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Parametric Study of Plate Girder Using Different Stiffener Arrangement

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ABSTRACT

Plate girders are deep I-shaped beam fabricated from standard shape (steel plates, angle etc). Their flanges usually consist of plates welded with deep thin steel plate with or without stiffeners. Plate girder is widely used where very heavy loads need to be supported over large span. In India for railway bridges of short and medium span are almost reverted plate girder construction. Most analytical and experimental work on plate girders has involved only stiffeners perpendicular or parallel to the flanges. Much less effort has been devoted to inclined stiffeners, whose superior performance when compared to perpendicular stiffeners is discussed. Inclined stiffeners would have the advantage of limiting the shear factor without requiring the expensive addition of horizontal stiffeners. A wide range of cross-sectional parameters have been considered in these studies, including ratio of length of stiffener/meter span, ratio of area/ meter span, stiffener spacing, position of the stiffener through the web depth. All the stiffener length/meter span are derived from the 40 m span of plate girder according to design of IS 800:2007. The Plate girder with different stiffener arrangement are modeled and analyzed in finite element software and optimized section is found. Whichever section gives most satisfactory results would be tested experimentally under frame loading.

Keywords— inclined stiffeners, perpendicular stiffeners, position of the stiffener and ratio of length/span

I. INTRODUCTION

- General

As is widely known, it is economical to make the web as thin as possible when designing plate girders that are frequently used for railway or highway bridge members beyond 20m span, because the section design of the girders is usually governed by bending moments and shear forces. To prevent such a reduction in the bending and shear resistance of a plate girder with a slender web, longitudinal, transvers or diagonally stiffeners could be applied to the webs. This additional strength can be attributed to the fact that the stiffened web provides improved restraint to the rotation of the compression flanges as well as web bend-buckling strength.

Transvers stiffener used for bearing shear web buckling, longitudinal stiffener used for bearing compression or bending buckling of web and diagonal stiffener improve local buckling of web under combination of shear and bending.

- Terminology of plate girder

Determining the proportions of plate girders constitutes the first step in the design process. The total design comprises not only of determining the depth of girder and selecting and proportioning its various components, but also of putting together an economical and efficient system of stiffeners to enable it to perform function safety and economically. The complete design of plate girder involve the following step

1. Design of web
2. Design of the flanges
3. Design of stiffener
4. Design of connection
5. Design of end bearing.

All of these component must be put together to enable he plate girder to perform its function efficiently.

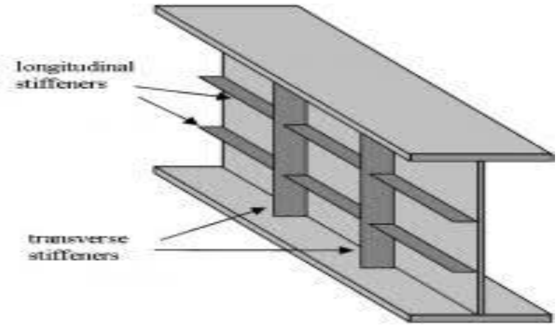

Fig. No.1. Terminology of plate girder

- Stiffener for plate girder

The web usually needs to be stiffened against a tendency to buckle. Such stiffener may be either transvers or longitudinal to be the girder span.

a) Bearing stiffener-

Stiffener designed to transfer and distribute heavy concentrated applied load through the depth of the girder web safely and without stress are called bearing stiffener.

b) Transvers stiffener-

Vertical stiffener is provided at specific interval along length of plate girder, they should be strong enough to offer adequate support to the web against buckling. Their size and spacing are also governed by specifications in IS 800:2007. Transverse web stiffeners are designed to transform the concentrated force to shear stresses in the web. Provisions of intermediate transverse stiffeners at certain intervals, in addition to preventing the torsion of flanges, serve as boundaries for tension field action in the web.

c) Longitudinal stiffeners-

Longitudinal stiffeners are provided between transvers stiffener to prevent the web from buckling either diagonally or longitudinally. They often allow for thinner web to be used which result in economy. Transvers stiffener required for stiff enough to offer adequate restraint to the web. Their size, location and other detail are governed by specification in IS 800:2007. Specifically in large bridge girders, it is common to use longitudinal stiffeners. The purpose of longitudinal stiffening may be to increase the resistance to concentrated loading but usually they are introduced to increase the resistance to shear and bending. Stiffening to prevent theoretical web bend-buckling during construction and under service conditions

II.METHODOLOGY ADOPTED IN ANALYSIS AND DESIGN OF PLATE GIRDER

- Selection of span of the plate girder with stiffener

Span of the plate girder is selected in view of practical consideration as well as economic considerations and market availability of section. As the span of plate girder is 40m selected, while tested in loading frame some limitations in length and maximum loading capacity of the loading frame hence, the selected section should be convert in aspect ratio according to testing consideration.

