PERFORMANCE ANALYSIS OF TUBED STEEL REINFORCED HIGH STRENGTH CONCRETE (TSRC) COLUMN TO STEEL BEAM JOINT

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Abstract - *Tubed steel reinforced high strength concrete (TSRC) column is a special type of column. It consists of an internal steel section, infilled concrete and an external steel tube. The steel tube is disconnected at the beam-column joint. Entire model works as a hoop confinement to minimize the possibility of local buckling of the column. In this study, a circular tubed steel reinforced concrete column to steel beam joint with external diaphragm was modeled and analysed using ANSYS 16.1. Three models were prepared and seismic behaviour is studied by varying column steel tube thickness. Various beam column joint behaviours in terms of total deformation, load carrying capacity, stress distribution, shear behaviour and equivalent total strain were studied.*

***Key Words*: TSRC, beam column joint, High strength concrete, Seismic behaviour**

1. INTRODUCTION

Steel-concrete composite structures show the excellent composite action of concrete and steel. Over the last few decades, steel-reinforced concrete (SRC) columns, and concrete-filled steel tube (CFST) columns have been commonly used throughout the world. In SRC column an external reinforcement cage and an internal steel profile are provided. The shear resistance and fire resistance of SRC columns are improved due to steel sections being encased in concrete. Tubed steel reinforced column (TSRC) is a special type of SRC Column here instead of external reinforcement a steel tube is used. The steel tube, is disconnected at the beam-column joint to avoid directly carrying the axial load. The entire section works as a hoop confinement to minimize the possibility of local buckling. At the same time, the strength and ductility of the concrete core will increase due to the confinement of the steel tube. Most importantly TSRC column avoids complexity of the densely arranged longitudinal reinforcements and stirrups at beam-column joints. As a new type of composite columns, TSRC columns show a better mechanical performance. The relevant test results indicate that the ultimate strength, ductility, deformation capacity, and energy-dissipating capacity of TSRC columns are superior to those of SRC column. Mainly it delays the local buckling of the external steel tube. Now a days the developments in technology increase the use of high-strength concrete. Which more used in high-rise and large-span buildings, to make the work more economical. By the use of high strength concrete decrease the high self-weight of structures and reduce the area of column cross sections effectively. But, brittleness of the concrete increases with the strength and deformation capacity reduces, which limits the application of high-strength concrete. If high-strength concrete is used in TSRC columns, the brittleness can be further decreased because of the double confinement provided by the internal profile steel and external steel tube. Previous studies mainly focused on the static and dynamic behaviors of TSRC columns. However, the behaviour of TSRC column to beam connections has not received much attention. So that here studies the seismic and shear behaviour of TSRC column to steel beam joint.

2. OBJECTIVES OF THE WORK

This work mainly carried out.

- To develop a FEA model for TSRC column to steel beam joint.
- To study the seismic behaviour of TSRC beam column joint under varying thickness of the column steel tube.
- To study the shear behaviour of outer steel tube, concrete core and internal profile steel.

3. GEOMETRIC DETAILS AND MATERIAL PROPERTIES

Three models of varying column steel tube thickness were modelled using ANSYS workbench 16.1. Three different thicknesses 2 mm, 3 mm, 4 mm were considered for the analysis. The models named as A2, A3, and A4 for 2 mm, 3 mm, 4 mm outer steel tube thickness. Here an exterior circular TSRC beam column joint is modeled. Column contain an outer steel tube, the steel tube infilled with I section and concrete. A cut of 10 mm is provided on the steel tube near the joint portion. The TSRC column is connected with a steel beam, the beam flanges made continuous with the corresponding cross diaphragm. A bolted connection is provided on the beam column joint portion. TSRC column consists of a steel tube of 3mm (thickness)×300mm (diameter)×2090mm (length) and an encased steel shape of 200mm (depth)×100mm (flange width)×4mm (web thickness)×14mm (flange thickness). The steel beam has the cross-section of 250mm x 150mm×8mm×10mm and is 3000mm long The material properties for steel tube, diaphragm and beam were kept constant and given in table 1.

