Comparative Thermal Analysis of Steel Built-up Columns

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Abstract - In design of structures , the properties of the material play very important role. They vary with change in external atmosphere or any internal physical change. The project is based on the idea that when different steel members are joined and configured together , then the thermal behavior of the complete built up column assembly of steel structure can be different from that of individual member . Different configurations and connections may also have significant effect on the behavior of the built up section as compared to that of individual ones. This project intends to analyze the thermal behavior of steel built up columns in different configurations and decide which one has more efficiency against thermal effects . Comparison will be based on graphs of equivalent stresses plotted against rising temperature which will decide the failure of columns at elevated temperatures.

Keywords –Thermal Behavior , Built up column , Equivalent stresses , Efficiency against thermal effects

I. INTRODUCTION

In the present world, steel is a major material used in the construction, steel structures are becoming popular day by day encouraging the various developments in steel industry in terms of steel as a material as well as in terms of innovative designs .The project is based on the behavior of steel built up columns .These columns are provided in different configurations in different combinations of bolted, welded, laced , battened or a combination of them . At elevated temperature there is considerable change in properties of steel (modulus of elasticity ,bulk modulus , yield strength etc.). The cause of the temperature could be fire accidents, blasts etc. where the temperature rises abruptly affecting the structure and its strength. But when different steel members are joined and configured together , then the thermal behavior of the complete built up assembly of steel structure can be different from that of individual member. The project intends to analyze the thermal resistance of different built up columns and come up with the most efficient built up column configurations . During the project different column sections have been designed in different configurations and analyzed in temperature conditions to obtain the failure stress. The failure stress will be the measure of the efficiency of column under thermal stress. The optimization of mess size will be done at failure stress value to obtain a more accurate value .All the columns are designed manually using IS800:2007 and SP6(1)-1964, modeled in CATIA V5R16 and analyzed in ANSYS 2014.

II. LITERATURE REVIEW

Choe, L., Varma, A., Agarwal, A., and Surovek, A. "Fundamental Behavior of Steel Beam- Columns and Columns under Fire Loading: Experimental Evaluation." (2011). In this journal , the researcher performed lab experiments on eleven steel columns by providing thermal conditions using the heating and control equipment and had developed load displacement curves under the thermal conditions showing thermal behavior of the steel columns under elevated temperature.

Ju Chen[1] ;Ben Young and Brian Uy "Behavior of High Strength Structural Steel at Elevated Temperatures" (2006) . The researcher has found the effect of the temperature on the mechanical properties of the high strength steel and the mild steel and has plotted the stress v/s strain curves for the steel types considered. The ultimate strength for each type has also been found out for elevated temperatures .

III. DESIGNING AND MODELLING

The designs of the built up columns has been done manually using IS 800:2007 , and SP6(1) – 1964 Steel Tables .The modeling has been done on CATIA-V5R16 .For designing purpose the load of 1500KN and 6 m length of column is assumed .The CATIA models are shown below which show the actual configuration of the columns.

Column 1 –
Section – 2 ISMC 350@ 42.1Kg/m
Configuration – Back to back + laced

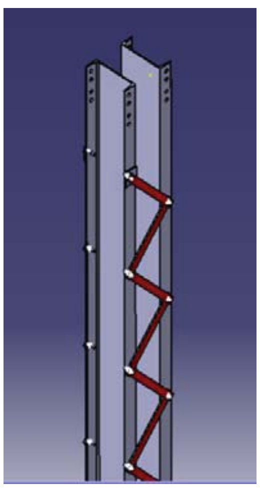

Fig 1 (a) Back to back channel section in laced configuration

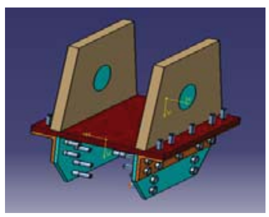

Fig 1(b) Hinged support

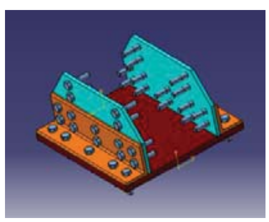

Fig 1 (c) Fixed support

Fig 1 – Models of laced back to back channel section configuration and end supports

Column 2 –
Section – 2 ISMC 350@ 42.1Kg/m
Configuration – Back to back + Battened