- Terminology in Plate Girder with Stiffener

The various basic terms involved in the analysis and design of plate girder are illustrated in Fig. No. 3.1 below;

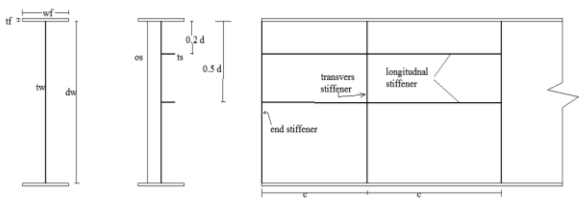

Fig. No.2. Typical cross section of plate girder

Where,

tf = thickness of flange

wf =width of flange

tw= thickness of web

dw =depth of web

c = Centre to Centre spacing between the transvers stiffener

ts = thickness of stiffener

os = outstanding of stiffener

tw = Thickness of web of I beam

- Guidelines for stiffener arrangement in plate girder

The Various stiffener arrangement made in the web greatly affects the structural performance of the plate girder. Therefore, it is essential to make some logical and practical consideration while providing different stiffener arrangement in plate girder. Following are the general guidelines which are given by the IS 800:2007 and some of them are based on the field or practical considerations. These standards in web different stiffener arrangement can be changed or modified without affecting the structural performance of the plate girder. These guidelines are as follows,

a) Span/depth ratio of web:

Constant depth in case of girder 12 to 20

(Girder having span/depth ratio less than 12 is deep beam)

b) Depth/thickness ratio of web:(clause 8.4.2.1)

d/tw > 67 €√kv/5.35 (for resistance to shear buckling)

Where kv is shear buckling coefficient

€w = √250/fyw = 1

kv = 4.0 + 5.35 (c/d)^2 for c/d < 1.0

kv = 5.35 + 4.0 (c/d)^2 for c/d > 1.0

c) Serviceability requirement (clause 8.6.1.1)

d/tw < 200 (in case of only transvers stiffener provided)

d/tw > 200 (in case of only transvers stiffener provided)

d/tw < 345 avoid buckling of compression flange

design of flange (clause 8.4.2.2)

width of flange = .03 times the depth of web

thickness of flange =

b/2tf must be less than 8.4 €

d) Design of stiffener (clause 8.7.2.1)

Spacing of end stiffener (c) = 0.74 x d

Spacing of intermediate stiffener (c) = 1 x d

Outstanding length of stiffener = 14 t q € to 20 t q € (clause 8.7.1.2)

Where t q = thickness of web

Spacing of longitudinal stiffener (c) = 0.2 x d

Outstanding length of stiffener = 14 t q € to 20 t q €

Where t q = thickness of web

- Design of plate girder with stiffener arrangement (800:2007)

Design of the plate girder includes checking of following;

a) Design of web:

Depth of web:

Depth of web = 12 to 20

Span/depth = 40000/12 = 3333mm ≈ 3500 mm

Thickness of web:

d/tw > 200 €w (transvers & longitudinal stiffener)

where €w = √250/fyw = 1

tw = 3500/230 =15.21 mm ≈ 16 mm

b) Design of flange:

Width of flange:

Width of flange = 0.3 x depth of web

= 0.3 x 3500

= 1050 mm ≈ 1100 mm

Thickness of flange:

Thickness of flange = b/2tf < 8.4 €f

where €w = √250/fyw = 1

tf = 1000/2 x 8 = 62 mm

c) Design of transvers stiffener:

Spacing of end stiffener:

Spacing of end stiffener (c) = 0.74 x d

= 0.74 x 3333

= 2466 mm ≈ 2500 mm

Spacing of intermediate stiffener (c) = 1 x d

= 1 x 3333

= 3333 mm ≈ 3500 mm

Outstanding length of stiffener:

Outstanding length of stiffener = 20 t q €

Where t q = 16 mm

= 20 x 16

= 320 mm

Provide stiffener size 320 mm x 16 mm

d) Design of longitudinal stiffener

Spacing of longitudinal stiffener:

1. Spacing of longitudinal stiffener (c) = 0.2 x d

= 0.2 x 3500

= 700 mm

And 2. Spacing of longitudinal stiffener (c) = 0.5 x d

= 0.5 x 3500

= 1750 mm

Outstanding length of stiffener:

Outstanding length of stiffener = 20 t q €

Where t q = 16 mm

= 20 x 16

= 320 mm

Provide stiffener size 320 mm x 16 mm

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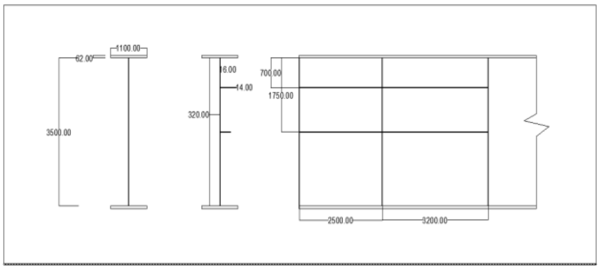

Fig. No. 3. Typical cross section of plate girder of given span

- Methodology adopted in parametric study of Plate girder with different stiffener arrangement

After understanding the design standards as per the IS 800:2007 the approach is decided to achieve objectives of the dissertation, this approach is discussed in upcoming points. It is decided to analyze the plate girder for different stiffener arrangement, and whichever section gives most satisfactory results would be tested experimentally for the purpose of validation of the research.

- Selection of dimensions for parametric study on plate girder with diagonal, pentagonal, hexagonal and octagonal shaped stiffener arrangement

Depending upon the limitations specified by the codes different stiffener arrangement is selected. The parameters which are selected to study are length of stiffener /meter span and conventional weight/area for different stiffener arrangement. These different parameters along with their respective cross sectional dimensions of different stiffener arrangement of plate girder are given in fig. below. All the stiffener length/meter span are derived from the 40 m span of plate girder according to design of IS 800:2007. The Plate girder with different stiffener arrangement are modeled and analyzed in Ansys software and optimized section is found out which are explained in detail in the chapter of results and discussion.

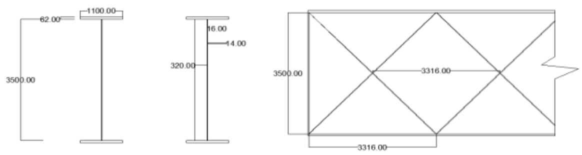

Fig. No. 4. Cross section of the plate girder with diagonal stiffener arrangement

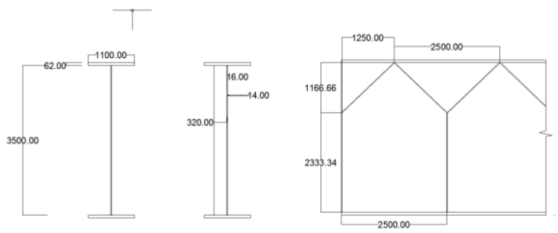

Fig. No. 5. Cross section of the plate girder with pentagonal stiffener arrangement

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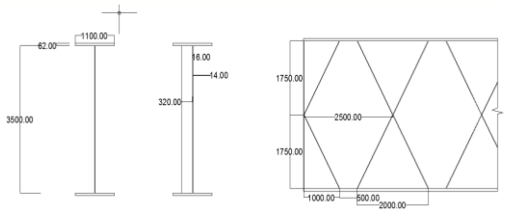


Fig. No. 6.Cross section of the plate girder with hexagonal stiffener arrangement

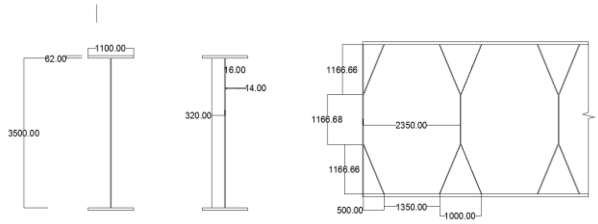


Fig No. 7. Cross section of the plate girder with octagonal stiffener arrangement

- Selection of method of analysis

In order to optimize the dimension of the different stiffener arrangement of plate girder, it is very important to decide proper analytical method. Due to complex geometry of plate girder the finite element analysis (FEA) is the best available to analyze the beam. FEA is done by the simulation software "Ansys workbench 15".

