GRD Journal for Engineering | Volume 2 | Issue 6 | May 2017
ISSN: 2455-5703

# An Increase in Elastic Buckling Strength of Plate Girder by the Influence of Transverse Stiffeners

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## Abstract

Steel I girders especially plate girders are subjected to bending, shear and patch loading, so the stability has to be considered in the design. The shear strength in the web panel can be improved by providing transverse stiffeners on both side of the web undergoing a tension field action. Shear buckling strength in the web panel has a significant effect in the shear strength of plate girder. This paper investigating elastic buckling strength of plate girder in which transverse stiffeners are provided in the web. Solution is based on finite element parametric study validated on laboratory tests. After validating the results, provide transverse stiffeners in the web by reducing its thickness and compare these results using specifications of Euro code, AASHTO, AISC, and British code..
**Keywords- Plate Girder, Transverse Stiffener, Shear Strength**

## I. INTRODUCTION

### *A. General Background*

Plate girders are deep flexural members used to carry loads that cannot be carried economically by rolled beams. A plate girder is basically an I-beam built up from plates using riveting or welding. Plate girder provide maximum flexibility and economy. In the design of a plate girder, the designer has the freedom to choose components of convenient size, but has to provide connections between the web and the flanges. Plate girders offers unique flexibility in fabrication and the cross section can be uniform or non-uniform along the length. It is possible for putting exact amount of steel required at each section along the length of the girder by changing the flange areas and keeping the same depth of the plate girder. Thus a plate girder offers limitless possibilities to the creativity of the engineer. Modern plate girders are, in general, fabricated by welding together two flanges, a web and a series of transverse stiffeners. Elements of plate girder were shown in figure 1. Flanges resist applied moment, while web plates maintain the relative distance between flanges and resist shear. In most practical ranges, the induced shearing force is relatively lower than the normal flange forces. Various forms of instabilities, such as shear buckling of web plates, lateral-torsional buckling of girders, compression buckling of webs, flange-induced buckling of webs, and local buckling and crippling of webs are considered in design procedures.

