A review on concrete filled tubular sections using self compacting concrete

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Abstract: Concrete filled tubular section (CFT’s) is a composite column of hollow steel and concrete filled into it. This composite action of concrete and steel gives better performance under service. CFT’s carries higher loads as compared to steel column and conventional reinforced concrete, due to this property CFT’s are highly recommended for tall structures. CFT’s can provide more carpet area as compared to the RCC column due to cross section reduction in CFT’s. Study shows that for high rise buildings composite construction is economical. CFT’s are filled with normal concrete where the filling problems arise due to dense reinforcement or smaller cross section or the distance between two profiles are less, self compacting concrete (SCC) can be recommended due to its workability. The previous researcher shows a comparison between normal concrete, SCC and light weight aggregate concrete inside CFT’s with L/D and D/t ratios and different curing techniques for SCC

1. INTRODUCTION

Now a day, the main focus has been shifted to economic aspects of the project, constructing safer buildings of residential and commercial purpose, generally, tall structures, high-rise buildings, blocks, and towers are constructed. They may also be known as a vertical city. The main focus is to provide more ground space and accommodating more people in less space. For fulfillment of all the requirements like strength, stability and stiffness, a new type of construction technic came into introduction which is called ‘Composite construction’. This type of construction system governs the non-residential high storey buildings sector. Its recognition is because it has stiffness and strength with the least use of material. The reason behind this can be expressed as steel is good in tension and concrete is good in compression. By combining these materials together, structurally these will give a light weight structure and very efficient. It also gives an advantage in terms of time-saving in construction. Also, it decreases in a floor depth of structure & can also provide a major role in saving the costs of services. Till 1970’s Composite Columns were hardly used from the second world war. The research started in the 20th century. In 1913, Emperger of Germany gave the first design formula for composite columns. The first experiment was conducted on a concrete column with strong horizontal reinforcement and a core of cast-iron outside. Fire resistance was achieved by encasing steel in concrete and concrete with reinforcement was commonly used till the 1950’s.

Recently, self-compacting concrete (SCC) is mostly used for higher workability, durability, strength, versatility and economy purposes. Self-compacting concrete (SCC) is a special type of concrete with a much higher fluidity without segregation and capable of filling every nook and corner of formwork and congested reinforcements under its self-weight only. SCC is found through various research and practical observations. Self-compacting concrete is also named as the self-consolidating concrete.
SCC is the flowing concrete that does not require any mechanical vibration for compaction of concrete and able to flow under its own weight without any segregation of the coarse aggregate, whilst maintaining homogeneity. By preventing vibration, the health effects of concrete construction disappear (white hand syndrome, hearing loss, noise disturbances for the neighbours), ease of placement operations, transport-placement, better life of formwork, energy savings, better aesthetics, and improved surface finishing. Slowly, SCCs have also won over architects by offering them, the possibility of playing with complex volumes. SCC is using both mineral and chemical admixtures to significantly increase the ease and rate of flow of concrete. SCC focuses on uniform quality, high performance, and better reliability. The self-compacting concrete (SCC) was developed by researchers at the University of Tokyo, Japan during the 1980s with the idea of overcoming the shortage of skilled labour. The first version of SCC was completed in 1988 on the named “High Performance Concrete” and after purposed as “Self-Compacting Concrete”. In 1989, the European Federation of National Association Representing for Concrete (EFNARC) was developed for the purpose of advancement in SCC for specialist building products. By the year 2001, EFNARC gives the guidelines and specifications for the use of high quality SCC and framework of design (EFNARC 2005) [10].

2. LITERATURE REVIEW

Guler et al. [1] made a comparative study on a circular and square high strength concrete-filled steel tube columns. In this study, the effect of bond strength and steel tube thickness between steel and concrete on ductility and axial load capacity were studied. Also, the performance indices like strength enhancement index, ductility index and concrete contribution ratio also calculated and compared between square and circular composite columns with varying H/t ratio. The result shows that the decrease in H/t ratio improves the ductility performance in both square and circular CFST. Furthermore, the bond stress capacity of the circular shape column is higher than the square.

Gupta et al. [2] experimented with the compressive strength of concrete filled steel tubes by varying D/t ratios and L/D ratios. In this study, D/t ratios vary from 25 to 39 and L/D ratios vary from 3 to 8. Experimental and results from finite element modelling (FEM) software ANSYS were compared. Authors conducted this experiment with different concrete like normal concrete, concrete with replacement of 15%, 20% and 25% fly ash by volume of cement, respectively. Different L/D ratios taken for study are 3.0, 3.8 and 7.2, D/t ratios are 2.89, 2.74 and 1.87, respectively. Authors concluded that good confinement was achieved with lower ratios of D/t, the load carrying capacity of composite column decreases with increase in D/t ratios and fly ash content in concrete.

