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Structural optimization of slender corrugated and flat I girder for patch loading resistance in steel bridges

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Abstract - *Steel I girders have been widely used in building and bridge engineering due to its ease of construction and high flexural strength. During the erection of beams or decks over the flanges of steel bridge girder it will exerts a load on the flange as concentrated load. This is also occurred during bridge launching generally termed as patch loading. Under patch loading the web starts buckling which will in turn causes serious structural damages.so this research aims at enhancing the resistance to patch loading which causes web buckling. In the present study the structural optimisation of flat and corrugated I girder is considered. The strengthening against patch loading is done by means of modifications in flange as well as web part of the girder. Hollow flange, concrete filled flange and web stiffeners are used here to resisting the web buckling caused by patch load. A non-linear static analysis is conducted on the models created in the finite element software ANSYS workbench*

Key Words: **Corrugated girder (CG), Flat girder (FG) Patch loading, Concrete filled flange and hollow flange, Nonlinear static analysis**

1. INTRODUCTION

Steel bridges are extensively utilised worldwide in a variety of structural shapes and span lengths, including for footbridges, railroad bridges, and highway bridges. Strength, ductility, ease of production, and quick construction are the key benefits of structural steel over other building materials. When beams or decks are built over the flanges of a steel bridge girder, a concentrated load is applied to the flange. This also happens when a bridge is launched, a process known as patch loading. A load instance where a concentrated force is applied perpendicular to a girder's flange is known as patch loading or partial edge loading of steel girder webs. The girder web typically fails locally around the loaded flange as a result of this.

Under patch loading, the web begins to buckle, which will lead to significant structural damage. Web buckling is the failure of the web caused by a focused load. When the web buckles, column action is applied to it. When the web is too thin to support the transverse force being transmitted from the flange, buckling of the web results. Steel I girders have a threat from the web buckling under patch stress, which compromises their stability and longevity. Consequently, a number of adjustments are made to improve their structural resistance to patch stress. Among these, utilizing web stiffeners was one of the best methods. Web stiffeners used in structural modification to lessen patch loading are commonly recognized. However, flange alteration is quite uncommon. If a change is made to the flanges, which are the major components under the focused load, it will offer relatively good resistance to that load. In terms of structure, hollow and concrete-filled flanges predominate over standard flanges.

To do comparative research Corrugated and flat I girders are the two types of I girders employed in this investigation. Web stiffeners are used as part of structural alteration, and hollow and concrete-filled flanges are included in flange modification. The

concrete-filled tubular flange in the new I-girder has substantially better torsional and flexural rigidity, which helps to increase resistance to global buckling. Because corrugated web has significantly stronger out-of-plane bending stiffness and shear stiffness than flat web with transverse or longitudinal stiffeners, which is much lighter in weight due to its extremely tiny thickness, it can increase the web's capacity to withstand local buckling more effectively [1]. The concrete-filled flange is discovered to give higher buckling resistance. This emphasizes the impact of the concrete infill, which makes the upper flange more rigid and enables the member to support higher forces [2].

2. OBJECTIVES

- To investigate the performance of flat and corrugated girder with hollow flange under different parametric patch loading condition
- To study the improvement of patch load resistance by modifying the flange with concrete filled flange and web by means of web stiffeners
- To compare the performance of girder after structural optimization

3. METHODOLGY

The main objective of the study is to increase web buckling resistance to patch loading. For that, corrugated and flat web-patterned I girders are employed. and for both I girders, the flange piece is built from a hollow section. these models experience various durations of patch loading (100 mm,150mm,200mm,250mm). The length of the patch load that results in the greatest buckling value is chosen as the ideal patch load length and is employed in subsequent research. then the flat and corrugated models are introduced for structural optimization for both flange and web. The web modification uses both vertical and horizontal stiffeners, while the flange modification uses a concrete filled flange. A nonlinear static analysis is performed for the all models in ANSYS WORKBENCH software.

