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Buckling Analysis of Plate Girder with Corrugated Web

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ABSTRACT

The corrugated steel profiles is widely used in many fields because of its favourable properties and has been applied since the 1920s.It has been increasingly used in web of steel and composite bridges and it increases the shear capacity of web. The corrugated web beams behaves in which the bending moments and applied forces are transversed only via flanges, while the transverse forces are only transferred through the corrugated web. This paper aims to develop three dimensional model using ANSYS 16.1 to study the effect of trapezoidal corrugated shape and compare this with plate girder with stiffeners. This software is employed to find the behaviour and ultimate load capacity of girders. Parametric study was conducted on the trapezoidal corrugated web and this involves the influence of corrugation angle, corrugation thickness and influence of the loading position. Then comparative study was done with plate girder with transverse stiffeners and find out the effect of stiffeners on the plate girder.

Keywords: Corrugated webs, Plate girder, Finite element analysis, Ultimate load carrying capacity, ANSYS.

I. INTRODUCTION

The plate girders are typically I-beams made up from separate structural steel plates (rather than rolled as a single cross-section), which are welded or, in older bridges, bolted or riveted together to form the vertical web and horizontal flanges of the beam used to support the horizontal surface of a bridge. In some cases, the plate girders may be formed in a Z-shape rather than I-shape. Plate girder bridges are suitable for short to medium spans and may support railroads, highways, or other traffic. Plate girders are usually prefabricated and the length limit is frequently set by the mode of transportation used to move the girder from the bridge shop to the bridge site. Plate girders are commonly used in bridge structures where large transverse loads and spans are encountered.

The main objective of this study is to determine the buckling strength of corrugated web subjected to uniformly distributed load. Also to check the economy and compared it with plane web plate girders and plate girder with transverse stiffeners. Stiffeners are secondary plates or sections which are attached to beam webs or flanges to stiffen them against out of plane deformations. Almost all main bridge beams will have stiffeners. However, most will only have transverse web stiffeners, i.e. vertical stiffeners attached to the web. Deep beams sometimes also have longitudinal web stiffeners. Flange stiffeners may be used on large span box girder bridges but are unlikely to be encountered elsewhere. Transverse stiffeners eliminates local buckling and it is also help to connecting the bracing and transverse beams. Though the corrugated webs are not commonly used in India but are used commonly in foreign countries. High-performance steels, which are becoming increasingly available, are well suited for highway bridge applications due to their high strength, excellent toughness, as well as good weld ability. Many types of corrugations are possible rectangular, trapezoidal, triangular and sinusoidal. Use of corrugated webs increases the shear stability and eliminate the need for transverse stiffeners. As we know, plate girders have the maximum moment carrying capacity than any other rolled sections. To avoid this buckling and to gain maximum strength we are focusing on providing corrugations to the web. The purpose of using corrugated web is that it allows the use of thin plates without the need of stiffeners thus it considerably reduces the cost of beam fabrication and improves the fatigue life. Also it improves the aesthetics of structures. In this research the finite element models of plane web as well as corrugated webs are developed and analysis is performed by using ANSYS software. There is less literature available on application of corrugated web. The result of available studies indicates that the strength of these girders can be higher as compared to girders with stiffened or un-stiffened web.

II. METHODS AND MATERIAL

Non linear finite element analysis is done to study the effect of transverse stiffeners on plate girder and compare it with the plate girder with corrugation. For this the parametric study done on the trapezoidal corrugated shape. The ultimate load carrying capacity of plate girder having length 24 m is being studied. The transverse stiffeners are flat sections having dimension 110 x 12 mm are taken. The boundary conditions are one end fixed and other end hinged. Models of plate girder with stiffeners and corrugated web is shown in Fig 1 and Fig 2. The notations of the geometry of the corrugated web is given in Fig 3. Dimensions of the plate girder with transverse stiffeners are given below.

