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A Study on Concrete Filled Steel Tubular Column Steel Beam Connection Using Light Weight concrete and Normal Concrete.

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Abstract - *This study presents, behaviour of steel beam to concrete filled steel tubular (CFST)column external diaphragm connection with comparision of light weight concrete and normal concrete. For high rise structure CFSTs is an effective construction system in composite structure. In concrete filled tubular structure conncetions is a key issue. To promote the use of CFST structure this study focosses on CFST column to steel beam connection. In this study two specimens were studied under satic loading with external diaphragm connection using light weight concrete and normal concrete. This connection is designed using AIJ code in ANSYS software. The results shows an panel zone effect of diaphragm connection with light weight concrete and normal concrete.*

***Key Words*: Concrete Filled Steel Tube, CFST column and steel beam, external diaphragm, light weight concrete, welded connection.**

1. INTRODUCTION

Now a days composite system are widely used because of the benefits of two material. A compression member in which steel and concrete element perform compositely called 'Composite Column system' so that steel and concrete elements resists compressive force and external loading as interacting together by bond and friction. In composite construction, the steel and concrete are combined in such a way that the advantage of both material can utilize sufficiently in composite column. Concrete filled steel tubular structure is the best concept in the composite structure because of their acceptable merit. Concrete filled steel tubular structure is an effective system in composite structure. Concrete filled steel tubular structure provide benefit of steel as good in tension and concrete as good in compression. In CFST, concrete is an infill material and steel is provided at outer periphery of concrete to perform as permanent formwork. Steel in CFST provides confinement to inner concrete and prevent concrete form spalling and bulging. Concrete in CFST prevents buckling of steel.

In CFST there is no additional requirement for reinforcement excepting fire protection condition. The various shape of concrete steel tubular column are becoming popular for high rise structures like circular, square and rectangular, they are also interesting from the architectural point of view. The tri axial confinement of CFST reduce the amount of steel as to support the loading condition, Hence the dimension of CFST column are smaller than those of reinforced column. The concrete core delays local buckling of the steel tube by preventing inward buckling, while the steel tube prevents the concrete from spalling.

CFST system is very advantageous because of steel and concrete merits but this CFST is not familiar in many of countries because of complexity in construction of CFST structure. Main issue in CFST is a connection problem. .many of researcher's study that external diaphragm connection fulfills the requirement of strong joint but there is panel deformation in beam column joint.

Many of researchers conducted analytical and design study of steel beam to CFST column connection. [1]Ahmed Elremaily et.al. Conducted experimental and analytical study of seven through beam column internal joint connection. Specimens were designed for strong column weak beam connection and strong beam weak column connection. If the joint panel is not capable of transferring forces, failure will takes place by joint shear failure. Beam failure, column failure, and shear failure takes place during test. [2]Bin rong et al. studied shear behavior of panel zone in diaphragm connection, to study behavior of panel zone of through diaphragm connection three diaphragm connection studied under cyclic loading. Non linear finite element model developed for simulation of connection behavior. Diaphragm connection exhibits good ductility and stable hysteresis behavior. [3]Chunyan Gao et al.perform experimental study on seismic behavior of light weight aggregate filled concrete filled steel tubular frame. Two CFRST frame were studied under cyclic and constant axial loading. Light weight concrete shows good plump hysteretic loop which shows good seismic performance and good energy dissipation capacity. Light weight concrete satisfies requirement of ductile frame, superior in seismic and mechanical performance.[4]Daxu Zhang et al. performed experimental study on seismic behavior of steel beam to circular column assemblies with external diaphragm under constant load on column and cyclic vertical load on beam ends. Failure mode of local buckling on beams and shear deformation of panel zone are observed during test.[5] cristian vulcu et al. focuses on high strength concrete filled steel tube column to beam welded connection under monotonic and cyclic loading. The load transfer from beam to side wall of RHS beam was proved. The performance of diaphragm joint is adequate. In concrete filled steel tubular structure various type of infill materials are used to make structure strong and economical. One can focus on reducing the self weight of CFST structure with lighter material to promote CFST system. The use of light weight concrete in CFST make structure 25%-30% lighter and economical than normal concrete However, thermal conductivity of lightweight concrete as well as the low specific gravity that produces lighter structures, resulting reduction in weight of structure by using in composite system.