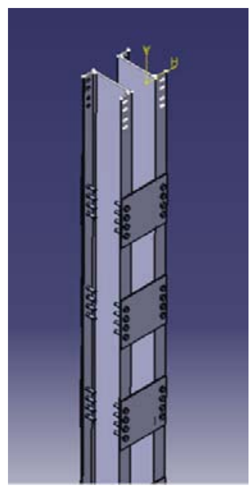

Fig 2 (a) Back to back channel section in battened configuration

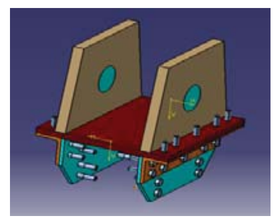

Fig 2 (b) Hinged support

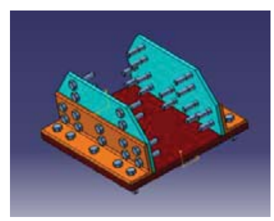

Fig 2 (c) Fixed support

Fig 2 - Models of battened back to back channel section configuration and end supports

Column 3 –
Section – 2 ISMC 350@ 42.1Kg/m
Configuration – Toe to toe + Laced

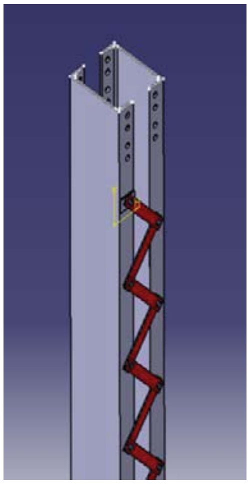

Fig 3 (a) Toe to Toe channel section in laced configuration

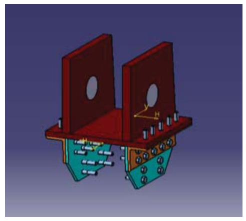

Fig 3 (b) Hinged support

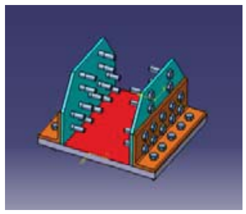

Fig 3 (c) Fixed support

Fig 3 - Models of laced toe to toe channel section Configuration and end supports

Column 4 –
Section – 2 ISMC 350@ 42.1Kg/m
Configuration – Toe to toe + Battened

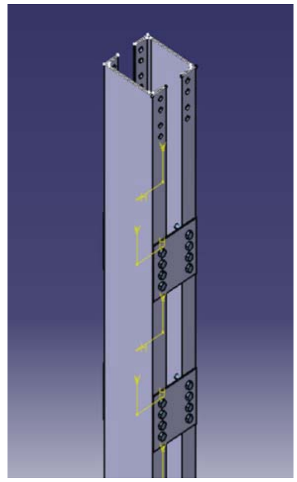

Fig 4 (a) Toe to Toe channel section in battened configuration

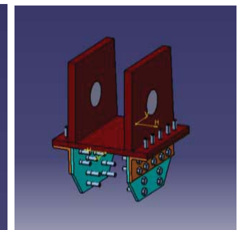

Fig 4 (b) Hinged support

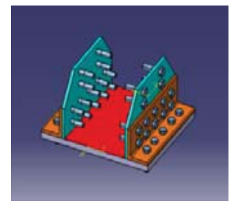

Fig 4 (c) Fixed support

Fig 4 - Models of battened toe to toe channel section configuration and end supports

Column 5 –
Section – 2 ISMB 300 @ 44.2 Kg/m
Configuration – Side by side + Battened

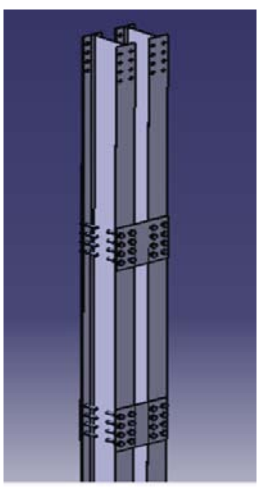

Fig 5 (a) Side by Side I section in battened configuration

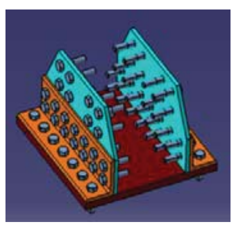

Fig 5 (b) Hinged support

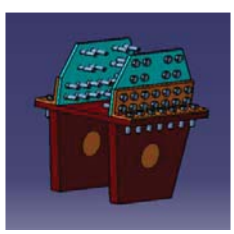

Fig 5 (c) Fixed support

Fig 5 - Models of battened side by side I section configuration and end supports

Column 6 –
Section – 2 ISMB 300 @ 44.2 Kg/m
Configuration – Side by side + Battened

