Study on the Effect of Corrugated Webs in Steel I-Girder Bridge

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Abstract The corrugated steel webs are used to allow without continuous stiffeners for the steel and composite bridges. This structure has many advantages compared to steel girder with flat web. A corrugated web steel bridge, corrugated steel webs increase the stability of the girder web, increase the torsional stiffness and reduce the weight of the steel girder. It is many beneficial qualities, such as lower dead-load, increased shear buckling strength and so on. In this article, the advantages and applicability of corrugated steel ribs are presented. The comparison between the behaviors of flat steel I-girder and corrugated web steel I-girder is performed to clearly see the effect of the corrugated webs.

Keywords Corrugated web · Steel bridge · Steel I-girder

1 Introduction

The I-girder structures with corrugated webs are widely used in industrial projects and bridges in many countries around the world. Though corrugated webs used not yet for highway bridges in Vietnam, but they have been constructed at many highway bridges in Europe and Japan [1]. Previous studies have shown that girder with corrugated web have a higher elastic critical moment than those with flat web. A lot of research in corrugated webs is focused on shear strength, and very limited studies have been performed on flange buckling and its influence on flexural behavior. In the case of the steel I-girder bridges with flat webs, most of the cross-sections of the girder's web are very thin, especially in the web of the girders (about 10–20 mm). The

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slender sections of the steel I-girders are usually sensitive to affected with buckling especially the web of girders subjected to shear stress. Hence to resist the buckling and shear strength of flat web, the corrugated webs was provided. Therefore, it will withstand greater loads on larger spans [2].

Corrugated steel web I-girders are made from sheet steel with a thin-walled corrugated web and the flanges. Under the action of applied loads, the local or global buckling in the web can be controlled depending on the corrugated form. Normally, the corrugated web of I-girder with trapezoidal shape was used. The weight of this type of girder is significantly reduced compared with hot rolled section or welded sections [3]. The buckling failure of web is prevented by the existence of corrugated web. The buckling resistance of corrugated web is comparable to the thickness of smaller flat webs.

Normally, the steel I-girder bridge requires thin webs, but if the web is less thin, the problem of buckling may arise. Thus, this structure can be improved with a new structure type to improve the web instability of the girder, it is corrugations on the web. The main benefit of the corrugated web girder is to increase the stability of the girder against buckling. A corrugated web I-girder provided a new structural system that has excellent load carrying capacity [4]. When comparing beams with bearing capacity, the weight of girders using corrugated web tends to decrease compared to girders using flat web. This reduction value is about 9–13% according to the study of Hamada et al. [5] and about 10.6% according to the study of Chan et al. [6].

However, corrupted web of girder has many advantages compared between corrupted web and flat web. This paper shows a brief of this study on corrugated steel web I-girder, the comparison between the behavior of steel I-girder and corrugated web steel I-girder is performed. From there, helping consulting companies consider applicability to steel I-girder of bridge structures.

2 Applications of Corrugated Web Girders

The scope of application of this type of structure is quite diverse, which can be applied to both steel girder structures as well as composite girder structures. Especially suitable for girder structures subjected to compression and bending such as cable-stayed bridge girders, extradosed bridges. Many types of corrugations were used in which trapezoidal and sinusoidal shapes are more commonly used. A typical profile of a corrugated web is shown in Fig. 1.

Evaluation of the effect of various types of corrugation shapes and parameters has been studied by Zhang et al. [8] and Li et al. [9]. Chan et al. [6] studied the corrugated webs of arc corrugation, which the research was based on I-beams with a length of 500 mm, a flanged width of 75 mm and a depth of 127 mm. Chan et al. [6] shown that the vertical corrugation produces higher strength than the horizontal corrugation and the plane web, at an average range of 1.8–2.1. The shear resistance of the girder is increased when corrugated steel is used. These corrugated irons can be produced from the hot rolled steel process or stamped from sheet steel. Depending on the scope