The aim of this study is to increase the use of CFST structure by producing economical CFST system. If the connections of beam column joint are not capable to transfer the load then structure will fail, however infill material, type of connection and size of connection affects on joint connection of CFST structure.

2. Advantages of CFST

- Steel and concrete interaction:

Due to restraining effect of concrete local buckling of steel tube is delayed and after buckling strength deterioration is moderated. Steel confinement effect increases the strength of concrete and prevents spalding of concrete. Ordinary reinforced concrete columns have much larger drying shrinkage and creep of concrete.

- Cross sectional properties:

In CFST cross section the steel ration is much larger than those in reinforced concrete and concrete encased steel cross sections. Steel located at outer side of CFST section is well plastified. Identical cross sections are produced with various steel thickness, reinforcement and concrete for different load and resistance. Thus it simplifies the construction and architectural view by held outer dimension of column keep constant over number of floors in building.

- Construction efficiency:

In CFST system tremie tube or pump-up method used to caste concrete, reinforcing bar and forms are omitted which leads to effective utilization of time, manpower and saving of constructional cost. Construction site remain neat and clean as CFST system involve no formwork, so there is no obstruction for movement.

- Fire resistance:

Concrete perform well in resisting fire and the amount of fireproof material can be eliminated.

- Cost performance:

CFST structure performs better as listed above and it is beneficial by replacing steel structure with CFST system.

- Structural capacity:

CFST system provides better ductility, retention of load even after extensive concrete damage and subjected to seismic loading. For rehabilitation of structure like bridge piers, high rise building CFST column is very useful.

- Ecology:

CFST system help to improve environmental condition by reusing constructional material such as steel, high quality concrete as recycled aggregate and eliminating formwork for construction.

3. AIJ Approach

Research based on 1960's the first edition of AIJ standard was published in 1967. The standard is revised in 1980 by including circular concrete encased tubes, concrete filled steel tubular sections and square section. AIJ code is lastly revised in 1987 by including the designing of connection ultimate strength, circular and square column-beam connection. AIJ code allows concrete strength up to 60Mpa.Recently AIJ publication introduce new research topic, CFT systems including braces, with trusses and also compression member with beam column joint connections. Formula for analysis and designing for strength of CFST beam column and frames. Japan research concentrated on investigation of strength, ductility, behavior of connection with exterior, interior or through steel plate as moment resisting connection, effect of temperature on connection, and performance of connection.

4. Experimental Program

In this paper beam column joint connection were studied under static loading. Two circular CFST column steel beam connection and two rectangular CFST column steel beam connection designed according to AIJ code. Total four specimens were designed with circular and rectangular diaphragm connection. These specimens were compared for material and shape of connection. Specimens were analyzed by using ANSYS software. From these results concluding remark were discussed. The details of specimen were listed in table no. 1 and material properties are listed in table no.2. The size of circular column joint is of 40x9.6mm and for rectangular column it is of 40x40x9.6mm. Normal weight concrete and light weight concrete of grade M40 is used to fill column. for steel young's modules is 201 GPa and poisons ratio for steel and concrete is 0.3 and 0.2 respectively.

Table-1: Details of Specimens.

	Normal concrete		Light weight concrete	
Specimen	Circular column	Rectangular column	Circular column	Rectangular column
Grade of concrete	M40	M40	M40	M40
Fcd	26.7	26.7	26.7	26.7
Fck (MPA)	40	40	40	40

Table-2: Material Properties.

