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Design Of Plate Girders For Deck Type Railway Bridges

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Abstract-Plate girder bridges are the most common type of steel bridges generally used for railway crossing of streams and rivers. It essentially consists of a girder made up of steel plates which are connected by rivets or welds. They are adopted for simply supported spans in the range of 20 to 50m and for continuous spans up to 250m.The loading of these bridges follow the stipulations as laid down by the concerned authority in the railways for each kind of track in the form of equivalent uniformly distributed loads(EUDL).The design of plate girder involves the section of the cross section and design of connection between flanges and web together with the design of intermediate and bearing stiffeners and their connections of the web of the plate girder. In the deck-type bridge, a wood, steel or reinforced concrete bridge deck is supported on top of two or more plate girders, and may act compositely with them. In the case of railroad bridges, the rail road ties themselves may form the bridge deck, or the deck may support ballast on which the track is laid.

Keywords – Plate girder, stiffeners, ballast

I. INTRODUCTION

A girder bridge, in general, is a bridge that uses girders as the means of supporting the deck. A bridge consists of three parts: the foundation (abutments and piers), the superstructure (girder, truss, or arch), and the deck. A girder bridge is very likely the most commonly built and utilized bridge in the world. Its basic design, in the most simplified form, can be compared to a log ranging from one side to the other across a river or creek. In modern girder steel bridges, the two most common shapes are plate girders and box-girders. A beam may be made of concrete or steel. Many shorter bridges, especially in rural areas where they may be exposed to water overtopping and corrosion, utilize concrete box beams. The term "girder" is typically used to refer to a steel beam. In a beam or girder bridge, the beams themselves are the primary support for the deck, and are responsible for transferring the load down to the foundation. Material type, shape, and weight all affect how much weight a beam can hold. Due to the properties of inertia, the height of a girder is the most significant factor to affect its load capacity. Longer spans, more traffic, or wider spacing of the beams will all directly result in a deeper beam. In truss and arch-style bridges, the girders are still the main support for the deck, but the load is transferred through the truss or arch to the foundation. These designs allow bridges to span larger distances without requiring the depth of the beam to increase beyond what is practical. However, with the inclusion of a truss or arch the bridge is no longer a true girder bridge.

The rest of the paper is organized as follows. Types of bridges are explained in section II. Loads on bridges are presented in section III. Analytical design are given in section V. Concluding remarks are given in section VI.

II. TYPES OF BRIDGES

Steel bridges may be classified into various types according to:

1. The kind of traffic carried,
2. The kind of main structural system,
3. The position of the carriage way subjective to the main structural system

Based on traffic carried, bridges can be categorized into following types:–

Road bridges or Highway bridges (b)Railway or rail bridges (c)Road cum rail bridges (facilitating both rail and road way)

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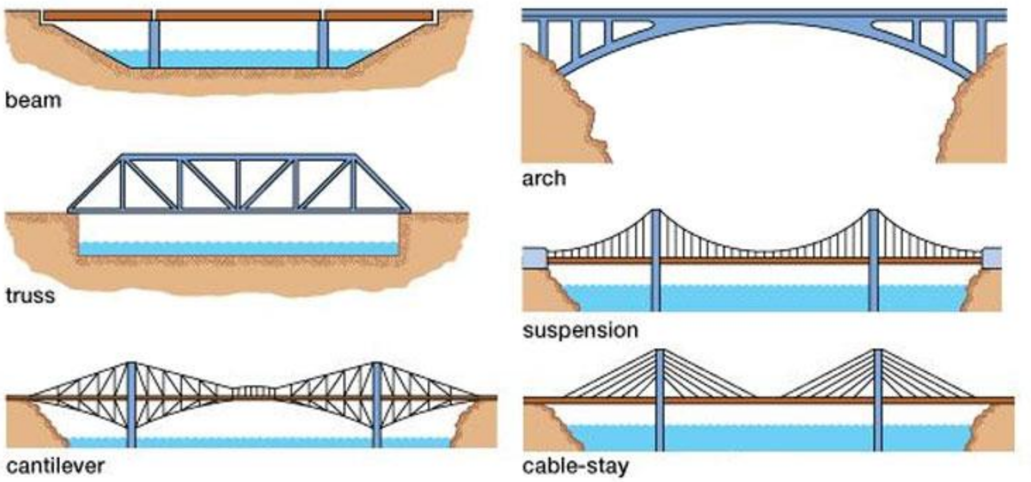
2.1 Railway bridge

2.2 Classification based on the main structural system.–



Bridges based on strucrural systems

2.3 Classification based on the position of carriageway The bridges may be of the deck type,through type or semi-through type–

(a)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.