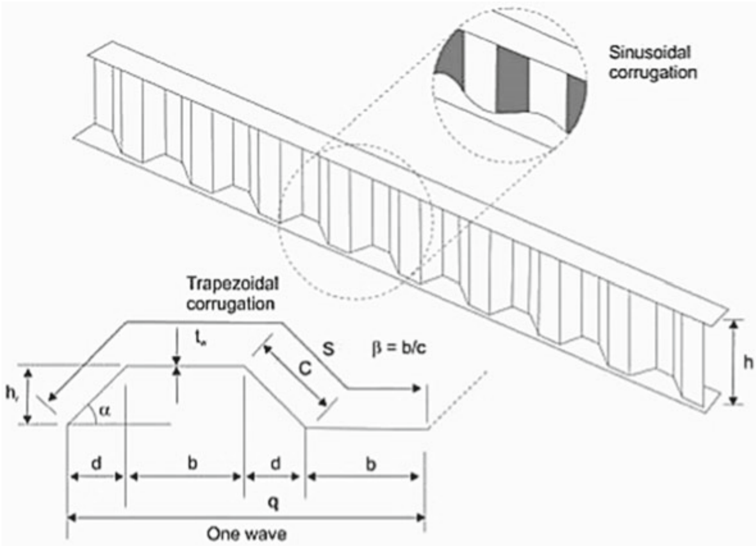


Fig. 1 Profile of I-girder using corrugated web [7]

of application, the dimension of the corrugated web can be changed to match the stability of the girder. Furthermore, reducing the thickness of corrugated web steel for the vertical corrugated webs would reduce more the weight of the girder when compared to the same maximum load between the corrugated web I-girder and the original I-girder.

In this study, to see more clearly the advantages and applicability of corrugated steel girder structure, we analyze two types of girders including a flat web steel I-girder and a corrugated web steel I-girder under the same impact load. From there, consider the effect of using corrugated girder under loading.

3 Structural Behavior of Corrugated Web

The previous studies including theoretical and experimental analysis have shown that the applied shear force is completely resisted by the corrugated steel webs in the I-girder. The bearing capacity and stability of the girder web depends on the height/thickness ratio of the web, the corrugated shape and the effect of defects that may have appeared during the girder's fabrication. In this section, two types of girders are investigated with the parameters of corrugated web as shown in Fig. 2. The parameters of the cross-section's girder are described in Table 1.

In this study, to clearly see the effect of torsion resistance, we use a torque of 10 kN·m/m uniformly distributed around the *X*–*X* axis. Then compare the analysis results between the two types of girders.

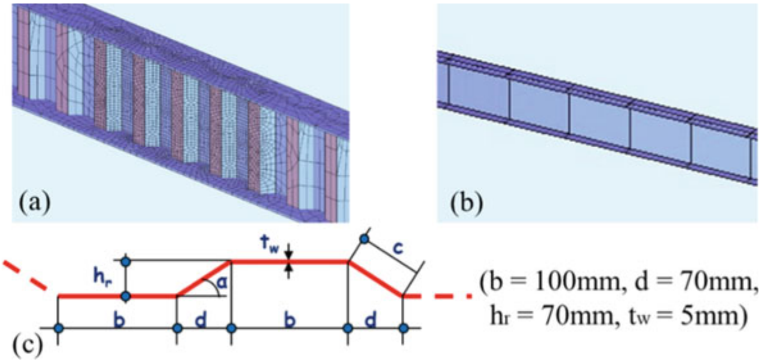


Fig. 2 The geometry of the corrugated web I-girder (**a, c**) and flat web I-girder (**b**)

The material properties of steel used for finite element modeling in this study include: Young's modulus E of 200 GPa, the yield stress of 403 MPa and Poisson's ratio of 0.3.

In this study, to see the effect caused by the shearing and torsion effects, three load cases were used to investigate them. The detailed load is described as follows:

- Self-weight, symbol is LC 1.
- Load uniform distributed (10 kN/m), symbol is LC 2.
- Torsion distributed around *X*–*X* axis (10 kN·m/m), symbol is LC 3.

The analytical results obtained as shown from Figs. 3, 4, 5, and 6 show that:

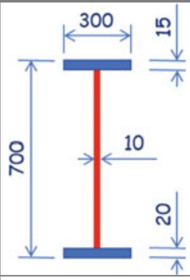
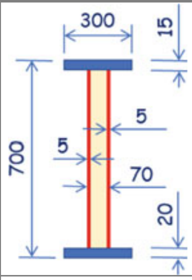
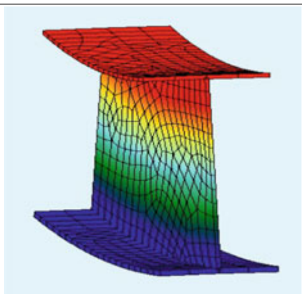
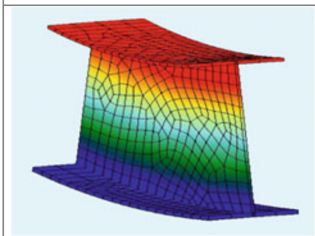
- For the load case LC2: The web of the steel I-girder is more bending (with greater stress) than the web of corrugated web steel I-girder, so the flexural resistance (bending stiffness) of the steel I-girder is higher.
- For the load case LC3: The web of steel I-girder is less torsion (with less stress) than the web of corrugated web steel I-girder, so the torsion resistance of corrugated web steel I-girder is larger than steel I-girder.

