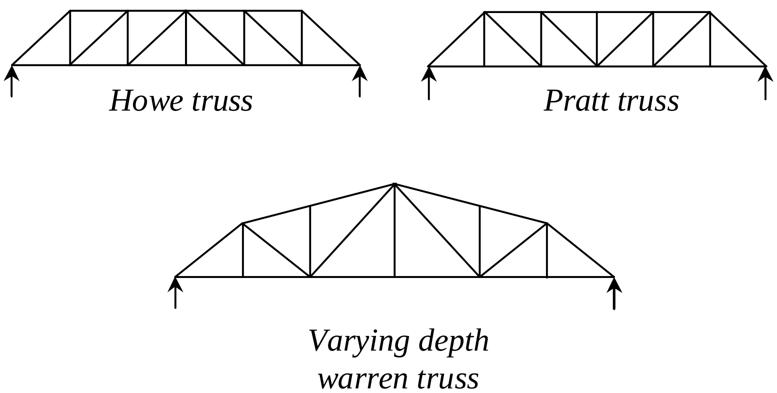


Fig. 2(c) Some of the trusses used in steel bridges

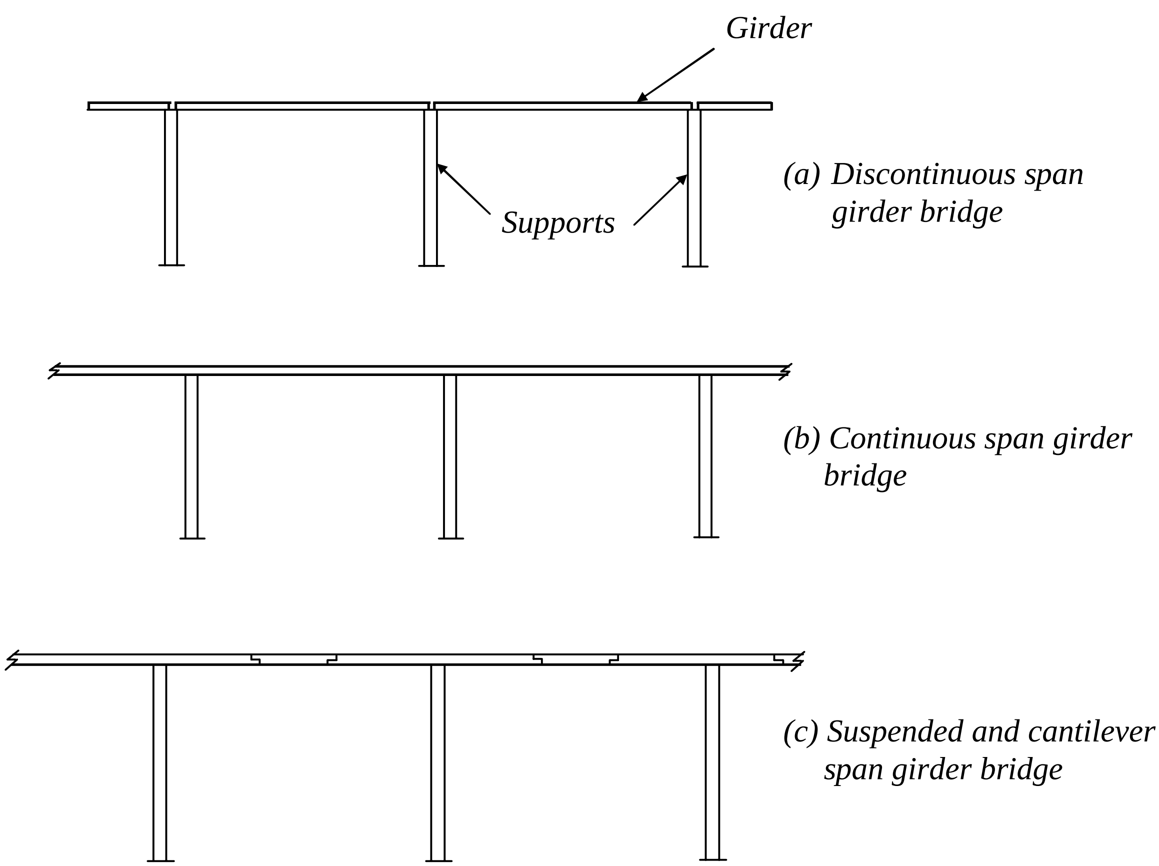


Fig. 3 Typical girder bridges

(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. 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.*

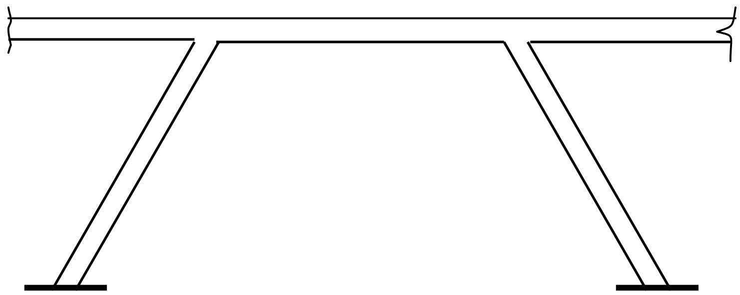


Fig. 4 Typical rigid frame bridge

(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*. Examples of arch bridges are shown in Fig. 5.

