University of Tabriz

Journal of Civil and Environmental Engineering
Volume 54 (2024), Issue 1 (Spring), 1-12

EXTENDED ABSTRACT

Evaluation of the Mutual Effect of Shear Force and Bending Moment in Plate Girders with Corrugated Webs

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Received: **Accepted:**

Keywords:
Plate girder, Corrugated web, Interaction of shear force and bending moment, Distributed loading.

1. Introduction

Plate girders are among the main load-bearing elements of large structures such as bridges, which, due to their type of application, must meet the necessary geometric and physical characteristics in terms of hardness and non-buckling. The existence of corrugated web in the bridges greatly increases the bending stiffness of the girder. With the removal of stiffeners, plate girders with corrugated web, in addition to significantly reducing the weight of the structure, save the cost and time required for welding operations, and also significantly reduce the fatigue of girder due to welding operations. This issue can have a significant impact on structures such as bridges that are subject to successive loading and unloading. In plate girders with corrugated web, the bending resistance is created by the flanges of the girder, and the corrugated web does not contribute significantly to it, but it provides the shear capacity of the plate girder to a high extent. The failure in such girders is caused by steel yielding, buckling or interaction of these two phenomena. lateral twisting and local buckling of the flange are also considered as other important criteria of failure in this type of girders. One of the problems that mankind has been constantly facing is the buckling of thin web. Therefore, the determination of the resistance of corrugated web will be of special importance. So far, few studies have been done on the resistance of corrugated web under distributed loading. The purpose of this study is to compare the strength of corrugated and flat web plate girders by considering the interaction effect of shear force and bending moment according to the types of web shapes.

2. Methodology

2.1. Experimental study

To validate the finite element model, the experimental results of Robert G. Driver et al have been used. The comparison of the force-displacement diagram of the G8 laboratory sample with the finite element model by ABAQUS software shows that the maximum resistance value for the laboratory sample and the finite element model will be equal to 364.7 ton and 350 ton, respectively. According to the mentioned values, the calculation error is equal to 4.2%, which is a small amount and can be ignored. This error may be caused by the initial imperfection of the modeled sample.

2.2. FE modeling

In this article, 12 models of plate girder with simple, 7 and 8-shape, angular, triangular and sinusoidal web under distributed loading are modeled using ABAQUS finite element software, then the best girder corrugation form is presented by comparing their resistance. In the following, the resistance of this type of

Publisher: Vice Chancellery for Research & Technology, University of Tabriz
DOI: ---
Online ISSN: 2717-4077

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plate girders with two spans will be investigated. In the recent study, the amount of steel used in all the samples is constant and the type of corrugation, the corrugation distance and the thickness of the web of the plate girders are variable.

Plate girders with one span have 2 fixed supports at both ends, and models with two spans have 2 fixed supports at both ends and an hinged support in the middle of the span. The applied load on two types of plate girder is distributed applied on the upper flange and continues until the final failure. Loading was applied using the modified RIKS method. In addition, stiffeners are placed at the ends of both sides and in the middle of the span of the girders to transfer the load from the flange to the girder and prevent crippling.

In the analysis of the models, the characteristics of the steel used, including the modulus of elasticity equal to 6.1 * 10^6 kg/cm^2, Poisson's ratio equal to 0.3, and the yield stress of steel equal to 2400 kg/cm^2 have been considered. Von Mises yield stress has also been used to model the samples. In the analysis of the models, the non-linear behavior of the materials and the geometry of the models is assumed.

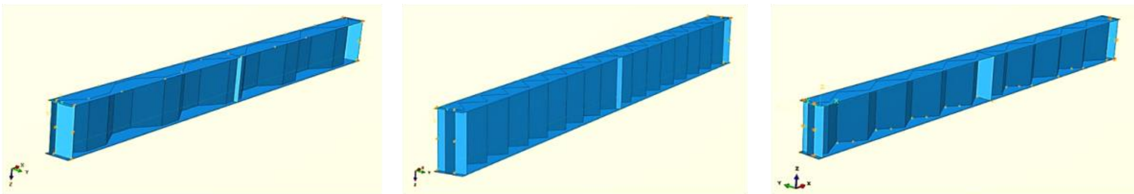
In Tables 1 and 2, you can see the variable values of corrugated webs in girders with simple and corrugated webs. Also, examples of girder modeling with corrugated web by ABAQUS software are given in Figure 1.

Table 1. Geometrical characteristics of 7 and 8-shape and angular corrugated plate girders.