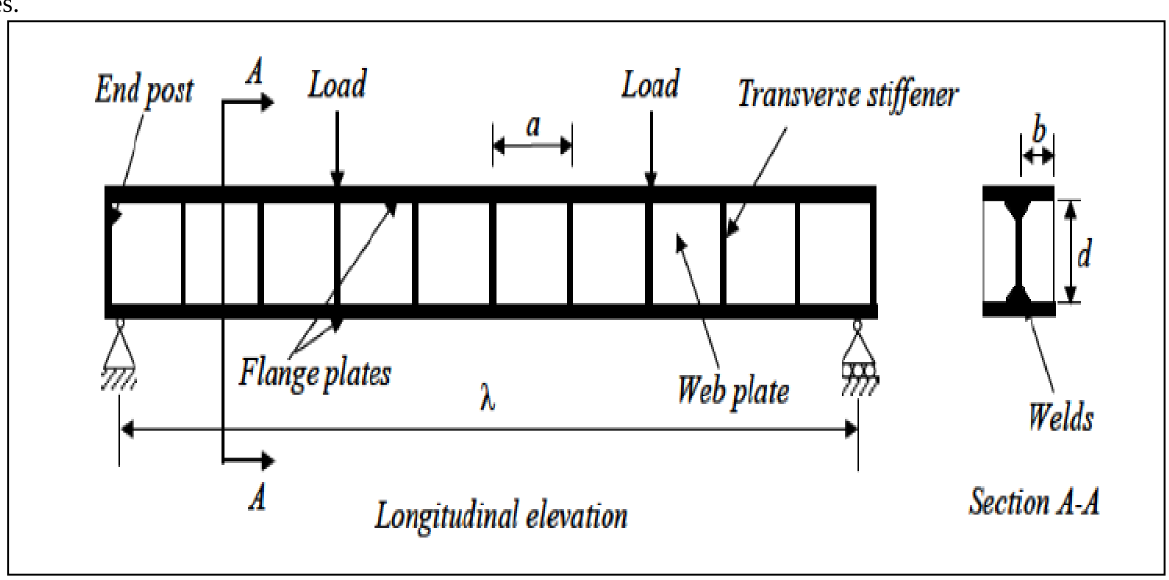


Fig. 1: Elements of Plate Girder

### *B. OBJECTIVES*

1) To compare the behaviour of plate girder with and without transverse stiffeners with load and support conditions specified in the literature using ANSYS.
2) To predict the changes in structural behaviour of plate girder with the influence of transverse stiffener.
3) To compare the ultimate load carrying capacities obtained with various standards.

### *C. SCOPE*

Transverse web stiffener in plate girder have been designed successfully more than 100 years. However the design bases and assumptions in different codes and proposals differ widely, and this has an important on web thickness/panel size optimization, and hence on the weight and cost of the stiffened web. Hence there is a need to find the effect of Elastic buckling strength of plate girder by the influence of transverse stiffener.

### *D. METHODOLOGY*

1) Conduct literature survey on numerical and experimental investigations on plate girders with stiffeners.
2) Standard sections of plate girder are used as examples available in the literature are selected and modelled in finite element software ANSYS.
3) Section is analysed for standard load and support conditions specified in literature.
4) Validate the model from results in literature.
5) Validating model technique is used to model plate girder section with and without transverse stiffeners.
6) Ultimate strength of plate girder is calculated using Finite Element Analysis, Euro, AISC, AASHTO and British codes.
7) Comparison of the results.

## II. LITERATURE SURVEY

### *A. Theorotical Investigation*

1) Alinia, M.M et al (2010) studies about Post buckling and ultimate state of stresses in steel plate girders. Nonlinear large deflection finite element analysis was implemented to depict the characteristics of the shear failure mechanism of steel plate girders. Plate girders are considered to have simple supports at their ends and are subjected to vertical point loads at their mid-spans. Girders considered in this study are made of mild steel with an elastic-perfectly plastic behaviour and no strain hardening. The finite element program ABAQUS and its predefined S4R element is implemented in all Eigen value and incremental non- linear analysis. Both geometrical and material nonlinearities are fully considered in FE analyses. Results conclude the principal tensile and compressive stresses on the two sides throughout the web plate increase during post buckling stages. However, in the center of the panel, the principal compressive stresses remain constant after elastic buckling, while the principal tensile stresses increase considerably. The tension field angles calculated via the geometrical fold angles and the inclination angles of principal stresses are in good agreement and lay between Cardiff's($\theta_{Cardiff}$) and the 45̊. All available theories are conservative in predicting elastic buckling strength of web plates. However, except an Eurocode, they overestimate the ultimate strength of plate girders.
2) Donald W. White, et.al (2008) discusses on Shear Strength and Moment shear interaction in transversely stiffened steel I-Girders. This paper presents the results from the collection and analysis of data from a total of 186 high-shear low-moment, high-shear high-moment, and high-moment high shear experimental I-girder tests. References to corroborating refined finite element studies are provided. The results of the study indicate that, within certain constraints that address the influence of small flange size, Basler's shear resistance model can be used with the flexural resistance provisions of the 2004 AASHTO and 2005 AISC specifications without the need for consideration of M – V strength interaction. Also, the research shows that a form of the Cardiff model can be used with these flexural resistance provisions without the need to consider M – V strength interaction.
3) Graciano C and J mendes (2014) finds the elastic buckling strength of longitudinally stiffened plate girder subjected to patch loading. Buckling coefficients are computed by means of finite element analysis using ANSYS. Shell elements S181 from the ANSYS element were used to model the web, flanges and longitudinal stiffener. From the study the most influential parameters on the buckling coefficients are relative position of the stiffener, Flexural rigidity of stiffener and patch load strength. A first order factorial design is performed, which allow experimenters to develop mathematical model to predict how input variables are interact to create output variables in a system. A second order analysis were conduct to obtain list of buckling coefficients that best fit the results. Study was based on only one aspect ratio, hence further study is needed to investigate the influence of aspect ratio.
4) Young Bong Kwon and Seung Wan Ryu (2015) develops a design shear strength formula of the end web panel of plate girder and application of DSM to the end web panel of plate girder. Four node quadrilateral shell element,QTS4 shell element of the LUSAS software were selected for elastic buckling and nonlinear analysis. Results showed that single double sided transverse stiffeners have lower post buckling reserve strength than two double sided transverse stiffeners and stiffened interior web panel.