4. ANALYSIS OF FLAT AND CORRUGATED I GIRDER WITH HOLLOW FLANGE UNDER DIFFERENT PATCH LOADING

4.1 Modelling and analysis of Girders

ANSYS WORKBENCH software is used to carry out the entire analysis. The investigation's model specifications call for both types of I girders to have 1500 mm length, 225 mm flange width, 20 mm flange thickness, and 500 mm web height and 6mm web thickness [3]. The Table 1 below lists the model's attributes.

Table -1: Model properties

Properties	Values
Youngs modulus (Gpa)	210
Poisons ratio	0.3
Yield stress of web(Mpa)	379
Ultimate stress of web(Mpa)	517
Yield stress of flange(Mpa)	373
Ultimate stress of flange(Mpa)	542

Figure 1 depicts the corrugated profile used to create corrugated girder. The corrugation profile is the same for all specimens. Hollow sections are of 225mm×75mm×10mm.

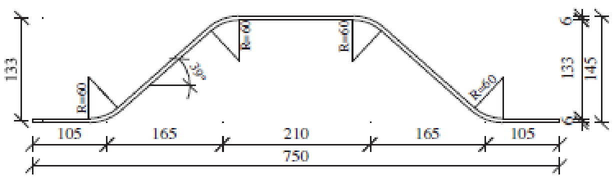

Fig. 1 Corrugated profile

All of the models were produced as 3D models for analysis. Four models of hollow-flanged flat girders with varying patching load lengths and four similar hollow-flanged corrugated girders with varying patch loading lengths were evaluated as part of the research. Consequently, eight of these models were developed under the titles FG-P100, FG-P150, FG-P200, CG-P100, CG-P150, CG-P200, and CG-P250.

The girders are only supported, with patch loads of varying lengths given to the top of the flange. The hexahedron-shaped meshing elements have an element size of about 25 mm and adaptive mesh control. To investigate the functionality of an I girder with hollow flanges, nonlinear static analysis is used. We study deformation, web buckling, and load bearing ability.

After performing a non-linear static analysis, it was possible to determine the maximum load bearing capacity and ultimate deflection for flat and corrugated girder with hollow flange. The data are shown in a table 2 along with the web's maximum load and buckling capacity.

The web buckling curve for flat girder (FG) shows that substantial buckling occurs whether the hollow portion is employed or not shown in Chart. 2. Additionally, the graph makes it evident that the longest patch loading times result in the greatest amount of buckling. In contrast, low web buckling values for corrugated girders with hollow flanges are seen for various patch loadings in Chart. 3. In cases where patch loading is higher, the load bearing ability is larger.

To determine the improved performance, the web buckling and load deflection curves for both FG and CG with hollow flange are compared in chart. 4. The web buckling is greatly reduced when hollow flanges are used in corrugated girders, according to a study of web buckling and ultimate load for FG and CG. Additionally, it is clear that FG has a lower load bearing capability than CG.

Table -2 Deflection maximum load value of different models

Model	DEFLECTION mm	LOAD KN
FG-P100	6.60	549.29
FG-P150	8.43	580.28
FG-P200	7.56	567.24
FG-P250	10.58	591.70
CG-P100	4.91	693.17
CG-P150	5.644	725.72
CG-P200	6.457	749.8
CG-P250	6.7397	766.96

