

## 7.4 Loads and Load combinations

### 7.4.1 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:

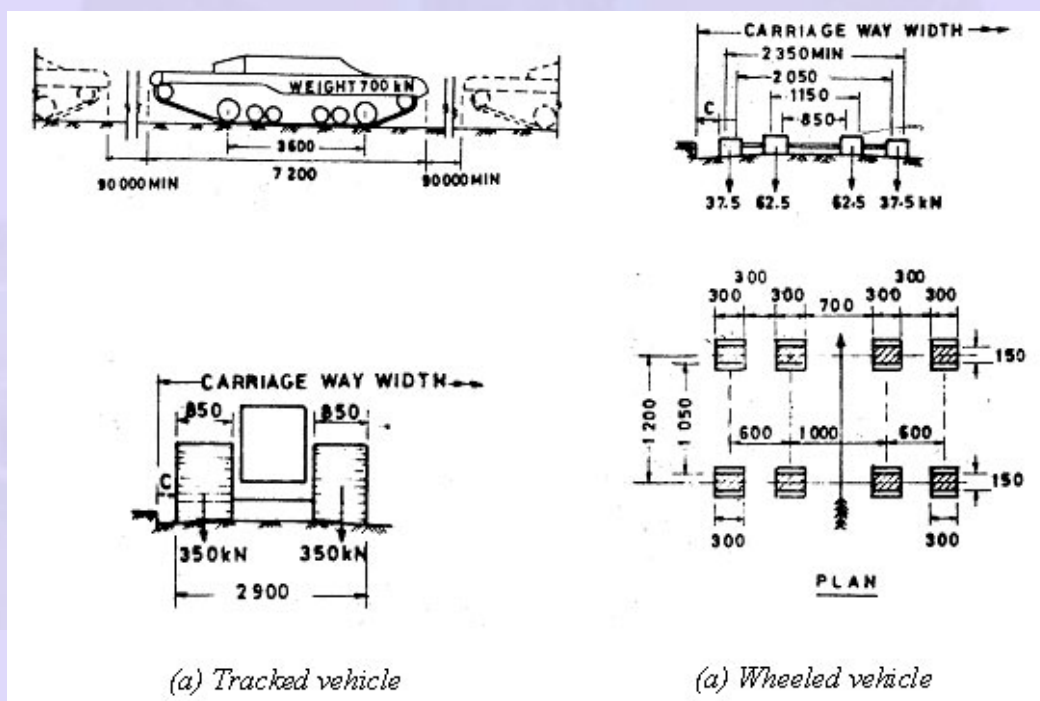
$$\text{EUDL in kN} = 317.97 + 70.83l + 0.0188l^2 \geq 449.2 \text{ kN} \quad (7.1)$$

For shear force:

$$\text{EUDL in kN} = 435.58 + 75.15l + 0.0002l^2 \geq 449.2 \text{ kN} \quad (7.2)$$

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.



**Fig.7.10 IRC 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. 7.10. 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.

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

The live load on footpath 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 -  $4.25 \text{ kN/m}^2$
- (ii) The intensity of load is reduced linearly from  $4.25 \text{ kN/m}^2$  for a span of 7.5 m to  $3.0 \text{ kN/m}^2$  for a span of 30m
- (iii) For effective spans over 30 m, the UDL may be calculated as given below:

$$P = \frac{1}{100} \left( 13.3 + \frac{400}{l} \right) \left( \frac{17 - W}{1.4} \right) \text{ kN/m}^2 \quad (7.3)$$

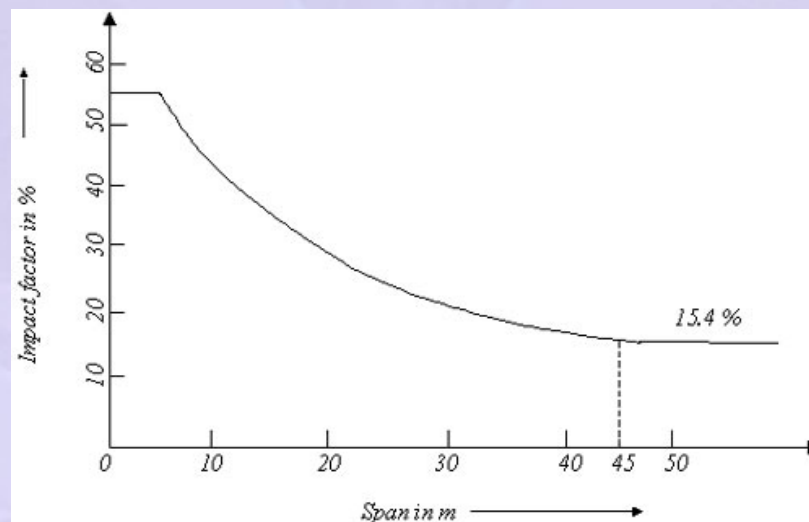
Where, P = Live load in kN/m<sup>2</sup>

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<sup>2</sup>.

### Impact load



**Fig 7.11 Impact percentage curve for highway bridges for IRC class A and IRC class B loadings**

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 7.1. Fig.7.11 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.

**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

$$F = \frac{W}{g} \frac{\delta V}{\delta t} \quad (7.4)$$

Where,  $W$  – weight of the vehicle

$g$  – acceleration due to gravity

$\delta V$  – change in velocity in time  $\delta t$

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 7.1: Impact factors for different bridges**

BRIDGE	LOADING		IMPACT FACTOR (I)
Railway bridges according to bridge rules	Broad and gauge gauge Meter	(a) Single track	$\frac{20}{14+l} \leq 1.0$
		(b) Main girder of double track with two girders	$0.72 \times \frac{20}{14+l} \leq 0.72$
		(c) Intermediate main girder of multiple track spans	$0.60 \times \frac{20}{14+l} \leq 0.60$
		(d) Outside main girders of multiple track spans	Specified in (a) or (b) whichever applies
		(e) Cross girders carrying two or more tracks	$0.72 \times \frac{20}{14+l} \leq 0.72$

	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		$\frac{9.5}{91.5+l}$
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 mand linearly reducing to 0.10 to spans of 9m
		(b) Wheeled vehicle	0.25
	IRC class A loading and IRC class B loading	(ii) Spans 9 m or more (a) Tracked vehicle	0.10
(b) Wheeled vehicle		0.25 for spans up to 23 mand in accordance with the curve indicated inFig .11 for spans in excess of 23 m	
			$\frac{9}{13.5+l}$
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  $11.7 \times 10^{-6} / ^\circ\text{C}$

**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  $2.40 \text{ kN/m}^2$  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  $6.0 \text{ kN/m}$  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  $1.0 \text{ m}$  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  $1.50 \text{ kN/m}$  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:

$$C = \frac{W V^2}{12.7 R} \quad (7.5)$$

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.

### 7.4.2 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 7.2 and are also specified in IS 1915 - 1961.

**Table 7.2: Load combinations**

SNo	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