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# Experimental Study of Torsional Effect on Flat Plate used in Built-up Column Section

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## ABSTRACT

The built-up columns are widely used in the field of steel industries. The built up columns are extensively used as a compression members in truss, roofing, industries and elevated steel water tanks etc. The lacing and batten are the main components of built up column, the steel flat plate are mainly used as lacing and battens in built up columns. The structural behaviour of steel column and its stability are studied by many researchers. When the loading is eccentric to the column and are fixed in bottom and moment at top so that the column undergoes the torsion forces and the twisting moment directly impacts on lacing and battens of column. This paper present the torsional behaviour of flat plate use in built up column, it show the torsional effect on flat plate by experimental and analytical modelling in ABAQUS 6.13.

**Keywords:** Built up Column, Flat Plate, Torsion, FEM (Finite element method) ABAQUS.

## I. INTRODUCTION

Built-up columns are widely used in the field of steel structures. The built-up column is used as compression members in buildings and bridges. The built-up columns are composed with two parallel steel components that are connected with each other along with their length by the lacing or battens. The I-shape and channel sections are most commonly used steel components in built-up columns. The plates, angles and flat bars are used as lacing or batten in built-up column. The main advantage of the built-up section is that the lower steel weight and higher moment of inertia. However as compared to solid columns, usually the built-up section are low in shear that is why the lacing and batten are provided to resist the shear forces where the buckling resistance of built-up column under axial load has been addressed by many researchers. It is also observed that intensity of axial load has a significant effect on the ultimate strength of column and only few studies have been carried out on seismic behaviour of built-up column. Whenever the earthquake occurs the built-up column under goes the shaking moment and forces due to these loadings are eccentric to the column. Due to sudden impact the torque generated into the column and the column fail due to the poor connection between two profiles that is lacing and batten, so in this paper the experimental study of torsional effect on flat plate which is used in built-up column section are carried out and the comparison between the experimental and analytical modelling of flat plate is been done ,this method is used for solving the problem of engineering and model typical problems area of interest including structural analysis. To solve the problems of FEM the flat plate is divided into number of meshes to get the accurate result, in this paper the Abaqus model of flat plate is analyses by FEM and the comparison between the experimental and analytical modelling is done to investigate the torsional behaviour of flat plate.

## II. METHODOLOGY

The torsion test is conducted on flat plat in torsion machine, flat plate is placed in the machine in such as a way that its longitudinal axis coincides with axis of the grips so that it remains same during the test. Rotation is applied at constant speed at one end and other end remains fixed, then twisting will develop in cross section of the flat plate whose behaviour is increase linearly. From torsion testing machine the force (N) & angle of twist (ɵ) can be plotted, The dimensions of the test sample are (4x40x300mm).The mild steel rectangular flat plate specimen is used as shown in Fig (2) Torsion test is been conducted on torsion testing machine of having the maximum capacity 600 kgf that is 5886 Nm and the results outputs parameters are given in tables 2

Table 1. Specimen details

| Specimen Thickness | Specimen Width | Specimen Length |
|---|---|---|
| 4mm | 40mm | 300mm |

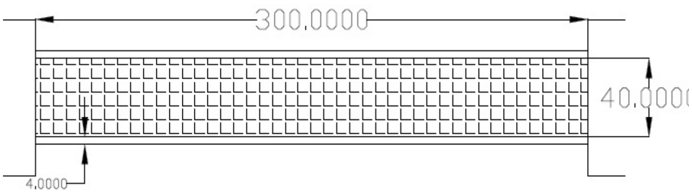


Fig (1) Flat Plate

**Modulus of Rigidity Calculation:**

**Formula:**

$$G = T/Ip \times L/\Theta$$

Where, $\Theta$ = angle of twist, Ip = polar moment of inertia, L = length of specimen T = maximum torque in (N)

