BEHAVIOUR OF GGBS CONCRETE INFILLED STEEL TUBULAR COLUMNS

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Abstract -*In this study, test on compressive strength of concrete filled steel tubular columns were performed. Compressive strength of hollow, conventional as well as* Ground Granulated Blast-furnace *Slag (GGBS) concrete* filled tubes were determined*. Cross section, Compressive strength and height of column* were *selected as the variables to be investigated. Circular* sections*(CS) and square* sections*(SS)* were *chosen for the experimental procedure. The relationship between the load and the lateral displacement at the mid-height of the columns in the directions of both the strong and weak axes and the relationships of load versus end shortening for each specimen were duly recorded. It was found that, load carrying capacity varies with respect to the cross section of the specimen, compressive strength of the infill and type of infill material. Circular specimens show a higher load carrying capacity compared to square specimens.* GGBS concrete infilled steel tubes have 6%-15% higher strength than conventional concrete filled steel tubes..

Key Words: Axial compressive load, CFST columns, GGBS concrete infill, Experimental values

1.INTRODUCTION

Steel-concrete composite columns were used over years for its advantages in fire protection. In recent years it is widely employed in many structural applications including the supporting platforms of offshore structures, bridges, columns in seismic zones and more as it combines the tensile and ductile properties of steel with compressive strength of concrete. Its advantages include :

Higher strength-to-weight ratio and higher rigidity than conventional reinforced concrete column.

Higher ductility and toughness for resisting reversal load.

Higher load carrying capacity due to the composite action between steel and concrete.

Saving in material and construction time.

Steel tubes are also used as permanent formwork.

In hollow steel tubular sections which are predominantly used in high rise buildings, both inward and outward buckling is found. Whereas for the concrete-filled steel tube, only outward buckling is found in the tube, and the inner concrete fails in a more ductile fashion.

The interaction between the concrete and the steel section in the composite enhances it to carry large axial load. The bending moments, tensile and shear forces are resisted by the concrete which is reinforced by steel section. The concrete in a composite column reduces the potential for buckling of the steel section in addition to resisting compressive loading.

There is an increase in the lateral expansion of the concrete infill until it reaches the lateral expansion of the steel, at a particular strain. The micro-cracking in the concrete begins to take place whereas the structural steel expansion remains the same at this stage. This acceleration in the concrete expansion results in an interactive contact between the two materials. Hence, bond stresses are developed and the concrete will be subjected to tri-axial stresses while the structural steel to biaxial stresses[3].

Based on the transfer of force between concrete and steel the longitudinal stress in the confining tube varies. The strain level at which confinement occurs is debated among researchers to range from 0.001 to 0.002. Some scientists such as Knowles and Park concluded that concrete confinement happens suddenly at about (strain of 0.002) just as the concrete starts dilation[4]. While other researchers as Tsuji, et al. and Zhang, et al. proposed a steady increase in the concrete confinement starting right after the occurrence of micro-cracking in the concrete (strain of 0.001), till full confinement is met at a strain around 0.001[5],[6].The circumferential stresses are developed in the structural steel due to two factors: 1. Longitudinal stresses from loading. 2. Lateral pressure from concrete dilation. Based on the steel utilized in the composite element, the steel could have reached its capacity prior to their yield in this stage. The tube would not be able to sustain the normal yield stress if tube yielding occurs before the biaxial state of stress leading in the transfer of load from tube to concrete. Conversely, if the confining tube has not yet yielded, the extra axial capacity needed from the steel tube before yielding will be reduced [7].

The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem. GGBS is the granular material formed when molten iron blast furnace slag is rapidly chilled by immersion in water. Cement is partially replaced by GGBS and the replacement level of 50% is employed in this experimental procedure.

2. TEST SPECIMENS AND MATERIAL PROPERTIES

Cross sections of both Square and circular specimens are mentioned in table1. The height of the specimens were fixed as 500mm and 1000mm. Steel plates of 150mm x150mm and thickness of 3mm was welded at top and at the bottom ends. A minimum 28-day curing time was applied to gain a standard concrete compressive strength of the core concrete specimens after pouring of concrete into the steel tubes.

