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"Parametric Study of Plate Girder Bridge"

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Abstract: *A bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage may be for pedestrians, a railway, a road, canal or pipelines. The obstacle to be crossed may be a road, rivers, railways or valley. There are many different designs that all serve unique purposes and apply to different conditions.*

The beam bridge carries vertical loads by flexure. The truss bridge of simple span behaves like a beam because it carries vertical loads by bending. The truss bridge of simple span behaves like a beam because it carries vertical loads by bending. The top chords are in compression and the bottom chords are in tension, while the vertical and diagonal members are either in tension or compression depending on their orientation. Loads are carried primarily in compression by the arch bridge, with the reactions at the supports (springing) being both vertical and horizontal forces.

Plate girders became popular in the late 1800's, when they were used in construction of rail road bridges. The plates were joined together using angles and rivets to obtain plate girders of desired size. By old 1950's welded plate girders replaced riveted and bolted plate girders in developed world due to their aesthetics, better quality, and economy. This arrangement is suitable and commonly used in railway bridges where the maximum permissible approach gradient for the track is less. 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.

Keywords: *Bridge, Plate Girder, Deflection, Stress, Shear Force, Bending Moment.*

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I. Introduction

A cantilever bridge generally consists of three spans, of which the outer span, known as anchor span, are anchored down to the shore, and these cantilever over the channel. A suspended span is rested at the ends of the two cantilevers, and act as a simply supported beam or truss. The cantilevers carry their loads by tension in the upper chords and compression in the lower chords. These loads are transferred to the ground through anchorages. In a cable stayed bridge, the vertical loads on the deck are carried by the nearly straight inclined cables which are in tension. The towers transfer the cable forces to the foundation through vertical compression. The tensile forces in the stay cables induce horizontal compression in the deck.

COMPONENTS OF A BRIDGE

The main parts of a bridge structure are following:

a) Decking, consisting of deck slab, girders, trusses etc.;
b) Bearing for the decking;
c) Abutments and piers;
d) Foundations for the abutments and the piers;
e) River training works, like revetment for slopes for embankments, and aprons at river bed level;
f) Approaches to the bridges to connect the bridges proper to the roads on either side; and
g) Handrails, parapets and guards stones.

CLASSIFICATION:-

Bridge may be classified are following:

a) According to function as aqueduct (canal over a river), viaduct (road or railway over a valley), highway, railway and road-cum-rail, pedestrian or pipe Line Bridge.
b) According to the material of construction of superstructure as timber, masonry, iron, steel, pre-stressed concrete, reinforced concrete, composite Bridge.
c) According to the form or type of superstructure as beam, slab, arch, truss or suspension bridge.

d) According to the inter-span relations as cantilever, simple or continuous bridge.
e) According to the position of the bridge floor relative to the superstructure, as deck, though, half-through or suspended bridge.
f) According to the method of connections of the different parts of the superstructure, in case particularly for steel construction, as riveted connection, pin or welded bridge.
g) According to the road level relative to the highest flood level of the river below, particularly for a highway bridge or submersible bridge.
h) According to the method of clearance for navigation as high-level, movable-swing, movable-bascule or transporter bridge.
i) According to span length as culvert (less than 8m), Miner Bridge (8 to 30m), major bridge (above 30m) or long span bridge (above 120m).
j) According to degree of redundancy as determinate or in determinate bridge.
k) According to the anticipated type of service and duration of use as, permanent, temporary, military (pontoon, Bailey) bridge.

PLATE GIRDER BRIDGE:-

Plate girders became popular in the late 1800's, when they were used in construction of rail road bridges. The plates were joined together using angles and rivets to obtain plate girders of desired size. By old 1950's welded plate girders replaced riveted and bolted plate girders in developed world due to their aesthetics, better quality, and economy. The use of plate girders rather than rolled beam sections for the two main girders gives the designer freedom to select the most economical girder for the structure. If very large embankment fills are required in the approaches to the bridge, in order to maintain with the at least minimum head-room clearance required, the half through bridge is more appropriate for that condition. This arrangement is suitable and commonly used in railway bridges where the maximum permissible approach gradient for the track is less. 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. A plate girder highway bridge will consist of the deck slab (normally of reinforced concrete) and stringers running longitudinally and resting on transverse floor beams, which in turn rest on the plate girder.

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. The cross bracings consist of angles and are provided at the ends at intervals of about 4 to 5m.

