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Strength Evaluation of a Steel Plate Girder

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Abstract*— *A plate girder is a steel beam that is widely used in rail and road bridges, which can be either box girder, beam bridges, military girder composite, etc. These are mainly built-up sections suitable to carry large bending moments and shear forces. Depending on the design requirements and as per the nature of the structure; the thicknesses for web, flanges, stiffeners, etc are determined. The strength of the material and the connections at the joints are the two main factors that governs the design considerations. In the present study, steel plate girders have been assigned I-shaped cross section with symmetrical flanges using flats (ISF). The girders have been designed as per Indian Standard codal provisions and is verified for Shear capacity and bending resistance. Modelling and Analysis is done using Staad Pro software. Parametric studies are performed for various thickness of web and flange plates.

Keywords*—*Flat Plates, I-Section, Steel Plate Girder, Shear and Bending resistance, Strengthening.

I. Introduction

The Plate girders are typical I-beams made up from separate structural steel plates. The vertical web and horizontal flanges are formed together by welding, bolting or riveting of the beam. In current days, an I section with three-two flange plates and one web plates are welded and built suitably. Plate girders are generally preferred for larger spans made with provision of extra cover plates. A plate girder has extensive flexural strength, the resistance to bending andshear can be increased by enlarging the distance between flanges. The web is a thin plate that buckle under the load and it can be averted providing web stiffeners in vertical and horizontal directions. Present days only welded plate girders are built which are aesthetically good and light in weight as compared to riveted /bolted plate girders. A Plate Girder consists of following components: i) web plate ii) flange plate iii) stiffeners iv) splices for web and flange plate v) endconnection.

II. Related Works

Hanady A.El-rahman El-Dehemy (2020), studied that the most economical Plate girder can be fabricated using minimum mass, equal sized flanges and no web stiffeners. Similar to the rolled I-section, for a given section modulus a section with greater depth will have a lower mass than one with a smaller depth, except for deeper section where thicker web is required. When the compression flange is laterally unrestrained, to resist the buckling tendency a wider flange plate is necessary. But the cost will increase due to the difficulties faced during assembling the procedure.

*Jurnal Kejuruteraan , et al.(2020),*due to the nature of the webs in steel plate girders, they are prone to local and shear buckling. The conventional way to prevent this is by providing vertical stiffeners at specified intervals. In additionto improving the strength of the girder, the presence of inclined stiffeners allows the beams to carry varying amounts of forces in the structure.

D C Gollangi and D Datta (2019), studied about the steel plate girder which is widely used structural element in many

fields of application mainly in long span railway bridges because of its numerous favorable properties. For bending and shear usually Plate girders are designed. Between rolled I-sections and truss girders, the plate girders have a moment resisting capacity. They are built up flexural members. By increasing the distance between the flanges their bending capacity can be increased. This also increases the shear capacity as the web area increases. If the self-weight of plate girder is minimum economy can only be achieved.

Gi- Ha Eom, et al.(2017), analysed about concrete plate system / I girder was achieved by the optimum cross sectional design. The test was conducted to evaluate the performance by constructing a single 20m to girder / plate system and two 20m to girder bridges . From this test failure behaviour, load carrying capacity, crack pattern, etc. are obtained. In this research the results are discussed in detail.

Kavitha, et al. (2015), this project involves the design of a grade separator at an intersection. The structure of the grade separator comprises of a deck beam, a pier, and a slab. The columns are designed to support the deck beams.

From the above discussion, it is observed that most of the studies are oriented towards the strength evaluation of plate girders for different combination. In the present work, the effect of shear strength and bending stress in plate girders are studied for Girders with and without stiffener plates.

III. Methodology

A. *Modelling of Plate Girder*

The plate Girder is Modelled using STAAD-Pro Software. The various properties adopted in modelling the girder are discussed below.

1) *Geometry:*

The structural model is prepared as I-section with three Plates. Span L in m, Depth d and breadth b are in mm are designed using nodes.