$\Theta = 360^{o}$, L = 300mm, T = 450 x 9.81, T = 4418.5 N

$Ip = b*d*(b^2+d^2)/12$

b = 300mm

d = 40mm

$Ip = 300x40x\,(300^2+40^2)/12$

$Ip = 9.16x10^{-5}\ mm^4$

Therefore, $G = 4418.5/9.16\ X\ 10^{-5}\ X\ 300/360^{O}$

**$G = 40.16\ X\ 10^6\ N/mm^2$**

Fig (2) Flat plate sample

## III. RESULTS AND DISCUSSION

Table 2. Modulus of rigidity on flat plate

| Specimen (4x40x300)mm | Modulus of rigidity (N/mm2) | Maximum torque (N) |
|---|---|---|
| 1 | $40.16x10^6$ | 4414.50 |
| 2 | $38.55x10^6$ | 4237.92 |
| 3 | $41.32x10^6$ | 4542.03 |
| Average Value | $40.01\ x\ 10^6$ | 4398.15 |

Table no (3) modulus of rigidity of standard bar

| | |
|---|---|
| modulus of rigidity standard bar | 78000 N/mm2 |

From the table no 2 it is been seen that the average value of modulus of rigidity of flat plate comes out to be **40.01 x 10⁶** and which is much higher than standard value as per table 3 . As per Table no 4, 5, 6 it shows that when the loading is increased then the specimen also increase its ductility, this may be due to the specimen compression in its longitudinal axis as specimen is constrained at its ends and in some axial strain the specimen failed at the point of maximum loadings.

Table no (4) Sample 1 Result

| Angle (Degree) | Torque (Kgf/cm) |
|---|---|
| 0 | 0 |
| 30 | 50 |
| 60 | 98 |
| 90 | 122 |
| 120 | 145 |
| 150 | 164 |
| 180 | 200 |
| 210 | 234 |
| 240 | 284 |
| 270 | 337 |
| 300 | 390 |
| 330 | 430 |
| 360 | 450 |

Table no (5) Sample 2 Result

| Angle (Degree) | Torque (Kgf/cm) |
|---|---|
| 0 | 0 |
| 30 | 45 |
| 60 | 97 |
| 90 | 124 |
| 120 | 146 |
| 150 | 160 |
| 180 | 200 |
| 210 | 235 |
| 240 | 280 |
| 270 | 340 |
| 300 | 388 |
| 330 | 432 |

Table no (6) Sample 3 result

| Angle (Degree) | Torque (Kgf/cm) |
|---|---|
| 0 | 0 |
| 30 | 48 |
| 60 | 97 |
| 90 | 120 |
| 120 | 146 |
| 150 | 166 |
| 180 | 201 |
| 210 | 234 |
| 240 | 284 |
| 270 | 340 |
| 300 | 390 |
| 330 | 432 |
| 360 | 463 |