Concrete mix designs were performed on cubes for both conventional as well as GGBS concrete and concrete compressive strength of trail mixes on seven, fourteen and 28 days were found. The amount of cement, GGBS , water and aggregates used during the pour of concrete in the steel tube for two different mixes are given in table 2. Cement is partially replaced by GGBS in the GGBS concrete and the replacement percentage is 50%.

Compressive strength of conventional and GGBS concrete for the mentioned mix was obtained as 28.4 MPa and 31.3 MPa for M20 grade of concrete.

For M40 grade of concrete the compressive strength was given by 47.2MPa and 48.1MPa for conventional and GGBS concrete respectively. Modulus of elasticity and yield stress of steel chosen is 200000 MPa and 355MPa.

Table -1: Cross sectional properties of specimens

LABEL	BREADTH/OUTER DIAMETER (mm)	THICKNESS (mm)	HEIGHT (mm)
CS1	114	2	1000
CS2	114	2	500
SS1	100	2	1000
SS2	100	2	500

Table -2: Material quantities

TYPE OF CONCRETE	MATERIALS	QUANTITY(kg)	
		M20 mix	M40 mix
Conventional concrete	Cement	13	15.13
	Fine aggregate	24.075	23.82
	Coarse aggregate	41.06	38.75
GGBS concrete	Cement	6.495	7.6
`	Fine aggregate	24.075	23.82
	Coarse aggregate	41.06	38.75
	GGBS	6.495	7.6

3.INSTRUMENTATION

Displacement gauges named Linear Variable Differential Transducer (LVDT) were used to measure elongation and shortening along a working axis. A strain gauge was the unit deformation measurement apparatus which worked the electrical output values of the elongation and shortening phenomena placed along the longitudinal direction according to the electrical resistance. The measurement resistance of the strain gauges had to be at 120+_0.5 Ω range. Universal testing machines of capacity 300 tonnes and 100tonnes were used to give the required load to the specimen. In total two strain gauges were placed on two sides of the specimens vertically and two displacement gauges were placed on the remaining two sides as shown in Figure 1. One displacement gauge was placed at the top to measure the axial shortening.

Fig-1: Experimental setup.

Experiments were performed only under the effect of an axial compression load assumption. Possible shear force and bending moment values caused by eccentric loading and deformation during the test process were ignored. The top and bottom ends were assumed to be roller supports that permit only axial force transition. This is achieved by placing steel balls at the top as well as bottom ends.

Fig-2: Failure mode of specimen

Table -3: Load capacity of different specimens

TYPE	CONCRETE GRADE	LOAD (kN)			
		CS1	CS2	SS1	SS2
Hollow	0	260	296.3	220	259.33
CFST infilled with conventional concrete	M20	446	620	411	600
	M40	490	675	476	660
CFST infilled with GGBS concrete	M20	464	700	420	640
	M40	580	806	518	749

4. RESULTS AND DISCUSSION

Average values of displacements are taken. Load at failure for all the specimens are tabulated in table-3. From the test performed, it was found that buckling occurs at the column bottom and at the top based on the end conditions.

From the results obtained circular specimens show a higher load carrying capacity compared to square specimens. It is clear that, when the compressive strength of the infill increases there is a corresponding increase the load carrying capacity of the composite section. The ultimate load capacity of composite sections are increased in comparison with the ultimate load capacity values of hollow steel tubes. Considerably, the strength of composite section infilled with GGBS concrete is more than that of using conventional concrete irrespective of the column height.

4.1 LOAD Vs DEFLECTION CURVES

Load deflection curves for hollow , conventional concrete infill , GGBS concrete infill steel sections are plotted above for both square as well as circular sections(Fig-3 to Fig-7).

