Design of Evener Beam for Lifting Plates

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Abstract— Boom or tower type crane consist hook facility to lift or move material and it is more flexibility than simple beam type horizontally established gantry crane. In this crane, beam is lifted by means of wire rope, link or chain to the distal end of boom and material can be lift by means of wire rope with lifting point. Beam is directly suspended using wire ropes and its move by boom crane. Wire ropes are fitted with lugs which are directly welded to the horizontally suspended beam for lifting material or objects. Generally, Beams are used to move slender materials specifically say slender plate as one industry application. Slender plate type objects are flexible in nature so, it may be sag or bend during a time of lifting because of only two lifting lug are generally used. Moreover, fixed size of beam is used for a single application of lifting plate so; this is a limitation of a beam, and in major cases it requires changing as application changes. On the other hand, due to two lifting point on a beam plate may be band or sag so it's require to solve two problem simultaneously. Also it is not solution to simply weld more number of lifting points say lug to beam, but need of specific and optimum design is requirement which is detail describe in this paper.

Key words: Evener beam, Upper & Lower lifting Lugs, FEA analysis, Bolt-Flange attachment

I. INTRODUCTION

In general there are two attachment lugs for lift the object, thus there is possibility of bending of object. Recently, they are using a 6 meter beam, to lift 10 meter length of plates fig.1.

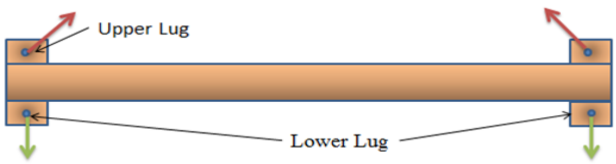


Fig. 1: Existing 6meter beam

Now company requires increasing scale of production. Due to bending in plates they cannot lift the plates of size between 10-13 meters. Thus for solve above problem they have to either purchase or manufacture new beam, which is uneconomical. So it requires providing an extra attachment for safe handling of various size of plates.

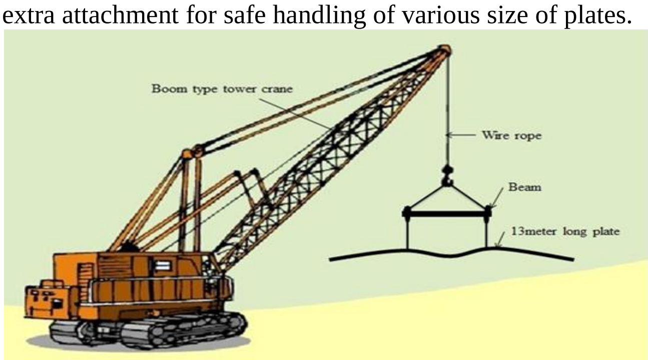


Fig. 2: 6meter beam lifting 13 meter plate

Moreover, due to only two lugs (lifting points) sagging take place while lifting. A lifting beam can also be used with multiple lugs for a relatively flexible object. Thirteen meter longer plate lifting with 6 meter beam and boom type crane is shown in fig.2.

This is not only solution to provide extra lifting points to beam but it also needs optimum redesign using extra lifting point. After completing the design of new beam it is require to check stress and deformation of the beam's upper and lower lugs in both maximum as well as minimum loading conditions.

II. MECHANICAL DESIGN

A. *Need of Evener Beam:*

For handle the plate of 10 & 13 meter in length 6 meter beam is not applicable due to plate sagging or bending due to two lifting lugs and span of lifting. For that it is also equally important to analyses plate deformation using existing beam as well. Plate is bending due to its own weight at the time of lifting which is shown following structural analysis of plate.