There is usually a choice available between

a) Using two widely spaced longitudinal girders, with the cross girder system supporting the deck, and
b) Providing multiple longitudinal girders with small spacing.

In the first case, the cross girder system may consist of closely spaced cross girders alone or cross girders supporting a system of longitudinal stringers. The two girder system necessitates deeper girders and may lead to economy in slightly larger than the gauge of the track to reduce the severity of the impact loads on the girders. In the half-through type of bridge, the railway load is carried at the lower flange. Flexure or bending between vertical supports is the main structural action in this type. Girder bridges may be either truss girders or solid web girders or box girders. Plate girder bridges are used for simply supported spans less than 30 mand box girders for continuous spans up to 250 m.

Plate girder bridges are commonly used for river crossings and curved interchange ramps. Typical span lengths range from 150 to 300 feet. Steel plate girders are also being used where limited vertical clearance requires shallow superstructure depth. They may be set over highway lanes with a minimum of disruption and false work, similar to precast concrete elements. Longitudinal launching of steel girder framing and transverse rolling of completed steel structures has been done successfully.

COMPONENTS OF PLATE GIRDER

a. AVAILABLE PLATE SIZES

Readily available lengths and thicknesses of steel plates should be used to minimize costs. Tables of standard plate sizes have been published by various steel mills and should be used for guidance.

These tables are available through the online or steel specialist.

In general, an individual plate should not exceed 12′-6″ feet in width, including camber requirements, or a length of about 60 feet. If either or both of these dimensions are exceeded, a butt splice is required and should be shown or specified on the plans. Some plates can be available in lengths over 90 feet, so web splice locations should be considered optional. Plate thicknesses of less than 5/16 inches should not be used for bridge applications. When metric units are used, all steel dimensions, thickness, should be hard converted.

For example, specify 20 mm, not 20.4 mm plate.
Preferred plate thicknesses, are as followings:
• 5/16″ to ⅞″ in 1/16″ increments
• ⅞″ to 1 ¼″ in ⅛″ increments
• 1¼″ to 4″ in ¼″ increments

b. GIRDER SEGMENT SIZES

Locate bolted field splices so that individual girder segments can be handled, shipped, and erected without imposing unreasonable requirements on the contractors. Also crane limitations need to be considered in congested areas near buildings or traffic. Transportation route options between the girder fabricator and the bridge site can affect the size and weight of girder sections allowed. Underpasses with restricted vertical clearance in sag vertical curves can be obstructions to long, tall segments shipped upright. The region should help determine the possible ways, and the restrictions they impose, during preliminary planning or early in the design phase. Segment lengths should be limited to 150 feet, depending upon the cross section. Horizontal curvature of plate girder segments may increase handling and shipping concerns. Weight is seldom a controlling factor for I-girders. However, 35 tons is a practical limit for some fabricators. Limit weight to a maximum of 100 tons if delivery by truck is anticipated. Consider the structure's span length and the above factors when determining girder segment lengths. In general, field splices should be located at dead load inflection points. When spans are short enough, some field splices can be designated optional if resulting segment lengths and weights meet the shipping criteria.

c. FLANGES

Flange thickness is limited to 4″ maximum in typical bridge plate, but the desirable maximum is 10cm. This requirement helps ensure the plate material has limited inclusions and micro-porosity that can create problems during cutting and welding. Recent inquires with major domestic steel mills found that the 3.0:1 reduction requirement can be obtained up to 10cmthick plate. The number of plate thicknesses used for a given project should be kept to a minimum. Generally, the bottom flanges should be wider than the top flange. Flange width changes should be made at bolted field splices. Thickness transitions are better done at welded splices. AASHTO LRFD Article 6.13.6.1.5 requires fill plates at bolted splices to be developed, if thicker than 0.8cm.Since this requires a significant increase in the number of bolts for thick fill plates, keeping the thickness transition 0.1cm or less by widening pier segment flanges can be a better solution. Between field splices, flange width should be kept constant.

d. WEBS

Maintain constant web thickness throughout the structure. If different web thickness is needed, the transition should be at a welded splice. Horizontal web splices are not needed unless web height exceeds12′-6″. Vertical web splices for girders should be shown on the plans in an elevation view with additional splices made optional to the fabricator. All welded web splices on exterior faces of exterior girders and in tension zones elsewhere shall be ground smooth. Web splices of interior girders need not be ground in compression zones.

