International Journal of GEOMATE, Sept. 2022, Vol.23, Issue 97, pp.180-187
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2022.97.3436
Geotechnique, Construction Materials, and Environment

EXPERIMENTAL BEHAVIOR OF BUILT-UP STEEL GIRDER WITH CORE WEB HAVING TRAPEZOIDAL CORRUGATED PANEL

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ABSTRACT: Girders with corrugated webs have multiple desired characteristics, including high shear strength and stability, lightweight, extended fatigue life, and reduced construction cost. As a result, they have been used to replace conventional flat web girders in newly completed structures. Two plates (skins) and one center corrugated plate are used to make a core web with a corrugated plate. The beneficial features of the corrugated web are increased by employing the corrugated core web rather than just the corrugated web. Several experimental experiments were carried out in this work to evaluate the behavior of steel plate girders with corrugated core webs under shear force. Nine simply supported girders were built and tested under mid-span concentrated stresses. Trapezoidal corrugated steel web was used in this study. Three shear span-to-depth ratios (a/d) of 1.0, 1,83, and 2.5 were examined. This study also looked at the influence of core thickness on girder performance. Two core thicknesses were examined (30 and 60 mm), and three standard flat web girders were built and tested for comparison. The tested beams' maximum displacement, ultimate load, and load-deflection diagrams were recorded and compared. Among the conclusions drawn in this study that the ultimate load capacities at a/d of 2.5 and 1.833 were lower by about 16% to 29 %, respectively, compared to the corresponding values at a/d =1.0. The core thickness was also determined to play a significant role in the behavior of the tested girders.

Keywords: Core web, Trapezoidal corrugation, Steel beam, Experimental test, Shear span

1. INTRODUCTION

Steel plate girders are efficient and have been widely used in bridges, industrial buildings, and many other structures [1,2]. In recent years, vehicle loads have increased rapidly, overstressing bridge elements, reducing service life, increasing repair costs, and even causing collapse [3]. Using standard steel plate girders in constructions with long spans and/or bearing significant loads may necessitate the use of very deep girders, which may result in web buckling issues [4,5]. As a result, the need has arisen to develop lighter and more efficient steel structures. Steel girders with corrugated webs have been investigated as an alternative to the traditional flat web (FW) girders. Over the past forty years, several experimental and numerical research works have been conducted to address the flexural and shear behavior [1, 6-11], torsional behavior [1,12,13], and fatigue life [14,15] of plate girders with the corrugated web. Different patterns of web corrugation were examined. According to the abovementioned researchers' experimental and computational analyses, steel girders with corrugated web exhibit superior shear strength, stability,out-of-plane stiffness, low weight, and fatigue life [1,3,4,5].

Recently, corrugated web manufacture has been mechanized (Fig. 1), and corrugated webs of various forms (trapezoidal, rectangular, triangular, sinusoidal) have been produced and employed. The automated technique enhanced productivity and cut labor costs dramatically [1,3,7,16,17].

Fig.1 Automated production process of beams with corrugated webs [17]

Many bridges and industrial buildings have been constructed using girders with corrugated steel webs [3,16,17,18,19]; examples of structures built using corrugated webs are shown in Fig. 2.

(a) Industrial Building [2]

(b) Crane way Column [17]

(c) Composite Bridge [2]

Fig.2 Structures with corrugated webs.

A corrugated plate core web is made by attaching two plates (skins) to a corrugated web (as shown in Fig. 3). By adopting a corrugated core web rather than a single one, advantageous qualities such as greater shear capacity, improved stability, and out of plane stiffness are enhanced [20,21,22].

2. RESEARCH SIGNIFICANCE

Enhancing plate girder properties such as strength, stiffness, and stability using the corrugated core web instead of a flat plate or even solely corrugated web is essential to designing and constructing economically efficient structures. Understanding the behavior of steel girders with core webs and corrugated plates is critical for understanding their performance in various construction applications. Several factors influence girder behavior, ultimate load capacity, and failure mode. Shear span to depth ratios and core thickness are two characteristics that researchers believe substantially affect girder performance. Such characteristics influence the buckling strength of the web and, eventually, the final strength of the girders. This study investigates the behavior of steel girders with the trapezoidal corrugated core web. Several girders with different span to depth ratios and core thicknesses are fabricated and tested until failure.