- Selection of type of loading

As reviewed in the literature it is clear that, the plate girder with stiffener arrangement tend to fail in local failure modes. Hence, type of loading which has to be applied on plate girder plays a vital role in causing the failure of beam. Two points loading is the most preferred loading method used for the plate girder which are susceptible to local failure modes. So, in this dissertation work the optimize section are analyzed and tested under two point loading.

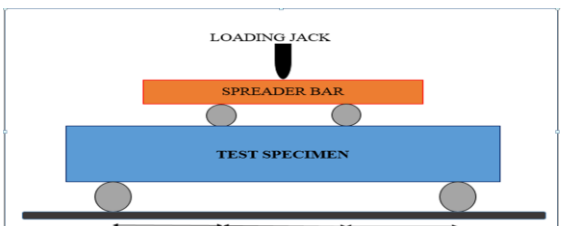


Fig No. 8.Cross section of lading frame

- Study of behavior of optimize section

In order to study comparative behavior both are results are check as follows the optimize section from FEA result by using software and optimize section is fabricated and tested in laboratory by loading frame. The results are discussed in further chapter.

III.FINITE ELEMENT MODELLING

- Fundamental concept in finite element modelling in Ansys

Ansys is the simulation software used for finite element analysis of different structural members, it also used for finite element analysis of many mechanical parts. Eigen buckling analysis is done in software ANSYS for To calculate ultimate load carrying capacity of the plate girder. Following are some important point to be consider while FEM of plate girder,

The step-by-step procedure in ANSYS software is given below

1. Static Structure
2. Engineering Data
   i. Material to be assigned
3. Design Modeler
   i. Sketch cross section
   ii. Extrude
   iii. Face split to apply load
4. Mechanical
   i. Assigning Material to section
   ii. Meshing
   iii. Assign load and support
   iv. Solution
5. Linear Buckling
   i. Select number of modes
   ii. Solution

a) Type of material

Now a days steel structures are designed and analysed by using plastic theory so we it is also important to give plastic behaviour of material. It is done by given plastic properties in terms of yield stress and respective plastic strain.

b) Geometry and modelling

In this section, the geometry of plate girder is made in Catia v5, and this geometry import in ansys software. Following fig shows modelling of various stiffener arrangements

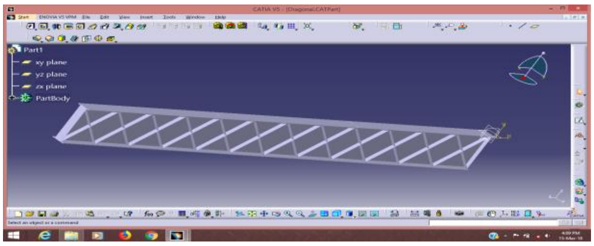


Fig.No.9. Geometry of the plate girder with diagonal stiffener arrangement

c) Meshing and solution

The results of FEA are mainly dependent on the meshing. So, to obtain accurate results in Ansys workbench, size of meshing and no of element should be consider while result,