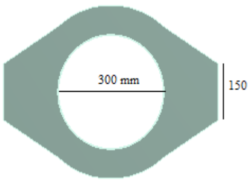

Fig-1 Cross diaphragm details

Table -1: Material properties

Compressive strength of concrete	95.9 MPa
Young's Modulus of concrete	48964 MPa
Poisson's Ratio	0.15
Yield strength of steel tube and internal section	325 N/mm2
Young's Modulus of steel tube and internal section	1.8 X 105 MPa
Poisson's Ratio of steel tube and steel section	0.291
Coefficient of friction	0.20

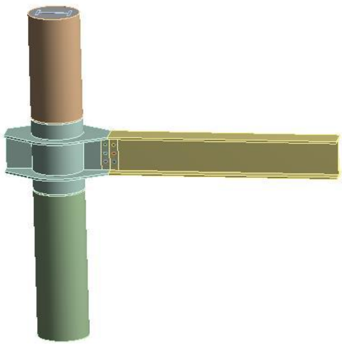

Fig-2: TSRC beam column joint

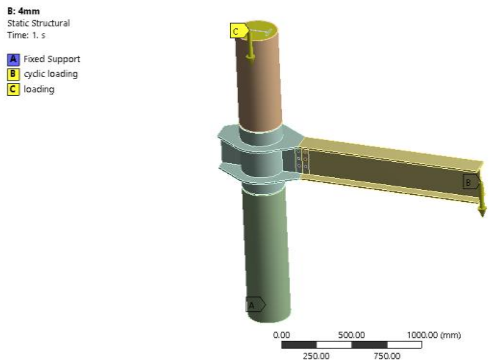

Fig-3: Boundary condition

4. LOADING AND BOUNDARY CONDITION

The bottom end of the column is fixed and an constant axial load is provided on the top of the column. A cyclic loading is provided at the beam end as per the loading protocol.

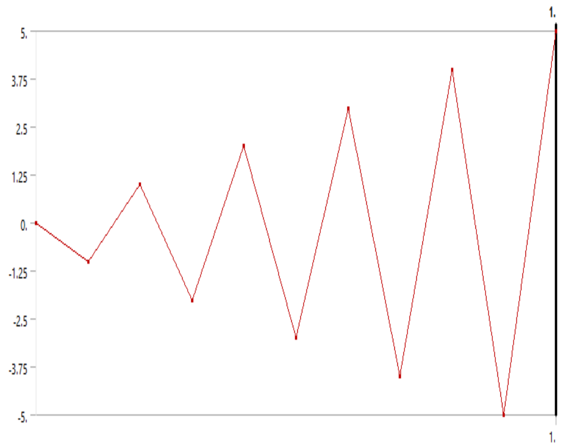

Fig -4: Cyclic loading pattern

5. FINITE ELEMENT ANALYSIS RESULT OF THE STUDY

Seismic behaviour of TSRC beam column joint is analysed. The models A2, A3, A4 of varying column tube thickness were used for analysis. Load v/s deformation hysteris loop were plotted and the load carrying capacity, Total deformation, equivalent stress distribution, shear behaviour and equivalent total strain were analysed.