3. EXPERIMENTAL PROGRAM

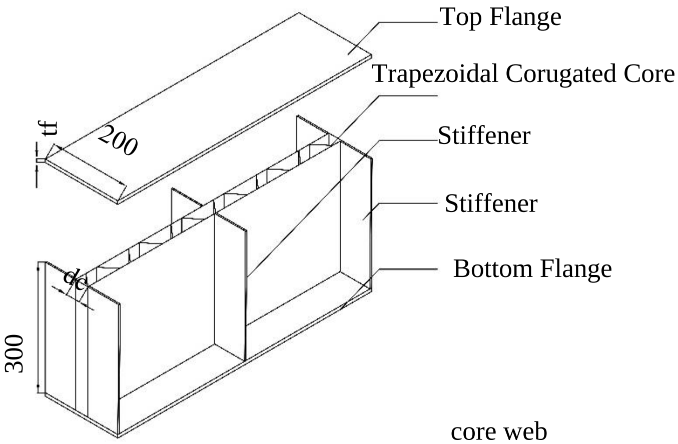
To accomplish the study's goal, nine simply supported girders with three a/d, and two core thicknesses were built and tested to failure. The tested specimens were divided into three groups which are three girders with flat webs, three girders with a core that has a trapezoidal corrugated web with 30 mm core thickness, and three girders with a core that have a trapezoidal corrugated web with 60 mm core thickness (See Fig.3 and Fig. 4).

The three girders in each group were designed to have a/d equals 1.0, 1.8333, and 2.5, respectively. the span length for the tested girders was 600 mm, 1100 mm, and 1500 mm. The same web height (300 mm), flange width (200 mm), and flange thickness (6 mm) were used for all the specimens. The specimens for each group were intended to have the same weight. Table 1 shows the material properties of the plates used in this work; the dimensions of the tested specimens are presented in Table 2.

Figures. 5 and 6 depict the specimen preparation and testing processes. All of the specimens were tested with a mid-span concentrated load. The load-deflection curves, as well as the failure load and maximum deflection, were recorded

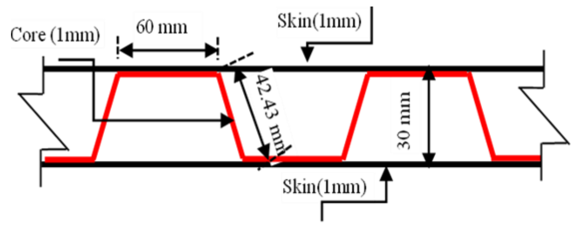
Table 1 Properties of the tested plates

Element	Strength (MPa)		Modulus of Elasticity (GPa)
	Yield	Ultimate	
Flange /stiffener	358	467	205
Flat web	402	455	203
Corrugated plate / Skin	305	410	206

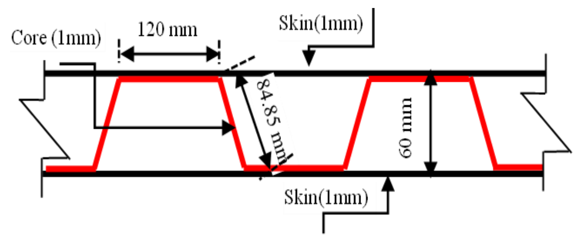


core web

having a trapezoidal corrugated plate.



(a) SCW30



(b) SCW60

Fig. 4 Details of the Core girders with trapezoidal corrugation used in this study.

Table 2 Dimensions of the flat web and core web girders

No.	Group	dc (mm)	(a/d)	Dimensions (mm)						span
				b_f	t_f	h_w	t_w	tc	ts	
1	A Flat web		1	200	6	300	3			600
2			1.833	200	6	300	3			1100
3			2.5	200	6	300	3			1500
4	B SCW30	30	1	200	6	300		1	1	600
5			1.833	200	6	300		1	1	1100
6			2.5	200	6	300		1	1	1500
7	C SCW60	60	1	200	6	300		1	1	600
8			1.833	200	6	300		1	1	1100
9			2.5	200	6	300		1	1	1500

Note b_f = Flange width, t_f =Flange thickness, t_w = Web thickness, t_c = Corrugated web thickness, ts =Skin thickness

(a) Trapizoidall Corrugated plate web

(b) Welding the web to the flanges

(c) Core web (middle corrugated plate and outer skins)

Fig. 5 Samples during construction.

(a) Flat web with a/d=2.5

(b) SCW30 with a/d =2,5

(c) SCW30 with a/d =1.0

Fig. 6 Samples during testing.

