Patch Loading Resistance on Inclined steel Plate Girders with Stiffened Cell Flanges

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Abstract - *Stiffening is always an important factor in the case of steel girders. Stiffening with different flanges are more effective when it comes to increasing the capacity to withstand concentrated loads caused by support reactions in steel bridge girders incrementally launched. Steel box girders are widely used in bridges when heavy loads are acting. During the construction or launching time of steel bridges there will be a concentrated force acting perpendicular to the flange of girders, this concentrated force during erection time of construction is known as patch loading. This patch loading case causes web bulking and premature bridge failure. Box girders with inclined web and their patch loading behaviour is studied. This paper aims at investigating the patch loading resistance on steel girders with different hollow flange shapes. Here it is designed and analysed by using finite element analysis method by ANSYS 2022 R2. The model is deigned with parametric studies and conducted in order to investigate the effect of various geometric parameters such as angle of inclination, web thickness and patch loading length and different patch loading length. The results showed that the use of rectangular hollow shaped cell flanges enhances the resistance of steel plate girders to patch loading*.

Key Words: Patch loading, Inclined steel girders, Hollow flanges, Finite element analysis, Concentrated load, Triangular cell flange, rectangular cell flange, Trapezoidal cell flange

1.INTRODUCTION

Steel bridges are widely used in Highway, Urban and Railway networks around the world. Steel bridges are often made using girders with thin webs with good shear strengths and flexural to cover lengthy spans and to be able to withstand heavy vertical loads during service. This causes premature failure of steel bridges or webs. To prevent buckling related failures and to increase the resistance to concentrated loads the following strategies are employed: (a) to increase the web thickness, (b) to use hollow flanges as stiffener (c) to add adequately spaced vertical or horizontal stiffeners

Euro Casanova researched on patch loading resistance of steel plate girders stiffened with triangular cell flanges [1]. Navarro-Manso [5] developed a steel bridge launching system based on a self-supporting double deck, in which the bottom flanges were stiffened with a triangular cell to withstand the concentrated load reactions in the end supports and connections. Dissertation Balázs kövesdI [6] patch loading resistance of girders with corrugated webs showed corrugation on webs can reduce patch loading.

This paper aims at investigating the patch loading resistance of inclined steel plate girders stiffened with cell flanges. to investigate the influence of various geometric parameters such as the angle of inclination, different hollow shapes. Here hollow shapes of rectangle, triangle and trapezoidal shapes are used for the hollow flange cases. The investigation is focused on a locally loaded single panel and thus, other important instability related phenomena are out of the scope of this paper. Patch loading resistance on inclined girders with various hollow flanges and comparison have to be studied other than from straight girders.

This paper provides a detailed description of the optimization process, including the methodology used, the results obtained, and their significance. Overall, the project has significant implications for the patch loading and its resistance.

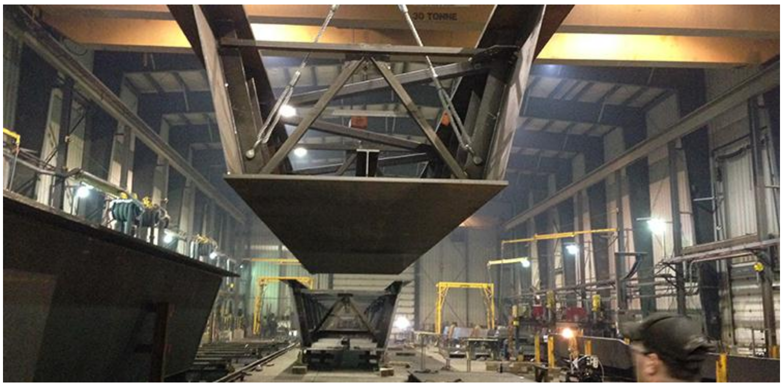

Fig -1: Inclined steel girder [7]

1.2. Parametric Analysis of Inclined Girder

Parametric analysis was done to find the optimum inclined girder which has higher patch loading resistance. The optimization of inclined girder was done using ANSYS Workbench 2022 R2. 14 models were analysed to find an optimum model with higher patch load resistance and prevention of buckling behaviour. The models were specified were specified with different angles to get optimum angle of inclination from 5^0 ,10^0, 15^0 , 20^0, and 25^0 . Thickness of web from 4 to 8 mm are studied. Models were analysed using trial and error method in which length of 750mm, patch loading length of 200mm. From the optimum model hollow flange cases were done to get better patch loading resistance on inclined girders.