e. BEARING STIFFENERS

The bearing stiffeners are provided at the points of supports and at the points of concentrated loads. The bearing stiffeners are provided symmetrical about the web as far as possible. The bearing stiffeners are fitted tightly between the top flange and bottom flange. The bearing stiffeners are solidly packed throughout. There are not joggled round the flange angles. As per the code of practice for the design of steel bridges published by Railway Board, the outstanding lags of each pair of stiffeners are so proportioned to transmit 75 percent of the reaction that, the bearing stress, on the part of their area in contact with the flange and clear of the root of the flange does not exceed = 0.75 f_y N/mm^2, the allowable bearing stress. The cross-sectional area of bearing stiffener consists of the cross-sectional area of the pair of angles together with the length of web on each side of center line equal to twenty times the thickness of web, wherever possible. The radius of gyration is taken about the center line of the web. The bearing stiffeners are connected with sufficient rivets to transmit whole of the support reaction.

f. INTERMIDIATE STIFFENERS

The intermediate stiffeners are provided to avoid the diagonal buckling of web. Depending upon the ratio of clear depth to the thickness of web, (d_1/t_w), vertical stiffeners (transverse stiffeners) or vertical and horizontal stiffeners (longitudinal stiffeners) are provided throughout the length of the plate girder.

g. VERTICAL STIFFENERS

When the thickness of web plate is less than the limits specified for the minimum thickness of the web plate, then, the vertical stiffeners are provided throughout the length of the girder. The intermediate vertical stiffeners are joggled round the flange angles and these are placed in pairs (one on each side of the web), or single (alternatively, on opposite side of web). The size of vertical stiffeners is found for the moment of inertial required. As the code of practice for the design of steel bridges, published by Railway Board. The moment of inertia of a pair of vertical stiffeners is found about the centre line of the web, and the moment of inertia of a single angle vertical stiffeners is found about the face of the web. The moment of inertia of a single angle vertical stiffeners is provided by the angle sections and a portion of the web, which acts with the stiffeners. The spacing of vertical stiffeners depends on thickness of web plate, the clear depth of web plate and the average shear stress in web. The vertical stiffeners are provided at a spacing mot greater than 1.5 d and not less than 0.33d, where d is distance between flange angles, also known as clear depth of web. For the railway bridges, the maximum spacing of the stiffeners should not exceed 1800mm.

h. HORIZONTAL STIFFENERS

When the thickness of web is less than the limits specified for minimum thickness of web plate, then the horizontal stiffeners (in addition to the vertical stiffeners) are provided on the web at a distance from the compression end of the unsupported web equal to the $2/5^{th}$ of distance of the compression flange from the neutral axis. This horizontal stiffener is provided at a depth from the top compression flange equal to the $2/5^{th}$ of distance compression flange from the neutral axis plus vertical leg length of flange angle. The moment of inertia, I, of the horizontal stiffeners should not be less than $4c_1t_w^3$, where c1 is the actual distance between the vertical stiffeners. The second horizontal stiffener is provided on one or both the sides of web, when the thickness of web is less than the limits specified in addition to the vertical stiffeners and horizontal stiffeners, at the neutral axis of the girder. The moment of inertia of this horizontal stiffener should not be less than dt_w^3.

OBJECTIVE OF THE STUDY

The aim of the project is to check the economic status of Plate Girder Bridge (Railway) on various spans keeping one parameter constant and other parameters varying. Software application in design and simulation of components is also taken into account as an objective.

Objective of the study are as follows:-

1. To perform parametric study on Simply Supported Span for the Suitability and Economy.
2. To establish multiplication factor, and to present generalized multiplication factor to be used as reference for future considerations in case of span and parameters design.
3. To collect data and information in tabular form.
4. To perform data computation and analysis done by EXCLE sheet.
5. To model same component in STADD-PRO design software.
6. To analyze modelled problem using STADD-PRO software.
7. To present software results and conclude with required multiplication factor establishment.