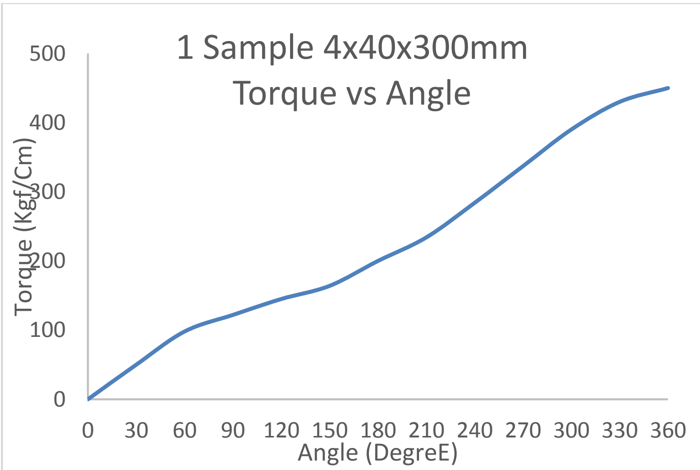


Fig (3) Sample 1 Graph

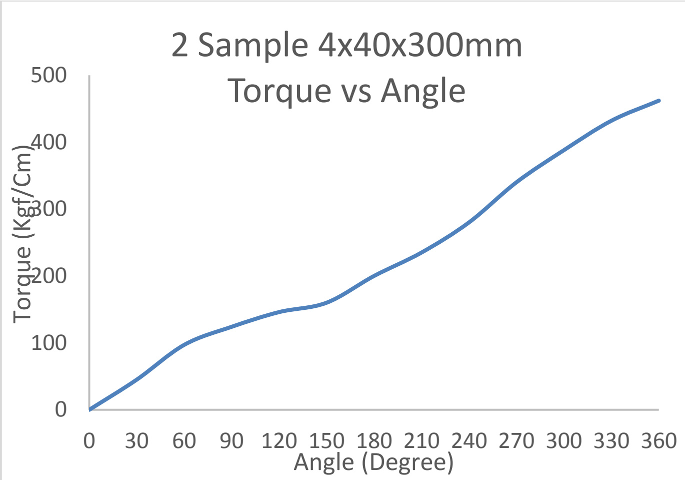


Fig (4) Sample 2 Graph

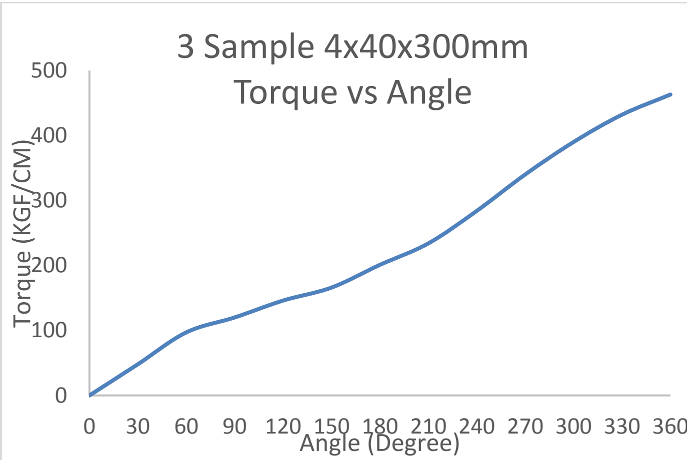


Fig (5) Sample 3 Graph

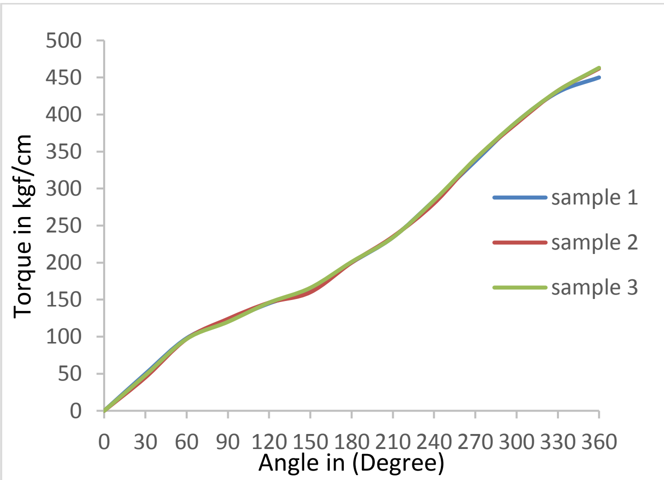


Fig (6) Combined graph

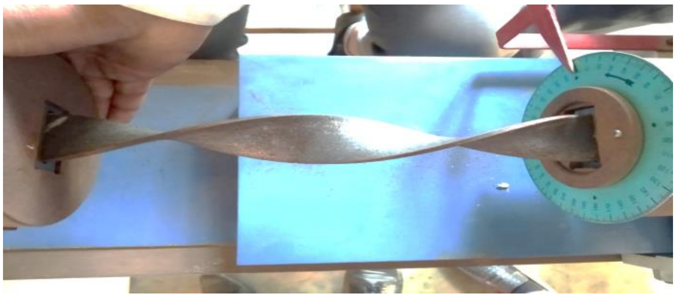

Fig (7) Specimen in torsion testing machine

**Finite Element modelling**

For better understanding the behaviour of flat plate under torsion ,the analysis of flat plate of size (40x300x4) mm is modelled in Abacus and the boundary condition is applied same as that in experimental set up that is one end is fixed and other is rotating Fig.10 shows the flat plate is fixed by boundary condition in Abacus at one end other is rotated with 6.28 rad that is $360^0$ rotation that is $U_1=U_2=U_3=0$ $UR_1=UR_2=0$ & $UR_3=6.28$ radius As torque is applied in which $UR_1=UR_2=UR_3=0$, $U_1=U_2=0$ and $U_3=$ Applied torque, Abacus model shows the good results and performance because of much lesser mesh in the flat plate. Figure 10 show the maximum strain developed in the flat plate and it is been observed from the figure that red mark show higher strain which are mostly comes at the periphery of the plate.