Specimen	Circular section (mm)	Rectangular section (mm)	Fy (Mpa)
Steel beam	50x4.6x175	50x4.6x175	415
Steel tube column	200x8	280x230	415
Diaphragm plate	40x9.6	40x9.6	500

4.1 Loading and Boundary Conditions.

In this analysis an axial load N is applied on the column in vertically downward direction. The yielding load and ultimate load is applied to the CFST column beam connection. A load is given to the specimen till deformation of specimen. To know the deformation of beam column joint and according to loading conditions boundary conditions are given to specimen. For equal distribution of load over a section a rigid plate is fixed on top and bottom of column, in all direction(x,y,z) displacements are restrained of plate.

5. Designing of CFST Column Steel Beam Diaphragm Connection.

Allowable stress design method based on the principle of elastic analysis is used in this standard for designing.

Width to thickness ratio of rectangular and circular tubes is as follows.

B/st≤1.5.735/√f (1)

D/st≤1.5.23500/f (2)

Allowable compressive strength of CFST column:

Lk/D≤4 $N_{c1}={}_cN_c+(1+n)_sN_c$ (3)

4≤LK/D≤12,$Nc_2=Nc_1-0.125\{Nc_1-Nc_3(lk/D=12)\}.(lk/D-4)$..(4)

12≤LK/D Nc3=cNc+sNc (5)

Where:

l_k: effective length of a CFT column

D: width or diameter of a steel tube section

η = 0 for a square CFT column

η = 0.27 for a circular CFT column

N_{c1}, N_{c2}, N_{c3} : allowable strengths of a CFT column

${}_cN_c$: allowable strength of a concrete column

${}_sN_c$: allowable strength of a steel tube column

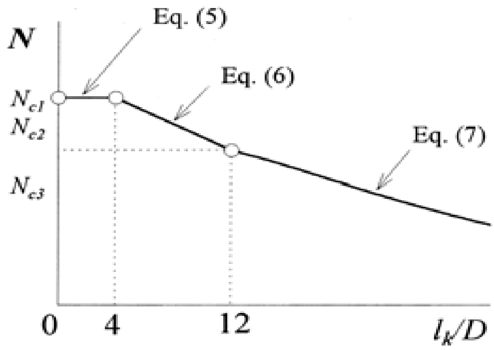

Fig-1: Allowable compressive strength of CFST column.

Ultimate compressive strength of CFST column is calculated as:

Lk/D≤4 $N_{cu1}={}_cN_{cu}+(1+n)_sN_{cu}$ (6)

4≤LK/D≤12,$Ncu_2=Ncu_1-0.125\{Ncu_1-Ncu_3(lk/D=12)\}.(lk/D-4)$ (7)

12≤LK/D, Ncu_3=cNcr+sNcr (8)

Bending strength of beam column is calculated as:

Nu=cNu+sNu (9)

Mu=cMu+sMu (10)

Nu is the axial load which produces bending strength Mu of CFST beam column joint.

For condition of short term design shear force for steel should be less than allowable shear strength of steel portion. Bond stress of steel and concrete must be checked when shear force of beam is transferred to concrete filled column tube as a compressive force.

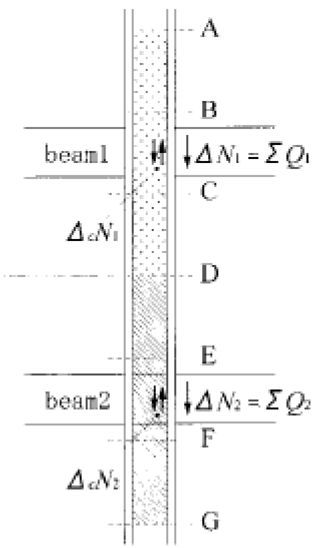

Fig -2: stress transfer of beam column joint

To transfer the stresses caused by beam to column diaphragm plates are necessary. Diaphragm plate is connected to beam (flange, web) and skin of column, while designing diaphragm effect of infill material should be consider, because each of member restrains deformation. Strength of diaphragm connection is calculated by Eq (11) & (12):

$$Pu=1.42\{2(4t+ts)tF1+4//3.hs.ts.F_2\} \quad (11)$$

$$Pu=1.42[1.53\{(0.63+0.88Bf/D)./D\overline{T}+ts\}tF1+1.7$$
$$7hs.ts.F_2] \quad (12)$$

Eq (11) is for outer diaphragm of rectangular CFST beam column connection. Eq. (12) is for outer diaphragm of circular CFST beam column connection.