4. RESULTS AND DISCUSSION

The bar chart graphic in Fig. 7 depicts the ultimate load capabilities of the three categories, flat web, SCW30, and SCW60, at various shear span to depth ratios. Figures 6–8 show the load-deflection curves for the same categories mentioned above at different a/d ratios. Figures 11–13 are replotting of Figures 8–10 that illustrate the load-deflection curves for all three types of webs (FW, SCW30, and SCW60) for a/d ratios of 1.0, 1.833, and 2.5, respectively.

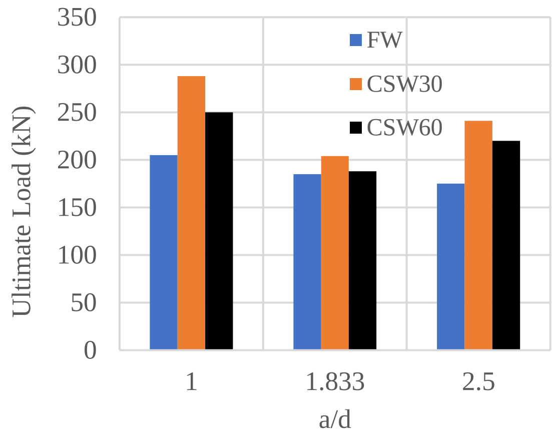


Fig.7 Ultimate load for FW, SCW30, and SCW60 at different a/d ratios.

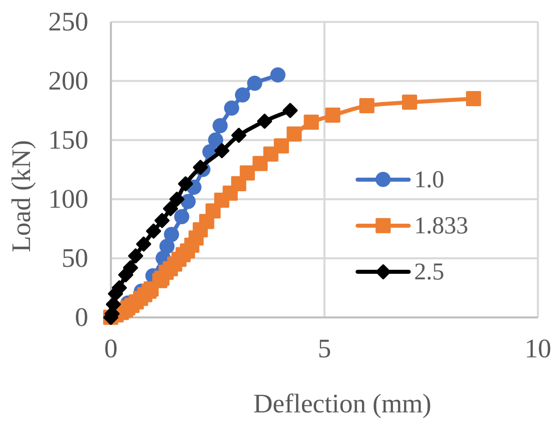


Fig. 8 Load deflection curve for flat steel web girder with different a/d ratios.

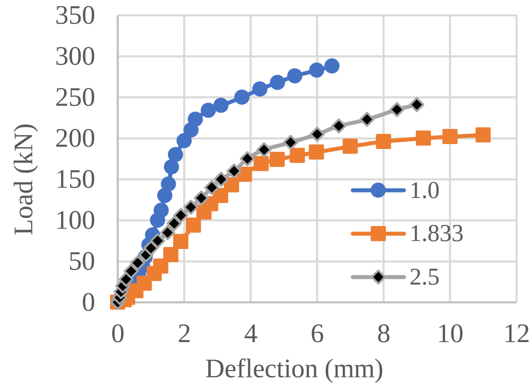


Fig. 9 Load deflection curve for SCW30 at different a/d.

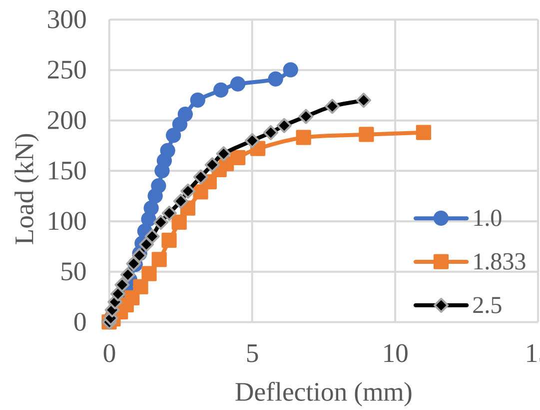


Fig. 10 Load deflection curve for SCW60 at different a/d.

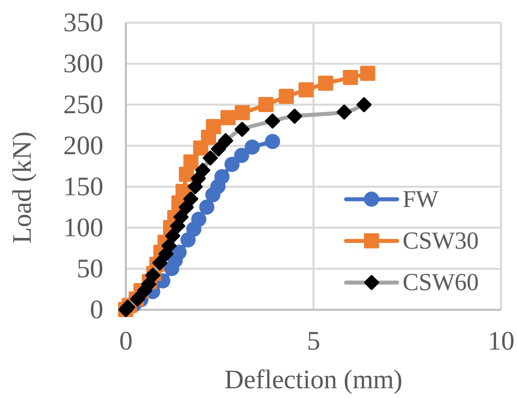


Fig. 11 Load deflection curve for girders with flat web, SCW30, and SCW60 at a/d =1.0.