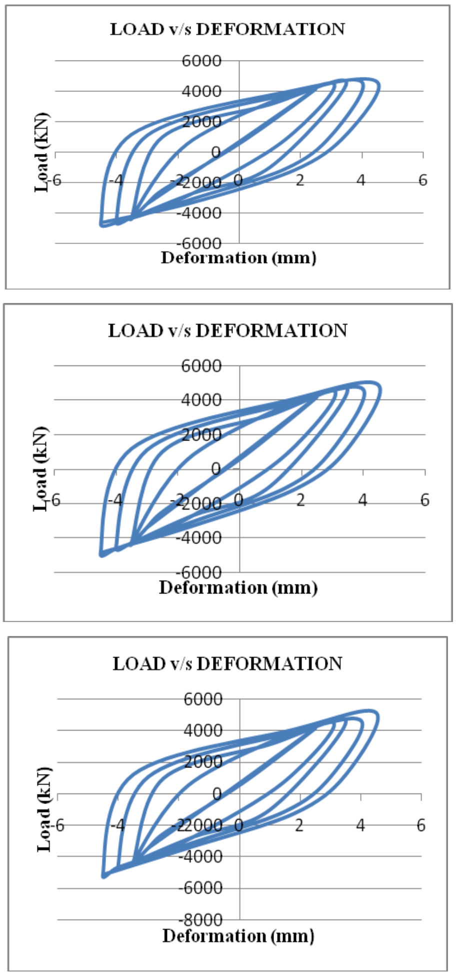

Fig -5: Load v/s deformation curve of model A2 to A4

It was observed from the graphs that the load carrying capacity of the specimens increases with increasing thickness of the outer steel tube. Area of the hysteresis curve for all the models was nearly equal. In model A2, A3, A4 shows load increment with increase in thickness of the outer steel tube. A4 shows 12% load increment than A2. The equivalent stress distribution decreased with increase in thickness of the outer steel tube. The decreasing stress distribution is indicating that the deforming tendency is decreased. So that the increasing outer steel tube thickness is good for the model.

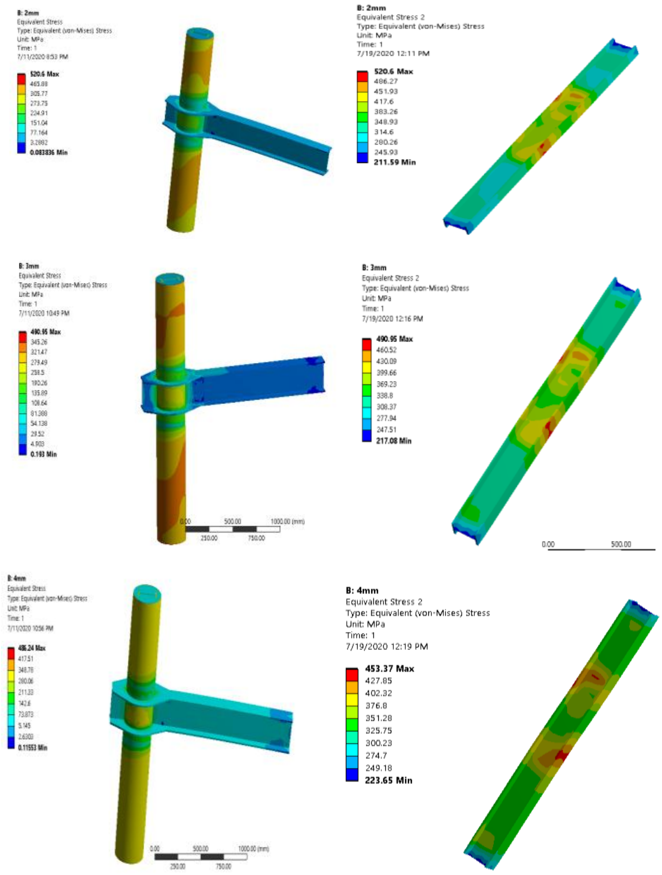

Fig -6: Equivalent stress distribution of model A2 to A4

Table -2: Load and deformation details

Model	Load (kN)	Deformation (mm)	Equivalent stress (MPa)
A2	4645	4.43	520.60
A3	4886	4.42	490.95
A4	5114	4.42	486.24