6. Predicted Failure Modes.

Displacement, behavior of column and beam, failure mode of beam column joint is discussed in this section.

6.1 Rectangular column:

Failure mode of panel is absent in this observation. In normal concrete stresses at panel zone is less as compare to light weight concrete.

6.2 circular column:

Panel zone failure and beam failure is observed in this observation. Maximum stresses at the column and beam column joint connection. Beam is deformed in normal as well as light weight concrete.

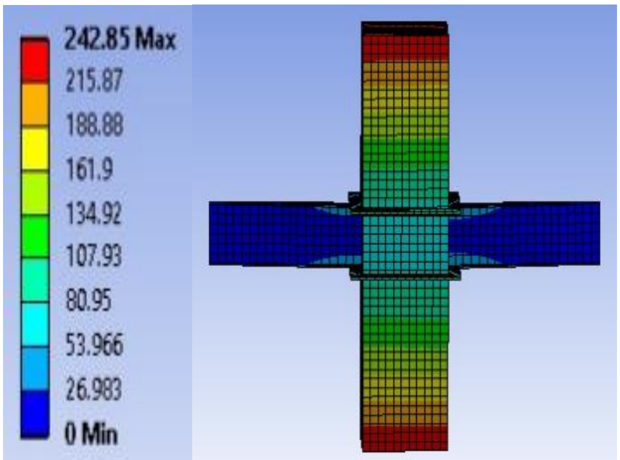

Fig-3: stress distribution of rectangular CFST column steel beam connection with light weight concrete

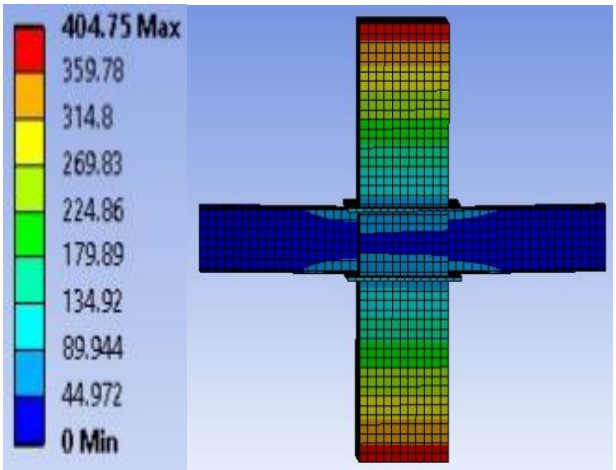

Fig-4: stress distribution of rectangular CFST column and steel beam connection with normal concrete

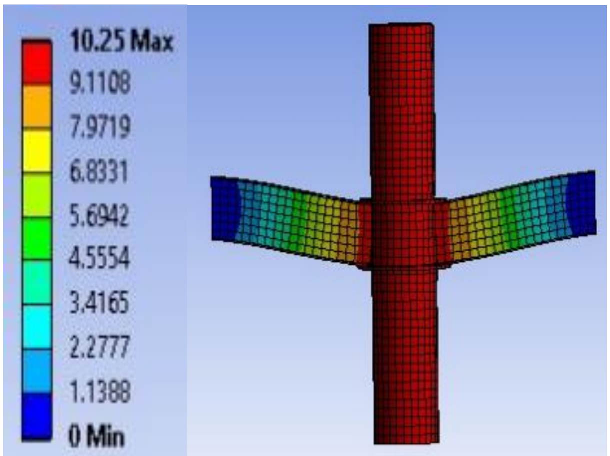

Fig-5: stress distribution of circular CFST column and steel beam connection with light weight concrete