Shah & Panchal [3] conducted a study on testing of high strength steel-concrete composite stub columns under uniaxial load. In this study, they checked the behaviour of a square and circular steel-concrete composite column with a different concrete mix like M20, M30, and M40 and kept the same steel wall thickness 4.5 mm under uniaxial load. Results show that the ultimate load carrying capacity of the square column is higher than circular. Also, it shows an increase in ultimate load with an increase in grade of concrete.

Panchal & Marathe [4] did a comparative study on R.C.C., Composite and Steel building of G+30 storey using ETABS software and proved that Steel building is better than R.C.C. but Composite building is best for high rise building. A dead load of R.C.C. frame building is 32% and 30% higher than Steel building and Composite building respectively. In Composite building, there is a 25% size reduction in main beams and a 60% size reduction in secondary beams as compared to steel members of Steel building. Ductility in Steel and Composite building is more as compared to the R.C.C. building. Finally concluded that in comparison to all three types, composite construction is a good option for high rise buildings.

Ghannam [5] conducted an experimental study to find out the buckling of a composite column using
axial loading condition. Concrete filled rectangular hollow sections and concrete filled circular hollow sections were used using different concrete that is lightweight aggregate concrete (LWA), normal concrete (NC) and bare hollow sections (HS). Steel sections used in this study were having 15, 20 and 25 slenderness ratio. Experimental values were checked using design load values as per Euro Code 4 and BS 5400. The test result showed that both concrete filled rectangular sections, as well as concrete filled circular sections, fail due to overall buckling, while hollow steel sections fail due to local buckling. Results show that there is a decrease in the strength of composite sections filled with lightweight aggregate concrete as compared to normal concrete.

Li et al. [6] discussed the mechanical properties of the dry mixing of Self-Compacting Concrete with high workability. SCC has been widely used in practice due to its adorable properties like efficiency in construction work, noise cancellation and improves the durability of concrete. Problems of hand mixing are replaced by dry mixing SCC (DMSCC) done through only definite water is adding in the construction site. They had investigated the relationship between the stress-strain. The result showed that by an increase in the water there is a decrease in mechanical properties of DMSCC, increase with an increase in pisolite with lower water content less than 14%, respectively. Early strength was achieved about 80% at 3 days that of 28 days and 40% of splitting tensile strength as compared to normal concrete (NC), respectively.

Sharifi [7] explained the used of self-consolidating concrete (SCC) in reinforced concrete beams with their structural performance. The structural behaviour of SCC reinforced was carried out by various experimental tests. They had also studied the comparison between theoretical calculations and experimental results which is based on ACI 318 (05) and CSA (04) code provisions. The workability of SCC is checked by the slump flow test, funnel test and L-box test. The optimum compressive strength of the concrete beam is 30 MPa the range of 0.15-1.38. In reinforced beams with normal concrete, the predicted ultimate moment of CSA (04) and ACI 318 (05) code provisions are lesser than the ultimate moment of the tested beams (0-7%). They concluded that the width of the crack within the limits under the service loads.

Pamnani et al. [8] studied Self-Compacting Concrete (SCC) by decreasing the volume ratio of aggregate using various enhancing superplasticizers and admixture. The mechanical properties such as flexural strength, compressive strength, split tensile strength and shear strength for M30 grades were investigated with the effect of non-water-based curing techniques. The non-water-based curing techniques used are polyethylene film, compound curing, and immersion method. Polyethylene film curing achieves the second-highest strength at 28 days for flexural strength and shear strength it was about 82% of immersion strength. Authors concluded that pond immersion method curing is much good as compare to others. Polyethylene film and curing compound methods can provide more than 90% strength (Compressive, flexure, etc.) compared to the conventional methods.

Kibriya & Iqbal [11] experimented on hollow steel sections (HSS) and SCC with blended cement. HSS of square and circular columns of D/t or b/t varying from 34.95 to 64 with normal concrete and SCC with rice husk agriculture waste were compared for repair and rehabilitation work. They concluded that smaller diameter section with SCC were more efficient than higher diameter section, also found out that smaller sections with rice husk were economical too. Load carrying capacity of HSS with SCC were much higher as compared to that of normal concrete.