2. Analysis and Design of Inclined Steel Girder Model (without Flange Case)

An elastoplastic material with a young's modulus E = 200 GPa and Poisson's ratio ν = 0.3 is considered to model the material nonlinearities. Taking one side (one web) part of inclined girder (box girder) For the study.

2.1 validation

The material with fy 345MPa steel and the components of the girders are modelled using shell elements SHELL181, a four-node element with six degrees of freedom at each node. Base journal adopted for validation was 'Patch loading resistance of steel plate girders stiffened with triangular cell flanges' by Euro Casanova, Carlos Graciano, Rolando Chacon, 2022. For validation, patch loading resistance of steel girders was analysed using ANSYS Workbench R2 and the results obtained were compared with the base journal results.

Table -1: Results of Validation

CONFIGURATION	LOAD (kN)
Finite Element Analysis value for the project	624.9
Journal value	593.96
Difference (%)	5.20

2.2 The Effect of Angle of Inclination with Patch Loading

The parametric study of angle of inclination or the effect of inclination angle have to be fixed in order to know from which angle onwards it reacts to patch loading, or still behave like straight girders rather than inclined. The total span (a) of girder taken is 750mm and patch loading length of 200mm (ss) for the studies [1] as shown in fig. 2. Angles of 5^0 , 10^0 , 15^0 , 20^0 ,25^0 are observed to select the model.

Table -2: Geometry and Material Properties Used in Parametric Studies

h_w(mm)	t_w(mm)	f_{yw}(Mpa)	b_f(mm)	t_f(mm)	f_{yf}(MPa)	ss(mm)
1000	4	345	150	8	345	200

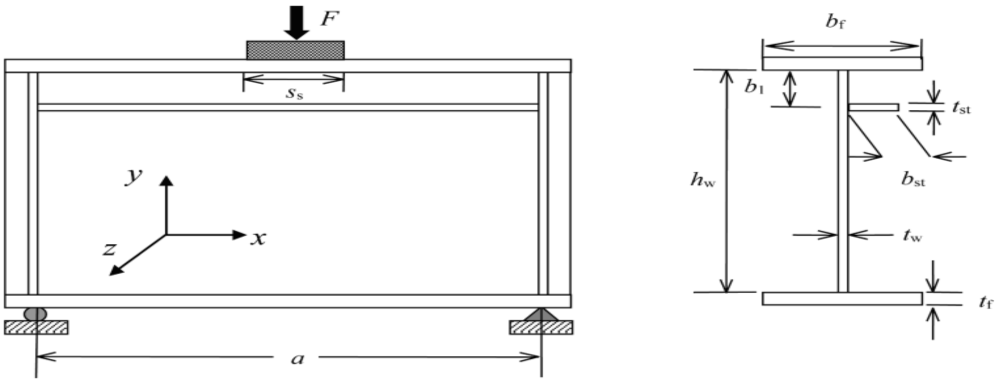

Fig -2: Patch loading in straight girders [1]