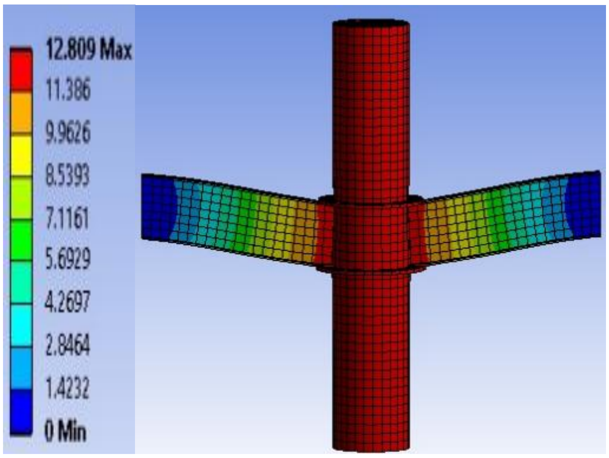

Fig-6: stress distribution of circular CFST column and steel beam connection with normal concrete

7. Conclusion

This study includes load caring capacity of light weight concrete and normal concrete with circular and rectangular column section. This paper concentrates various failure modes like beam failure, column failure, panel zone failure.

1. Failure of beam column assembly is influenced by the infill material.

2. Light weight concrete is less capable to take load than normal concrete.

3. Failure is also affected by the shape of column.

4. Strength and ductility is affected by infill material, shape of specimen, type of joint.

5. The shape of steel tube is greatly enhancing the strength of steel tube.

6. Ansys software is capable to study the stress distribution, failure modes of concrete filled steel tubular structures.

REFERENCES:

[1] Ahmed Elremaily, Atorod Azizinamini, "Experimental behavior of steel beam to CFT column connections,"57, 2001, pp. 1099–1119, doi: 10.1016/S0143-974X(01)00025-6.

[2] Bin Ronga,b, Shuai Liua, Jia-Bao Yana,b, Ruoyu Zhanga, "Shear behaviour of panel zone in through-diaphragm connections to steel tubular columns,"122, 2018, pp.286–299, doi: org/10.1016/j.tws.2017.10.029.

[3] Chunyan Gao, Bin Li, "Experimental Research on Seismic Behavior for Lightweight Aggregate Concrete-Filled Steel Tubular Frame," Vols163 167,2011,pp.2194-2198, doi:10.4028/www.scientific.net/AMR.163167.2194.

[4] Daxu Zhang, Shengbin Gao, Jinghai Gong, "Seismic behaviour of steel beam to circular CFST column assemblies with external diaphragms," Journal of Constructional Steel Research 76, 2012, pp. 155–166, doi:10.1016/j.jcsr.2012.03.024.

[5] Cristian Vulcu, Aurel Stratan, Adrian Ciutina, Dan Dubina, "Beam-to-CFT High-Strength Joints with External Diaphragm. II: Numerical Simulation of Joint Behavior,"143(5), 2017, pp. 04017002, doi: 10.1061/(ASCE)ST.1943-541X.0001693.

[6] Zhong Taoa, Wei Lib, Bo-Lin Shic, Lin-Hai Hanb, "Behaviour of bolted end-plate connections to concrete-filled steel columns," 134 2017, pp. 194–208, doi.org/10.1016/j.jcsr.2017.04.002.

[7] M.M. Arabnejad Khanouki, N.H. Ramli Sulong, Mahdi Shariati, M.M Tahir, "Investigation of through beamconnection to concrete filled circular steel tube (CFCST) column," 121, 2016, pp. 144–162, doi.org/10.1016/j.jcsr.2016.01.002.

[8] Ying Qin, Zhihua Chen, and Ning Han, "Research on Design of Through-Diaphragm Connections between CFRT Columns and HSS Beams," Vol 14, No 3, September 2014, pp. 589-600, doi :10.1007/s13296-014-3017-6.

[9] Ning Wang, Myung-Jae Lee, "Structural Behavior of Beam-to-Column Connections of Circular CFST Columns by Using Mixed Diaphragms," 15(2), 2015, pp.347-364, doi: 10.1007/s13296-015 6007-4.