3. CONCEPT OF COMPOSITE COLUMN

A steel with concrete composite column is fully compression type member, Composite column has mainly two types, namely concrete encased steel section and concrete filled tube steel section and is normally used as a load-bearing member in a composite structural frame. In Composite columns, steel and concrete will resist external load by joining with each other by bond or in between their friction.
Because of large constructions and high-rised buildings of 10 storey and above, the size of columns increases because of the revised IS Codes. In such cases, the size of columns increases tremendously in ordinary RCC structures. Composite columns are solution for this type of problems to reduces size of column and provide also good strength and stability. Concert infilled steel columns use the benefit of both materials steel as well as concrete. Generally, steel hollow section is filled with plain or reinforced concrete. It is mostly used in high-rise structure like tall buildings, skyscrapers.

It is providing number of advantages in both terms like performance of structure and construction order. The inherent buckling in steel tube wall is because of infill concrete expansion under load. Besides, the ability of concrete infilled column to resist load is increased because of it has confinement effect applied by the steel thin wall. The another factor like the way of materials distribute over the cross-section helps to enhance structural performance. Because of steel cover provided outer side, it behaves most efficiently in tension and buckling. Also, it gives the ultimate stiffness and high modulus of elasticity and high impact on moment of inertia of section. Concrete core offers great contribution to resisting the axial compression.

Figure 1 shows the structural steel is embedded in concrete which can be called as totally encased concrete filled sections. Figure 2 shows the concrete is filled in the empty part of the I section which can be called partially encased concrete filled sections. Figure 3 shows the concrete is cased with the steel which can be called as fully cased concrete filled sections. These sections shown in Figure 1 to Figure 3 can be with and without reinforcement. Euro Code 4 (EC4) is the most recently completed international standard in composite construction. EC4[9] covers concrete filled steel section sections with or without reinforcement. The ultimate load is shown below Equation 1.

\[
P_{pu} = f_y A_a + f_{ck} A_c
\]

Where, \(P_{pu}\) is ultimate load; \(f_y\) is yield strength of steel section; \(A_a\) is area of steel cross section; \(f_{ck}\) is characteristic strength of concrete cylinder; \(A_c\) is area of concrete.

Some important parameters are defined to compare ductility and strength enhancement of the CFST
specimens. Those are ductility index (DI), strength index (SI) and concrete contribution ratio (CCR) which are shown in Equation 2 to Equation 4

\[
DI = \frac{\delta_u}{\delta_{85\%}}
\]

\[
SI = \frac{N_u,\text{filled}}{A_c f_{ck} + A_s f_y}
\]

\[
CCR = \frac{N_u,\text{filled}}{N_u,\text{Hollow}}
\]

\[
N_{pl,\text{rd}} = A_a + 0.85 A_c f_{cd} + A_s f_{yd}
\]

where \(N_u,\text{filled}\) is ultimate load of filled section; \(N_u,\text{Hollow}\) is ultimate load of un-filled section; \(\delta_u\) is the vertical axial deformation at ultimate load; \(A_c\) and \(A_s\) is cross sectional areas of concrete and steel tube; \(A_a\) is cross-sectional area of the structural steel section; \(f_{cd}\) is design value of the cylinder compressive strength of concrete; \(f_{yd}\) is design value of the yield strength of reinforcing steel and \(f_y\) and \(f_{ck}\) are the yielding stress of steel and concrete characteristics strength, respectively.

Here, SI is described as the ratio of axial load capacity to sum of individual strength of steel section and concrete. CCR defined as ratio of load carrying capacity of concrete-filled section to hollow steel section generally it gives level of enhancement in strength by filling steel tube with concrete. DI is defined as ratio of deformation at ultimate load to deformation when load falls to 85% of ultimate load carrying capacity. \(N_{pl,\text{rd}}\) is plastic resistance of member.

4. CONCLUSIONS

Current trend for structure designing is to achieve economy and better strength with smaller cross sections. CFT’s fit as a perfect solution for the problem. CFT’s provide good strength against normal and lateral loadings, economy and fast construction for high rise buildings [3]. With the limitations of cross section of members for tall structures, CFT’s was filled with different concrete like NC, LWA, HS, SCC, SCC with different admixtures [5], [7], [11] to provide strength with lower cross sectional area. As current research is found out with limited L/d and D/t ratios of CFT’s with SCC, so there is research gap for short and long CFT’s column with SCC of different L/D, D/t and t/D ratios with DI, SI and CCR by comparing results experimentally, theoretically and using simulation software for the future predictions.

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