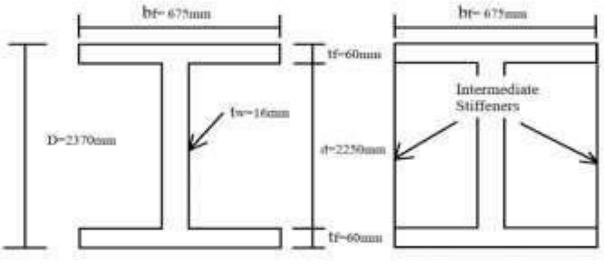

Fig. 1: Cross-section of Plate Girder with and without stiffeners

The cross section of the plate girder is shown in fig.1. The top and bottom flange has a thickness of 60 mm , thickness

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of web is 16 mm, breadth of the flange is 675 mm, height of the I section is 2370 mm and span of the model is 36000mm.

In the present investigation steel plates of thickness 60mm as per the capability of plate for with or withoutstiffeners are investigated and find the comparative parameters of plate stress.

2) Properties:

- For both top and bottom flange thickness remains same, and also web thickness.
- We are adding the top plate, bottom plate and webplate for the designed plate girder.
- Span of 36m is divided sufficiently with 2 and 3 stiffeners at a distance of 9m respectively.
- Properties are assigned with respect to plates.
- After assigning the properties, the plate meshing is carried out for square plates of length/breadth ratio 1. Meshing of I-section is carried by AB:CD ratio that is 2:30.

3) Materials:

Modelling of the girder is carried out using IS Steel sections prescribed by the code and the same is adopted in defining the cross sections of the structural members.

4) Support:

Fixed supports are provided on the one end and hinged supports are provided at the other end andalso to connect plates to stiffeners after meshing.

5) Loading:

The combination of UDL and point loads is adopted in the present investigation. A magnitude of 50 kN/m and point loads of 400 kN are considered as shown in Fig. 2. Parameters considered in the study include Plate thickness and different number of stiffeners.

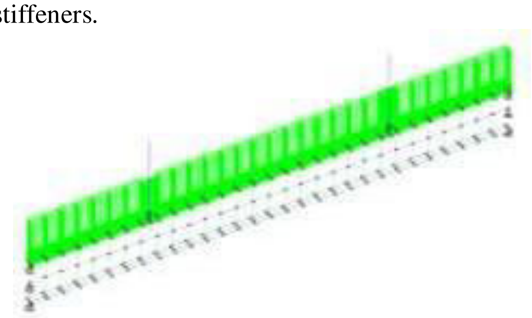

Fig. 2: Loading on the girder plate

TABLE 1: PLATE PARAMETERS

Span in meter	No. of Stiffeners	Steel Plate Thickness
36	0	60
	2	60
	3	60

The models are represented in the form of $M_{\text{no. of stiffener/span-plate thickness}}$. Table 1 represents the various spans considered in the study. For a 36 m span girder with 2 stiffeners of 60mm thickness, the $M_{2/36\text{-}P60}$ is the symbolic representation of the models.

6) Analysing:

- After loading, all the models will be analyzed without any error.
- The displacement, reactions, deflection, plate results value that includes bending resistance, shear force are obtained for all the models generated as shown in Fig. 3.and 3D rendered image of the model in Fig.4.
- Comparative studies are performed for various plate parameters and the results with varying plate thickness is interpreted for ideal strengthening of the girder. A relative improvement in strength on up- gradation of steel plate with that of laminated plate is also investigated.

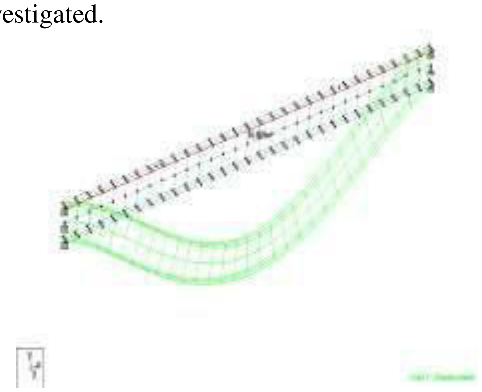

Fig. 3: Displacement diagram for 36m span model

Fig. 4: 3D Rendered Diagram of Plate Girder with 3 stiffeners

IV. Interpretations Of Results

Design has been carried out by referring Textbook[6] for validation of the results.