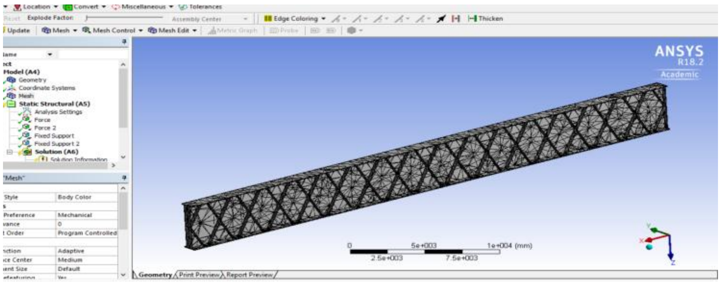


Fig. No.10. Meshing done of span

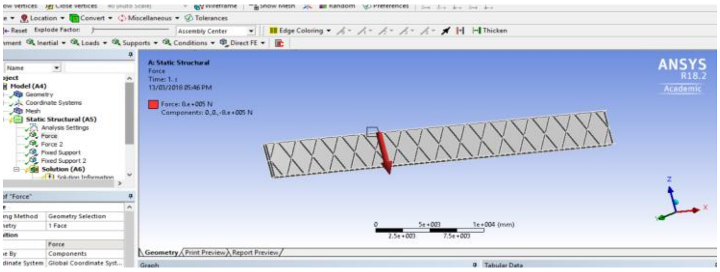


Fig No. 11 load apply on 1/3 of span

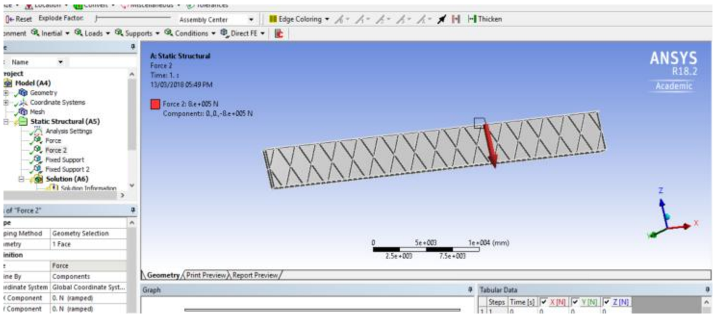


Fig No. 12 load apply on 2/3 of span

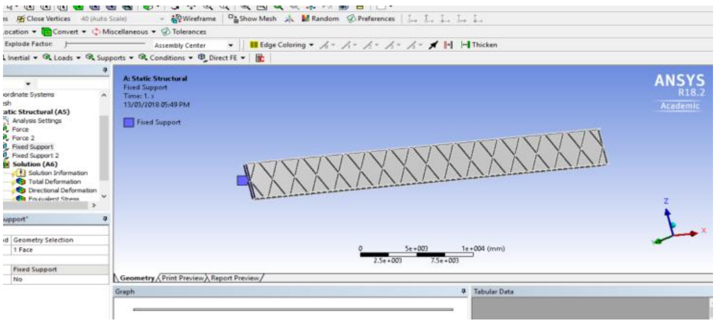


Fig No. 13 fixed support apply on one end of span

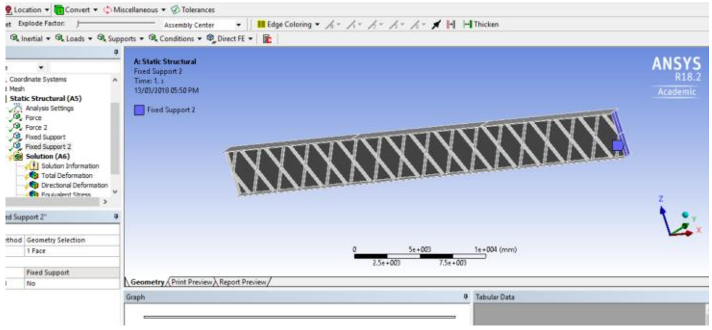