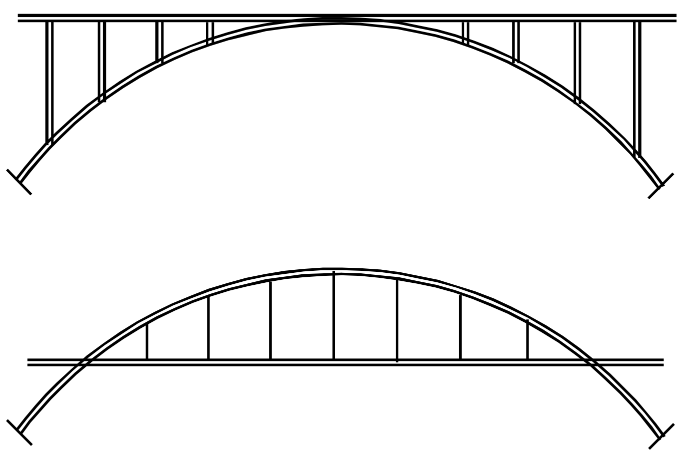


Fig. 5 Typical arch bridges

(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. 6.

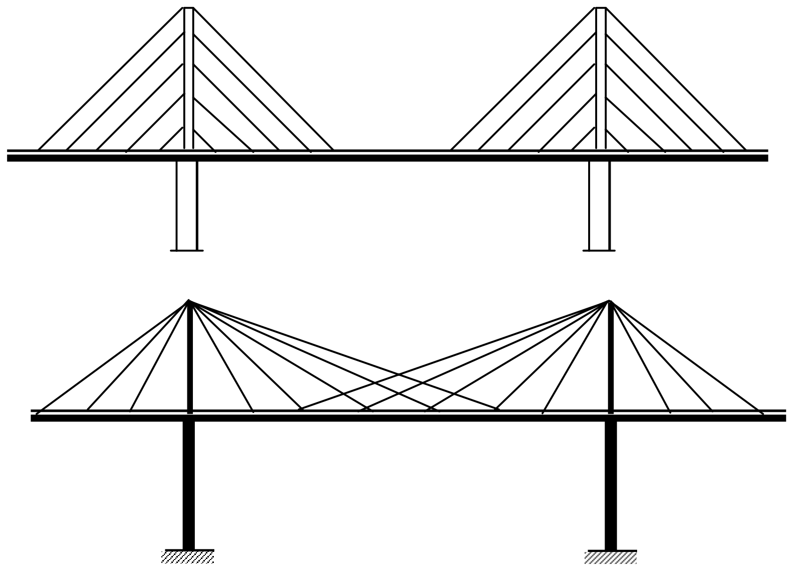


Fig. 6 Layout of cable stayed bridges

(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. 7 shows a typical suspension bridge. Fig. 8 shows normal span range of different bridge types.

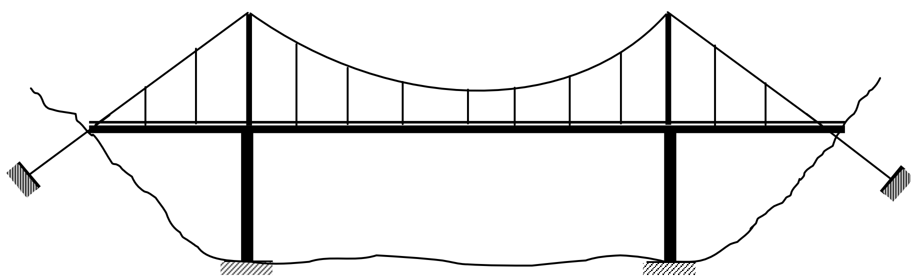


Fig. 7 Suspension bridge

3.3 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. 9(*a*).