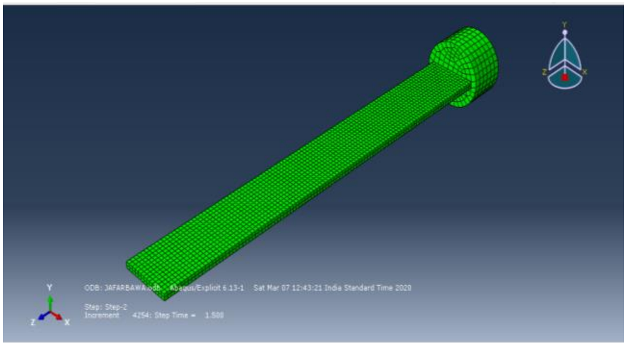

Fig (7) flat plate on Abacus

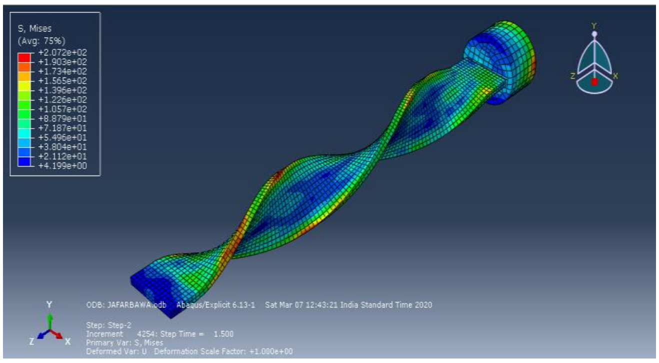

Fig (9) flat plate under torsion in Abacus

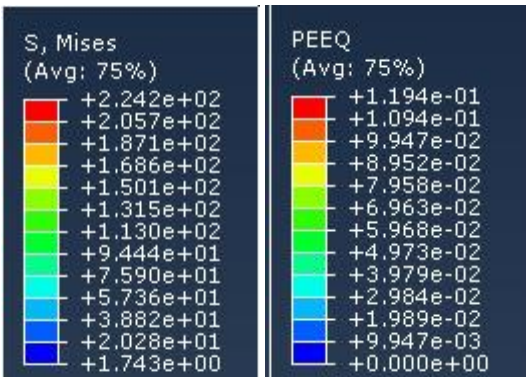


Fig (10) output from abaqus

## IV. CONCLUSION

Torsion test is been done on mild steel rectangular flat plate specimen by using torsion testing machine the following conclusion are made.

1) Based on the experimental test conducted on flat plate , it is been observe that it gives the modulus of rigidity as $41.32 \times 10^6 N/mm^2$.which is much use full in the calculation of torsional buckling of column
2) More different types of flat plates having different thicknesses will give much satisfactory results.

From the above study it is been concluded that the rectangular flat plate used in built up columns as lacing or battening are highly resistible to the torsion forces as compare to bars or angles because of higher modulus of rigidity and moment of intertia.

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