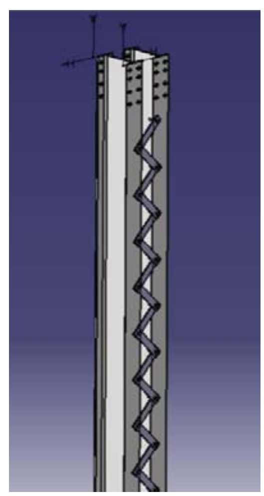

Fig 6 (a) Side by side I section in laced configuration

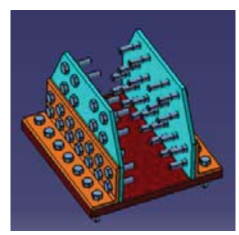

Fig 6 (b) Hinged support

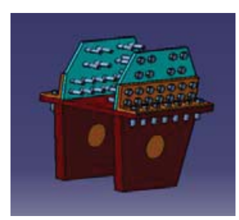

Fig 6 (c) Fixed support

Fig 6 - Models of laced Side by side I section configuration and end supports

IV. ANALYSIS

Each of these columns are analyzed for the 4 standard boundary conditions stated as –

1. Both ends free to rotate but restrained against translation
2. Both ends fixed against rotation and translation.
3. One end restrained against rotation and translation and other end free.
4. One end restrained against translation and rotation and other end restrained against translation but free to rotate.

The analysis includes the finite element analysis of models prepared in CATIA V5R16 and imported in ANSYS Workbench 14 .

A. Assigning Supports

Multiple ways are there to simulate the end supports , the following configuration has been assigned for the analysis purpose in ANSYS Workbench 14 for this project.

a) Assigning Fixed End

The condition used to assign the fixed support in ANSYS is Remote Displacements on top end and bottom end with different configuration as shown.

For top end – The dis placement is allowed only in z direction and other components of rotation and displacement are restricted.

For bottom end – All the components of displacement and rotation are restricted.

b) Assigning Hinged End –

The conditions used in ANSYS Workbench 14 to assign the hinge support after modeling hinges are the remote displacement and the cylindrical support with configurations mentioned below .

For top end – The displacement in z direction is set free and other components of displacement are restricted. The rotation is allowed only about y direction and other components of rotation are restricted.

For Bottom end – All the components are restricted but radial component is set free.

B. Assigning Load

a) Through Fixed Support
Load is directly applied on the top plate of the fixed support assembly in direction of gravity .

b) Through Hinged Support
The load is applied as a shear force in hinge cross section in four parts each of 375KN magnitude totally making 1500KN load.

c) Static Thermal Condition
To bring the effect of the temperature the static thermal condition is used. The density , modulus of elasticity , yield strength , bulk modulus , shear modulus vary with temperature

V. RESULTS AND DISCUSSION

The results are obtained after the analysis of each model at different temperature and graph has been plotted between temperature (x axis) and equivalent stress(y axis) at different temperature . The graph rises initially and after a temperature it falls down at a certain stress value. This value is the failure point of the column .

On the basis of this graph , it can be decided that which configuration is more efficient in taking thermal stress in particular boundary conditions. Following are the graphs showing the variation of the maximum stress developed in columns with the rising temperature .

a) Results for boundary condition 1 (Both ends free to rotate but restrained against translation)

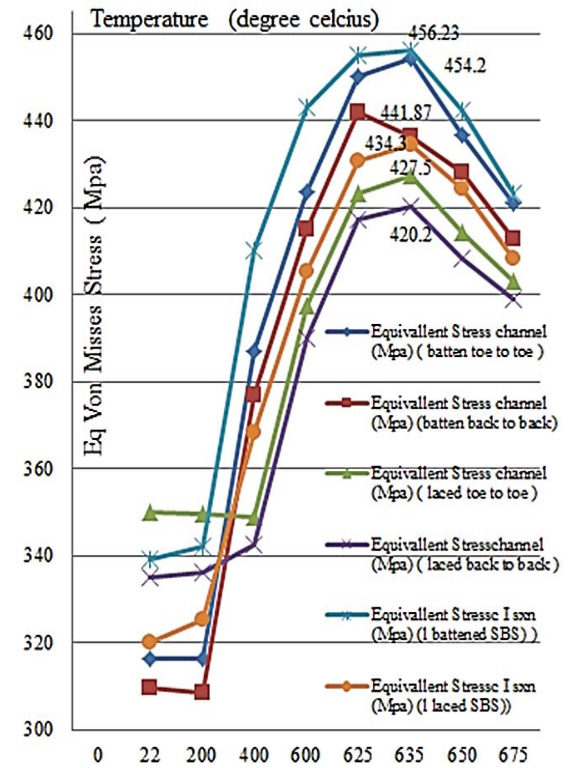

Fig 7 – Curves showing the equivalent stress values for boundary condition 1

The I section placed side by side comes up as most efficient failing at 456.23 M.Pa. in Boundary condition 1

b) Results for boundary condition 2 (Both ends fixed against rotation and translation)