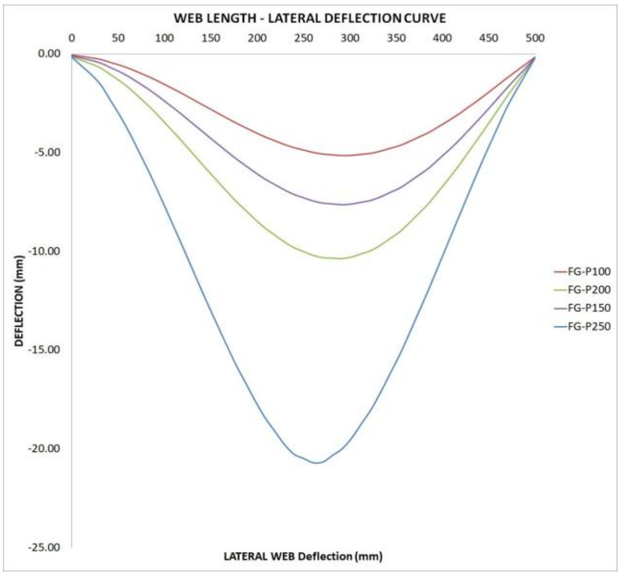

Chart-2: Web deflection curve for FG

The studies mentioned above demonstrate that for a given increase in patch load, flat girder and corrugated girder load bearing capacities improve by up to 7% and 10%, respectively. The percentages of axial distortion for flat and corrugated girder are 10 and 6 percent, respectively. Accordingly, flat girder with hollow flange performs worse overall than corrugated girder with hollow flange. Accordingly, flat girder with hollow flange performs worse overall than corrugated girder with hollow flange.

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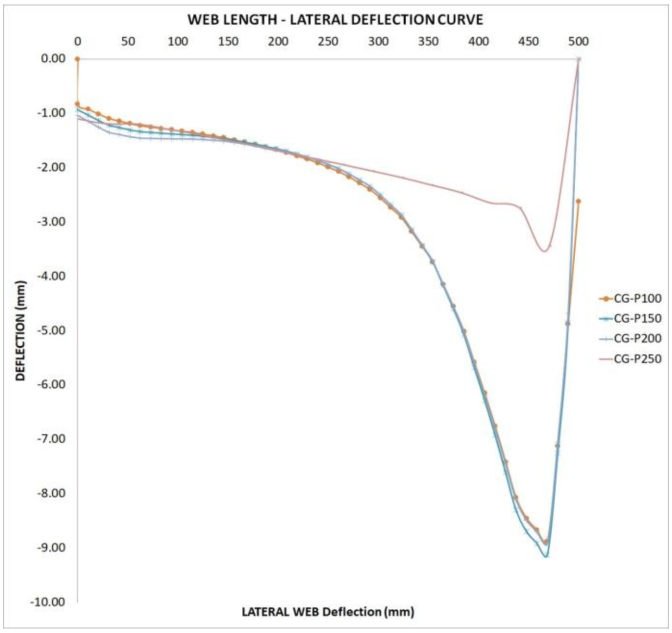

Chart-3: Web deflection curve for CG

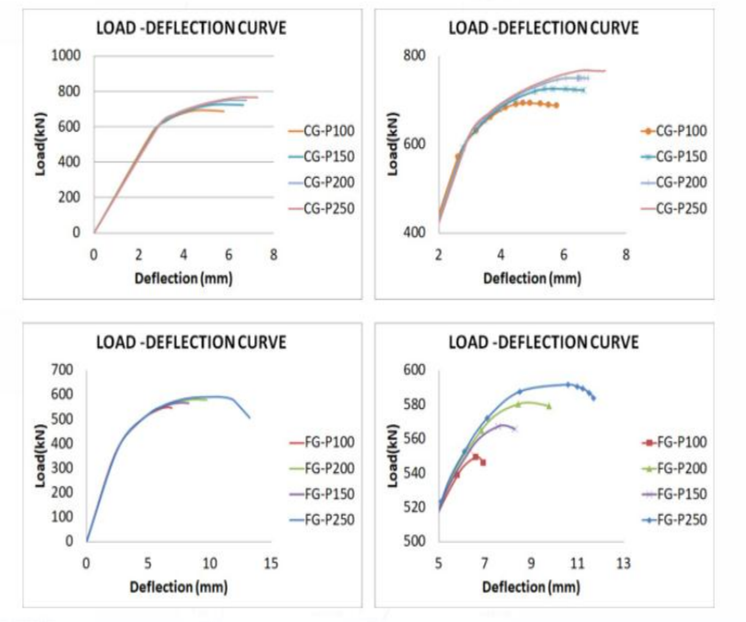

Chart-4: Comparison for load deflection curve

5. ANALYSIS OF FLAT and CORRUGATED I GIRDER WITH FLANGE AND WEB STRENGTHENING UNDER 250 mm PATCH LOAD

According to earlier research, a patch loading with a 250 mm length delivers the greatest load bearing ability. Analysis with a 250 mm patch load is a better alternative for the upcoming research than choosing other patch loading lengths. It is examined in this section how alternative structural modifications to flat and corrugated I girders under 250 mm patch loading compare. The flange modification involves r filling the flange with M25 grade concrete. table 3's description of the concrete's qualities. reinforcing the web by adding web stiffeners in both the horizontal and vertical directions.

