Optimization of height at Delta Stiffened in Steel Girders by Numerical Modeling

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Abstract: Steel girders being built with longitudinal stiffeners were mainly used in bridges for increased resistance along of applied moments. Althogh application of stiffeners will increase the flextural and shear capacity of girders; however the optimized dimensions or thickness of them will be more suitable. In this paper, critical buckling load of the stiffened girders due to applied momets and shears was investigated by using ABAQUS software. For this purpose, by changing load location and stiffener thickness, the buckling load was calculated. The results shows that increasing the web thickness up to certain percent value at compared with web height of girder, critical buckling load, economic position and weight of section will be optmizied.

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1. Introduction

I-girder and plate girders are especially used in bridges and industrial structures. Concentrated loads applied perpendicularly to the flange and introduced to the web are very common case of loading these structural members. As a result of loading on upper I-profile flange the web under loading is locally pressed [1]. Therefore to stabilize the girder against this type of loading usually the web thickness increased or the unsupported web height is reduced.

In spite of extensive research on I-girders, loading is recognized as a complicated problem and the present analytical solutions are not able to predict the ultimate load with sufficient accuracy. Therefore, one must use numerical analysis in a preliminary investigation to identify the factors that have considerable effects on the capacity of girders. Numerical simulations may also be useful to refine parametric range of the proposed design recommendations and to get a better understanding of the physical mechanisms during concentrated loading. Finite element method was used in this paper to investigate the effects of loading and achieve optimum geometry of I-girders stiffened with Delta stiffeners. Modes of failure were also obtained with different cross sectional parameters and critical load capacity of Delta girders has been compared with I-shaped girders and those stiffened by longitudinal stiffeners.

2- Background Research

After AISC National Engineering Conference in 1959 that lateral stability of steel members was presented as an important problem in design, Delta section was one of the major methods that proposed for providing lateral stiffness in steel members. In the Delta sections, corner plates were welded to the compression flange and the web form two-celled triangular box. So, it was offers great lateral stiffness and considerable torsion strength. In practice, Homer M. Hadley developed Delta girders for construction of two bridges. The first one is Taylor Creek Bridge; consist of a simple span structure over Seattle's Cedar River watershed to carry occasional heavy loading. The second bridge, known as Parker Bridge, located a few miles downriver from Yakima, WA. Figure 1 shows the profile of a typical the Delta girder.

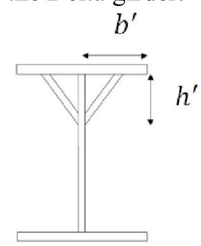


Figure 1. Delta girder cross section

Girkmann [1] in 1936 was the first researcher to study the elastic stability of a rectangular, simply supported rectangular plate subjected to a single edge load. His results is only applied to plates with slender aspect ratio less than 1.1 and solution was given in the form of a determinant which had to be evaluated for any particular case. Based on the energy method, Zetlin[5] investigated the elastic buckling of rectangular plates with different aspect ratios under loading. It was assumed that the applied load was equilibrated by parabolic distributed shear stresses along the two vertical edges of the plate. White and Cottingham [3] studied loading using the finite difference method. Rockey [11] presented an investigation of buckling of simply supported and clamped rectangular plates under partial edge loading, using a finite element method. The study was expanded to web of I-girders. After comparing the buckling of the rectangular plate with identical size, it was found that buckling coefficient of the web increased significantly because of the flange and buckling mode was also different from that of a rectangul A numerical nonlinear large deflection elastoplastic finite element study is performed by Alinia [12] to clarify how, when, and why plastic hinges that emerge in experimental tests actually form. It is observed that shear-induced plastic hinges only develop in the end panels. These hinges are caused by the shear deformations near supports and not due to bending stresses arising from tension fields. Simple shear panels, in the form of detached plates, do not accurately represent the failure mechanism of web plates. The problem of stability of web plates with imperfections, subjected to patch load, is studied by Maiorana [13]. The results obtained with a three-dimensional model of the whole real beam with stiffeners, with experimentally measured imperfections, and each corresponding single web panel are compared and discussed obtaining some insights about the accuracy of the simplified (and conservative) model of the single panel. A system reliability analysis of an oil tanker bottom component which consists of a stiffened panel under combined uniaxial compression and lateral sea pressure loads is presented by Gaspar [14]. The effect of corrosion on the stiffened panel reliability is quantified. The importance of considering the lateral sea pressure and correlation between the local and global wave-induced loads in the reliability problem are evaluated. During bridge erection employing the incremental launching method, plate girders are subjected to a combined loading situation [15]. Due to the support reaction, the thin webs are withstanding concentrated loads, and due to the self weight of the launching nose and the span between the piers the web is also under the action of bending and shear force. The results shows limits in the resistance when all three loads are applied.