## III. Analysis Of Plate Girder With And Without Stiffener

### *A. Analysis and Results Evaluation*

Analysis was carried with simply supported boundary conditions. Linear as well as nonlinear properties were defined. Load v/s deflection values were obtained for each of these sections. The ultimate load was also obtained from the analysis. Total deformation contour plot along with scaled deformed shape can be obtained from ANSYS. Model, Contour plot of stress diagram and deformation curves of sections analysed without stiffener are shown in figure 2.

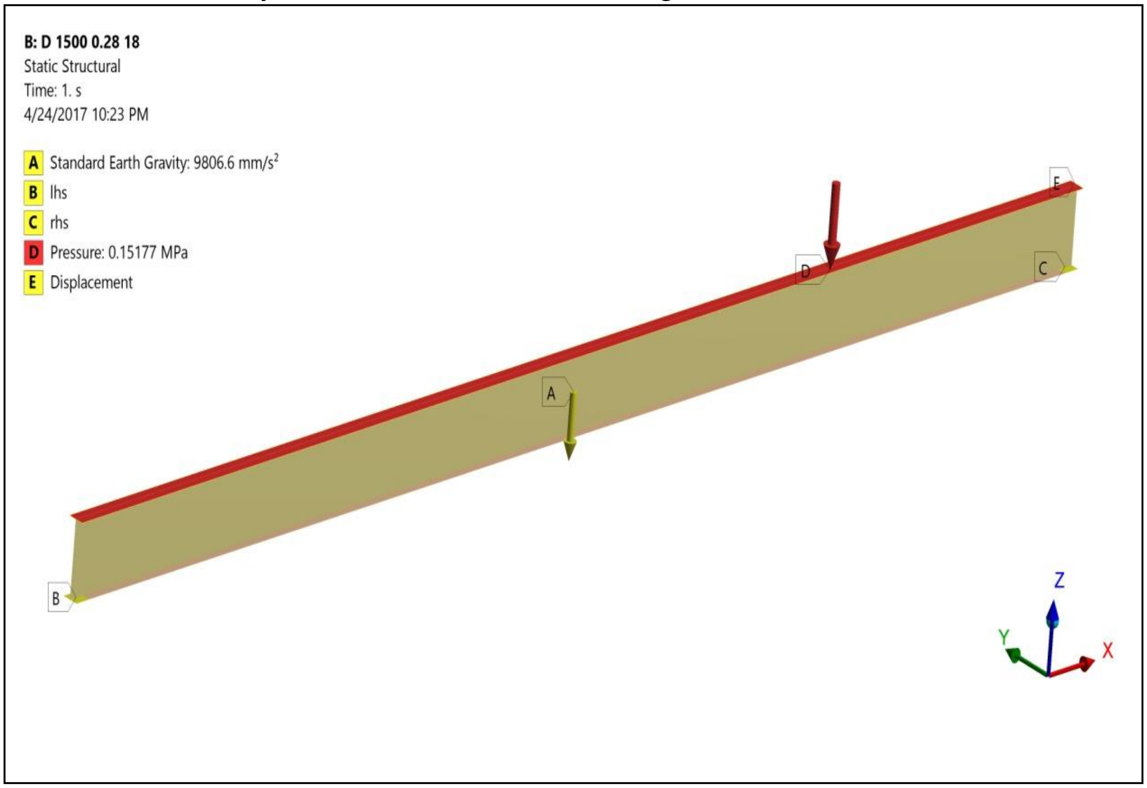


Fig. 2: Loading diagram of plate girder without stiffener for dw =1500mm, tw =20mm, bf =420, tf =23.33