Table -3: Characteristics of M25 Concrete

M25	Tensile strength	Compressive strength	Poisons ratio
	3.2	25	0.2

Section 4 has previously made reference to the specification and characteristics of both I girders. Consequently, six models were created, three for flat girders with concrete-filled flanges and horizontal and vertical stiffeners and three for corrugated girders in a similar fashion. CF-FG-250, H-FG-250, V-FG-250, AND CF-CG-250, V-CG-250, H-CG-250 are the names of the models. Here, 50 mm wide by 5 mm thick vertical and horizontal stiffeners are employed. The vertical stiffeners are 10

0 millimetres apart

5.1 Analysis and Comparison of Results

After analysis, the corrugated girder with the concrete-filled flange exhibits the most web buckling, whereas the corrugated girder with vertical stiffeners as shown in Chart 5 and Chart. 6 exhibits the smallest. However, the concrete filled modification employed in the flange exhibits good corelation in terms of load bearing ability. For both FG and CG, the load capacity improves by more than 83 percent (Chart- 7)

Overall, stiffeners do not offer as much load capacity as the concrete filled flange modification.

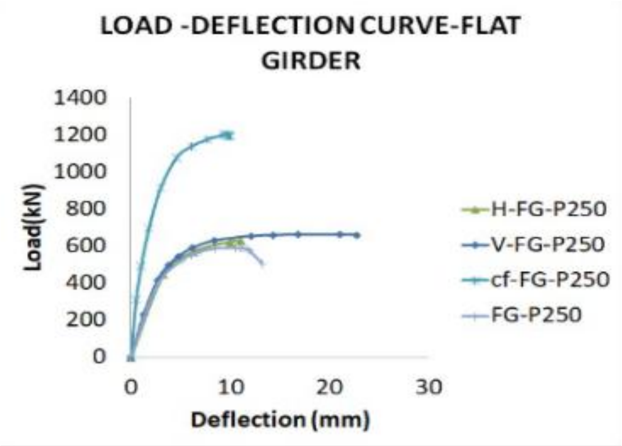

Chart-5: Flat girder load deflection curve

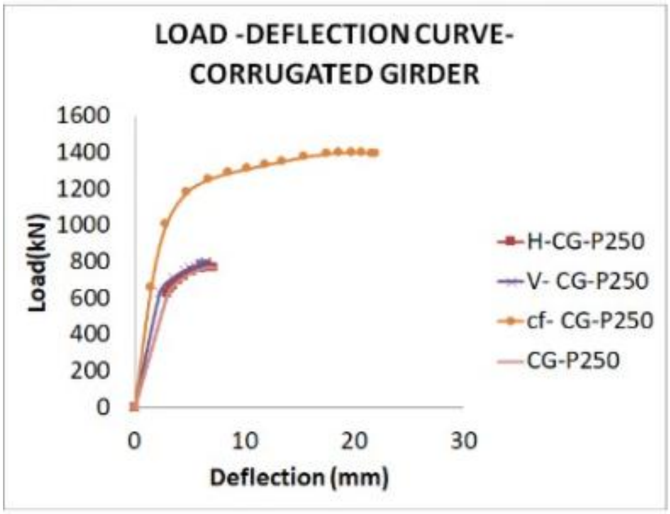

Chart-6: Corrugated girder load deflection curve

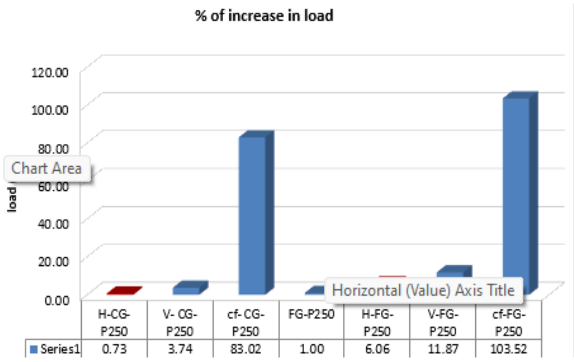

Chart-7:% increase in load for modified FG and CG

We had determined in the last section that corrugated girders have less web buckling than the competition. Thus, it is once more demonstrated that the corrugated girder model's modification decreases web buckling more effectively than flat girder which is shown Chart .9. The use of stiffeners in corrugated girder is the greatest alternative for decreasing buckling caused by patch load among those adjustments, as is evident from Chart. 7.