The maximum shear stress is the maximum concentrated shear force in a small area. The results obtained from the analysis shows that the maximum shear stress in column steel tube, concrete core and internal profile steel reduced as the thickness of the steel tube was increased. This shows that the shear capacity of the column increases as the thickness of the column steel tube increases. Thus the shear behaviour of the connection was enhanced with the increase in column steel tube thickness. Table 3 shows shear stress distribution in column steel tube for the models with varying thicknesses. The increase in thickness of the column steel tube reduces the stress in the concrete core because of the increased confinement in the concrete. The analysis results shows that the majority of the stress was taken by the internal profile steel. The concrete core exhibit minor shear stress only so that there is only minimum deformation is occurring in the concrete core. From this result it is clear that the double confinement in the TSRC specimen decrease the brittleness of high strength concrete.

Table -3: Maximum shear stress distribution details

Model	Maximum shear stress in steel tube (MPa)	Maximum shear stress in concrete core (MPa)	Maximum shear stress in internal steel section(MPa)
A2	234.29	23.302	265.09
A3	219.33	23.171	249.53
A4	215.85	23.114	232.05

Table -4: Equivalent total strain distribution details

Model	Equivalent total strain in steel tube (MPa)	Equivalent total strain in concrete core (MPa)	Equivalent total strain in internal steel section(MPa)
A2	2.25×10^{-3}	5.28×10^{-3}	2.60×10^{-3}
A3	2.01×10^{-3}	4.43×10^{-3}	2.45×10^{-3}
A4	1.98×10^{-3}	3.60×10^{-3}	2.29×10^{-3}

Equivalent total strain is the sum of elastic and plastic strains. After changing the thickness of the column steel tube in exterior joints the equivalent total strain in concrete core, column steel tube and internal profile steel were also analysed. The equivalent total strain values obtained from the analysis are given in table 4. The obtained results show that the equivalent total strain in column steel tube, concrete core and internal steel section is decreased with increase in thickness of the outer steel tube.

6. CONCLUSIONS

The study was carried out to analyse the seismic behaviour of circular tubed steel reinforced high strength concrete column to steel beam connection with an external diaphragms. There is three models A2, A3, A4 for varying column steel tube thickness were analysed under cyclic loading. Total deformation, equivalent stress distribution, equivalent total strain, and shear behaviour is analysed from the analysis following conclusions were achieved.

- Double confinement from the steel tube and profile steel, and the Infilled concrete are significantly enhanced the axial strength of the TSRC beam column joint.
- The entire TSRC beam column joint show same modes of failure on application of load. Major failures are observed at the mid height of the internal profile steel. The load carrying capacity of the TSRC beam column joint increased with increase in thickness of the external steel tube
- The equivalent stress distribution was maximum in the TSRC column in the entire model. No severe stress concentration was observed in external diaphragms and the steel beams.
- The equivalent stress in the connection, shear stress and equivalent total strain in column steel tube, concrete core and internal profile steel had a decrease, due to the increase in steel tube thickness in all the models.
- Concrete core exhibit minor shear stress only so that there is only minimum deformation is occurring in the concrete core. From these results it is clear that by the use of TSRC concept we can able to promote the use of high strength concrete. If high-strength concrete is used in TSRC columns, the brittleness decreased due to the double confinement effect

REFERENCES

[1] Xuhong Zhoua, Jie peng Liu.2010. "Seismic behavior and strength of tubed steel reinforced concrete (SRC) short columns" Journal of Constructional Steel Research, Vol- 66 , 885-896

[2] Hongtuo, LanhuiGuo, Jiepeng Liu, DanGan, SumeiZhang.2011. "Axial load behavior and strength of tubed steel reinforced-concrete (SRC) stub columns" Thin-Walled Structures Vol-49,1141–1150

[3] Xu Chang, You-Yi Wei, Yan-Chun Yun.2011. "Analysis of steel-reinforced concrete-filled steel tubular (SRCFST) columns under cyclic loading" Construction and Building Materials vol-28, 88–95

