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Buckling Analysis of Plate Girders with Rectangular Corrugated Web

Gaya K Vinod[1], Manju P M[2]
[1](Department of Civil Engineering, SNGCE, India)
[2](Department of Civil Engineering, SNGCE, India)

Abstract: *Plate girders became popular in the late 1870's, when they were used in construction of railroad bridges. The plates were joined using angles and rivets to obtain plate girders of desired size. By 1940's welded plate girders replaced riveted and bolted plate girders in developed world due to their better quality, aesthetics and economy. The corrugated steel plates are widely used structural elements in many fields of application because of its numerous favorable properties. To increase the shear capacity of web for large steel plate girders, the web with different types such as tapered web, haunches, corrugations of different shapes are used. Corrugated steel panels have been recognized as excellent load carrying members. In this project the buckling strength of plate girders with different corrugation parameters were compared and it was established that corrugated web plate girders are better than plane web plate girder.*

Keywords - *Buckling Strength, Corrugated Web, Finite Element Analysis, Moment Carrying Capacity, Plate Girder.*

I. Introduction

In present study webs with rectangular corrugations were used [1]. The main objective of this project was to compare the buckling strength of corrugated web plate girders with different corrugation parameters [2]. Also to compare the stiffness of plate girders with corrugated web [3].Though the corrugated webs were not commonly used in India they were used commonly in foreign countries. As we know, plate girders have the maximum moment carrying capacity than any other rolled sections used. To carry the moments, the section has to be slender and the slender sections are susceptible to web buckling. So the webs lose its buckling strength. Hence to avoid this buckling and to gain maximum strength we provide corrugations to the web. The purpose of using corrugated web is that it permits the use of thin plates without the need of stiffeners; hence it considerably reduces the cost of beam fabrication and improves the fatigue life. Also it gives good aesthetics to structures. In this thesis the finite element models of corrugated webs were developed and analysis was performed by using ANSYS 14 software. The literature available on application of corrugated web is less. The results of available studies indicate that the strength of these girders can be higher as compared to girders with stiffened or un-stiffened web.

II. Scope of the Study

The corrugated steel plate is a widely used structural element in many fields of application because of its numerous favorable properties. To increase the shear capacity of web of large steel plate girders, the web with different patterns such as tapered web, haunches, corrugations of different shapes are used. Corrugated steel panels have been recognized as excellent load carrying members. The scope of this project is to compare the buckling strength of plate girders with different corrugation parameters and to establish that corrugated web plate girders are better and economical than plane web plate girder.

III. Outlay of the Study

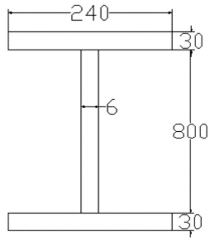
In this study the finite element models of corrugated webs with different corrugation parameters were developed and analysis was performed by using ANSYS 14 software. The results obtained from analysis were then compared to find the plate girder with highest buckling strength.

During this study following cases were taken into account.

Case 1:- Compare the buckling strength of plate girders with corrugated web plate girder based on different corrugation parameters.

Case 2:- Compare the buckling strength of plane web plate girder with corrugated web plate girder with highest buckling strength.

IV. Design of Plate Girder as per IS 800-2007



Data: Length = 6000 mm
Section classification as per IS 800-2007

$\frac{d}{t_w}$ = 400 > 126ε, therefore web is slender.

$\frac{d}{t_w}$ = 200 > 126ε, therefore web is slender.

$\frac{d}{t_w}$ = 133.33 > 126ε, therefore web is slender.

$\frac{b}{t_f}$ = 8 < 8.4ε, therefore flange is plastic.

V. Finite Element Analysis

Plate girders of corrugated web with different corrugation parameters were modelled in AutoCAD 2012 and exported to finite element software ANSYS 14 for analysis.

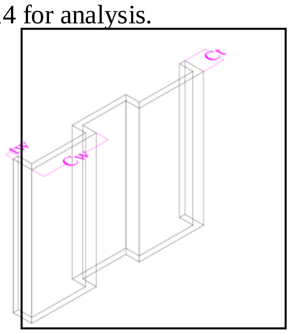


Fig.1. Corrugation Parameters

Table 1. Variation in Corrugation Properties

Web thickness (t_w) (mm)	Corrugation Width (C_w) (mm)	Corrugation Thickness (C_t) (mm)		
2	100	10	20	30
	200	10	20	30
	400	10	20	30
4	100	10	20	30
	200	10	20	30
	400	10	20	30
6	100	10	20	30
	200	10	20	30
	400	10	20	30

Table 2. Geometric Parameters of Plate Girders with Corrugated Web

Web height (h) (mm)	Web thickness (t_w) (mm)	Flange width (b_f) (mm)	Flange thickness (t_f) (mm)	Corrugation Width (C_w) (mm)	Corrugation Thickness (C_t) (mm)	Overall depth (H) (mm)	Length (L) (mm)
800	2	240	30	100	10	860	6000
	4			200	20		
	6			400	30		

