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An Experimental Investigation on Axial Strength of Steel Tubular Short Columns Infilled with High Volume GGBS.

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Abstract- Recently the use of composite structures consisting of cold formed steel tubes infilled with concrete has become increasingly popular in civil engineering constructions. This is because of their excellent earthquake resistance properties namely high ductility, high stiffness and large energy absorption capacities. The subject of this work is to investigate the effect of high volume replacement level of cement with GGBS on the strength of concrete filled steel tubular short columns. A theoretical investigation of these experimental results with Euro code is also conducted. GGBS can be used as a replacement for cement or as an additional cementations material in concrete. By conducting cube strength test on 18 specimens with different percentage replacement level of cement, Optimum percentage of GGBS were found out. Infilling the hollow section columns with M30 grade concrete,concrete with GGBS as a replacement for cement were studied. Totally 8 columns were tested and load versus elongation, axial stess- strain behaviour for each type of column was studied. The results show that concrete filled steel tubular columns with optimum percentage of GGBS have the highest compressive strength at age of 28 days than steel tubular column with normal M30 concrete. In the case of ggbs concrete column, the maximum load that can be taken by that specimen is found to be 720 kn, which is 9.3% more compared with normal concrete specimen. The failure mode for column infilled with M30 grade concrete was outward folding failure at bottom of the column and separation of steel and concrete at ultimate load due to bond failure between steel tube and concrete

Index Terms- Infilled steel tubes, GGBS, Optimum percentage

I. INTRODUCTION

In concrete-filled tubes (CFTs) or steel reinforced concrete members, the concrete and the steel forms a composite. A successful composite is one in which the final properties are better than those of the individual components, or the summation of the properties of the individual components. Many studies have proven the superior structural behavior of CFTs when compared to reinforced concrete or steel members. A steel hollow section in-filled with concrete has higher strength and larger stiffness than the conventional structural steel section and reinforced concrete.[1] . Composite column are structural members, which are mainly subjected to forces and end moments. The steel tube serves as a formwork for casting the concrete, which reduces the construction cost. No other reinforcement is needed since the tube itself act as a longitudinal and lateral reinforcements for the concrete core The structural behaviour of a CFT is governed by the member strength, reflecting the fact that the load resistance is dependent not only on the material properties but also on the geometric properties of the entire member[1][2] Also, the use of pozzolans as additives to cement, and more recently to concrete, is well accepted in practice.

Ground granulated blast furnace slag (GGBS) is one such pozzolanic material (termed by a few as a supplementary or complimentary cementitious material) which can be used as a cementitious ingredient in either cement or concrete composites. Granulated blast-furnace slag is a by-product in the manufacture of pig iron and the amounts of iron and slag obtained are of the same order. The slag is a mixture lime, silica, and alumina, the same oxides that make up Portland cement, but not in the same proportion .The composition of blast-furnace slag is determined by that of the ores, fluxing stone and impurities in the coke charged into the blast furnace[4][5]. Typically, silicon, calcium, aluminum, magnesium, and oxygen constitute 95% or more of the blast-furnace slag. However, it was found that incorporation of ggbs as cementitious materials in concrete can decrease the demand of Portland cement, dry and autogenous shrinkage in early ages, carbonation depth and effect of sulfate corrosion on concrete damage as well as improve the strength in early ages and workability of fresh concrete slurry.[8]To assess the effectiveness of GGBS in Concrete some of the parameters like chemical composition, hydraulic reactivity, and fineness have been carefully examined earlier [9]. It was also seen that among these, the reactive glass content and fineness of GGBS alone will influence the cementitious/pozzolanic efficiency or its reactivity in concrete composites significantly[10][11]. In this paper, an effort is made to investigate the influence of combination of ground granulated blast-furnace slag (GGBS) on the strength development of concrete filled steel tubular columns

II.EXPERIMENTAL INVESTIGATION

Material properties:

In order to study the material properties of the sheets used for making the specimen, tension tests were conducted in standard coupons.The values of yield stress ,ultimate stress, young's modulus are given in table 1.