[4] Jiepeng Liu, Jasim Ali Abdullah, Sumei Zhang.2011. "Hysteretic behavior and design of square tubed reinforced and steel reinforced

concrete (STRC and/or STSRC) short columns" Thin-Walled Structures vol-49, 874–888

[5] Dan Gau, Lanhui Guo, Jiepeng Liu,Xuhong Zhou.2011. "Seismic behavior and moment strength of tubed steel reinforced-concrete (SRC) beam-columns" Journal of Constructional Steel Research vol-67 1516–1524

[6] Xu Chang, You-Yi Wei, Yan-Chun Yun.2011. "Analysis of steel-reinforced concrete-filled steel tubular (SRCFST) columns under cyclic loading" Construction and Building Materials Vol-28 ,88–95

[7] Linhai Hana, Qinghua Tana, Tianyi Song.2013. " Fire performance of steel reinforced concrete (SRC) structures", Procedia Engineering Vol-62, 46 – 55

[8] Hua Yang, FaqiLiu, Leroy Gardner.2014. "Post fire behavior of slender reinforced concrete columns confined by circular steel tubes", Thin-Walled Structures Vol-87,12–29

[9] XuhongZhou, BiaoYan, JiepengLiu.2015. "Behavior of square tubed steel reinforced-concrete (SRC) columns under eccentric compression", Thin-Walled Structures Vol-91,129–138

[10] Jingming Cai, JinlongPan, YufeiWu.2015." Mechanical behaviour of steel-reinforced concrete-filled steel tubular (SRCFST) columns under uniaxial compressive loading", Thin Walled Structures Vol 971–10

[11] XuandingWang, Jiepeng Liu, Xuhong Zhou.2015. "Behaviour and design method of short square tubed-steel-reinforced-concrete columns under eccentric loading", Journal of Constructional Steel Research Vol-116,193–203

[12] Xuhong Zhou, Jiepeng Liu, Xuanding Wang.2016. "Behavior and design of slender circular tubed-reinforced-concrete columns subjected to eccentric compression", Engineering Structures Vol-124 , 17–28

[13] Xuhong Zhoua, Xingzhen Zanga, Xuanding Wangb.2017. "Seismic behavior of circular TSRC columns with studs on the steel section", Journal of Constructional Steel Research, Vol-137, 31-36

[14] 17. Piotr Lacki, Anna Derlatka, Przemysław Kasza.2017. "Comparison of steel-concrete composite column and steel column", Composite Structures,Vol-147,32-45

[15] Jiepeng Liua, Xiang Lia, Xingzhen Zang, Y. Frank Chenc.2018. "Hysteretic behavior and modified design of square TSRC columns with shear studs", Thin-Walled Structures Vol - 129,265–277

[16] Guozhong Chenga, Xuhong Zhoua, Jiepeng Liua,Y. Frank Chenb.2018. "Seismic behavior of circular tubed steel-reinforced concrete column to steel beam connections", Thin-Walled Structures Vol - 135,320-329

[17] Jiepeng Liua, Xiang Lia, Xingzhen Zang, Xuanding Wanga.2018. "Seismic behavior of shear-critical circular TSRC columns with a shear span to depth ratio of 1.3", Thin-Walled Structures Vol-134 373–383

[18] Biao Yan, Xuhong Zhou, Jiepeng Liu.2018. "Behavior of circular tubed steel-reinforced-concrete slender columns under eccentric compression", Journal of Constructional Steel Research Vol-155, 342–354

[19] Xuhong Zhou, Weiyong Wang, Keyan Song.2019. "Fire resistance studies on circular tubed steel reinforced concrete stub columns subjected to axial compression", Journal of Constructional Steel Research Vol-159, 231–244

[20] Junlong Yang, Jizhong Wang, Xinpei Wang.2019. "Compressive Behavior of Circular Tubed Steel-Reinforced High-Strength Concrete Short Columns", Journal of Structural Engineering, vol-149, ISSN 0733-9445.