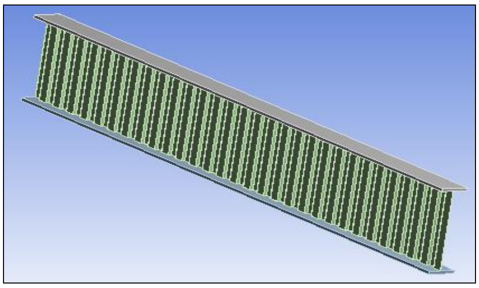


Fig.2. Corrugated Web Plate Girder Model

5.1 Analysis of Corrugated Web Plate Girder

Buckling analysis:-

- Buckling loads are critical loads at which certain types of structures become unstable. Each load has an associated buckled mode shape; the shape that the structure assumes in its buckled condition.
- Buckling depends upon the loading conditions and the geometrical and material properties of the structure.
- Buckling analysis gives the buckling strength and buckling behavior of girders.

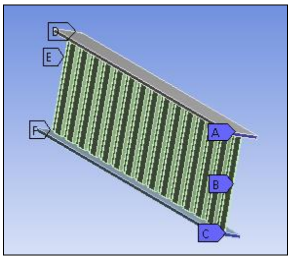


Fig.3. Boundary Condition Application in Software

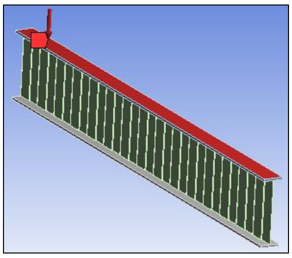


Fig.4. Load Application in Software

5.2 Analysis Results

Typical deformation pattern of a corrugated web plate girder with the following geometric parameters is given below:

Web height, h = 800 mm
Web thickness, t_w = 2 mm
Flange width, b_f = 240 mm
Flange thickness, t_f = 30 mm
Length, L = 6000 mm
Corrugation width, C_w = 100 mm
Corrugation thickness, C_t = 10 mm

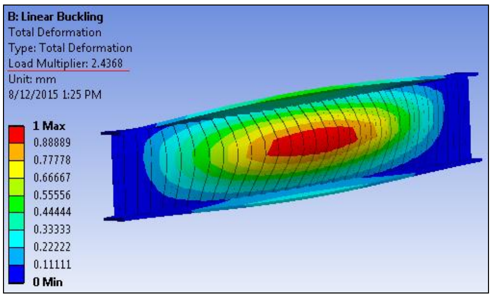


Fig.5. Buckled Shape of Corrugated Web Plate Girder

5.3 Buckling Load Comparison

(i) For t = 2 mm

Table 3. Buckling Load (× 10^3 kN) for t_w = 2 mm

Parameters	C_w = 100 mm	C_w = 200 mm	C_w = 400 mm
C_t = 10 mm	3.509	2.745	0.2767
C_t =20 mm	7.109	5.207	0.389
C_t =30 mm	11.423	8.654	8.553

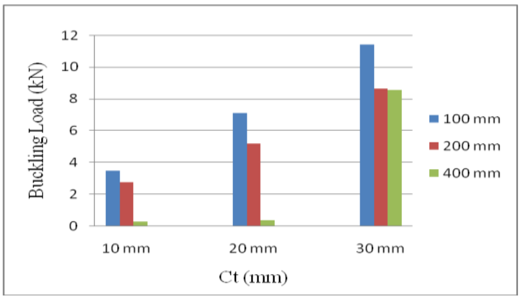


Fig.6. Graph Representing Variation in Buckling Load

(ii) For t = 4 mm

Table 4. Buckling Load (× 10^3 kN) for t_w = 4 mm

Parameters	C_w = 100 mm	C_w = 200 mm	C_w = 400 mm
C_t = 10 mm	4.385	3.426	1.120
C_t =20 mm	10.013	6.860	1.844
C_t =30 mm	15.526	14.776	12.370

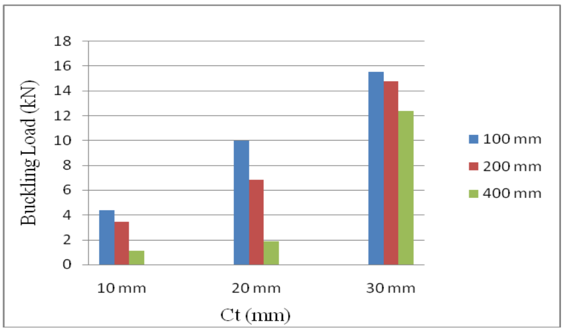


Fig.7: Graph Representing Variation in Buckling Load

(iii) For t = 6 mm

Table 5. Buckling Load (× 10^3 kN) for t_w = 6 mm

Parameters	C_w = 100 mm	C_w = 200 mm	C_w = 400 mm
C_t = 10 mm	6.195	4.778	2.782
C_t =20 mm	12.793	11.387	4.227
C_t =30 mm	18.655	17.902	15.034