Table1: Coupon test results

Description	E (N/mm^2)	Fy (N/mm^2)	Fu (N/mm^2)
Steel sheet	$2X10^5$	375	470

Table 2: Properties of sand,cement, aggregates,GGBS

	Coarse aggregate	Sand
Specific gravity	2.85	2.75
Water absorption	0.98	1.23

	Cement	GGBS
Specific gravity	3.15	2.79
Specific surface(m2/kg)	392	599
SiO2	20.6	34.4
Al2O3	4	9
Fe2O3	3.1	2.58
CaO	62.8	32.8

Compressive strength of cubes and optimum percentage of fly ash :

- Normal mix

Concrete of M30 mix was prepared using 10mm size chips and 2 mm size fine aggregates with cement content of 53 grade. The water cement ratio was maintained at 0.42. 3 cubes were cast. After 28 days curing , compression test was conducted. The details of mix and compression test results are given in table3.

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Table 3:Compressive load for control concrete

Compressive Load (kN)	1	2	3
	750.3	740.3	704

Average compressive load is calculated as 721.3 kN

- Normal concrete with replacement of cement with different percentages of GGBS

Concrete of M30 mix was prepared using 10mm size chips and 2 mm size fine aggregates with cement content of 53 grade. cement was replaced with GGBS by different percentage . The water cement ratio was maintained at 0.42. 3 cubes were cast. After 28 days curing , compression test was conducted. The details compression test results are given in table 4.

Table 4: Compressive load of fly ash

	GGBS content(percentage wt of cement)		
	30	40	50
Avg compressive load(kn)	874.33	710.13	705.17

Optimum percentage of GGBS is found to be 30%.

a) b) c)

Figure1: a) control cubes, b)GGBS cubes c) hollow steel column

Preparation of test specimens:

All columns are of size 100x100x700 mm

Table 5: Specimen details

Specimen number	D(B) m	T Mm	H mm	Fy MPa	Fck MPa
1	100	2	700	375	33
2	100	2	700	375	38.8
3	100	2.5	700	375	38.8
4	100	2.5	700	375	33

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Test procedure:

The specimens were placed over the end bearing plates so that the centre of gravity of the column sections coincides with centre of gravity of the end plates.

Tests were conducted in a 100 tone universal testing machine. The specimen with end bearing plates was placed on the base of the press and properly centred for loading axially. The strain gauges were tested by applying small loads and after necessary adjustments, initial readings were taken in all the electrical strain gauges. The initial readings on dial gauges were also noted.

A load interval of 1 kn was used. Each load interval was maintained for about I sec. at each load increment the strain readings were recorded. All the specimens were loaded to failure. All the specimens behaved in a relatively ductile manner and testing proceeded in a smooth and controlled way.

The longitudinal strains on two directions were noted for each load. Near ultimate stage strains were not steady therefore could not be recorded accurately. The ultimate load was observed and recorded for all specimen.