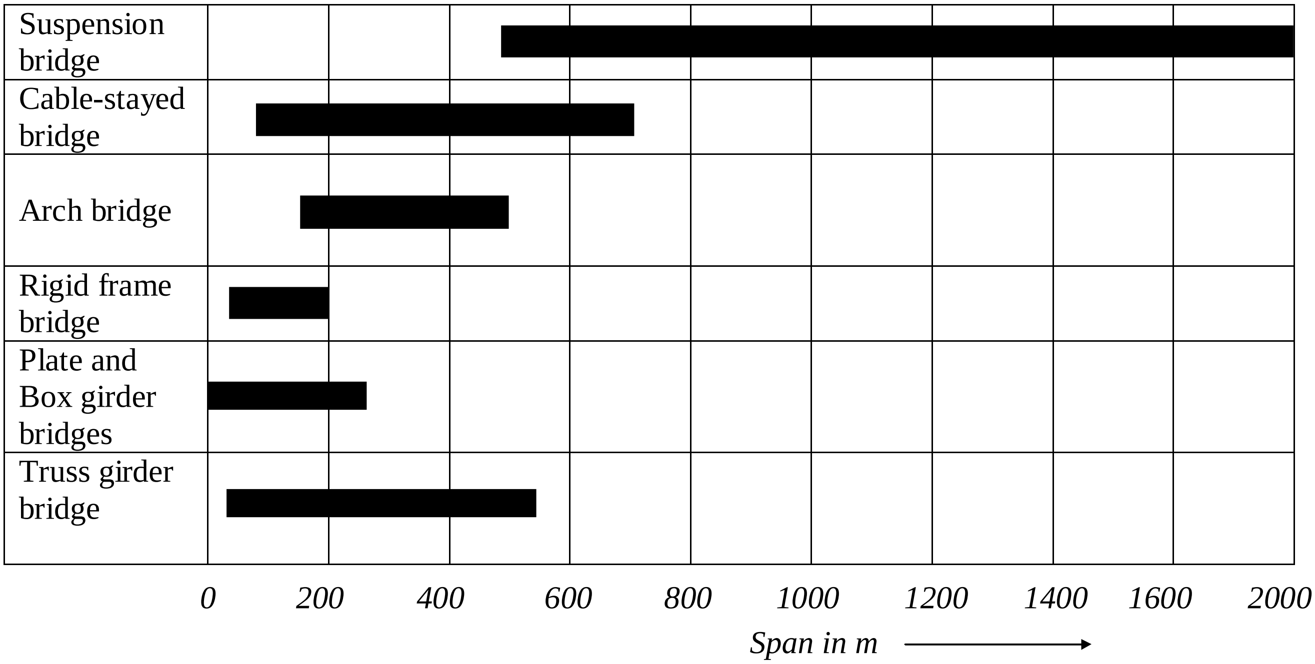
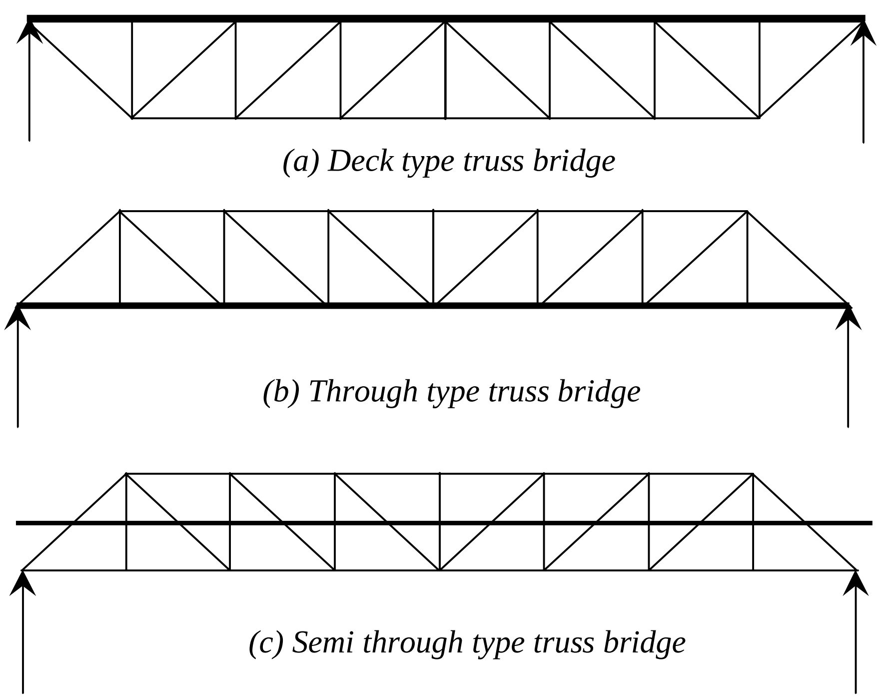


Fig. 8 Normal span ranges of bridge system



(a) Deck type truss bridge

(b) Through type truss bridge

(c) Semi through type truss bridge

Fig.9 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 [Fig. 9(*b*)]. 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 as shown in Fig. 9(*c*). The lateral restraint in the system is obtained usually by the U-frame action of the verticals and cross beam acting together.

4.0 LOADS ON BRIDGES

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

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

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

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

Railway bridges: Railway bridges including combined rail and road bridges are to be designed for railway standard loading given in bridge rules. The standards of loading are given for:

- Broad gauge - Main line and branch line
- Metre gauge - Main line, branch line and Standard C
- Narrow gauge - H class, A class main line and B class branch line

The actual loads consist of axle load from engine and bogies. The actual standard loads have been expressed in bridge rules as *equivalent uniformly distributed loads* (EUDL) in tables to simplify the analysis. These equivalent UDL values depend upon the span length. However, in case of rigid frame, cantilever and suspension bridges, it is necessary for the designer to proceed from the basic wheel loads. In order to have a uniform gauge throughout the country, it is advantageous to design railway bridges to Broad gauge main line standard loading. The EUDLs for bending moment and shear force for broad gauge main line loading can be obtained by the following formulae, which have been obtained from regression analysis:

For bending moment:

$$\text{EUDL in kN} = 317.97 + 70.83\ell + 0.0188\ell^2 \geq 449.2 \text{ kN} \qquad (1)$$