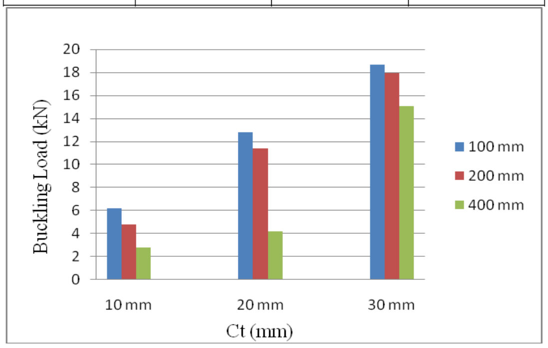


Fig.8. Graph Representing Variation in Buckling Load

From the above graphs it is seen that the plate girder with corrugated web of 6 mm thickness, corrugation width of 100 mm and corrugation thickness of 30 mm have the highest buckling load. So it can be concluded that buckling strength increases with decrease in corrugation width.

VI. Comparison of Corrugated Web Plate Girder with Plane Web Plate Girder

A plane web plate girder with and without stiffeners were modelled and analysed in the finite element software. The weight of the corrugated web of 6 mm thickness, corrugation width of 100 mm and corrugation thickness of 30 mm, for which highest buckling strength was obtained from the analysis, was calculated and this equivalent weight was used to obtain the thickness of the plane web plate girder.

6.1 Weight and Thickness Calculation for Plane Web Plate Girder

(i) Weight Calculations

Data: Length, L = 6000 mm
Web height, h = 800 mm
Web thickness, t_w = 6 mm
Corrugation width, C_w = 100mm
Corrugation thickness, C_t = 30 mm

Weight of stiffeners = 54.26 kg

(ii) Thickness calculation
(a) Without stiffeners
$t_w = 8$ mm
(b) With stiffeners at Both Ends and in the Middle
$t_w = 6.4$ mm

6.2 Analysis of Plane Web Plate Girder
(a) Without stiffeners
Load multiplier obtained for plate girder with plane web is 1.9097
Buckling load obtained = 2749.97 kN
(b) With stiffeners at Both Ends and in the Middle
Load multiplier obtained for plate girder with plane web is 1.7888

Buckling load obtained = 2576 kN

Table 6. Buckling Load (kN) Comparison for Plane and Corrugated Web

Parameter	Plane Web		Corrugated Web	% increase	
	Without Stiffeners	With Stiffeners		Without Stiffeners	With Stiffeners
Buckling Load (kN)	2749.97	2576	18655.2	85.26 %	86.20 %

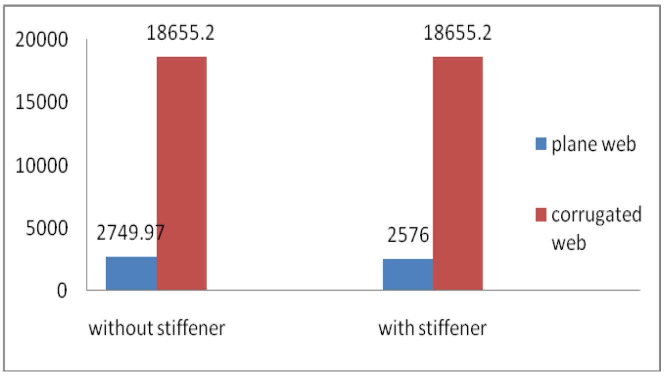


Fig.9. Graph Representing Variation in Buckling Load

From the above graph it can be concluded that the buckling strength of corrugated web plate girder is much more than that of a plane web plate girder.

VII. Conclusions

(i) In this thesis the buckling strength of corrugated plate girders with different corrugation parameters were studied. The variation in buckling strength of these plate girders were plotted with the help of a bar chart and it was observed that the buckling strength of corrugated web plate girder with 6 mm web thickness, corrugation width of 100 mm and corrugation thickness of 30 mm have the highest buckling load. So, it can be concluded that buckling strength increases with decrease in corrugation width.

(ii) The buckling strength of plane web plate girders with and without stiffeners was also studied. The weight of the corrugated web of 6 mm thickness, corrugation width of 100 mm and corrugation thickness of 30 mm, for which highest buckling strength was obtained from the analysis, was calculated and this equivalent weight was used to obtain the thickness of the plane web plate girder. From the buckling strength obtained it was concluded that the corrugated web plate girder have much more buckling strength than the plane web plate girder.

Thus it can be concluded that the buckling strength of corrugated web plate girder increases with decrease in corrugation width, also, corrugated web plate girder have more buckling strength than plane web plate girder. So, corrugated web plate girder is much better than plane web plate girder.

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