III.RESULTS AND DISCUSSION

- Control concrete columns and GGBS concrete columns with 2 mm thick steel tube

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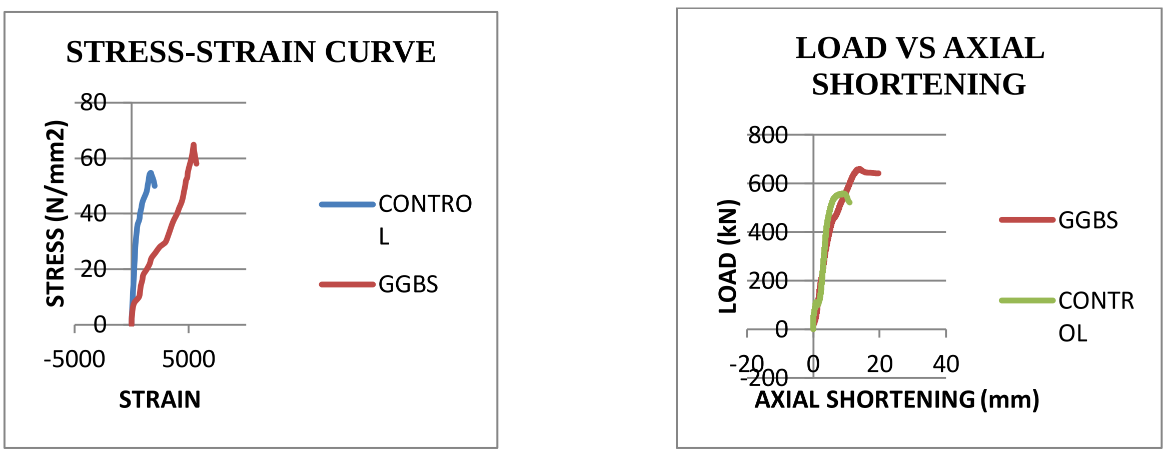
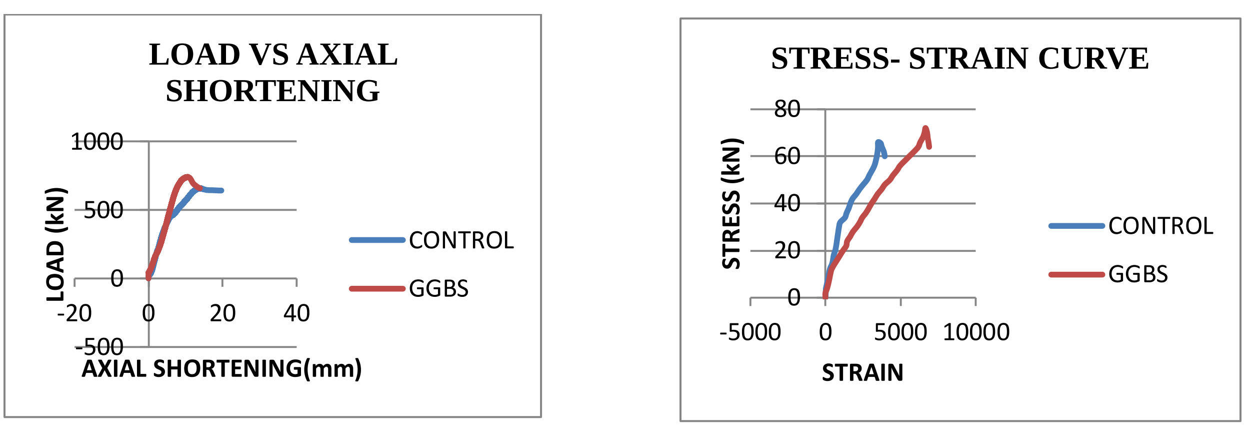


a) b)

Figure2 : a)&b) behaviour of control and GGBS concrete column

On testing control concrete and GGBS concrete specimens the load carrying capacity for ggbs concrete columns are found to be 648.5 kn. So 18.6% increment in ultimate load carrying capacity was obtained while removing 30% cement with ggbs. Strain corresponding to ultimate load is 0 .056.

- comparison between control , GGBS concrete infilled short column with 2.5mm steel tube



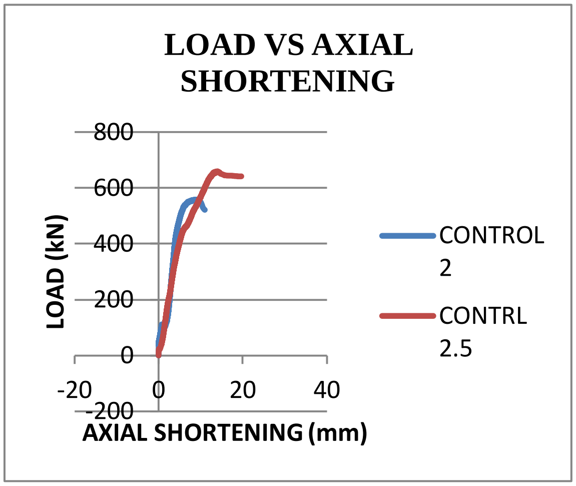
a) b)