Length of girder =24000 mm
Overall depth of girder =21000 mm
Width of flange =560 mm
Thickness of flange = 50 mm
Thickness of web =10 mm

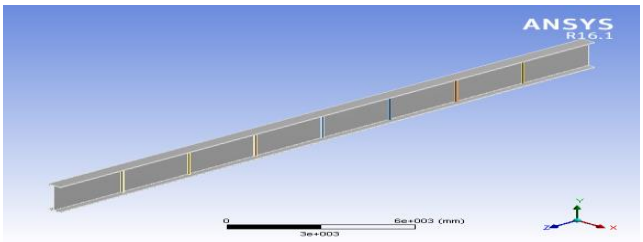

Figure 1. Plate girder with stiffeners

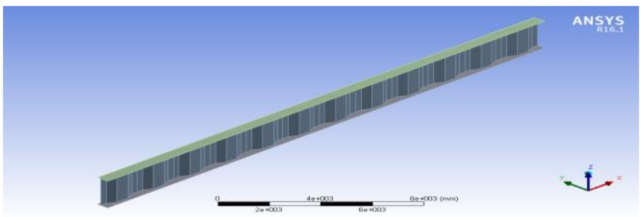

Figure 2. Plate girder with trapezoidal corrugation

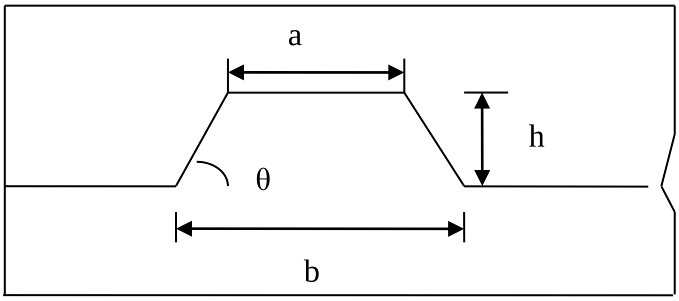

Figure 3. Notations of the geometry of corrugation

III. RESULTS AND DISCUSSION

A. Effect of transverse stiffeners

The spacing of the stiffeners on the plate girder is not greater than 1.5 d and not less than 0.33 d where d is the depth of the web. So the spacing of the stiffeners are in between 660 to 3000 mm. For study the effect of transverse stiffeners the number of stiffeners varies as 7,9,11,13,15 and spacing changes from 1500 mm to 3000 mm. Then it compared with the plane plate girder. The details of the models are given on Table 1 and load deformation curve shown in Fig4.The weight comparison is shown in Fig 5. Result comparison of plate girder with transverse stiffeners with different spacing is given in Table 2.

Table 1. Details of the models having transverse stiffeners

Number of stiffeners	Spacing between stiffeners (mm)
15	1500
13	1714.3
11	2000
9	2400
7	3000