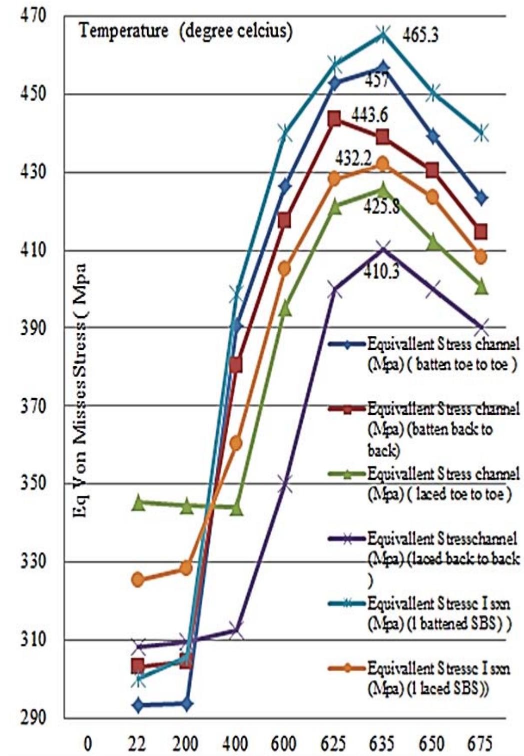

Fig 8 – Curves showing the equivalent stress values for boundary condition 2

The I section placed side by side comes up as most efficient failing at 465.3 M.Pa. in Boundary condition 2

c) Results for boundary condition 3 (One end restrained against rotation and translation And other end free.)

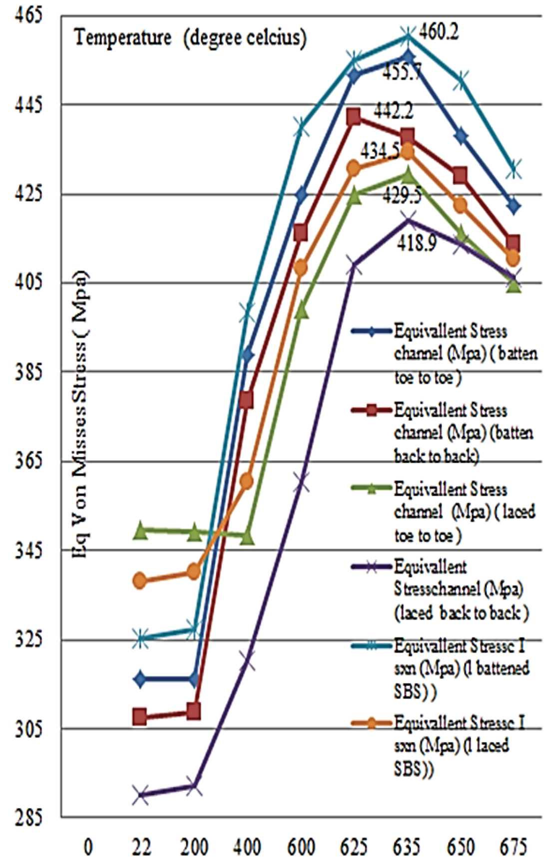

Fig 9 – Curves showing the equivalent stress values for boundary condition 3

The I section placed side by side comes up as most efficient failing at 460.2 M.Pa. in Boundary condition 3

d) Results for boundary condition 4 (One end restrained against translation and rotation and other end restrained against translation but free to rotate.)