Model	Label	L (cm)	t_w (cm)	a (cm)	b (cm)
7 and 8-shape	SH1	1000	0.69	30	104
	SH2	1000	0.56	30	60
	SH3	1000	0.4	30	34
Angular	SH4	1000	0.74	30	155.86
	SH5	1000	0.663	30	90
	SH6	1000	0.533	30	51.96
	SH8	1000	0.4	30	30

Table 2. Geometric characteristics of simple, triangular and sinusoidal corrugated plate girders.

Model	Label	L (cm)	t_w (cm)	a (cm)	b (cm)
Simple	SH7	1000	0.6	-	-
Triangular	SH9	1000	0.725	155	30
	SH10	1000	0.62	90	30
Sinusoidal	SH11	1000	0.65	25	25
	SH12	1000	0.45	12.5	12.5



(c) (b) (a)

Fig 1. girder models modeled with Abaqus.(a):SH1.(b):SH2.(c):SH4

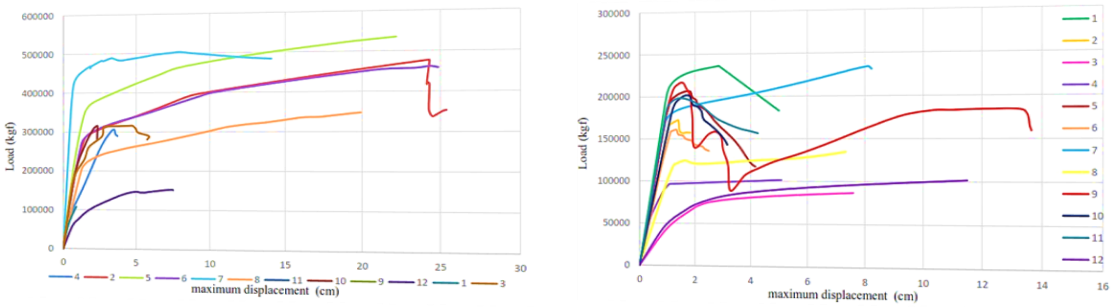
3. Results and discussion

3.1. Numerical models with one span under distributed loading

By investigation the force-displacement diagrams and studying the resistance and deformation of all the numerical models of plate girders with simple and corrugated webs (7 and 8-shape, angular, triangular and sinusoidal) with a span under the effect of distributed loading, it can be understood that SH1, SH7 and SH9 models have the maximum strength between the samples, which indicates the great influence of the wave height (a), the distance of the waves from each other (b) and the thickness of the web (t_w) so that the girders with large fold and the great thickness show the greatest tolerance against the applied loads. Also, by investigation the wave shape of plate girder models, it can be concluded that among all the models, girder with 7, 8-shape and triangular web are the best and the most optimal type of wave shape under the effect of distributed load. In addition, the SH9 and SH12 models have the most deformation among the numerical samples under distributed loading, which indicates the favorable deformation of the girder models with triangular and sinusoidal webs. (figure 2a)

3.2. Numerical models with two spans under distributed loading

Under the same conditions and loading, the study of the force-displacement diagrams as well as the resistance and deformation of all numerical models of plate girders with simple and corrugated webs (7, 8-shape, angular, triangular and sinusoidal) with two spans under the effect of the distributed loading shows that the best and the most optimal form of the girder is the plate girders with simple web and angular web, which show the maximum resistance against the applied loads (Figure 2b). Also, the web thickness in this type of girders has a greater effect compared to the two wave variables (a,b).



(b) **(a)**

Fig 2. Force-displacement diagrams 12 of numerical models.(a): with with one span.(b): with two spans

4. Conclusions

By analyzing all the models with one span, it can be understood that the best and the most optimal shape of web among the samples under the effect of distributed loading are the 7, 8-shape and triangular models, which show the maximum resistance against applied loads. . Also, the study of numerical models shows that the girders with large folds, such as SH1 and SH9 samples, have endured the applied load more than all the samples, so that the more angular the folds, the more resistance they have endured. It can be concluded that folds with larger angles have the best and the most optimal state (such as the SH1 sample). Of course, it should be noted that in all the samples, the steel used is the same, only the shape, type and dimensions of the folds and the thickness of the web, were different due to the constant final weight. Also, the study of corrugated girders with two spans under the effect of distributed loading shows that the best and the most optimal form of the web is the models with a simple web and an angular shape, which show the maximum resistance against applied loads. In addition, the thickness of the web has a significant effect on the resistance of the girders, so that models SH5 and SH7 with a minimum thickness of 6 mm have the maximum resistance among the studied models.

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