1) *10meter Plate FEA Using 6meter Beam*

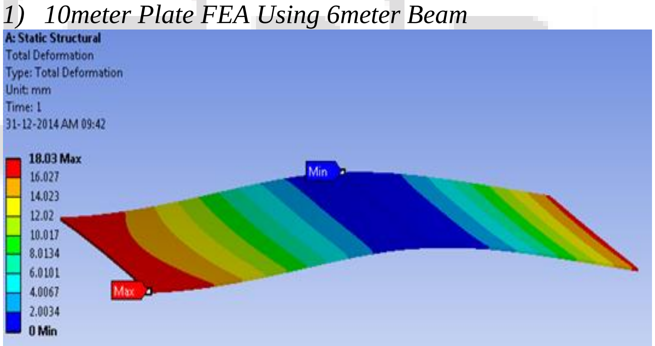


Fig. 3: Deformation in 10meter plate

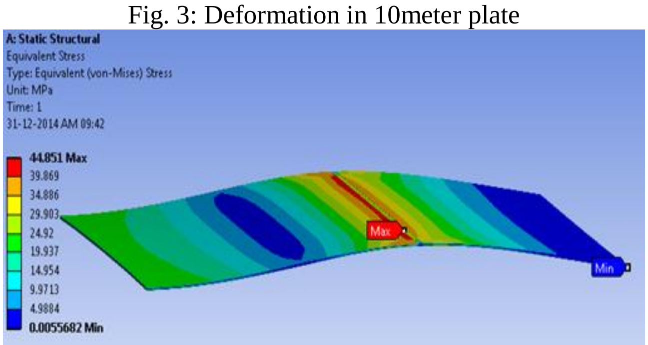


Fig. 4: Stress in 10meter plate

2) *13meter Plate FEA Using 6meter Beam*

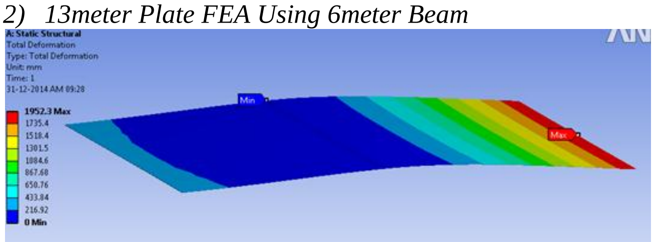


Fig. 5: Deformation in 13meter plate

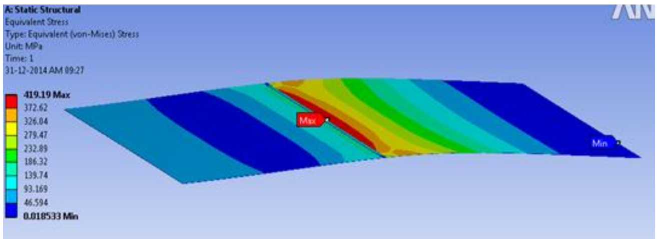
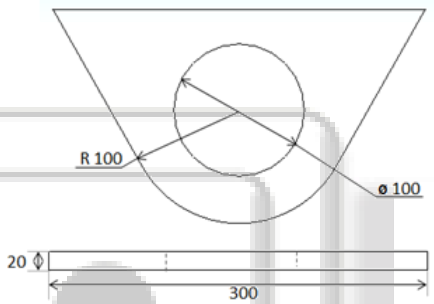


Fig. 6: Stress in 13meter plate

From above analysis it observed that, when 6 meter beam with two lugs is used to handling 13meter long plate, then stress & deformation values are as 419.19MPa & 1952.3mm respectively. So, FoS of 13 meter plate is 0.59638. which is not safe so, new beam design require to handle 10 & 13meter long plate.

Plate Details	Minimum	Maximum
Length	10 m	13 m
Width	2.8 m	3 m
Thickness	0.026 m	0.04 m
Weight	7.2 MT	12 MT

B. Design of Lower Lugs:



Load in downward direction at each lug can be calculate as

$$= \frac{25.2 \times 1000 \times 9.81}{4 \text{ lugs}}$$

= 6.3 MT (at each lower lug)

Stress at lower lug support = $\frac{6.3 \times 1000 \times 9.81}{2000}$

= 30.9015 MPa < 96 MPa safe.

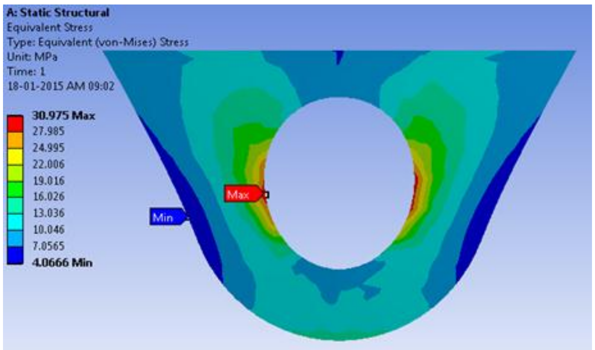
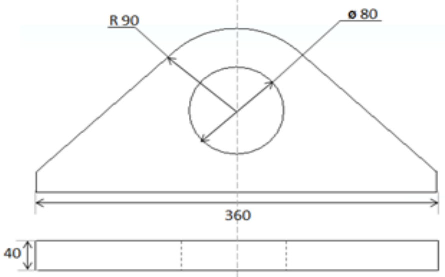


Fig. 7: Stress in Lower Lug

C. Design of Upper Lugs:



1) Shear Stress Due To Direct Force:

Load on lug = Self Weight of Beam + Wire Rope Weight

=25.2 MT + 2.4806 MT ≈ 27.7 MT

Load in upward direction at each lug can be calculate as

$$= \frac{27.7 \times 1000 \times 9.81}{2 \text{ lugs}}$$

= 13.9 MT

(at 45˚ with horizontal each upper lug)

Hence, actual load applied is

$$F = \frac{13.9}{\cos 45^\circ} = 19.657 \text{ MT}$$

Stress at upper lug support $= \frac{19.657 \times 1000 \times 9.81}{4000}$

= 48.2088 MPa < 96 MPa safe.