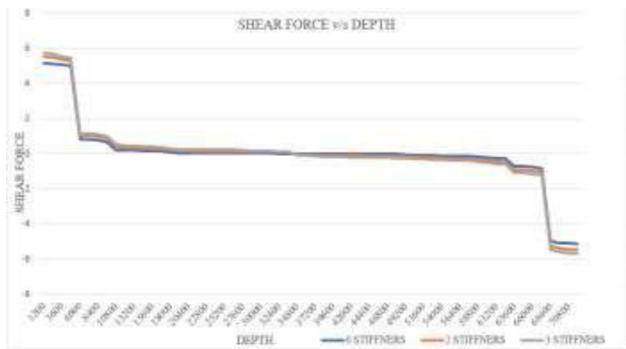

Fig: Shear v/s Depth Force Graph

As per the previous studies, we know that shear force is maximum at the ends.

As per our present study, for without stiffeners shear force has been found maximum for 0 stiffeners is at 0.202 N/mm^2 and minimum at -0.202 N/mm^2.

Thus stiffeners are provided at equidistance from the midpoint of the span. With respect to the design, for 36m span 2 stiffeners are provided at a distance of 12m from the centre. The shear force has been found maximum for 2 stiffeners is at 0.365 N/mm^2 and minimum at -0.365 N/mm^2. Further analysis is done for three stiffeners in which the stiffeners are provided at 9m from the centre of the span. The shear force has been found maximum 3 stiffeners is at 5.14 N/mm^2 and minimum at -5.126 N/mm^2.

From the above result we can justify that as the stiffeners are added to girder span the values are increasing, thus increase in shear forces results for better design of the structure.

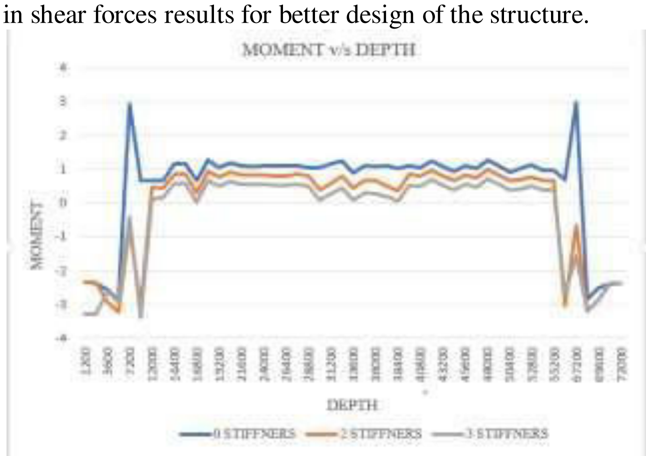

Fig.: Moment v/s Depth Graph

- As per the previous studies, we know that moments are maximum at the mid span and atpoint loads.
- In current study, the moment can be seen maximum where the point loads are applied onthe span.
- For girder without stiffeners, moment can be seen maximum where the point load is applied.
- For girder with 2 stiffeners, moment will be high where the point loads are provided and sudden decrease in moment is found at the stiffeners.
- For girder 3 stiffeners, moment will be high where the point loads are provided and suddendecrease in moment is found compare to 2 stiffeners, 3 stiffeners will be maximum.
- As we compare the moment difference between without stiffener,2 stiffener and 3 stiffeners with the help of moment v/s depth graph, whereas 3 stiffeners is showing very lesser moment in the place where we provided the stiffener compare to others.
- Hence we can conclude that in present study for 36m span 3 stiffeners are sufficient to withstand the shear and moment acting on the girder.
- Hence we can say lesser the span, less number of stiffeners are adequate.

V. Conclusions

When the web of plate girder is without stiffeners, it proves insufficient. Stiffeners are provided to the plate girder to meet certain requirements like Intermediate web stiffeners are provided to improve the buckling strength of web to shear and load carrying stiffeners are provided to prevent local buckling of the web due to concentrated loading. However when thick web plates are used, the stiffeners are not required since the web can itself resist the shear forces at the section without buckling. Hence the stiffener is safe against buckling.

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