4 Conclusions

In this study, we initially survey and compare the effects of two types of girders, consist of types of steel I-girder and corrugated web steel I-girder are investigated. This initial study focusing only through finite element analysis showed a relatively good resistance to instability for corrugated web girders. The study results are also consistent with the results of previous studies.

In the coming time, detailed studies combined with experiments will clarify the effectiveness of this type of structure. From there, it will be applied in bridge projects in Vietnam in the future.

Table 1 Comparison between steel I-girder and corrugated web steel I-girder

	Steel I-girder	Corrugated web steel I-girder
Cross-section		
Total weight (tons)	2.746	2.290
Maximum deflection at mid-span due to self-weight–LC 1 (mm)	8	9
Maximum deflection at mid-span due to uniform static load–LC 2 (mm)	61	74
Maximum angular displacement around *X*–*X* axis due to torque–LC 3 (mrad)	450	290
Image depicting when cutting 1 m of girders in the middle of span		
		

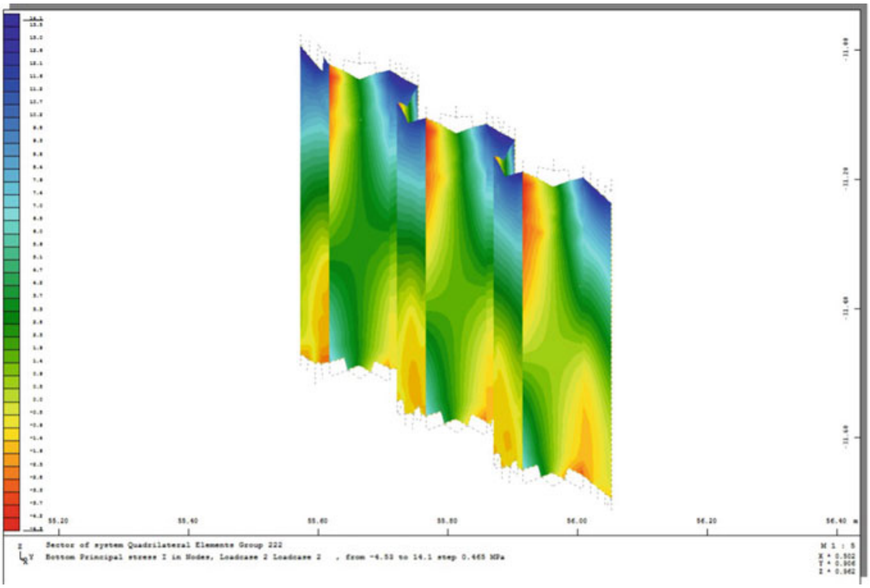


Fig. 3 Stress in web of corrugated web steel I-girder type–in case of LC2 (from −4.53 to 14.1 Mpa)