Fig No. 14. fixed support apply on other end of span

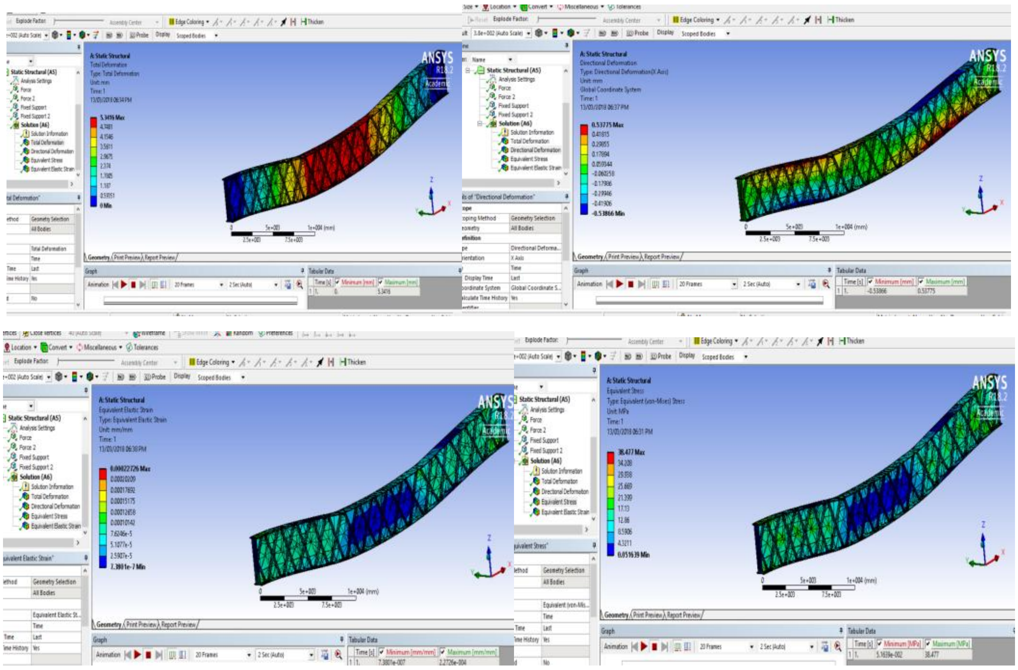
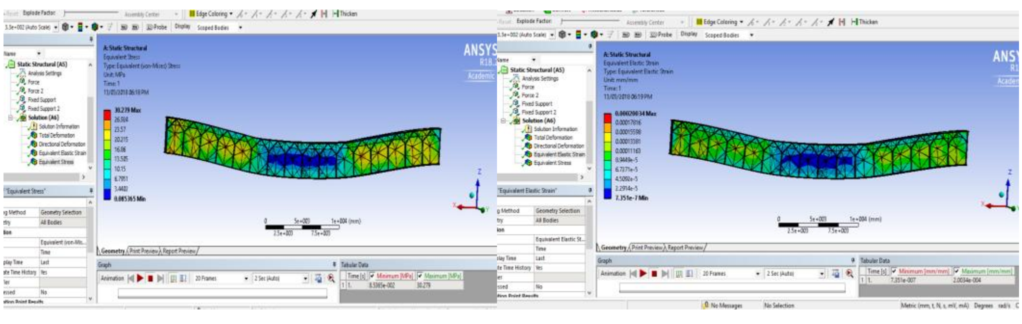


Fig.No.15. analysis result of the plate girder with diagonal stiffener arrangement



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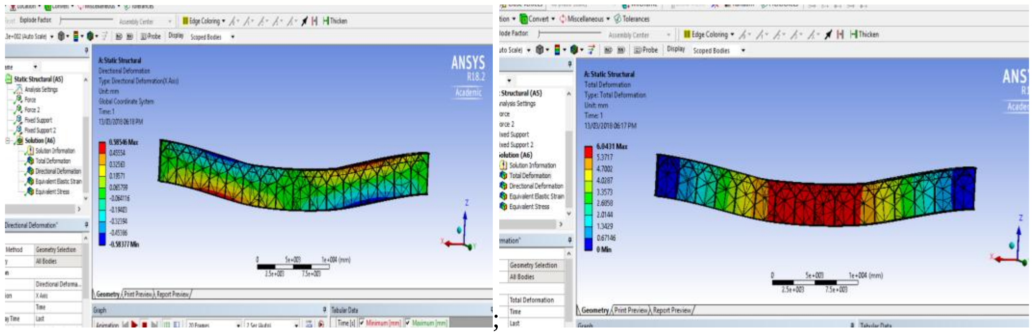


Fig.No.16. analysis result of the plate girder with pentagonal stiffener arrangement