For shear force:

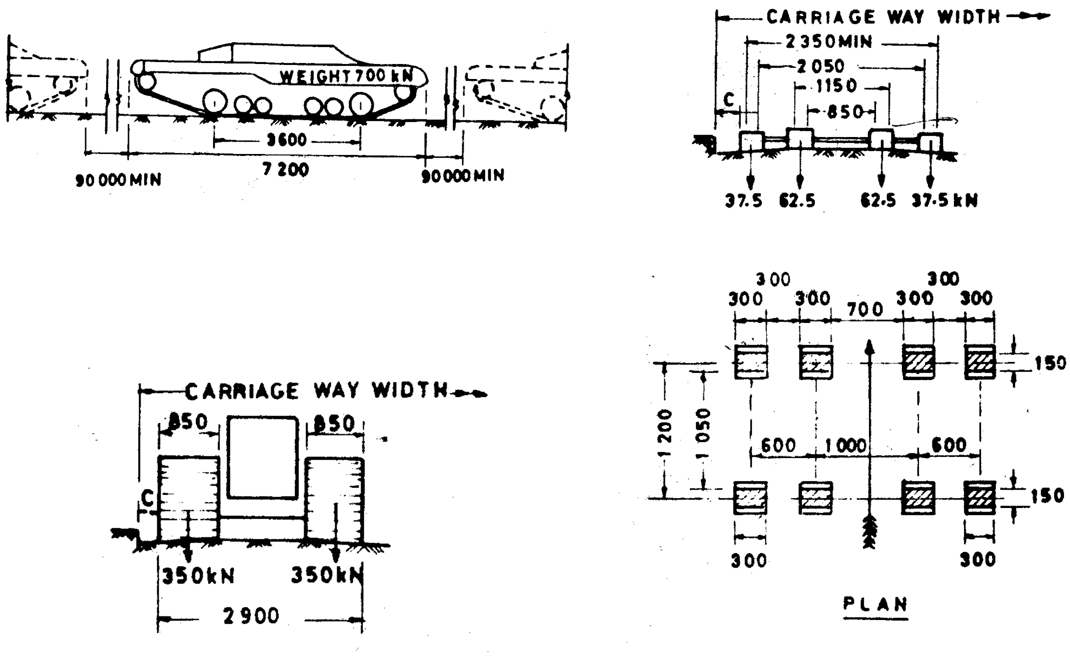
$$\text{EUDL in kN} = 435.58 + 75.15\ell + 0.0002\ell^2 \geq 449.2 \text{ kN} \qquad (2)$$

Note that, ℓ is the effective span for bending moment and the loaded length for the maximum effect in the member under consideration for shear. 'ℓ' should be in metres. The formulae given here are not applicable for spans less than or equal to 8 m with ballast cushion. For the other standard design loading the reader can refer to Bridge rules.

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

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

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



(a) Tracked vehicle *(a) Wheeled vehicle*

Fig. 10 IRC AA loading

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

The live load on foot path for the purpose of designing the main girders has to be taken as follows according to bridge rules:

(i) For effective spans of 7.5 m or less - 4.25 kN/m^2
(ii) The intensity of load be reduced linearly from 4.25 kN/m^2 for a span of 7.5 m to 3.0 kN/m^2 for a span of 30 m.
(iii) For effective spans over 30 m, the UDL may be calculated as given below:

$$P = \frac{1}{100}\left(13.3 + \frac{400}{\ell}\right)\left(\frac{17 - W}{1.4}\right) kN/m^2 \qquad (3)$$

where, P = Live load in kN/m^2
ℓ = Effective span of the bridge in m.
W = Width of the foot path in m.

Where foot-paths are provided on a combined rail-road bridge, the load on foot-path for purpose of designing the main girders should be taken as 2.0 kN/m^2.

Impact load – The dynamic effect caused due to vertical oscillation and periodical shifting of the live load from one wheel to another when the locomotive is moving is known as impact load. The impact load is determined as a product of impact factor, *I*, and the live load. The impact factors are specified by different authorities for different types of bridges. The impact factors for different bridges for different types of moving loads are given in the table 1. Fig. 11 shows impact percentage curve for highway bridges for class AA loading. Note that, in the above table ℓ is loaded length in m and B is spacing of main girders in m.