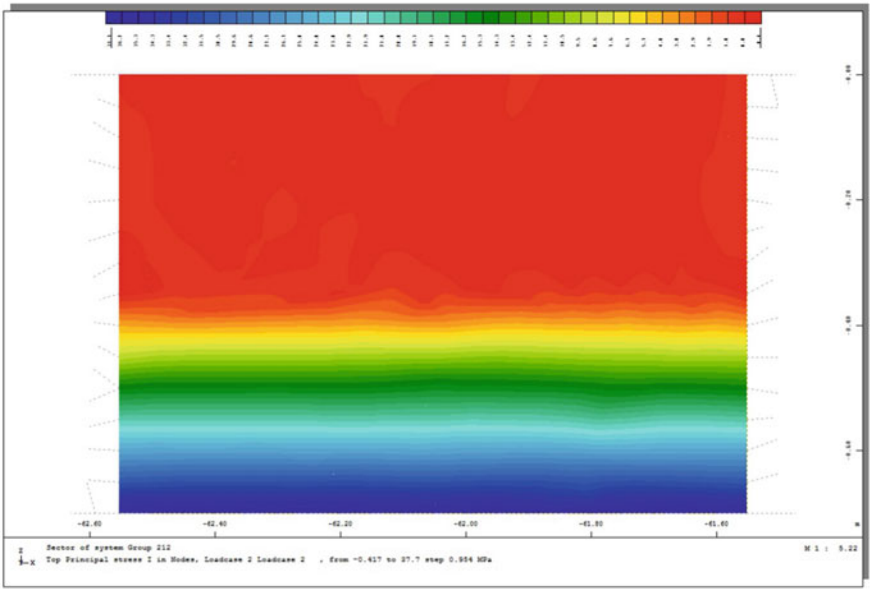


Fig. 4 Stress in web of I-girder type–in case of LC2 (from −0.417 to 37.7 Mpa)

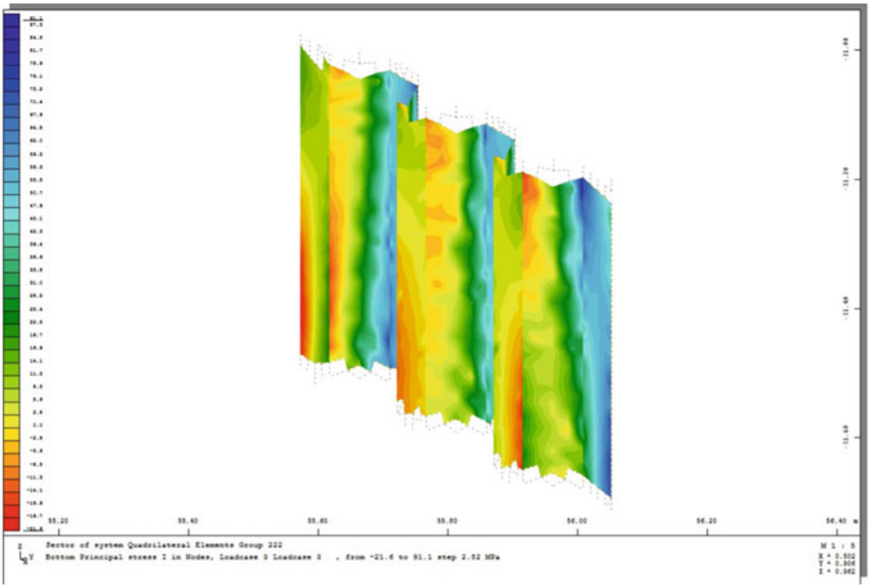


Fig. 5 Stress in web of corrugated web steel I-girder type–in case of LC3 (from −21.6 to 91.1 Mpa)

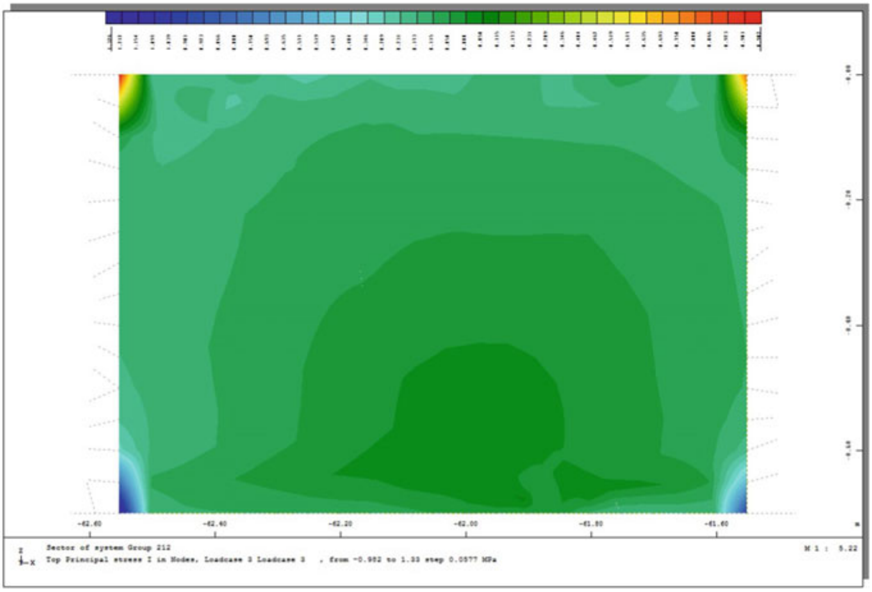


Fig. 6 Stress in web of I-girder type–in case of LC3 (from −0.98 to 1.33 Mpa)

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