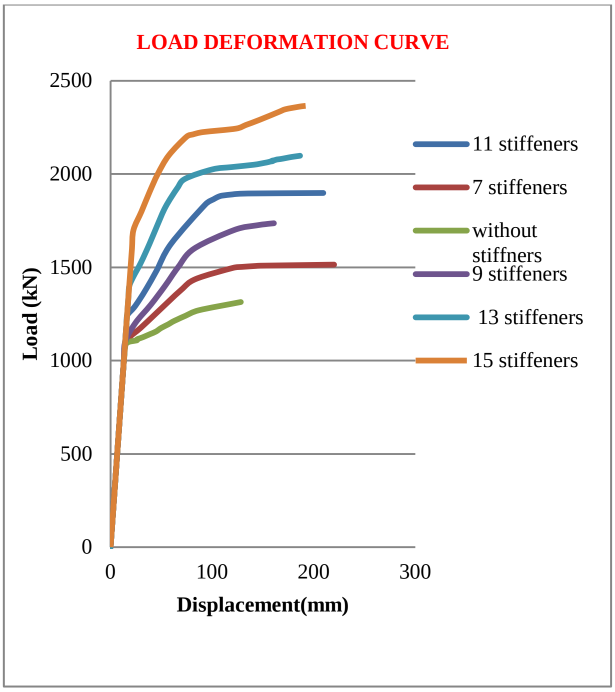

Figure 4. Load deformation curve of plate girder with transverse stiffeners

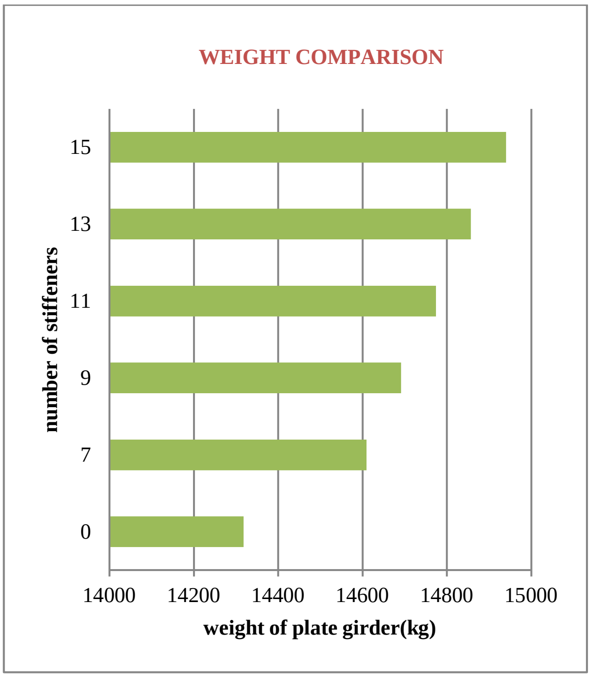

Figure 5. Weight comparison of plate girder with stiffeners

The analysis shows that the transverse stiffeners increases the load carrying capacity but cannot save the cost of steel. Load carrying capacity was inversely proportional to the spacing between the stiffeners. When spacing was reduced from 3000 to 1500 mm, load carrying capacity increased by 35.9 % and the weight of plate girder with 15 number of stiffeners was 4.2 % more than that of plane plate girder. So it leads to use the corrugated web in plate girder instead of transverse stiffeners.

B. **Effect of angle of corrugation**

Four girders with corrugation angle θ=15º, 30º, 45º, 60º are considered here. The other geometric parameters kept constant are overall height of plate girder = 2100 mm, length of plate girder = 24000 mm, thickness of web t_w =7 mm, number of folds =12, height of fold (h) =100 mm, width of flange b_f = 560 mm. In every case spacing between two folds kept constant as 2000 mm. The ultimate load capacity of trapezoidal corrugated web was compared with the plate girder with 15 number of transverse stiffeners and that of the plane plate girder are given in Table 2. The weight comparison table of trapezoidal corrugated web plate girder with plate girder with 15 number of stiffeners is given in Table 3.

Table 2. Ultimate load carrying capacity with varying corrugation angle

Angle of corrugation	Ultimate load (kN)	% increase of ultimate load (than plate girder with 15 stiffeners)	% increase of ultimate load (than plane plate girder)
15º	5890.1	59.8	77.5
30º	5915.9	60	77.9
45º	6398.8	63.02	79.47
60º	6120.8	61.34	78.54

By analysing the Table 2 can understand that load carrying capacity is increased when the corrugation angle is varying from 15º to 45º and then get decreased. Beyond the 60º the trapezoidal corrugation is gradually changed to rectangular corrugation. The displacement of the plate girder with rectangular corrugation is higher than that of trapezoidal corrugated web plate girder and load carrying capacity is less than that of trapezoidal corrugated web.

Table 3. Weight comparison of plate girder with varying corrugation angle

Angle of corrugation	Weight (kg)	% decrease of weight (compared with plate girder with 15 stiffeners)
15º	13221	11.5
30º	13264	11.21
45º	13297	10.9
60º	13340	10.7

C. Influence of thickness (t_w)

To investigate the influence of web thickness on ultimate load carrying capacity girders with the web thickness of t_w =6 mm, t_w =7 mm, t_w =8 mm are considered. Geometric parameters kept constants are overall height of plate girder = 2100 mm, length of plate girder = 24000 mm, number of folds =12, height of fold (h) =100 mm, Angle of corrugation θ = 45º ,width of flange b_f = 560 mm.