3- Investigation of the delta section under flexural loads

In order to obtain the buckling loads of the delta section under flexural loads, various models were investigated. For this target, 3 different schemes were assigned.

Parameters for all case studies was: height=1m, flange width=400mm, web thickness=10mm and flange thickness=30mm.

Amount of parameter h' was varies and it is equal to 150mm, 200mm and 250mm. The buckling load is computed for different stiffener' thickness (t_s) and finally the graphs were illustrated for more convenience.

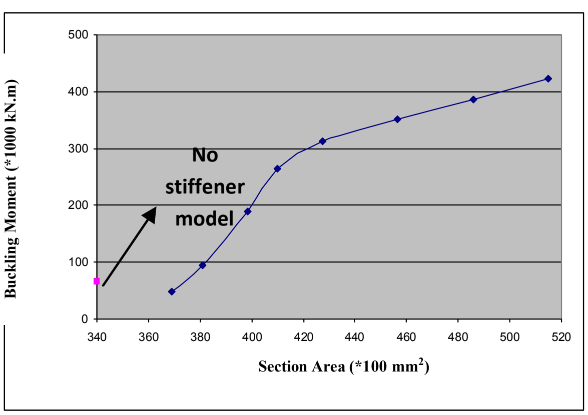
3-1-Scheme1: h'=250mm

In Table 1, the results for h'=250mm are presented.

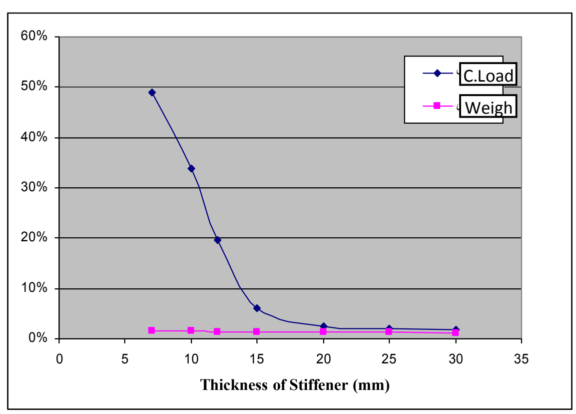
There is a single node on Figure 2.a which shows the strength in case of without stiffener. In the Figure 2.b, changes of the strength and the weight in relation with stiffener thickness was plotted. As observed increase of thickness up to 15mm is very acceptable, up to 20mm it is somehow tolerable, but more than this amount it is not economic.

Table 1. Increasing rate of weight and strength for first condition

Stiffener thickness (mm)	Buckling moment $(kN.m)$	Critical Load increase %	Section area $\times 10^2 mm^2$	Area increase %
5	47667	-	369.15	-
7	94398	49.02	380.81	1.58
10	190140	33.81	398.3	1.53
12	264963	19.67	409.96	1.46
15	313536	6.11	427.45	1.42
20	351660	2.43	456.6	1.36
25	386752	2.00	485.75	1.28
30	423479	1.90	514.95	1.20



a. Increase of Buckling strength



b. Rate of increasing in weight and critical load

Figure 2. Investigating the rate of strength increasing versus thickness of stiffener (h'=250mm)