(b)Through type bridge - The carriageway rests at the bottom level of the main load carrying members [Fig. 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.

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

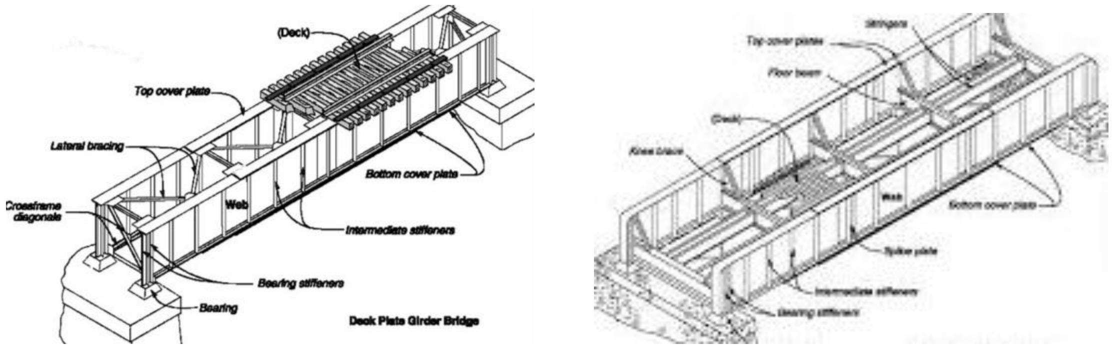


Figure 3. (a) deck type bridge (b) through type bridge

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

Dead Load: The dead load refers to the mass of the structure and any stable load fixed thereon. The dead load is at first understood and checked after design is undertaken.
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.
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.
Meter gauge - Main line, branch line and Standard C ·
Narrow gauge - H class, A class main line and B class branch line.
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.

IV. ASSUMPTIONS FOR THE DESIGN OF PLATE GIRDER BRIDGES

Following assumptions are made in the design of plate girder bridges:
1.The web plates of plate girders resist the shear force and the shear stress is uniformly distributed over entire cross sectional area of the web .
2. The flanges of plate girders resist the bending moment.

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V. ANALYTICAL CALCULATIONS FOR THE DESIGN OF PLATE GIRDER AS PER IS 800:2007

Datas required:

A deck type plate girder bridge for single meter gauge track and standard main loading.

Center to center span of main girder =24m, provided at a spacing of 1.3m,

0.6kN per meter stock rails and 0.4kN per meter guard rails are provided,

weight of fastening may be taken as 0.12kN per meter,

The sleepers are placed at 400mm from center to center and size 2mx 250mmx 250mm.unit weight of timber is 7.5kN/m3.

The floor is open deck type.

Step 1: Calculation of dead loads

Weight of stock rail= 0.6kN/m

Weight of 2 stock rail $=0.6\times2=1.2$kN/m

Weight of guard rails$=0.4\times2=0.8$ kN/m

Weight of Sleepers$=7.5\times2\text{x}0.25\times0.25\times\frac{1000}{400}=2.34$ kN/m

Total UDL=4.54 kN/m

Total dead load on span$=4.54\times24=108.96$kN

Step 2: Calculation of live loads

From table , equivalent UDL for Live Load bending moment for 24m span =1658kn (BRIDGE RULES)

Considering Impact, equivalent UDL $=1658\times1.526=2530$kN

Total load=108.96+2530= 2638.96 kN

Load acting on one plate girder$=\frac{2638.96}{2}=1319.5$ kN

Self-weight of plate girder$=\frac{WL}{300}=105.56$ kN

Total weight on one plate girder including self-weight=1319.5+105.56=1425.06 kN

Maximum BM$=\frac{wl^2}{8}=\frac{1425.06\times24}{8}=4275.2$ kNm, (wl=1425.06)

Factored BM =6412.8 kNm

Load for live load shear force from table =1802kN

Load for live load shear force considering impact$=1802\times1.526=2750$ kN

Load for shear force including dead load= 2750+108.96=2858.96 kN

Load on one girder= 1429.5 kN

DL on one girder=105.96kN

Total load=1535.06kN

Maximum shear force $=\frac{wl}{2}=\frac{1535}{2}=767.03$kN

Factored SF $=1.5\times767.03=1150.54$kN

Step 2: Design of plate girder

Let us assume the plate girder is without stiffeners. So thickness should be large. As per IS 800:2007, assume k=67

Depth of web, dw$=\frac{Mk}{f_y}^{0.33}=\left[\frac{6412.8\times10^6\ \ \times67}{250}\right]^{0.33}=1115.86$mm

Assume dw=1200mm.