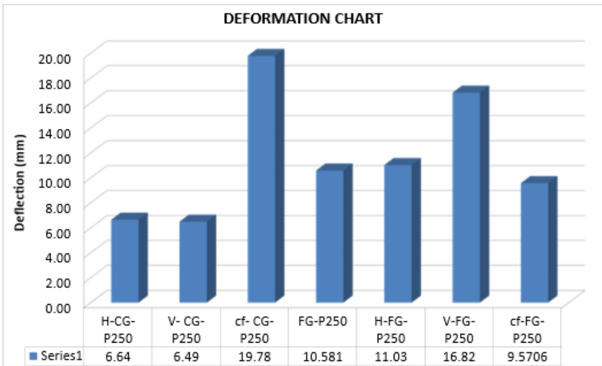

Chart-9: Deflection In Modified Models

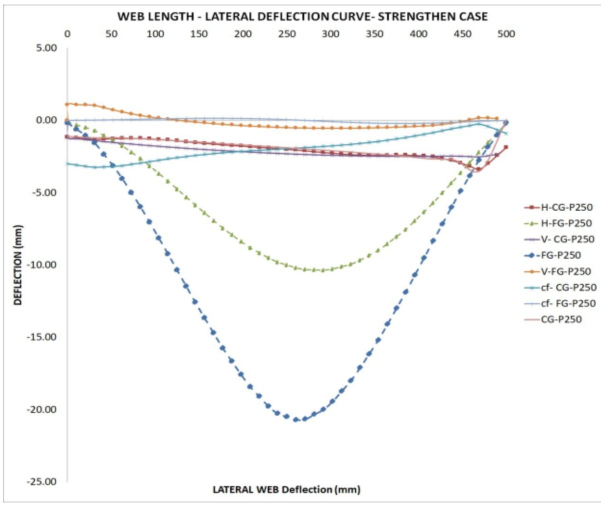

Chart-8: Web deflection curve for strengthend models

6 CONCLUSIONS

This study examined the resistance of several I-girder types to patch loading, which results in web buckling, and the structural optimization thereof. In order to analyse the developed 3D models of the flat and corrugated I girders, a nonlinear static analysis was conducted. Different loadings of the parametric patch are used to test the models. The ideal patch loading length is determined and then utilised for girder structural optimization. The findings were as follows:

- According to the analysis's findings, corrugated and flat I girders both suffer less web buckling when hollow flanges are used. Flat girder with hollow flange's load carrying capacity for the increase in patch load increases by up to 7%, while corrugated girder with hollow flange's load carrying capacity improves by up to 10%.

- The maximum value for both load bearing capacity and deflection is provided by a set patch loading length of 250 mm..

- The structurally modified flat and corrugated I girder provides superior results for web buckling and load bearing capability under a patch load of 250 mm.

- When it comes to load bearing capacity, structural optimization employing a concrete-filled flange shows strong correlation. Increased than 83 percent more load capacity is gained for both FG and CG.

- Using stiffeners in corrugated girder is the best solution for reducing buckling brought on by patch load in the web.

From a comprehensive review of the literature, it can be inferred that structural optimization in steel bridges increases resistance to web buckling brought on by the patch load.

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