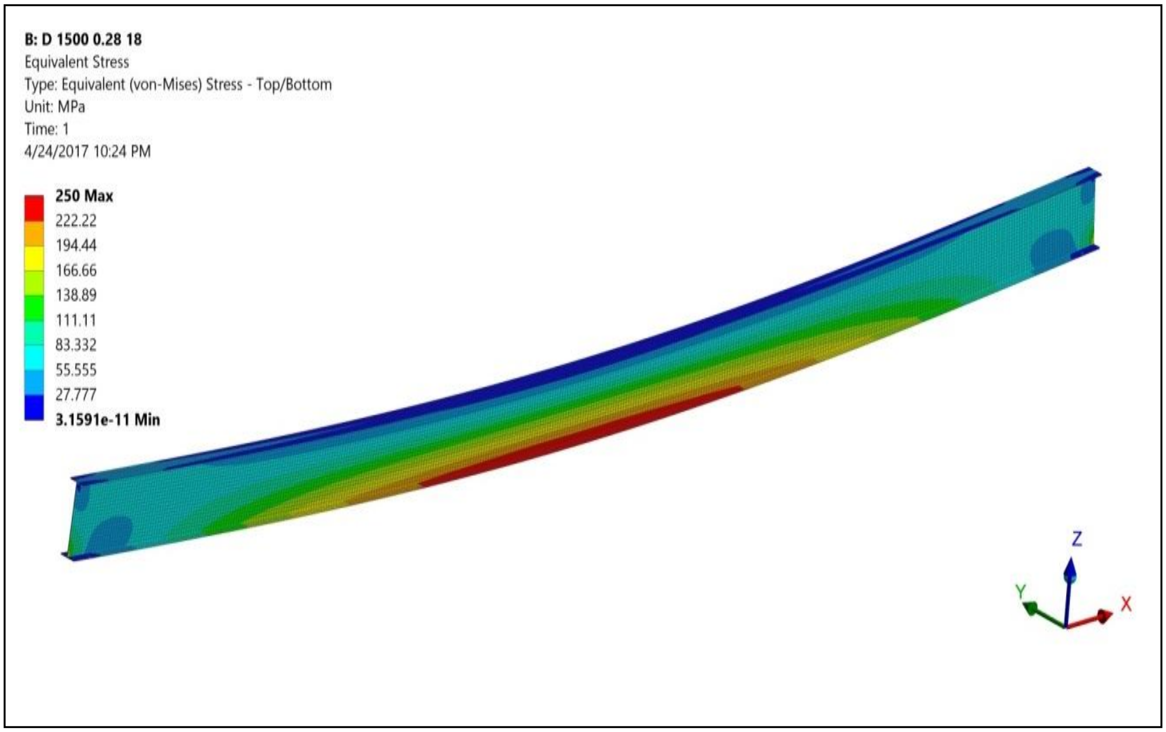


Fig. 3: Contour plot of the von-Mises stress diagram of plate girder without stiffener, dw =1500mm, tw =20mm, bf =420, tf =23.33