Thickness of web$=\left[\frac{M}{f_y k^2}\right]^{0.33}=\left[\frac{6412.8\times10^6}{250\times67^2}\right]^{0.33}$

Assume web thickness as 18mm.

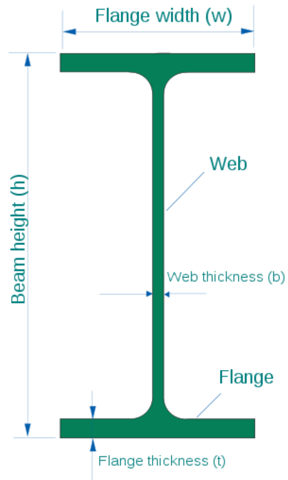

Figure 4. Plate girder

Step 3: Design of flange

M = $\frac{A_f \, f_y \, d}{\gamma_{mo}}$

Af = $\frac{\frac{M \, f_y}{\gamma_{mo}}}{d}$ = $\left[\frac{6412.8\times10^6 \times1.1}{250\times1200} \right]$

bf = $\frac{d}{3}$ =400mm

tf = $\frac{23514}{400} = 58.78 = 60mm$

outstand of flange= $\frac{400-18}{2}$ =191mm

b/tf=3018<8.4t

hence the flange is plastic

Step 4: check for bending strength

As per IS 800:2007, cl 8.2.1.2

Md = $\frac{\beta_b \, Z_p \, f_y}{\gamma_{mo}}$

Zp= Af (D-tf) =30.24x106mm3

Md = $\frac{1\times30.24\times10^6\times250}{1.1}$ =6872knm>6412knm

Hence safe

Step 5: check for shear carrying capacity

As per IS 800:2007, cl 8.4

Vd = $\frac{A_v \, f_{yw}}{\sqrt{3}\gamma_{mo}}$ = $\frac{1200\times18\times250}{\sqrt{3}\times1.1}$ =2834.2kn>1150.54kn, hence safe.

Step 6: check for bearing strength

As per IS 800:2007, cl 8.7.4

Fyw = = $\frac{(b1+n2)tw \, f_{yw}}{\gamma_{mo}}$

Assume width of bearing,b1=200mm

n2=2.5tf=2.5$\times$60mm=150mm

Fyw = $\frac{(200+150)\,18\times250}{1.1}$ =1431.8kn>1151kn, hence safe

Step 7: Design of connection

The connection should be designed to take up the horizontal shear force developed at the junction of the web and flange

$\tau = \frac{VAy}{I}$

Ixx= $\frac{18\times1200^3}{400} + 2(\frac{400\times60^3}{12} + 400\times60(630)^2) =$ 2.166$\times 10^{10}$ mm4

= $\frac{1151\times10^3\times400\times60\times630}{2.166\times10^{10}}$ =803.56N/mm

This shear force is to be taken by the weld. Providing continuous weld on either side,

the strength of weld of size S is given by= $\frac{fu\times t_t}{\sqrt{3}\gamma_{mo}} = 646.63\text{N/mm}$

where, tt= throat thickness=0.7$\times$ s=5.6mm,(Assume size of the weld, s=8mm)

shear to be resisted by one weld = $\frac{803.56}{2}$ =401.78 N/mm.

Now 646.63N/mm >401.78 N/mm. Hence provide 8mm fillet weld within athroat thickness of 5.6mm throat at the span of girder on both sides of the web.

VI. CONCLUSION

It is concluding that the Steel is being used on highway and railway bridges successfully all over the world because of its inherent quality of better strength, resistance against fracture toughness, weld ability and a very good resistance against weathering / corrosion. The weight of the structure is reduced tremendously reducing the cost of substructure and foundations and over all reduced life cycle costs. Its introduction on highway and Indian railways will be a very good decision for the up gradation of the present technology of design, fabrication and maintenance of steel bridges. In comparison to the developed countries, the steel being used in plate girder bridges is of inferior quality. If the construction depth is not critical, then a deck-type bridge, is a best solution, in which case the bracings provide restraint to compression flange against lateral buckling. In the case of Railway Bridge, the plate girder carries the wooden sleepers over which the steel rails are fastened. The girder bridges will be braced the lateral load due to the top flange and the bottom flange, besides cross bracings to resist the lateral load due to wind. Also, IS 800: 2007 helps to plan for systematic design of rolled steel beams of economic sections.

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