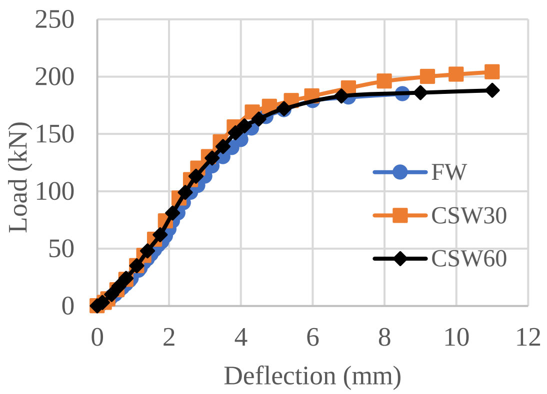


Fig. 12 Load deflection curve for Girders with flat web, SCW30, and SCW60 at a/d =1.833.

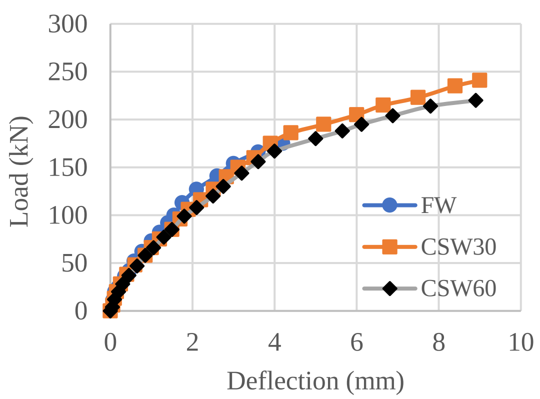


Fig. 13 Load deflection curve for girders with flat web, SCW30, and SCW60 at a/d =2.5.

Table 3 Ultimate load capacities for the tested specimens.

a/d	Ultimate load (kN)		
	Flat web	SCW30	SCW60
1.0	205	288	250
1.833	185	204	188
2.5	175	241	220

The ultimate load for each tested girder is provided in Table 3. The percentage change in ultimate load for each category is presented in Tables 4 and 5.

Table 4 Percentage change in ultimate load compared to a/d=1.0.

a/d	Change in ultimate load %		
	Flat web	SCW30	SCW60
1.0	100	100	100
1.833	90	71	75
2.5	85	84	88

Table 5 Percentage Change in ultimate load compared to the flat web.

a/d	Change in ultimate load %		
	Flat web	SCW30	SCW60
1.0	100	140	122
1.833	100	110	102
2.5	100	138	126

The following can be observed based on the results obtained from this experiment

- Girders with a/d = 1.0 perform better and have higher load capacity than those with 1.833 and 2.5 in all categories (FW, SCW30, and SCW60). The ultimate load capacities at a/d of 2.5 and 1.833 dropped by roughly 16% to 29% compared to the same values at a/d of 1.0.
- Corrugation notably improves ultimate load capacity and ductility, especially for specimens with a core depth of 30 mm (SCW30), where the ultimate load is enhanced by 40% compared to the same value of a girder with a flat web.
- The core thickness is critical to the performance of girders with core webs. Girders with a core thickness of 30 mm outperform girders with a core thickness of 60 mm in terms of both ultimate strength and ultimate displacement capacity. This is due to the impact of local buckling since the unsupported length of a corrugated web with a core thickness of 30 mm is half that of girders with a core thickness of 60 mm (See Fig. 3).
- Table 3 shows that the ultimate load capabilities of girders with core webs were the lowest, at a/d =1.833, compared to a/d =1.0 and 2.5. The decrease in ultimate load is since shear and flexure interaction effects are more significant than for a/d equals 1.0 and 2.5.

5. CONCLUSIONS

The following conclusions can be noted from the results presented in this work

- The span to depth ratio considerably influences the performance of the tested beams for both conventional girders (with flat web) and girders with trapezoidal corrugated plates in the core web.
- Using a core web with a trapezoidal corrugated plate instead of a conventional flat plate enhanced the tested specimens' ultimate load capacity and ductility.
- The span to depth ratio has noticeable effects on the performance of the tested beams for both conventional girders (with flat web) and girders with core web having trapezoidal corrugated plates.
- The ultimate load capacity of conventional beams and beams with core webs was the highest at a/d=1.0.
- The performance of steel girders with the core web was affected by core thickness; girders with a core thickness of 30 mm perform better in terms of both ultimate load and maximum displacement than 60 mm.

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