2) Bending Of Lug Due To Inclined Force:

Force 19.657 MT acting at angle of 45˚.

Thus, horizontal force is = F×cos45˚ = 13.9 MT

Horizontal force component is responsible for bending stress in upper lug.

For that Bending moment B.M. = (13.9 × 1000 × 9.81) × 80 = 10908720 N·mm

$$I = I_{xx} + I_{yy}$$

$$= \frac{40 \times 50^3}{12} + 40 \times 50 \times 65^2 + \frac{50 \times 40^3}{12} + 50 \times 40 \times 65^2$$

$= 17583333.2 \text{ mm}^4$

$Y_{max} = 80$ mm

Total section modulus $Z = \frac{I}{Y_{max}} = \frac{17583333.2}{80}$

$= 219791.665 \text{ mm}^3$

Now, bending stress $= \frac{B.M.}{Z} = \frac{10908720}{219791.665}$

= 49.6321 MPa < 158.4 MPa safe

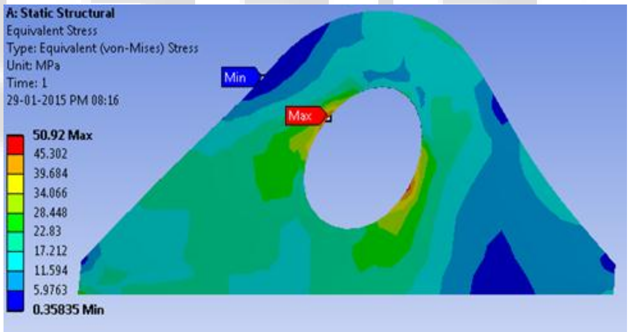


Fig. 8: Stress in Upper Lug

D. Design of Bolt for Attachment:

So far discussed, for extension of beam bolt flange arrangement is useful for existing beam. Let consider one lug at each end of extension for handling 13meter plate.

Total force applied on bolt

W = (weight of 2 meter beam with one lug) + (plate weight which is to be lifted by 2 meter beam)

Weight of 2 meter beam = c/s of beam × extension length of beam × density

= 0.030947 × 1.8 × 7833

= 436.33 kg

Weight of a lower lug = volume × density

$= 0.00069482 \text{ m}^3 \times 7833 \text{ kg/m}^3$

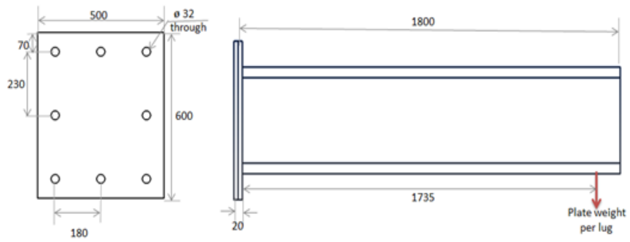
= 5.4426 kg

Weight of 13 meter plate = 25.2 MT

W = (436.33+5.4426) × 9.81 + weight of plate

$$= 2834.57 + \frac{25.2 \text{ MT}}{4 \text{ lugs}} \times 1000 \times 9.81$$

= 66136.79 N



Direct shear load on each bolt

$$W_s = \frac{W}{n} = \frac{66136.79}{8} = 8267.09875 \text{ N}$$

Maximum tensile load on upper bolt

$$W_t = \frac{W\,L\,L_2}{2 \times [(L_1)^2 + (L_2)^2]}$$

$$= 106396.2303 \text{ N}$$

Here bolt are subjected to shear as well as tensile loads, then equivalent loads are given as follow.

Equivalent tensile load

$$W_{te} = \frac{1}{2} \times [W_t + \sqrt{(W_t^2 + 4W_s^2)}\ ]$$

$$= 107034.7603 \text{ N}$$

Equivalent shear load

$$W_{se} = \frac{1}{2} \times \sqrt{(W_t + 4W_s^2)}$$

$$= 53836.645 \text{ N}$$

$$\sigma_t = \frac{W_{te}}{\text{cross section area of bolt}}$$

where, σ_t = permissible tensile stress = 648 MPa

$$648 = \frac{107034.7603}{\frac{\pi}{4} d_c^2}$$

$\therefore$ d_c = 14.50 mm

from table of coarse series, the standard core diameter is 14.50 mm and corresponding size of bolt is M18.

Total maximum load on bolt (tensile + shear).

$W_{total} = W_s + W_t$

= 8267.09875 + 106396.2303

= 114763.3291 N

Maximum stress on bolt based on permissible shear stress.