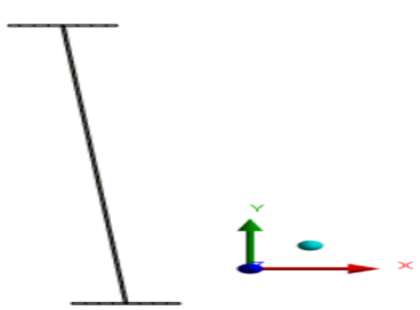

Fig -3: Mesh provided (front view) with angle 5^0

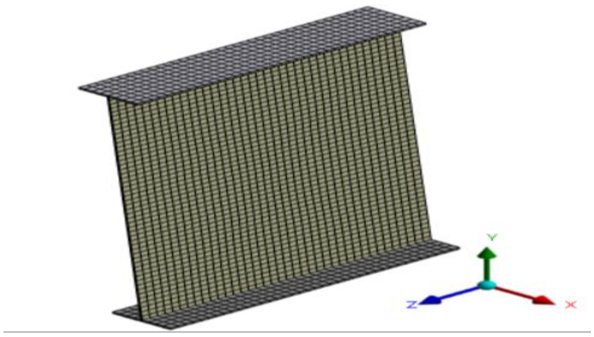

Fig -4: Mesh provided (isometric view)

Mesh size is a crucial factor in finite element analysis (FEA), as it determines the level of detail and accuracy of the simulation. In this case, the mesh size of 20 mm was provided. The meshing process involves creating a finite element model of the structure, which consists of small elements that are connected to form a mesh.

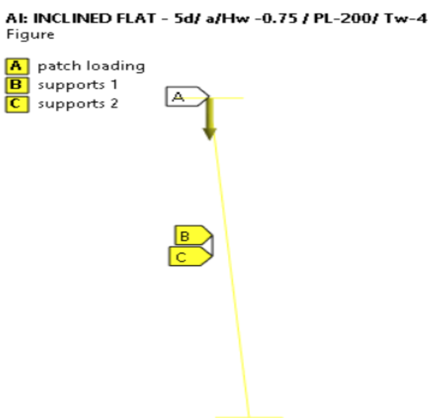

Fig -5: Boundary Condition Front View

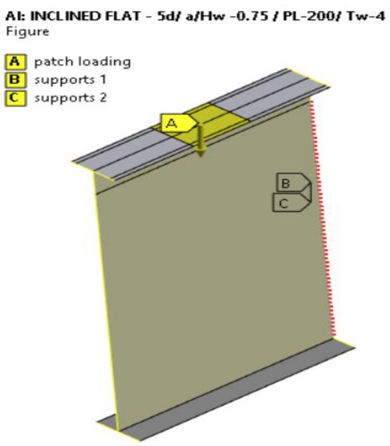

Fig -6: Boundary Condition Isometric View

Boundary conditions refer to the restrictions imposed on a structure at its edges or boundaries. The inclined steel girder is a type of structural member used in bridges to transfer heavy loads to protect the structure from damages. Here, fixed support was provided. The fixed supports ensure that the structure remains stable and does not undergo significant deformation under the applied loads

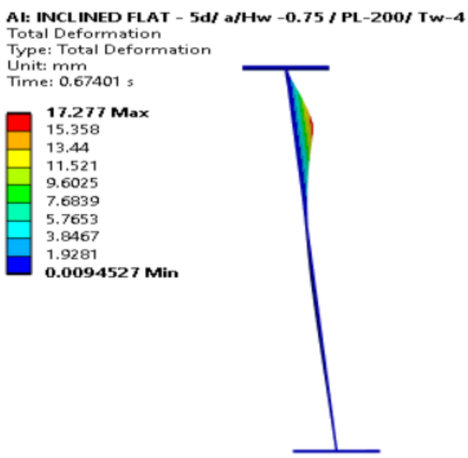

Fig -7: Total Deformation Inclined at 5º

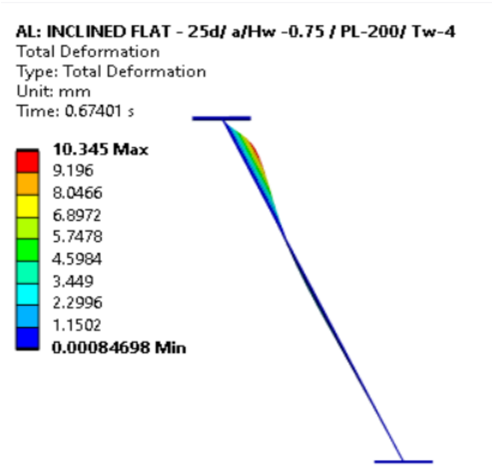

Fig -8: Total Deformation Inclined at 25º

The deformation values observed from the angles from 5º to 25º at the interval of 5º. The angle on inclination is an important part for inclined girders and their behaviour to patch loading is a major consideration (fig. 7 and fig. 8).