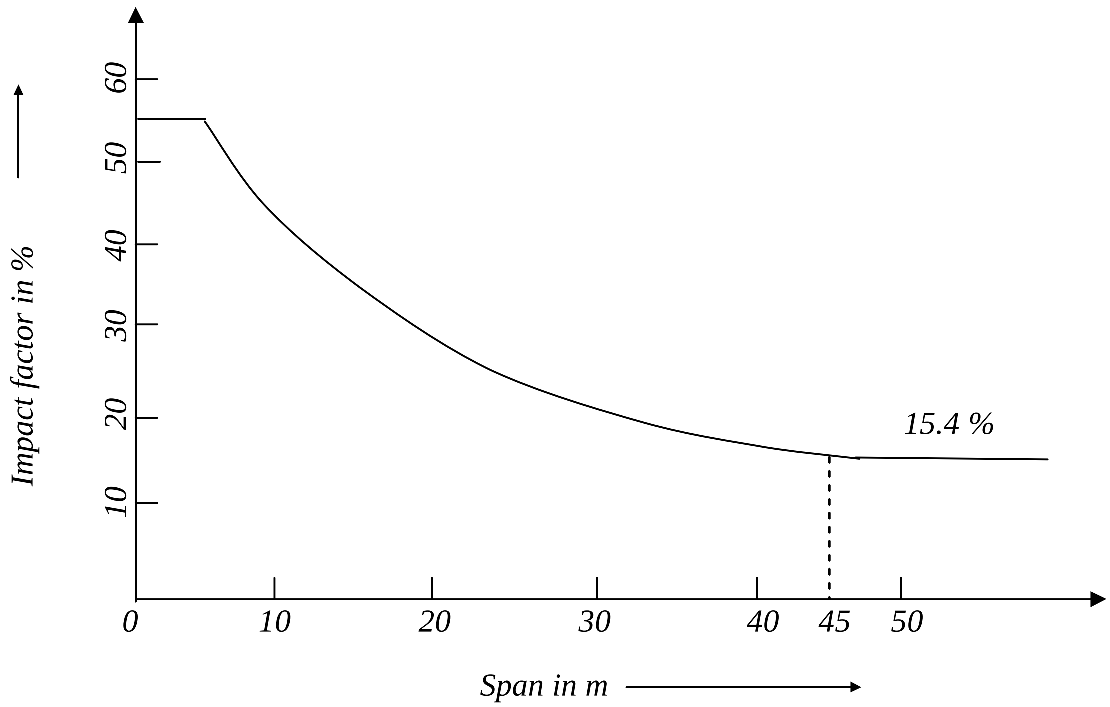


Fig. 11 Impact percentage curve for highway bridges for IRC Class A and IRC Class B Loadings

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

$$F = \frac{W}{g}\frac{\delta V}{\delta t} \tag{4}$$

where, W – weight of the vehicle
g – acceleration due to gravity
δV – change in velocity in time δt

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

Table 1: Impact factors for different bridges

BRIDGE	LOADING		IMPACT FACTOR *(I)*
Railway bridges according to bridge rules	Broad gauge and Meter gauge	(a) Single track	$\frac{20}{14+\ell} \le 1.0$
		(b) Main girder of double track with two girders	$0.72 \times \frac{20}{14+\ell} \le 0.72$
		(c) Intermediate main girder of multiple track spans	$0.60 \times \frac{20}{14+\ell} \le 0.60$
		(d) Outside main girders of multiple track spans	Specified in (a) or (b) whichever applies
		(e) Cross girders carrying two or more tracks	$0.72 \times \frac{20}{14+\ell} \le 0.72$
	Broad gauge	Rails with ordinary fish plate joints and supported directly on sleepers or transverse steel troughing	$\frac{7.32}{B+5.49}$
	Meter gauge		$\frac{5.49}{B+4.27}$
	Narrow gauge		$\frac{9.5}{91.5+\ell}$
Highway bridges according to IRC regulations	IRC class AA loading	(i) Spans less than 9 m. (a) Tracked vehicle	0.25 for spans up to 5 m and linearly reducing to 0.10 to spans of 9 m
		(b) Wheeled vehicle	0.25
		(ii) Spans 9 m or more (a) Tracked vehicle	0.10
		(b) Wheeled vehicle	0.25 for spans up to 23 m and in accordance with the curve indicated in Fig .11 for spans in excess of 23 m
	IRC class A loading and IRC class B loading	Spans between 3 m and 45 m	$\frac{9}{13.5+\ell}$ In accordance with the curve indicated in Fig .11 for all spans
Foot bridges			No separate impact allowance is made

***Thermal forces* –** The free expansion or contraction of a structure due to changes in temperature may be restrained by its form of construction. Where any portion of the structure is not free to expand or contract under the variation of temperature, allowance should be made for the stresses resulting from this condition. The coefficient of thermal expansion or contraction for steel is $11.7 \times 10^{-6} /^{0}$ C

***Wind load* –** Wind load on a bridge may act

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

Wind load effect is not generally significant in short-span bridges; for medium spans, the design of sub-structure is affected by wind loading; the super structure design is affected by wind only in long spans. For the purpose of the design, wind loadings are adopted from the maps and tables given in IS: 875 (Part III). A wind load of 2.40 kN/m^2 is adopted for the unloaded span of the railway, highway and footbridges. In case of structures with opening the effect of drag around edges of members has to be considered.

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

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

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

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

This force is given by the following formula:

$$C = \frac{W V^2}{12.7 R} \tag{5}$$

where, C - Centrifugal force in kN/m
W - Equivalent distributed live load in kN/m
V - Maximum speed in km/hour
R - Radius of curvature in m

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

5.0 LOAD COMBINATIONS

Stresses for design should be calculated for the most sever combinations of loads and forces. Four load combinations are generally considered important for checking for adequacy of the bridge. These are given in Table 2 and are also specified in IS 1915 - 1961.