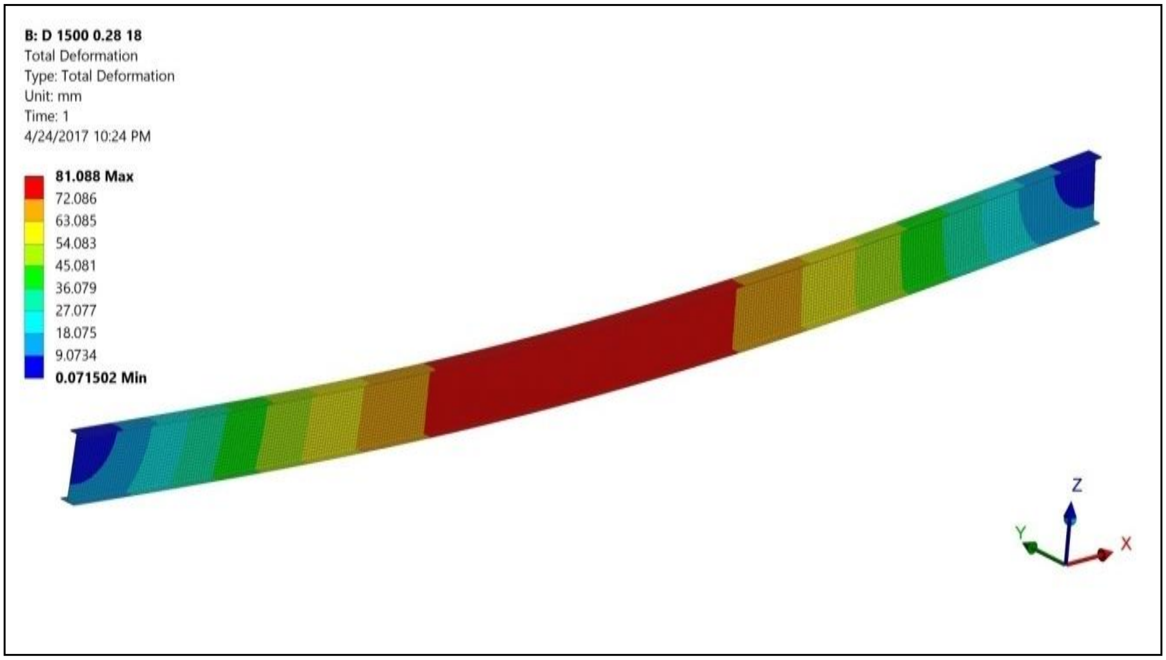


Fig. 4: Contour plot of deformation of plate girder without stiffener for dw =1500mm, tw =20mm, bf =420, tf =23.33

The experiment is repeated by changing the dimensions of flange and web. Web depth is increased to 1500mm, 2000mm, 2500mm, and 3000mm. The results are shown below.