Figure3 : a)&b) behaviour of control and GGBS concrete column

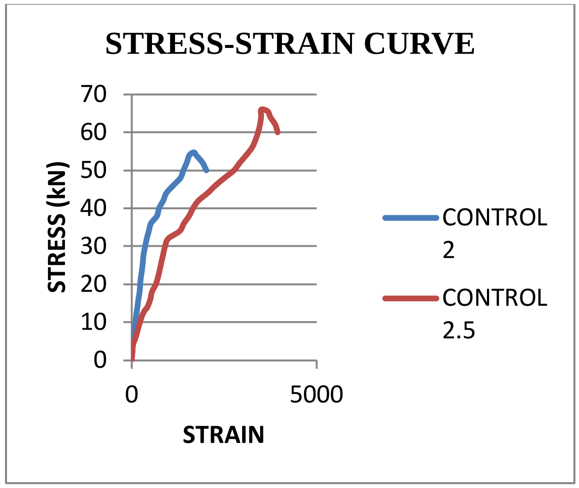
In the case of ggbs the maximum load that can be taken by that specimen is found to be 720 kn, which is 9.3% more compared with normal concrete specimen. 100% increase in strain for ggbs specimen in comparison with control specimen.

Comparison of 2 and 2.5mm steel tubular short column behavior:

1) control concrete columns



a)



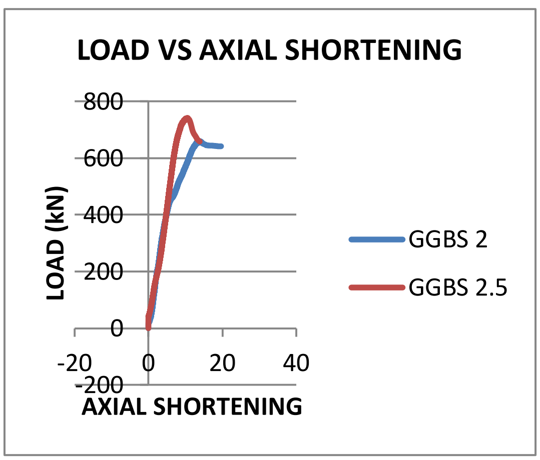
b)

Figure 4:a)&b) behaviour of control concrete column

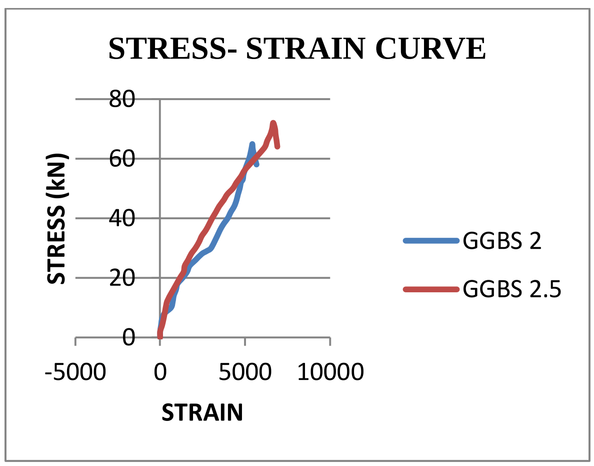
This comparison is to study the confining effect of steel on infilled concrete. Due to increase in thickness the load carrying capacity of control specimen get inceased to about 20.5%. the maximum strain it can take at ultimate load also get increased to 153 %.