2.3 Results and Discussions

The load values of different angles with flat straight girders. From this 5^o onwards the deflection started therefore 5^o inclined girder is selected for hollow flange cases for stiffening. The results of various angles as shown in table 3.

Table -3: Load Deflection Value of Different Angles

MODEL	LOAD MAX (kN)	DEFLECTION (mm)	% DIFFERENCE IN LOAD
FLAT STRAIGHT o^0	433.26	0.81	1
FLAT FLANGE 5^0	403.81	1.86	6.79
FLAT FLANGE 10^0	364.34	3.53	15.01
FLAT FLANGE 15^0	366.21	3.13	15.4
FLAT FLANGE 20^0	365.00	5.22	15.02
FLAT FLANGE 25^0	365.91	3.17	15.03

And also, the web thickness (w_t) of 4mm selected from the thickness of 4 to 8mm, as thickness increases load capacity increases, so selected the lower (fig.9) value itself for the model for stiffening methods. That is angle of 5^o, w_t of 8mm and patch load length of 200mm for the optimum model for stiffening

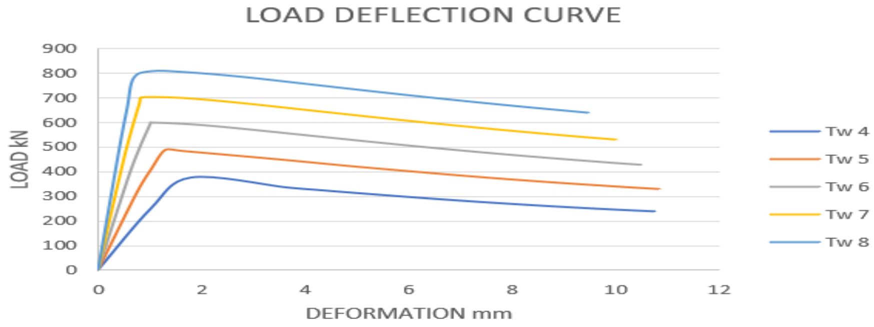

Fig -9: Various thickness of web with selected model of angle of 5^0

3. Design and Analysis of Inclined Girder with Stiffened Hollow Cell Flanges

For the stiffening of inclined girder for patch load resistance of angle inclination 5^0, and w_t of 4mm and thickness of plates used is 4mm for flange cases. The hollow shapes of triangular, rectangular and trapezoidal were made and compared for better resistance is compared with flat flange. The total deformations were studied.