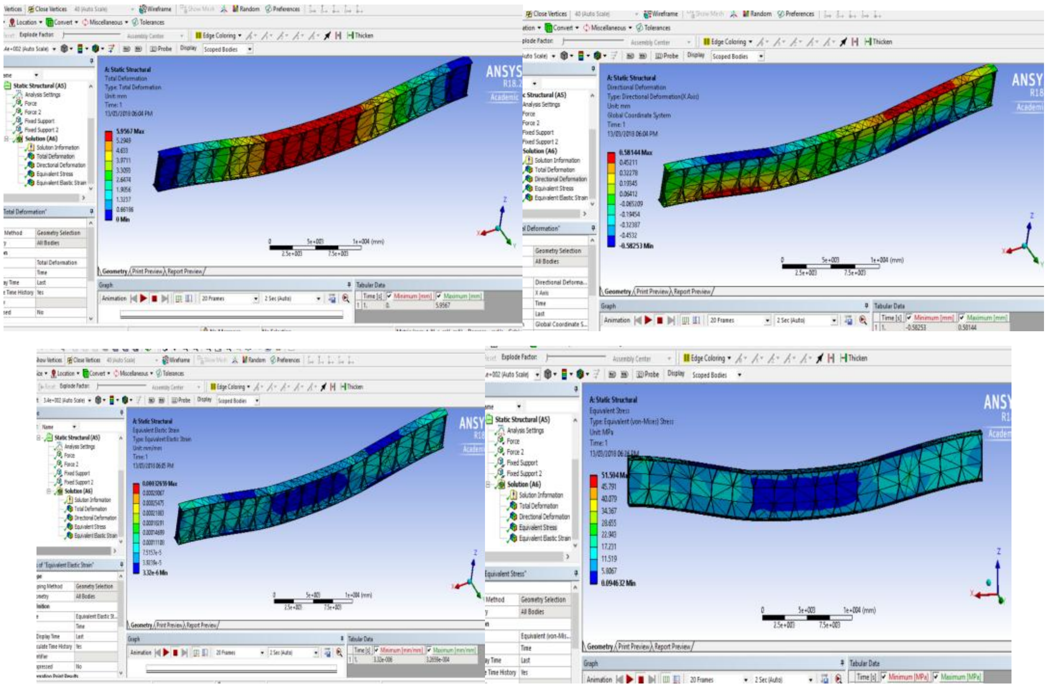
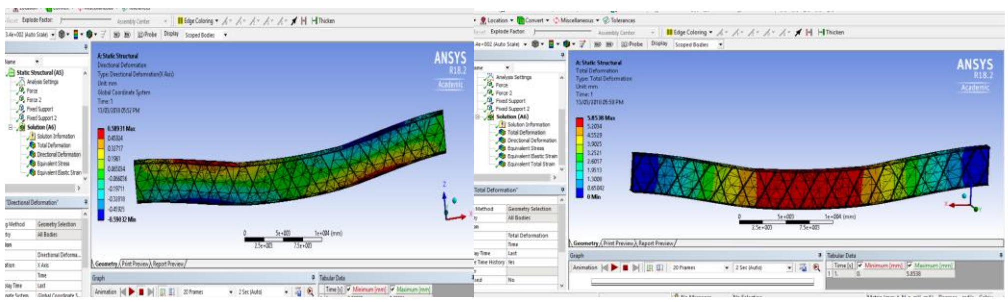


Fig.No.17. analysis result of the plate girder with octagonal stiffener arrangement



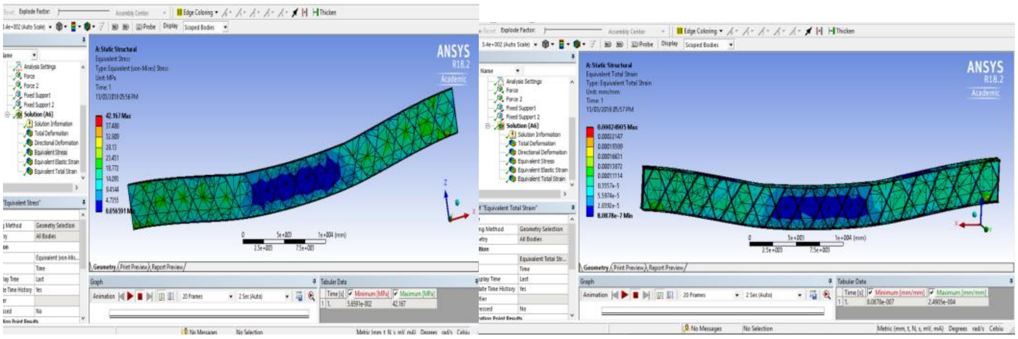


Fig.No.18. analysis result of the plate girder with hexagonal stiffener arrangement

IV.RESULTS AND DISCUSSION

- General

In this chapter, all the results of parametric study obtained by FEA software Ansys are presented.