## IV. Results And Discussions

| $h_w$ (mm) | $b_f$ (mm) | $t_f$ (mm) | Weight (ton) | Weight - stiffener (ton) | % reduction in wt | Force (KN/m) | Force-stiffener (KN/m) | % change in force | Deflection (mm) | Deflection stiffener (mm) | n times deflection |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1500 | 420 | 26.25 | 12.421 | 10.744 | 1.677 | 67.6452 | 72.4584 | 7.11 | 81.153 | 6.9561 | 11.67 |
| | | 23.33 | 11.837 | 10.16 | 1.677 | 63.7434 | 73.2858 | 14.97 | 81.088 | 7.1222 | 11.38 |
| | | 21 | 11.369 | 9.692 | 1.677 | 60.6144 | 73.9368 | 21.98 | 81.055 | 7.2895 | 11.119 |
| | 450 | 28.125 | 13.2 | 11.523 | 1.677 | 72.8775 | 70.173 | -3.7 | 81.407 | 6.8856 | 11.82 |
| | | 25 | 12.529 | 10.852 | 1.677 | 68.4045 | 72.7155 | 6.3 | 81.323 | 7.0533 | 11.53 |
| | | 22.5 | 11.992 | 10.315 | 1.677 | 64.8135 | 73.449 | 13.32 | 81.272 | 7.2221 | 11.25 |
| | 480 | 30 | 14.032 | 12.355 | 1.677 | 78.4704 | 71.088 | -9.4 | 81.683 | 6.817 | 11.98 |
| | | 26.67 | 13.268 | 11.592 | 1.677 | 73.3824 | 72.0864 | -1.76 | 81.573 | 6.9847 | 11.68 |
| | | 24 | 12.657 | 10.981 | 1.677 | 69.3024 | 72.8976 | 4.17 | 81.507 | 7.1546 | 11.39 |
| 2000 | 560 | 35 | 18.9 | 16.288 | 2.612 | 88.5304 | 72.1952 | -18.45 | 41.898 | 5.4336 | 7.71 |
| | | 31.11 | 17.861 | 15.248 | 2.612 | 89.9248 | 72.932 | -18.89 | 45.123 | 5.5795 | 8.08 |
| | | 28 | 17.029 | 14.417 | 2.612 | 91.1064 | 74.614 | -18.1 | 48.105 | 5.732 | 8.39 |
| | 600 | 37.5 | 20.284 | 17.672 | 2.612 | 87.276 | 71.448 | -18.13 | 38.55 | 5.3645 | 7.18 |
| | | 33.333 | 19.091 | 16.479 | 2.612 | 88.728 | 71.942 | -18.92 | 41.659 | 5.5092 | 7.57 |
| | | 30 | 18.137 | 15.524 | 2.612 | 85.02 | 69.835 | -17.86 | 42.139 | 5.6612 | 7.44 |
| | 640 | 40 | 21.764 | 19.151 | 2.612 | 86.112 | 70.4704 | -18.16 | 35.578 | 5.3137 | 6.69 |
| | | 35.556 | 20.406 | 17.794 | 2.612 | 87.5968 | 71.7632 | -18.07 | 38.55 | 5.4564 | 7.06 |
| | | 32 | 19.32 | 16.708 | 2.612 | 84.5968 | 72.5704 | -16.83 | 39.075 | 5.6071 | 6.96 |

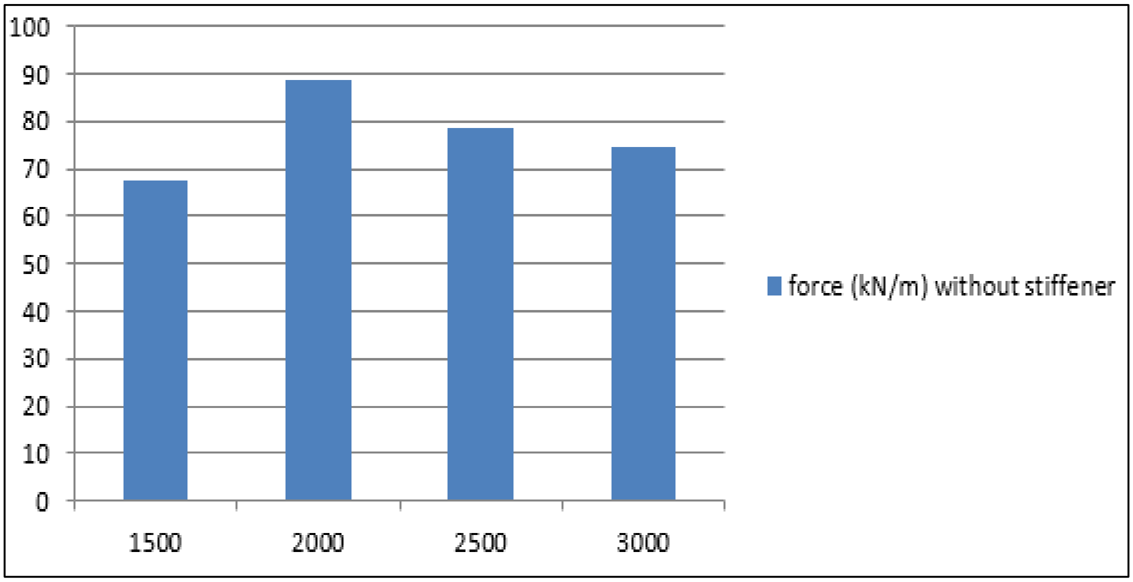


Fig. 5: Force comparison among different web depth, $t_f = b_f/16$, $b_f = d_w \times 0.28$