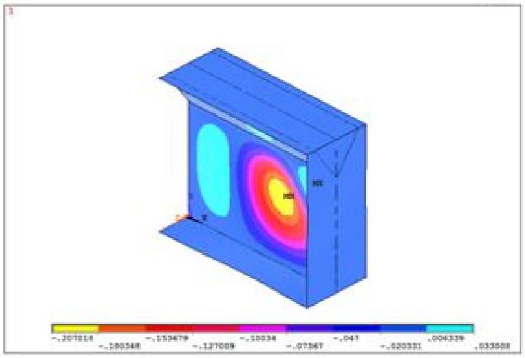


Figure 3.a. Thickness of Stiffener = 5mm

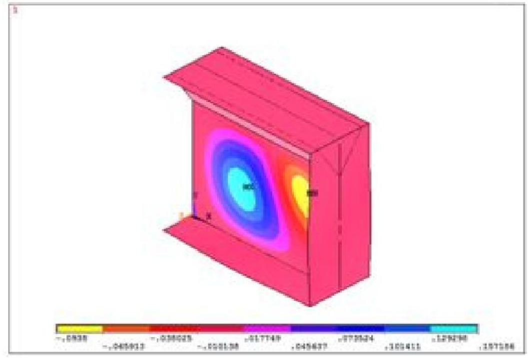


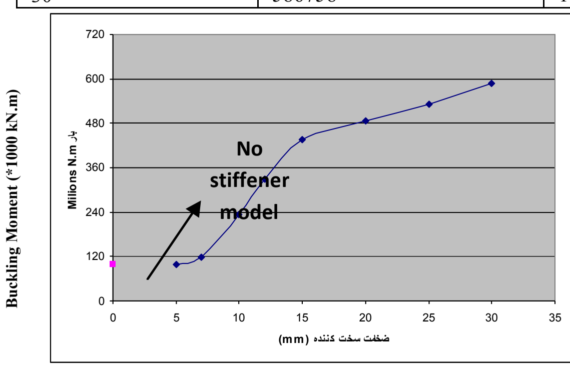
Figure 3.b. Thickness of Stiffener = 20mm

3-2-Scheme2: h'=200mm

The second case study investigated the same scheme1 with h'=200mm. The results are presented in Table 2.

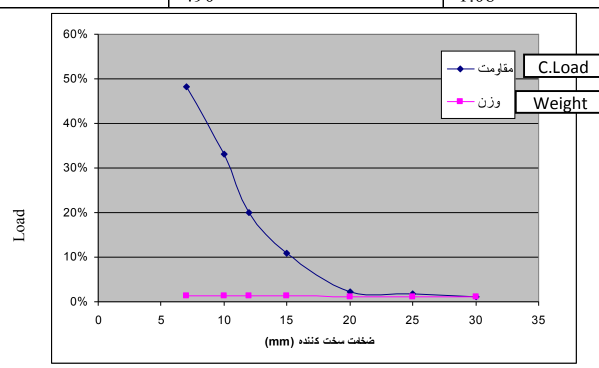
Table 2. Rate of increasing in weight and strength for second condition

Stiffener thickness) mm(	Buckling moment $(kN.m)$	Critical Load increase %	Section area $\times 10^2\ mm^2$	Area increase %
5	97185	-	365	-
7	117400	48.29	375	1.37
10	234047	33.12	390	1.33
12	328171	20.11	400	1.28
15	436094	10.96	415	1.25
20	487005	2.33	440	1.20
25	532801	1.88	465	1.14
30	586758	1.03	490	1.08



Section Area (*100 mm^2)

a. Increase of Buckling strength

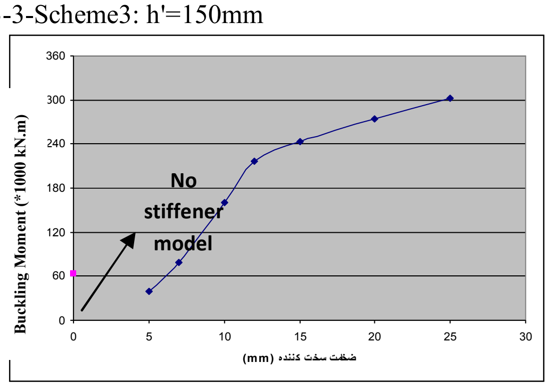


Thickness of Stiffener (mm)

b. Rate of increasing in weight and critical load

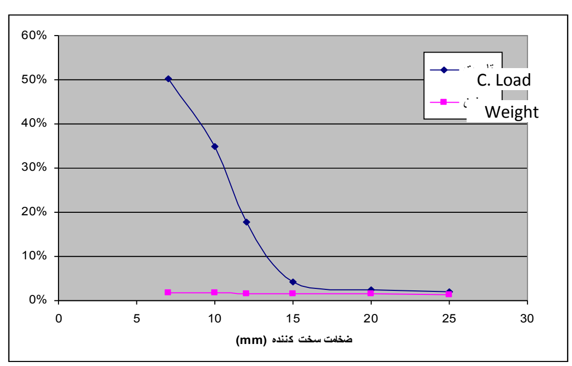
Figure 4. Investigating the rate of strength increasing versus stiffener thickness (h'=200mm)