$\therefore$ d_c = 18.53 mm

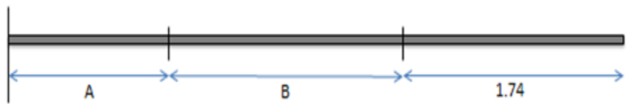
Hence, bolt design is safe as we take M30 bolts.

III. LUG SPAN DESIGN

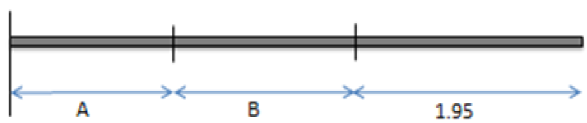
A. Lower Lug Space:

For lower lug consider plate which is to be handle by evener beam. Here one beam is used to handling 10 & 13meter plate. For that let consider two lug at each extreme end positions and change distance of middle two lugs.

For 13meter plate consider middle lugs distance as follows.



For 10meter plate consider middle two lugs distance as follows



For 13 meter plate

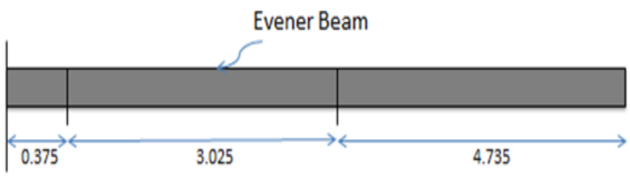
A (m)	B (m)	Deflection (mm)	Stress (MPa)
0.075	4.585	3.4481 mid	18.853
0.175	4.485	3.2095 mid	17.495
0.275	4.385	3.2116 mid	16.495
0.375	4.285	3.2137	16.835
0.475	4.185	3.2156	16.455
0.575	4.085	3.2175	16.456
1.475	3.185	3.2325	16.475
1.585	3.075	3.234	16.477
1.595	3.065	3.2342	16.477
1.695	2.965	3.2354	16.478
1.795	2.865	3.2367	16.48
1.895	2.765	3.2379	16.481

For 10 meter plate

A (m)	B (m)	Deflection (mm)	Stress (MPa)
0.075	2.875	5.8107	22.148
0.175	2.775	5.8109	22.145
0.275	2.675	5.8111	22.141
0.375	2.575	5.8113	22.139
0.475	2.475	5.8115	22.135
0.575	2.375	5.8116	22.132
1.475	1.475	5.8124	22.111
1.585	1.365	5.8125	22.109
1.595	1.355	5.8125	22.108
1.695	1.255	5.8126	22.109
1.795	1.155	5.8125	22.106
1.895	1.055	5.8126	22.106

From ANSYS Design Xplorer for lug distance it is seen that lower lug is safe as very less difference in Deflection and Stress also it is safe.

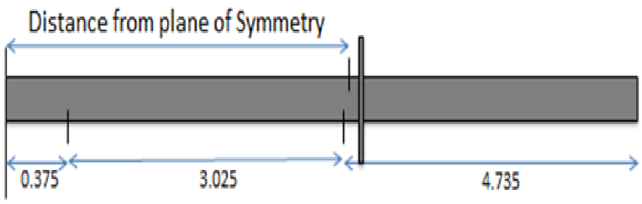
For that let consider following lug distance on beam.



B. Upper Lug Space:

For upper lug consider weight of beam+plate. Here single beam is used to handling 10 & 13meter plate.

For 13meter plate handling operation consider lugs distance as follows.



For 13meter plate

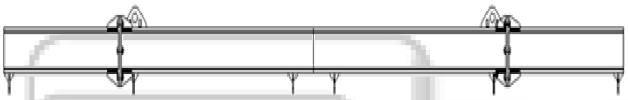
Distance from plane of symmetric (mm)	Deflection (mm)	FoS
2800	1.6508	1.0708
2700	2.0042	2.4325
2600	2.3335	3.6768
2500	2.6875	3.6533
2400	3.056	3.5725
2300	3.4419	3.3085
2200	3.8666	3.0257
2100	3.9014	3.1346

For 10meter plate

Distance from plane of symmetric (mm)	Deflection (mm)	FoS
2800	1.04	2.0082
2700	0.91605	2.2391
2600	0.80338	2.5192
2500	0.69727	3.7663
2400	0.59944	4.4234
2300	0.51263	5.1556
2200	0.43366	5.0236
2100	0.42629	5.5424

So, distance from plane of symmetry is 2100mm with safety factor 3.134.

Thus, Evener Beam Design is as follows.



IV. CONCLUSION

From finite element analysis of plate it is observed that, while 10 meter plate is handling by existing beam it is safe operation. On other hand while same beam is used to lift 13 meter long plate then plate bends beyond its limit. So, new design of beam is necessary for lift up to 13 meter plate using the same beam by extra attachment and safe handling. For flange attachment with M30 bolt is use for extension of beam. And evener beam is capable to handling 10meter & 13meter plate.

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