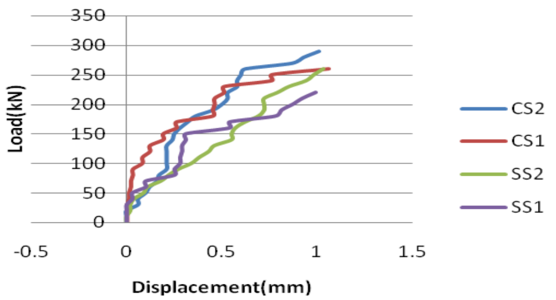

Fig-3: Hollow specimens.

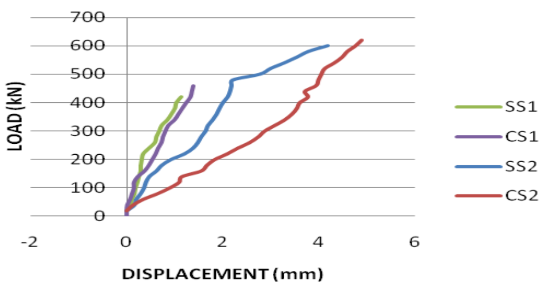

Fig-4: Conventional concrete infill M20 specimens.

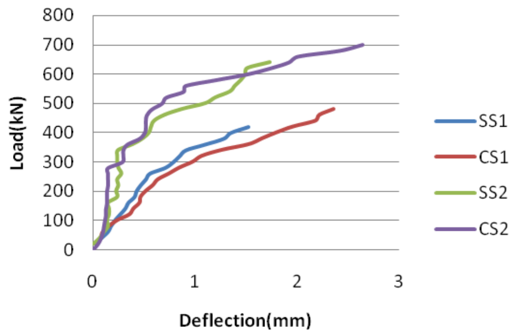

Fig-5: GGBS concrete infill M20 specimens.

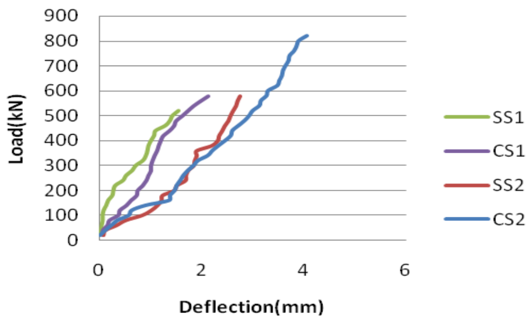

Fig-6: GGBS concrete infill M40 specimens.

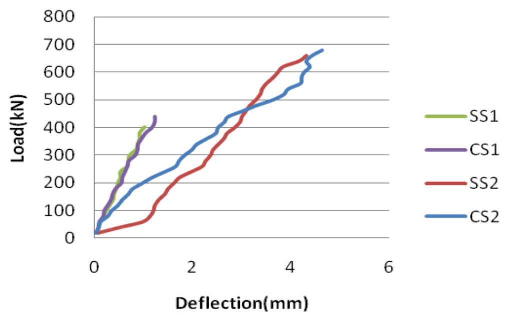

Fig-7: Conventional concrete infill M40 specimens

From the above graphs it is clear that GGBS concrete infilled specimens shows a higher displacement compared to conventional concrete infilled specimens. Core concrete prevents the buckling of steel tube in an inward direction and steel tube provides a confinement effect for axially loaded CFST stub columns at the same time. All the specimens with infill fail by outward buckling(Fig2)

6.CONCLUSION

The following conclusions were made from the experiments performed:

i. Concrete filled steel tubes have 1.8times higher strength than hollow tubes.
ii. The increase in compressive strength of infill increases the load carrying capacity by 10% for conventional concrete infill and 20% for GGBS concrete infill
iii. GGBS concrete infilled steel tubes have 6%-15% higher strength than conventional concrete filled steel tubes.
iv. Circular sections have 10% higher load carrying capacity compared to square sections.
v. Load carrying capacities of specimens is observed to increase by 35%-40% with a decrease in the height/thickness ratio.

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