Table 2: Load combinations

S.No.	Load combination	Loads
1	Stresses due to normal loads	Dead load, live load, impact load and centrifugal force
2	Stresses due to normal loads + occasional loads	Normal load as in (1) + wind load, other lateral loads, longitudinal forces and temperature stresses
3	Stresses due to loads during erection	-
4	Stresses due to normal loads + occasional loads + Extra-ordinary loads like seismic excluding wind load	Loads as in (2) + with seismic load instead of wind

6.0 ANALYSIS OF GIRDER BRIDGES

As discussed above, bridge decks are required to support both static and moving loads. Each element of a bridge must be designed for the most severe conditions that can possibly be developed in that member. Live loads should be placed in such a way that they will produce the most severe conditions. The critical positions of live loads will not be the same for every member. A useful method for determining the most severe condition of loading is by using “influence lines”.

An influence line represents some internal force such as shear force, bending moment etc. at a particular section or in a given member of girder, as a unit load moves over the span. The ordinate of influence line represents the value of that function when the unit load is at that particular point on the structure. Influence lines provide a systematic procedure for determining how the force (or a moment or shear) in a given part of a structure varies as the applied load moves about on the structure. Influence lines of responses of statically determinate structures consist only of straight lines whereas this is not true of indeterminate structures. It may be noted that a shear or bending moment diagram shows the variation of shear or moment across an entire structure for loads fixed in one position. On the other hand an influence line for shear or moment shows the variation of that response at one particular section in the structure caused by the movement of a unit load from one end of the structure to the other. In the following section, influence lines only for statically determinate structures are discussed.

6.1 Influence lines for beams and plate girders

Fig. 12(*a*) shows the influence line for shear at a section in a simply supported beam. It is assumed that positive shear occurs when the sum of the transverse forces to the left of a section is in the upward direction or when the sum of the forces to the right of the section is downward.

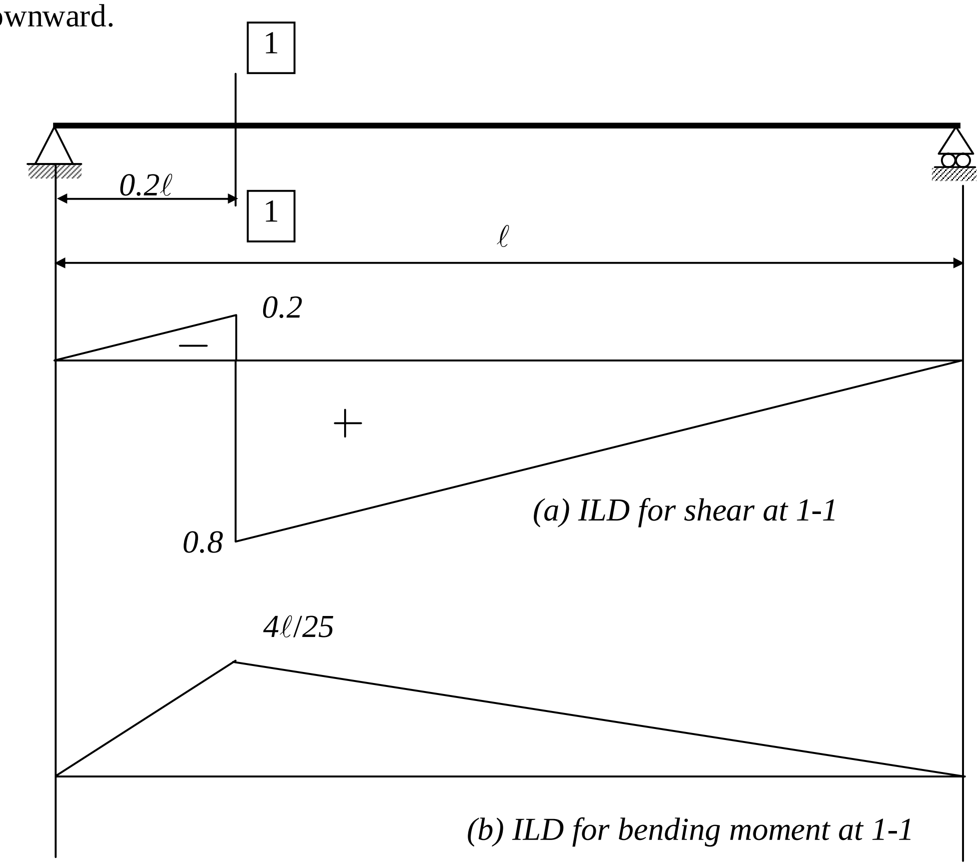


Fig. 12 Influence lines for shear and bending moment

A unit force is placed at various locations and the shear force at sections 1-1 is obtained for each position of the unit load. These values give the ordinates of influence line with which the influence line diagram for shear force at sections 1-1 can be constructed. Note that the slope of the influence line for shear on the left of the section is equal to the slope of the influence line on the right of the section. This information is useful in drawing shear force influence line in all cases.