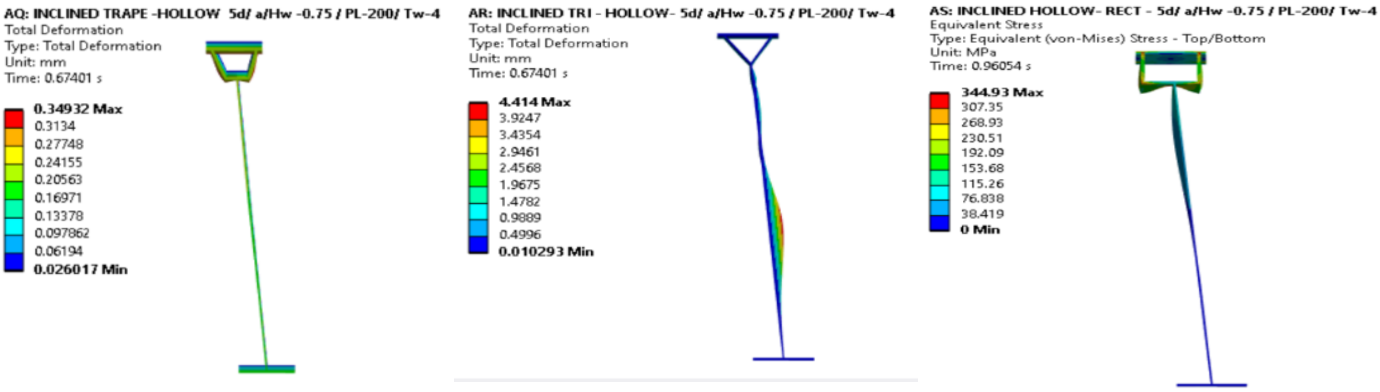

Fig -10: Hollow Flange of Trapezoidal, Triangular, and Rectangular Hollow Shapes

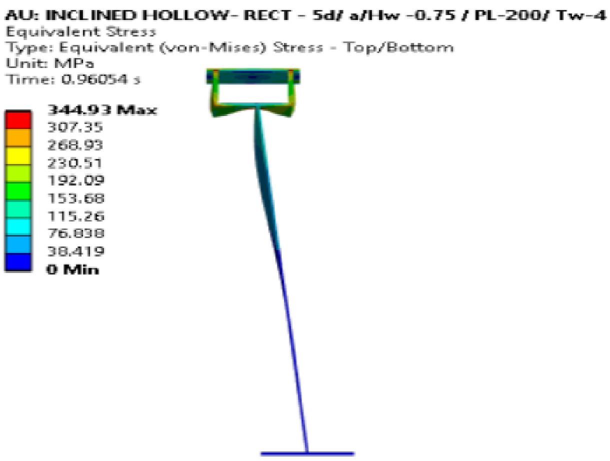

Fig -11: Equivalent Stress of Rectangular Hollow Flange

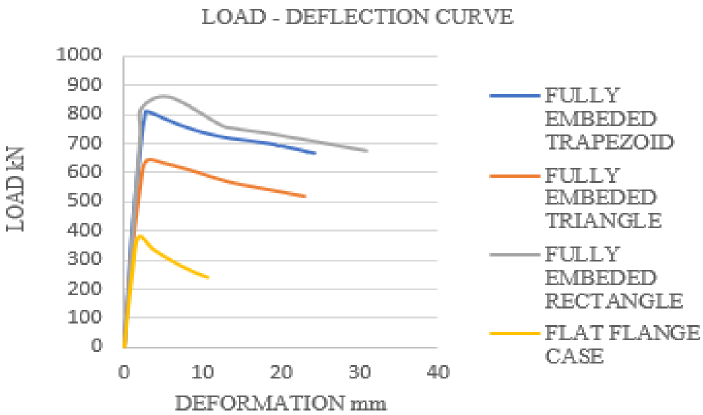

Fig -12: Load Deformation Curve of Flange Cases

From the load deformation curve, it was observed that rectangular shaped hollow flanges showed better patch loading resistance among other triangular and trapezoidal shapes. Comparing with deformation value taken and load bearing capacity, the rectangular shape has better patch loading resistance is due its rectangular shape. The max load of 608.86 kN with deformation of 7.80mm.

3. Conclusions

This study contributes to the advancement of knowledge in the field of steel bridges and other steel structures and can serve as a valuable resource for researchers and practitioners in the field of structural engineering. The insights gained from this project can be used to inform the design of more resilient steel structures. It has provided valuable sights into the effectiveness of this type of rectangular hollow flange in inclined steel girders with load bearing capacity. Overall, the study provides valuable insights into the behaviour of patch loading on inclined girders and its resistance methods, suggests a promising method to enhance the resistance of patch loading activities.

- The resistance is enhanced by of hollow flange cases on inclined cases and the effect of inclination begins from 5º onwards
- Rectangular hollow flanges showed better patch load resistance when compared with other triangular and trapezoidal hollow flanges
- Hollow flange can provide lightweight and maximum delay in web buckling
- The rectangle has equal wider flanges, therefore transfer or distribution of patch load towards the flanges is higher, while comparing with other triangle or trapezoidal shape
- The buckling due to patch loading is reduced on web due to equal sharing of loads on rectangular shaped flange on inclined steel girder
- Further study on the patch loading resistance on inclined steel girders with circular cell flanges cases, which is a special case to be carried out

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