II. Literature Review

Cooke, et al. (1983) have studied the experimental behavior of four steel plate girder webs stiffened either transversely or transversely and longitudinally is considered. **Guarneri (1985)** has presented extensive results of tests to collapse I-section plate girders with stiffeners at various angles of inclination, along with an analytical interpretation of the results, are presented. **Cynthia (1987)** Plate girder design according to LRFD is very similar to the ASD method presented in the 8th Edition Manual of Steel Construction. **Takashi and Tamakoshi (1988)** The subjects of this research were non-composite and composite steel plate girder bridges, which were selected because they are the most common types of bridges in the country. **Philbrick, et al. (1995)** have studied the behavior of two through plate girder railway bridges and investigated to determine a better approach to fatigue assessment.**Bhatti and Gahtan (1995)** Optimum design of plate girders subjected to Highway Bridge loading is presented in this paper. The formulation is capable of handling composite or noncomposite designs, shored or unshared construction, stiffened or unstiffened design, symmetric or unsymmetrical cross-section, simple or continuous spans, and prismatic or no prismatic girders.**Lee, et al. (1998)** have investigated Nonlinear analyses on three-dimensional finite element models of transversely stiffened plate girder web panels (without longitudinal stiffeners) subjected to pure shear, including the effects of initial out-of-flatness.**Sause, et al. (2001)** have studied about the High Performance Steels (HPS) are providing new opportunities to design cost-effective steel bridges by exploiting the high strength, corrosion resistance, fracture toughness, and weld ability of HPS.**Itani, et al. (2004)** has presented the recent earthquakes exposed the vulnerabilities of Steel Plate Girder Bridge when subjected to ground shaking and the behavior of Steel Plate Girder Bridge during recent earthquakes such as Petrolia, Northridge, and Kobe.

Yail, et al. (2013) This paper has addressed an extensive parametric study on the flexural behavior of various steel I-girder bridges subjected to selected MLC trucks, including the rating of the bridges, based on validated 3-dimensional FEA models. A total of 144 load models were used to evaluate the load effects of the selected MLC trucks on 6 different bridge superstructures. **Kavitha, et al., (2015)** project deals with the Design of a grade separator in an intersection. The location is at four roads junction at SALEM town, which is facing major traffic problems due to the construction. We have done a traffic survey and designed all the structural parts for this grade separator. The deck beam is designed as a cantilever on a pier. The Pier is designed for the axial dead load and live load from the slab, girders, deck beam. **Abid (2015),** In this paper a detailed parametric design optimization of the main girder of box type is performed for a 150Ton capacity and 32m long span crane, after its basic design using available design rules. Design optimization is performed using detailed 3D finite element analysis by changing the number, shape and location of horizontal stiffeners along the length of the girder and number and location of stiffeners along the vertical direction to control any possible buckling, with minimum possible weight and for safe stress and deflection. **Ehab and Ellobody (2017)**The nonlinear behaviour and design of double track open timber floor plate girder railway deck steel bridges under combined buckling modes have been investigated and reported. Most of the aforementioned parameters were not incorporated in current design rules and has been highlighted in this research. **Gi-Ha Eom, et al. (2017)** the optimum cross-sectional design of the I-girder/concrete plate system was achieved. Then, a single20 m TO girder/plate system and two 20 m TO girder bridges were constructed and tested to evaluate their performance. From the test, failure behavior, load carrying capacity, crack pattern, etc., are obtained. The results are discussed in detail in this research.

Literature Critiques

The thorough extensive study of the literature predicts that Plate Girder Bridge designed in India is maximum with only Simply Supported span. It is reviewed that cost of Simply Supported Span Bridge may be high as compare to Continuous span. Some others deficiencies are as follows:-

- It was found that the studies were made only keeping depth of web constant.
- Suitability of span based on variation of other parameters were not checked.
- Excel programs are not used in literature, which avails easy calculations with varying values.
- It is not tried to make a design aids spread sheet to overcome the problems.
- There is lack of verification of analytical calculation results with software simulation results in a single research paper.
- Detailed calculation and software implementation with standard multiplication factor is not found in literature, hence is taken as aim of present research.

III. Staad Pro Software Analysis

STAAD Pro is used as a software to simulate selected part with different size cases.

Analysis Part Considered is shown in figure below:

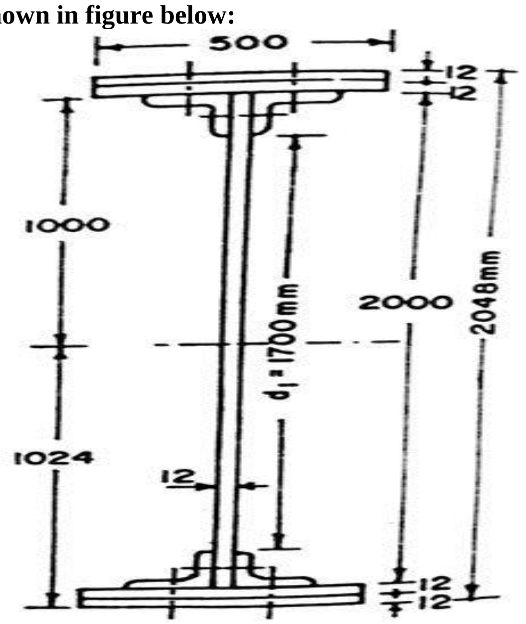

Fig.: Cross Section of Girder

Cases Considered for Analysis

Load considered for all cases is same i.e. Dead Load and 245.2kN as per Bridge Rules (Railway Board, India)