Influence line for bending moment at the same section 1-1 of the simple beam is shown in Fig. 12(*b*). For a section, when the sum of the moments of all the forces to the left is clockwise or when the sum to the right is counter-clockwise, the moment is taken as positive. The values of bending moment at sections 1-1 are obtained for various positions of unit load and influence line is plotted. The detailed calculation of ordinates of influence lines is illustrated for members of the truss girder in the following section.

6.2 Influence lines for truss girders

Influence lines for support reactions and member forces for truss may be constructed in the same manner as those for beams. They are useful to determine the maximum force that may act on the truss members. The truss shown in Fig. 13 is considered for illustrating the construction of influence lines for trusses.

The member forces in U_3U_4, U_3L_4 and L_3L_4 are determined by passing a section *X-X* and considering the equilibrium of the free body diagram of one of the truss segments.

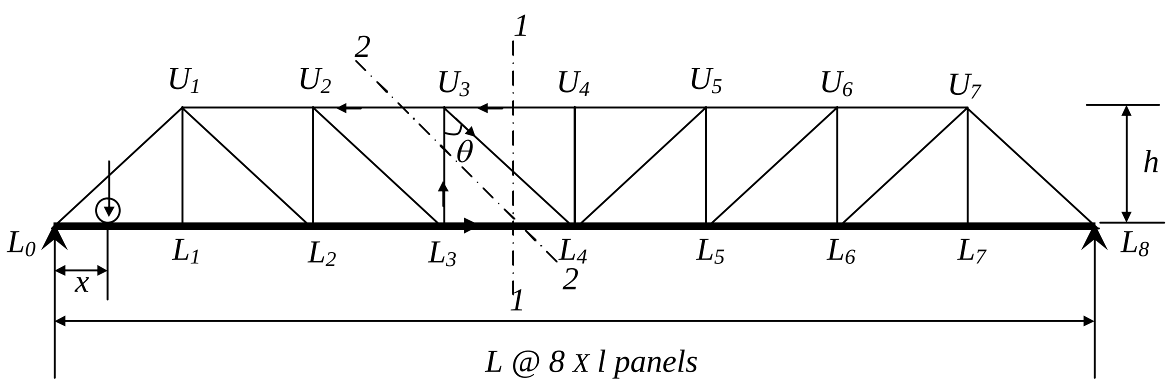


Fig.13 A typical truss

6.2.1 Influence line diagram for member U_3U_4 (Top chord member) [Fig. 14(a)]

Consider a section *1-1* and assume unit-rolling load is at a distance x from L_0. Then, from equilibrium considerations reactions at L_8 and L_0 are determined. The reactions are:

Reaction at L_8 = $\left(\frac{x}{L}\right)$

Reaction at L_0 = $\left(1-\frac{x}{L}\right)$

Consider the left-hand side of the section and take moments about L_4 by assuming appropriate directions for the forces in the members.

When unit load is in between L_0 and L_4:

$$\sum M_{L4} = 0$$

$$U_3U_4 \times h - \frac{x}{L} \times 4l \quad = 0$$

$$U_3U_4 = \frac{x}{h}\frac{4l}{L} = 0.5\,\frac{x}{h}$$

When unit load is in between L_4 and L_8:

Then, there will not be rolling unit load in the left-hand side section.

$$U_3U_4 = \frac{4l}{h}\left(1 - \frac{x}{L}\right)$$

Note that the influence diagram gives force in the member U_3U_4 directly, due to the unit load.

6.2.2 Influence line diagram for member U_3L_4 (Inclined member)[Fig 14(b)]

Again consider the left-hand side of the section 1-1, and use the equilibrium equation for vertical forces i.e. $\sum V = 0$ where, V represents the vertical force.

When unit load is in between L_0 and L_3:

$$\frac{x}{L} + U_3\,L_4\,Cos\theta = 0$$

$$\Rightarrow U_3L_4 = \frac{-x}{Lcos\theta}$$

$$where,\ \theta = \tan^{-1}\left(\frac{\ell}{h}\right)$$

When unit load is in between L_4 and L_8:

$$U_3L_4 = \frac{1}{Cos\theta}\left(1 - \frac{x}{L}\right)$$

When unit load is in between L_3 and L_4:

Since the variation of force in member U_3L_4 is linear as the unit load moves from L_3 to L_4 joining the ordinates of influence line at L_3 and L_4 by a straight line gives the influence line diagram in that zone. Note that, U_3L_4 represents the force in that member.