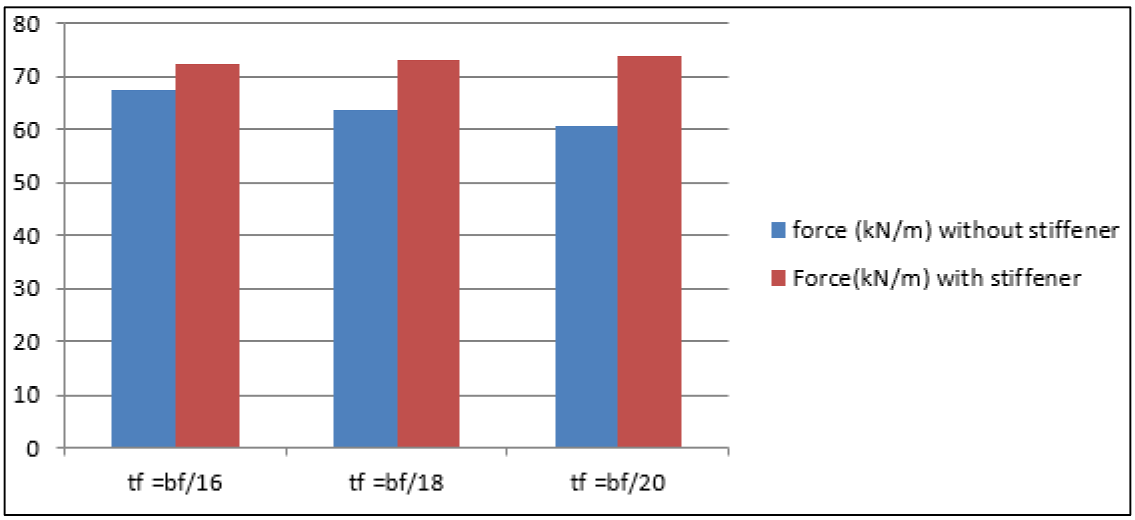


Fig. 6: Force comparison among different thickness of flange, bf =420mm, $d_w$ =1500mm