A. 15 M span with 10 mm, 12mm, 14mm, 16mm, 18mm, 20mm, 22mm, and 25mm Web Thickness respectively.
B. 20 M span with 10 mm, 12mm, 14mm, 16mm, 18mm, 20mm, 22mm, and 25mm Web Thickness respectively.
C. 25 M span with 10 mm, 12mm, 14mm, 16mm, 18mm, 20mm, 22mm, and 25mm Web Thickness respectively.
D. 30 M span with 10 mm, 12mm, 14mm, 16mm, 18mm, 20mm, 22mm, and 25mm Web Thickness respectively.

IV. Staad Pro Results

Table: Stress Comparison

STRESS COMPARISON TABLE								
	WEB THICKNESS							
SPAN	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**25**
15	1.572	1.581	1.59	1.599	1.607	1.616	1.625	1.638
20	2.076	2.092	2.107	2.123	2.138	2.154	2.170	2.193
25	2.589	2.614	2.638	2.663	2.687	2.712	2.736	2.773
30	3.113	3.148	3.183	3.218	3.254	3.289	3.324	3.377

Table: Bending Moment Comparison

Bending Moment COMPARISON TABLE								
	WEB THICKNESS							
SPAN	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**25**
15	1060	1067	1074	1081	1088	1094	1101	1111
20	1912	1927	1943	1959	1974	1990	2005	2028
25	3022	3052	3083	3113	3143	3173	3173	3249
30	4399	4451	4503	4555	4607	4659	4711	4789

Table: Shear Force Comparison

Shear Force COMPARISON TABLE								
	WEB THICKNESS							
SPAN	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**25**
15	19.8	20.2	20.6	21	21.3	21.5	21.8	22.2
20	27.6	28.2	28.7	29.2	29.6	30	30.4	31
25	35.6	36.4	37	37.7	38.3	38.8	39.4	40.2
30	43.8	44.7	45.6	46.4	47.2	48	48.8	49.9

Table 6.26: Deflection Comparison

DEFLECTION COMPARISON TABLE								
	WEB THICKNESS							
SPAN	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**25**
15	2.455	2.363	2.297	2.247	2.207	2.176	2.151	2.121
20	3.075	2.938	2.839	2.765	2.707	2.662	2.626	2.584
25	3.684	3.501	3.37	3.272	3.198	3.140	3.094	3.042
30	4.29	4.061	3.899	3.780	3.69	3.621	3.566	3.505

V. Conclusion

In this study, 16 different bridge span lengths 15m, 20m, 25m and 30m were studied. Thickness of web constant and other parameters varies.

The following conclusions were made from this study:-

1. Depth of web varies linearly with span for the constant web thickness.
2. With depth of web to thickness of web ration remains the same.
3. At constant thickness of web, area of flange varies as per the variation of span.
4. Using the transverse stiffeners, the weight of girder is controlled with span variation.

SOFTWARE ANALYSIS CONCLUSION

It is concluded and verified from research and analysis that design for bridge girder plate can be consider following facts:

- If span is kept constant and web thickness varies in increasing order then stress, bending moment and shear force increases while deflection decreases.
- If web thickness is kept constant and span varies in increasing order then stress, bending moment, shear force and deflection increases.

SCOPE FOR FURTHER STUDIES

Based on the experience gained during the study following extensions are suggested:-

1. The study presented in this thesis should be extended beyond 30m span. Continuous bridges, frame bridges, composite bridges and steel truss bridge must be considered for designing in future.
2. Flange width can be kept constant with constant web thickness for economical consideration.
3. Field data can be made to verify the results obtain from the thesis.
4. An investigation could be made to calculate the weight of girder with the stiffeners and without stiffeners.
5. A comparison can be made between simply supported and continuous span bridge keeping constant parameters.

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