To study the effect of thickness on web portion, uniformly distributed load is applied at the top flange portion throughout the area. Plate girder used in the case of bridges have min web thickness of 6 mm. Fig 6 shows the load deformation curve of varying web thickness obtained in the finite element analysis are plotted .Table 4 shows the ultimate load comparison of plate girder with varying the web thickness and it is compared with the web thickness of 6 mm.

From the Table 4 show that the load carrying capacity is directly is directly proportional to the web thickness because as the web thickness increases the web becomes so stiff and it can withstand more load. This shows that relation between web thickness, stiffener thickness and flange thickness is an important factor of load carrying capacity of girder . Here the web thickness changes from 6mm to 8mm, the load carrying capacity get increased 21.4 %. In this thesis only study the thickness of web, other factors are not studied because of the limited space.

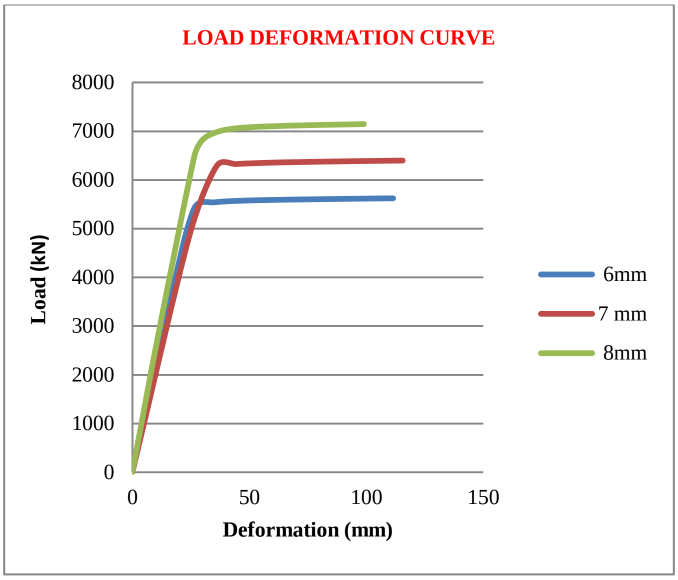

Figure 6. Load deformation curve of plate girder with varying web thickness

Table 4. Ultimate load comparison with varying web thickness

Web thickness (mm)	Ultimate load (kN)	% increase of ultimate load compared with web thickness 6mm
6	5623.7	
7	6398.8	12.11
8	7162.6	21.4

D. Influence of loading position

For finding the effect of loading position a simply supported girder with trapezoidal corrugated web plate girder having following dimensions are taken, length of girder =1000mm, overall depth of girder = 1500 mm, thickness of web t_w=2mm, thickness of flange=10mm, width of flange =250mm, corrugation angle θ = 45º, Sub panel width a=140 mm, length of oblique part l = 70.71, loading length c= 40 mm. The influence of the following three loading positions are (Fig 7) namely.

(1) Centre of flat part of corrugation
(2) Corner of corrugation
(3) Centre of oblique part of corrugation

For finding the effect of loading position patch load is applied at the centre of flat part, centre of oblique part, and at the corner portion . Patch load is applied at the distance of 500mm, 430 mm and 595mm for the above case respectively.