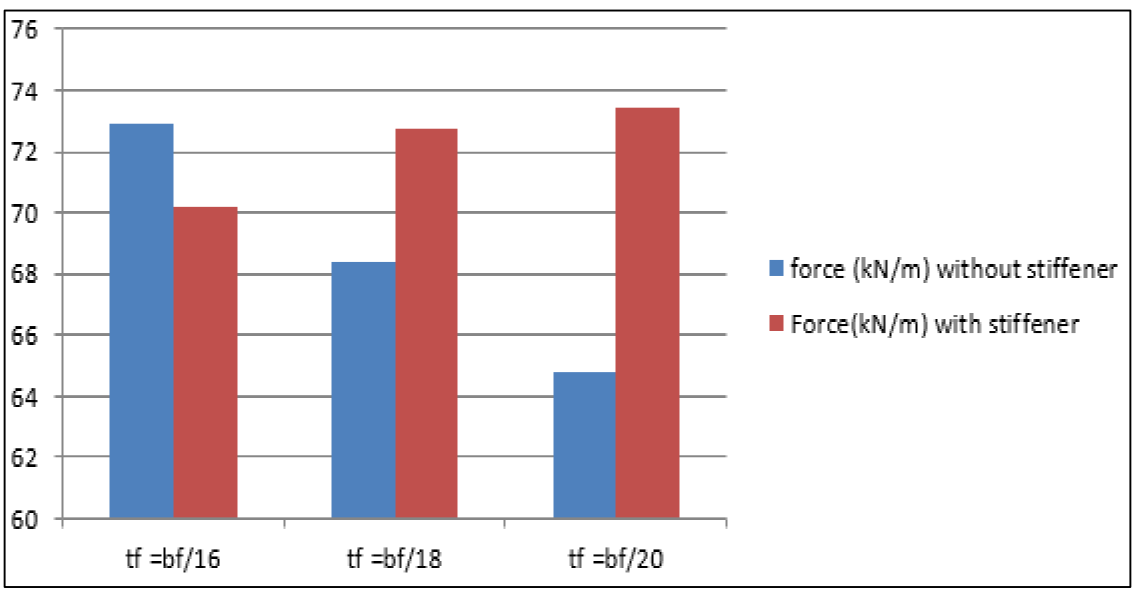


Fig. 7: Force comparison among different thickness of flange, $b_f$ =450mm, $d_w$ =1500mm

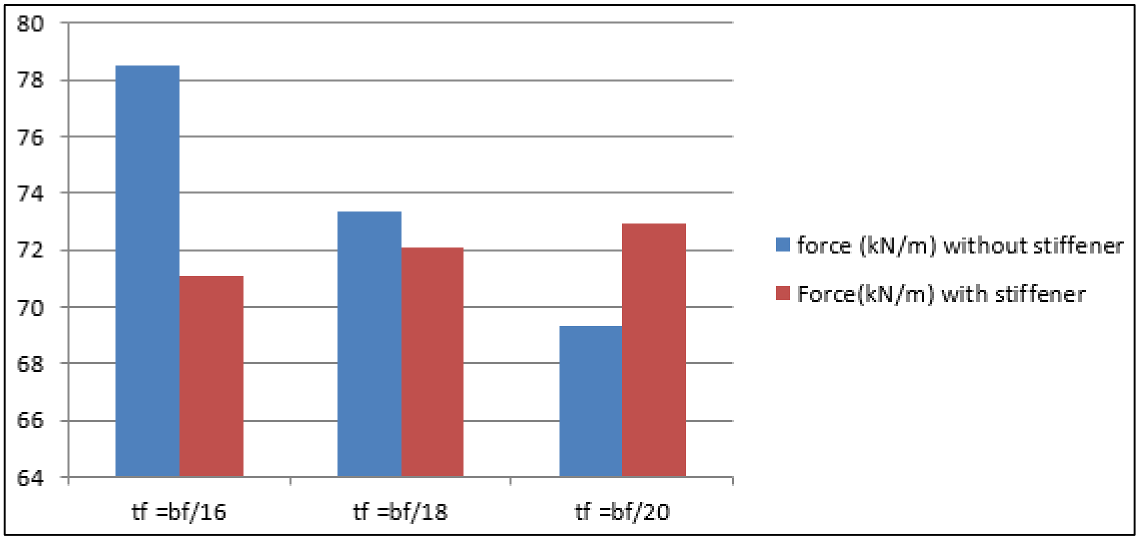


Fig. 8: Force comparison among different thickness of flange $b_f$ =480mm, $d_w$ =1500mm

- When the breadth of flange is constant, Force carrying capacity increases in plate girder without stiffener with increase in thickness of flange. And vice versa in plate girder having stiffener.
- Force carrying capacity increases in plate girder without stiffeners when breadth of flange ($b_f$) increases. In case of stiffeners there is no sufficient increment in force carrying capacity.
- Influence of stiffeners reduces deflection to almost 11times for 1.5m deep web. and increases the force carrying capacity to 7 to 20%
- When comparing overall results of plate girder of 1.5m web depth, the smallest depth of flange and highest thickness of flange of plate girder gives economic results on force carrying capacity in less weight.
- When the depth of web increases to 2m, force carrying capacity of plate girder without stiffeners were increased. Further increment in web depth beyond 2m reduces the force carrying capacity.
- Force carrying capacity decreases for plate girder with stiffener of 2m and above web depth when comparing to plate girder without stiffeners.
- Influence of stiffeners reduces deflection to almost 7times for a 2m deep web.

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