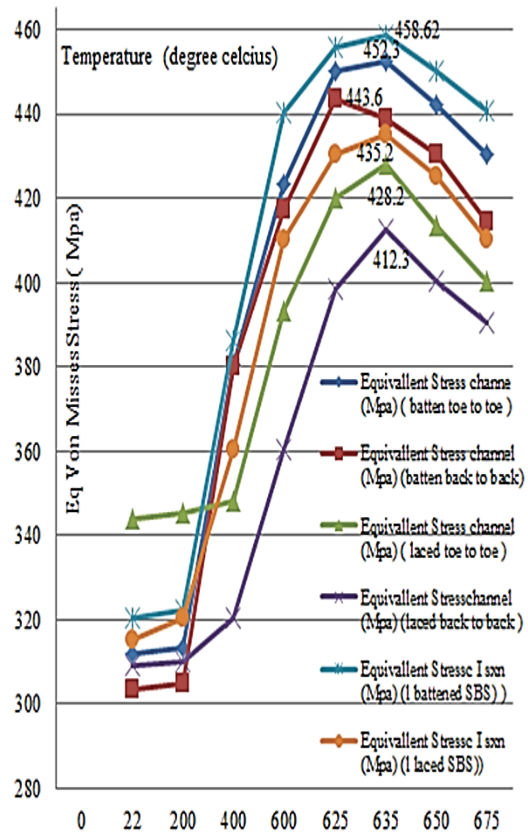

Fig 10 – Curves showing the equivalent stress values for boundary condition 3

The I section placed side by side comes up as most efficient failing at 460.2 M.Pa. in Boundary condition 3

VI MESH OPTIMIZATION

The results obtained for the analysis are for 20 mm mesh size .As per the plan, once the failure stress is found out for 20 mm mesh size, it will be optimized for 1 mm mesh size in order to get more accurate value. This optimization will be done for the failure stress value only mentioned as below.

Table 1 – Optimized values of the equivalent stress for 1 mm size of mesh

S. no	Boundary Condition	Column Section	Position	Configuration	Failure stress (M.Pa) For 20 mm mesh size	Optimized Failure stress (M.Pa.) for 1 mm mesh size
1	1	2 ISMC 350 @ 42.1 Kg/m weight	B to B	Battened	441.87	419.77
2	1	2 ISMC 350 @ 42.1 Kg/m weight	B to B	Laced	420.2	402.5
3	1	2 ISMC 350 @ 42.1 Kg/m weight	T to T	Battened	454.2	426.3
4	1	2 ISMC 350 @ 42.1 Kg/m weight	T to T	Laced	427.5	406.13
5	1	2 ISMB 300 @ 44.2 Kg/m weight	S b S	Battened	456.23	430.1
6	1	2 ISMB 300 @ 44.2 Kg/m weight	S b S	Laced	434.3	409.5
7	2	2 ISMC 350 @ 42.1 Kg/m weight	B to B	Battened	443.6	421.42
8	2	2 ISMC 350 @ 42.1 Kg/m weight	B to B	Laced	410.3	385.3
9	2	2 ISMC 350 @ 42.1 Kg/m weight	T to T	Battened	457	430.23
10	2	2 ISMC 350 @ 42.1 Kg/m weight	T to T	Laced	425.8	406.33
11	2	2 ISMB 300 @ 44.2 Kg/m weight	S b S	Battened	465.3	442.03
12	2	2 ISMB 300 @ 44.2 Kg/m weight	S b S	Laced	432.2	411.3
13	3	2 ISMC 350 @ 42.1 Kg/m weight	B to B	Battened	443.6	423.36
14	3	2 ISMC 350 @ 42.1 Kg/m weight	B to B	Laced	412.3	391.68
15	3	2 ISMC 350 @ 42.1 Kg/m weight	T to T	Battened	452.3	429.68
16	3	2 ISMC 350 @ 42.1 Kg/m weight	T to T	Laced	428.2	406.79
17	3	2 ISMB 300 @ 44.2 Kg/m weight	S b S	Battened	458.62	435.36
18	3	2 ISMB 300 @ 44.2 Kg/m weight	S b S	Laced	435.2	411.52
19	4	2 ISMC 350 @ 42.1 Kg/m weight	B to B	Battened	442.2	420.09
20	4	2 ISMC 350 @ 42.1 Kg/m weight	B to B	Laced	418.9	396.56
21	4	2 ISMC 350 @ 42.1 Kg/m weight	T to T	Battened	455.7	430.22
22	4	2 ISMC 350 @ 42.1 Kg/m weight	T to T	Laced	429.5	410.23
23	4	2 ISMB 300 @ 44.2 Kg/m weight	S b S	Battened	460.2	438.2
24	4	2 ISMB 300 @ 44.2 Kg/m weight	S b S	Laced	434.5	412.77

VII. CONCLUSION

1. In all the cases the I section, battened, side by side configuration comes up as the most efficient configuration and channel section, laced, toe to toe configuration is the least efficient configuration considering the individual boundary conditions .

2. The I section , battened , side by side configuration is most efficient over all , when placed in the boundary condition 2 i.e. when both the ends of column are in fixed condition .

3. The variation in the behavior is due to the connections , member sizes and thicknesses which cause different volumetric strain in the bodies making them behave considerably different comparatively.

4. Column configuration had a considerable effect when the thermal conditions are considered because under different bolting and end conditions the stresses generated due to resistance will differ and this will lead to difference in thermal stress at failure .

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