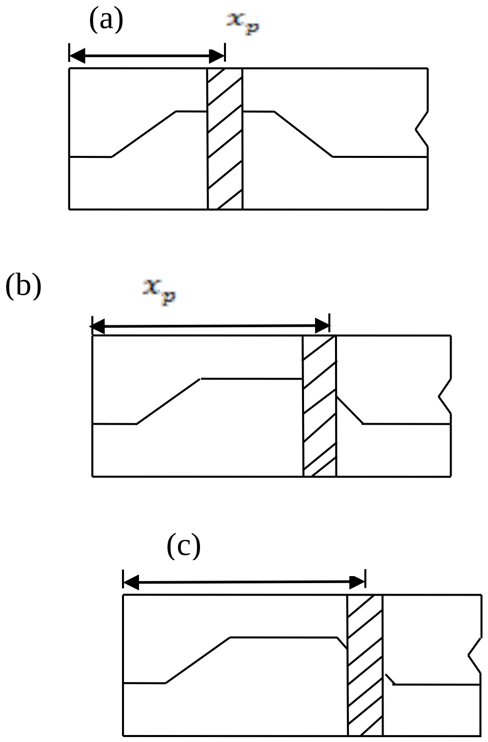

Figure 7. Three loading positions (a) loaded at the centre of flat part (b) loaded at the corner part (c) loaded at centre of oblique part

Load deformation curve (Fig 8) is obtained by the finite element analysis are plotted .From Fig 8, it can be noted that, when load is applied at the flat part load capacity decreases gradually, but when the load is applied at the centre of oblique part and at the corner load carrying capacity decreases rapidly after the ultimate load is reached. Here the load applied at the oblique part is nearer to the central axis of the beam so it has higher load carrying capacity, but load applied at the flat portion is far away from the central axis so it has less load carrying capacity .

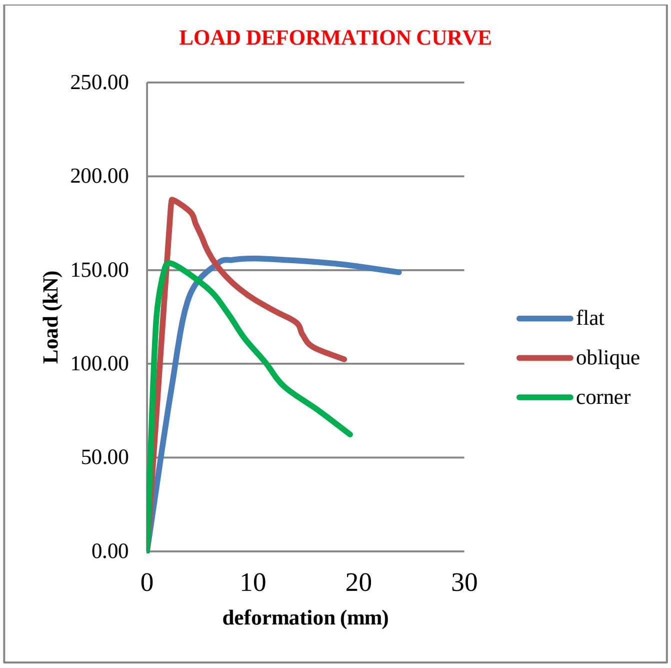

Figure 8. Load deformation curve of plate girder with varying the loading position

IV.CONCLUSION

In this work was studied the effect of transverse stiffeners on plate girder and it was compared with plate girder with corrugated web. Then parametric study was done on the plate girder with trapezoidal corrugated web then findout the ultimate load carrying capacity of plate girder. The parametric study involves the effect of corrugation angle, effect of corrugation thickness, effect of loading position .The conclusions obtained was given below.

- Transverse stiffeners helps to increase the load carrying capacity of the plate girder.
- Load carrying capacity is increased by decreasing the spacing between the stiffeners.
- Number of stiffeners used for analysis was 7,9,11,13 and 15. when number of stiffeners increased from 7 to 15, load carrying capacity increased by 35.9 %.
- Load carrying capacity get increased from 15º to 45º angle of fold and then get decreased.
- Trapezoidal corrugated web of 7 mm web thickness and 45° angle of fold having load carrying capacity 63.02 % higher than that of the plate girder with 15 numbers of transverse stiffeners.
- Corrugated web is economical than plate girder with zero stiffeners and plate girder with transverse stiffeners.

- When load is acting on the oblique part of the trapezoidal corrugation has higher load carrying capacity than flat and corner part of the corrugation.

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