Sr. No.	Section	Load Apply (kN)	Stress (Mpa)	Directional Deformation (mm)	Strain (mm/mm)	Total Deformation (mm)
1	Section with diagonal stiffener arrangement	800	38.47	0.53	0.00022	5.34
2	Section with pentagonal stiffener arrangement	800	30.27	0.58	0.00020	6.04
3	Section with hexagonal stiffener arrangement	800	42.16	0.58	0.00024	5.85
4	Section with octagonal stiffener arrangement	800	51.50	0.58	0.00032	5.95

Table 1. Analysis results obtained from software ANSYS

Optimize section of plate girder with different Stiffener arrangement is found from analysis results obtained by ANSYS software shows in above table.

Result of Optimize section by using ansys software as follows:

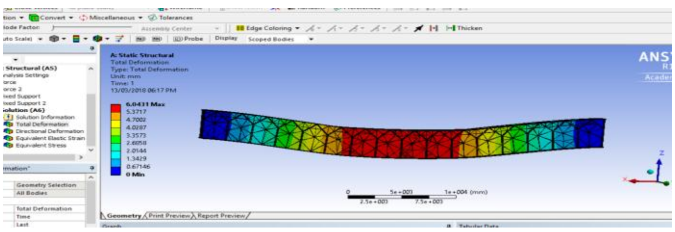


Fig.No.19. analysis result of total defor. of the plate girder with pentagonal stiffener arrangement

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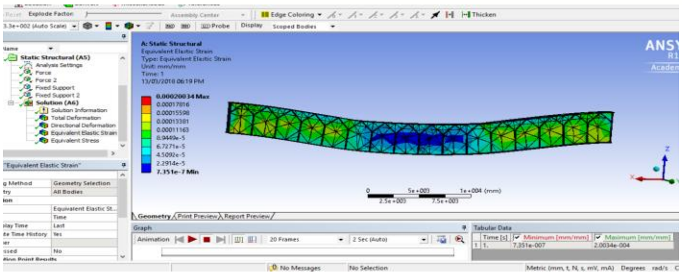

Fig.No.20.analysis result of equivalent strain of the plate girder with pentagonal stiffener arrangement

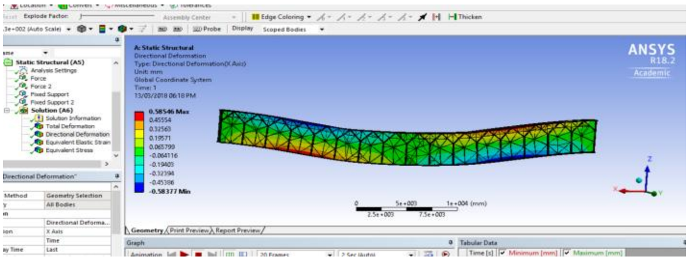

Fig.No.21.analysis result of directional defor. of the plate girder with pentagonal stiffener arrang.

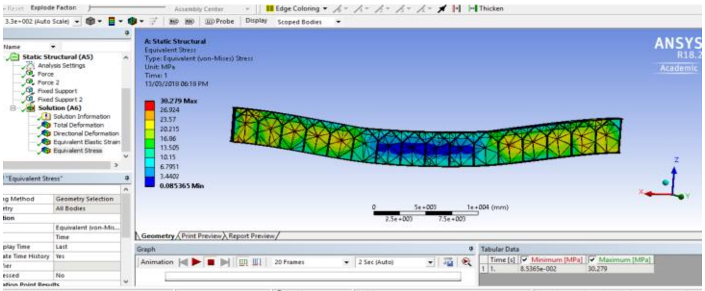

Fig.No.22.analysis result of equivalent stress of the plate girder with pentagonal stiffener arrangement

V.CONCLUSION

1. The non-linear finite element analysis gives the effective result of plate girder.
2. Based on analysis and result, the pentagonal stiffener arrangement more strength as compare to other stiffener arrangement.
3. Analysis and result of stress and total deformation of pentagonal stiffener arrangement are 30.27Mpa and 6.04mm respectively under constant 800KN load.
4. As per failure criteria of mild steel Factor Of Safety of pentagonal stiffener arrangement is 8.25

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