3-3-Scheme3: h'=150mm



Section Area (*100 mm^2)

a. Increase of Buckling strength



Thickness of Stiffener (mm)

b. Rate of increasing in weight and strength

Figure 5. Investigating the rate of strength increasing versus stiffener thickness (h'=150mm)

As observed while the thickness of stiffener is low, the h'=150 mm is in a better condition compared with the h'=200 mm model. However, increasing the thickness of stiffener will be reduced the risk of buckling for stiffener.

According to Figure 6, it can be concluded that in the model with height of 150 mm, the width for stiffener is less than the model with 200 mm height.

As compared between the results for the mentioned conditions, the model that has %20 of total girder height has an optimum behavior and better performs at compared with another model.

Comparison between schemes that have a stiffener equal %25 of web height with %20 of it, it is observed that the latter models are in a better situation. Finally, it is concluded that the girder with stiffener equal %20 of web height has the better economic condition. This is exactly same for condition of using longitudinal stiffeners cases.

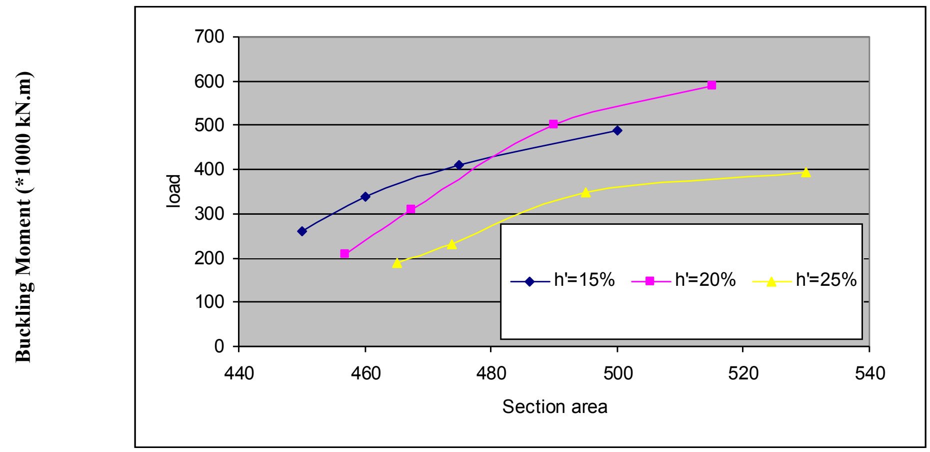
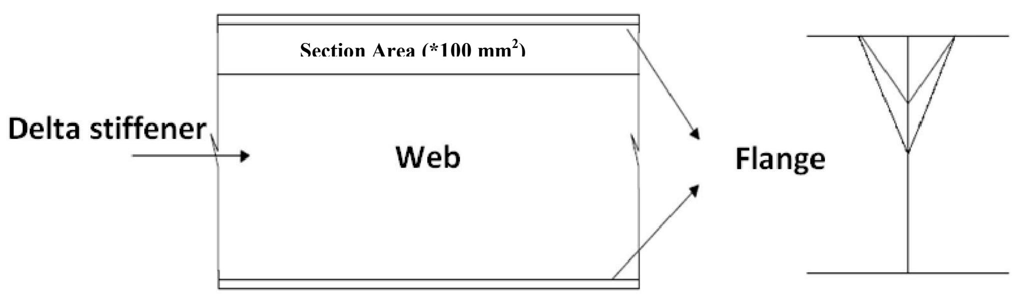


Figure 6. Comparison of critical buckling loads based on various h'



a. lateral view **b. side view**

Figure 7. The Delta Stiffener

4- Conclusion

It is concluded that:

- When the location of stiffener to pressure flange is %20 of web height, it leads to best situation for flexural buckling.
- The thickness of the stiffener should not be so much that it buckles before the buckling of the panel.
- Investigation of various models show that the thickness more than 2.5 times the web thickness is not economic.
- Applying the delta stiffener can increase the buckling load up to 2.5 times rather than increasing the web thickness.
- Applying delta stiffener can increase the buckling strength up to %60 in comparison with longitudinal stiffener.

5- Acknowledgement

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