In case of M30 grade concrete infilled column ,the curves gradually increases then the sudden drop of curve takes place after the ultimate load is reached. Bulging of the column took place when the ultimate load reached 85% .

- GGBS concrete short columns



a)



b)

Figure 5:a)&b) behaviour of control concrete column

Similar in case of ggbs also. 13% increase in ultimate load and 19% increase in stress level. After the load reaches 90%,the crushing of concrete took place more compared to other cases. Even though the load carrying capacity was more , the crushing was also more. After reaching the ultimate load sudden failure took place.

Almost all columns failed due to local buckling and concrete crushing. Local buckling took place after the elastic range, and after this concrete crushing followed. The failure mode of almost all columns at the bottom or the top was a typical crushing failure mode where the steel wall was pushed out by the concrete core, which in turn was confined by the steel. When the steel was removed from the specimen after failure, the concrete was found to have taken the shape of the deformed steel tube, which illustrates the composite action of the section. In the case of square columns, it is necessary to take into consideration a capacity reduction due to local buckling of the steel tube wall of the column with large B/t ratio rather than the confinement effect of the steel tube.

IV.THEORETICAL INVESTIGATION

- Strength index

A strength index is defined to quantify the section strength

$$SI = Nue/Nuo$$

Nuo=As*fy+0.85*Ac*fc ,giving sectional capacity as in ACI

Nue= experimental ultimate strength

- Ductility index

One of the parameter used to quantify section ductility is ductility index. It is expressed as

$$DI = €_{85}/€_{ue}$$

$€_{85}$ =strain when the load falls to 85% of the ultimate load

$€_{ue}$ = experimental ultimate strain

Table 2: Material properties, section capacities and ductility index

specimen	D(B) Mm	t(mm)	Fy	Fck	Nue	SI	$€_{ue}$	DI
control	100	2	380	33	547000	1.08	1500	0.8
GGBS	100	2	380	38.8	649000	1.185	5500	0.88
control	100	2.5	380	33	659000	1.15	3500	0.914
GGBS	100	2.5	380	38.8	720000	1.2	6800	0.98

Theoretical ultimate load of columns:

Strength Comparison by Design Codes

- Eurocode-4

$$N_{p1,R} = A_a f_y + A_c f_c$$

Where A_a and A_c are the area of steel and concrete, and f_y and f_c are the strength of steel and concrete.
For circular columns, confinement effects have to be incorporated if the relative slenderness λ is less than 0.5

- ACI code

. The squash load for square, rectangular, and circular columns is determined by

$$N_u = 0.85\ A_c f_c + A_s f_y$$

Table 6:strength comparison using different codes

	D or B Mm	Aa Mm^2	Ac Mm^2	EC4 kN	ACI kN	EXPERIMENTAL kN
2 mm	100	784	9216	655	601	540
2.5mm	100	975	9025	725.16	687	650

V.CONCLUSION

Based on the experimental and theoretical investigation done on cold formed steel tubular short columns infilled with high volume pozzolanic materials, the following conclusions were drawn.

- Infilling the hollow section columns with M30 grade concrete, ggbs concrete increases the load carrying capacity, ductility and ultimate strain value.
- The failure mode for column infilled with M30 grade concrete was outward folding failure at the bottom of the column
- For column infilled with ggbs concrete, crushing of the concrete and outward bulging occurs. When the load reached 90% of ultimate load crushing occurred.Due to the higher load carrying capacity compared to M30 grade concrete, the concrete withstood more load, the steel yielded first and then the concrete
- 15-20% increment in ultimate load carrying capacity was obtained while removing 30% cement with ggbs
- Increasing the thickness also increase the ultimate load carrying capacity. 10-20% increment in strength occurs.
- Since, large amount of cement is considerably reduced by the usage of 30% ggbs, it can save economy, reduce environment impact by reducing the heat of hydration.
- And can also reduce size of the structural elements to carry high loads because of the usage of composite members.

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