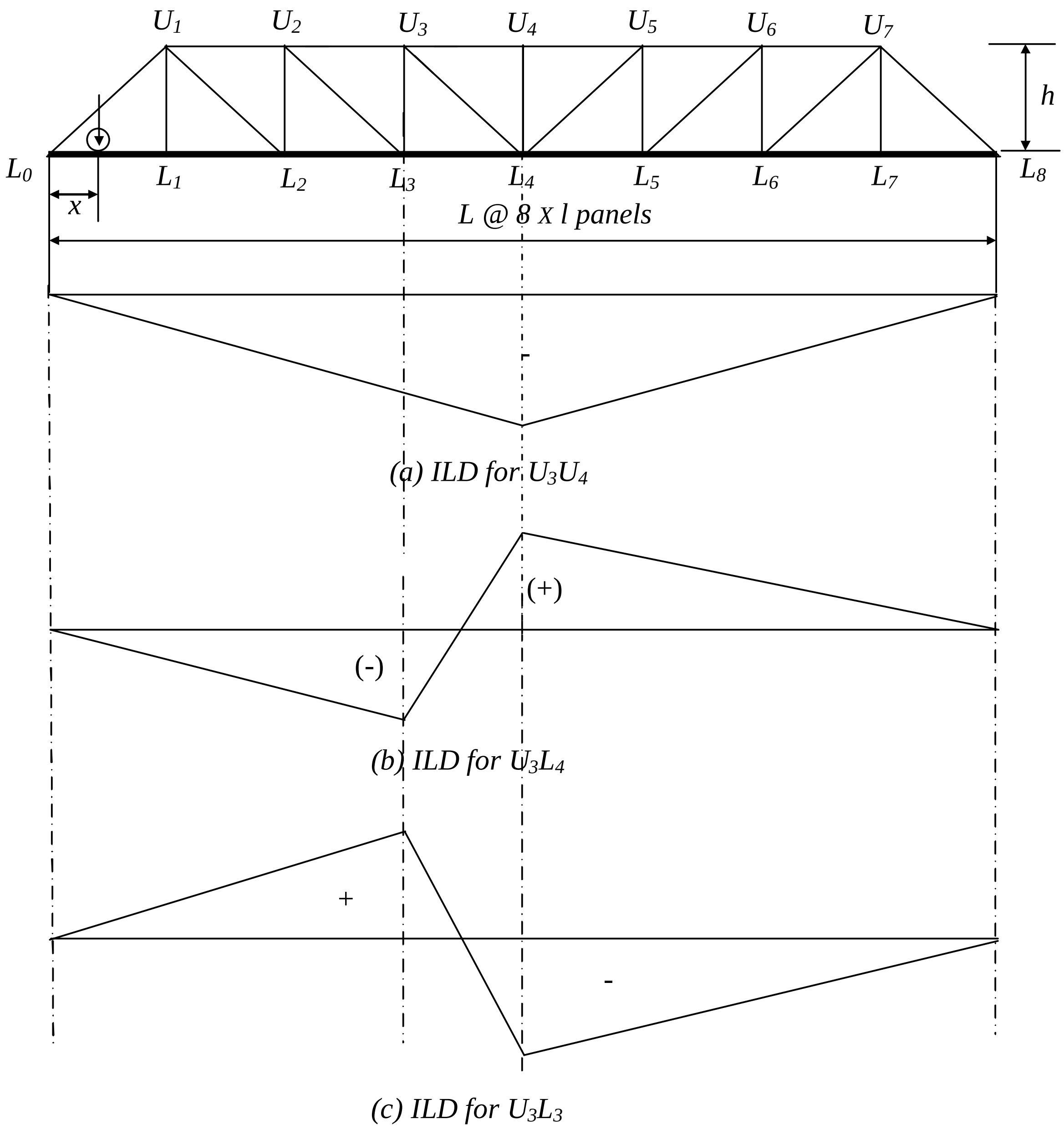


Fig. 14 Typical shapes of influence lines

6.2.3 Influence line diagram for U_3L_3 (Vertical member) [Fig. 14(c)]

Consider the left-hand side of the section *2-2* shown in Fig. 13 for illustrating the construction of influence line for vertical member.

When unit load is in between L_0 and L_3:

By considering the equilibrium equation on the section left hand side of axis 2-2.

$$U_3 L_3 - \frac{x}{L} = 0$$

$$\Rightarrow U_3 L_3 = \frac{x}{L}$$

When unit load is in between L_4 and L_8:

$$U_3 L_3 = -\left(1 - \frac{x}{L}\right)$$

When unit load is in between L_3 and L_4:

Joining the ordinates of influence line at L_3 and L_4 by a straight line gives the influence line diagram between L_3 and L_4.U_3L_3 represents the force in that member.

Similarly influence line diagrams can be drawn for all other members. Typical shapes of influence line diagrams for the members discussed are shown in Fig. 14. The design force in the member is obtained in the following manner. In this chapter, compressive forces are considered negative and tensile forces are positive.

Case (1): If the loading is Railway loading (UDL)

- Influence line diagram for force is drawn for that member
- The algebraic sum of areas of influence line under loaded length multiplied by magnitude of uniformly distributed load gives the design force.

Case (2): If the loading is Highway loading (Concentrated loading)

- Influence line diagram for force is drawn for that member
- The algebraic sum of the respective ordinates of influence line at the concentrated load location multiplied by concentrated loads gives design load of that member
- The series of concentrated loads are arranged in such a way that the maximum value of the desired member force is obtained.

7.0 SUMMARY

After brief introduction, the steel used in bridges and its properties were discussed. The broad classification of bridges was mentioned and various loads to be considered in designing railway and highway bridges in India were discussed. Finally analysis of girder bridges was discussed using influence line diagrams.

8.0 REFERENCES

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