

Behaviour of Cold Formed Steel Tubular Short Columns Infilled with High Volume Fly Ash

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ABSTRACT: VA combination of steel and concrete in structural members and components of load-bearing structures appears very efficient due to the advantageous properties of both materials complementing each other. It results in the design of highly reliable and cost-saving structures. Concrete-filled hollow steel sections are more and more frequently used as compression members in structures nowadays. The subject of this work is to investigate the effect of high volume replacement level of cement with fly ash on the strength of concrete filled steel tubular short columns. A theoretical investigation of this experimental results with Euro code is also conducted. Fly ash can be used as a replacement for cement or as an additional cementations material in concrete. Optimum percentage of fly ash were found out by conducting cube strength test on 21 specimens with different percentage replacement level of cement. Infilling the hollow section columns with M30 grade concrete, concrete with fly ash as a replacement for cement as a replacement for cement were studied. Totally 10 columns with 2 mm and 2.5 mm thick steel were tested and load versus elongation, axial stress- strain behaviour for each type of column was studied. The results show that concrete filled steel tubular columns with optimum percentage of fly ash have the highest compressive strength at age of 28 days than steel tubular column with normal M30 concrete. 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

KEYWORDS: CFST column, Fly ash concrete, Cementitious material.

I. INTRODUCTION

Since past few decades, composite steel-concrete construction of column and girder is being used in the construction industry. These composite sections have the rigidity and formability of reinforced concrete with the strength and speed of construction associated with structure, thereby making them economical. The steel and the concrete element in a composite member complement each other ideally. Composite members consisting of rectangular steel tubes filled with concrete are extensively used in structures involving very large applied moments, particularly in zones of high seismic risk. Concrete Filled Tubes (CFTs) have been used as girder, beam and columns in frame structures.

A steel hollow section in-filled with concrete has higher strength and larger stiffness than the conventional structural steel section and reinforced concrete[3]. 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[2]. The continuous provided to the concrete core by the steel tube enhances the core's strength and ductility. The concrete core delays bending and buckling of the steel tube, while steel tube prevents the concrete from spalling. Also concrete filled tube (CFT) columns are suitable for tall buildings in high seismic regions since concrete delays the local buckling of steel hollow sections and increases the ductility of the section significantly[1] and [5]. While there is a large number of studies on the behaviour of CFT columns and beam-columns; there is relatively little research reported on the flexural behaviour of concrete-filled hollow structural steel column. 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

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Fly ash is a by-product of coal-fired electric power stations. It improves the durability when used in concrete as a cement replacement. It also contributes to concrete strength by pozzolanic and filler effects[8]. Recently, fly ash has been increasingly used in the concrete industry.. However, as pozzolanic reaction is a slow process that its contribution to strength occurs only at later ages, the early strength of concrete will be significantly reduced if a large amount of fly ash is used . This limits the wide use of high-volume fly ash concrete by engineers. Different approaches are used to accelerate the pozzolanic reaction of fly ash and therefore increase the early strength of the concrete containing fly ash[2]. These approaches include

- (i) mechanical treatment (grinding),
- (ii) accelerated curing and autoclaving,
- and (iii) chemical activating

It is important to ensure that in the extreme event of the structural failure it should behave in a ductile manner. This means ensuring that the structure will not fail in brittle fashion without warning of failure. In areas subjected to earth quake a very important design consideration is the ductility of the structure when subjected to seismic type loading. The present seismic design philosophy relies on energy absorption and dissipation by post elastic deformation for survival in major earthquake. When a ductile structure is subjected to overloading it will tend to deform inelastically and in doing so, will redistribute the excess load to elastic part of the structure. if a structure is ductile it can be expected to adapt to unexpected overloads, load reversal, impacts and structural movements due to foundation settlements and volume changes.

II. EXPERIMENTAL INVESTIGATION

Material properties:

In order to study the material properties of the sheets used for making the specimen,3 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	2.04X10 ⁵	380	450

Table 2: Properties of sand,cement,and aggregates

	Coarse aggregate	Sand
Specific gravity	2.8	2.75
Water absorption	0.97	1.23

	Cement	Fly ash
Specific gravity	3.15	2.42
Specific surface(m ² /kg)	392	565
SiO ₂	20.6	63.5
Al ₂ O ₃	4	11.1
Fe ₂ O ₃	3.1	5.2
CaO	62.8	14

Compressive strength of cubes and optimum percentage of fly ash :

- Normal mix

Concrete of M30 mix was prepared using 10mm size chips and 2.36 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

	1	2	3
Compressive Load (kN)	754.3	743.3	704

Average compressive load is calculated as 754.3 kN

- Normal concrete with replacement of cement with different percentages of fly ash

Concrete of M30 mix was prepared using 10mm size chips and 2.36 mm size fine aggregates with cement content of 53 grade. cement was replaced with fly ash by optimum percent. 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 table 4.

Table 4: compressive load of fly ash

	Fly ash content(percentage wt of cement)		
	30	40	50
Average compressive Load(Kn))	735.5	801	647.4

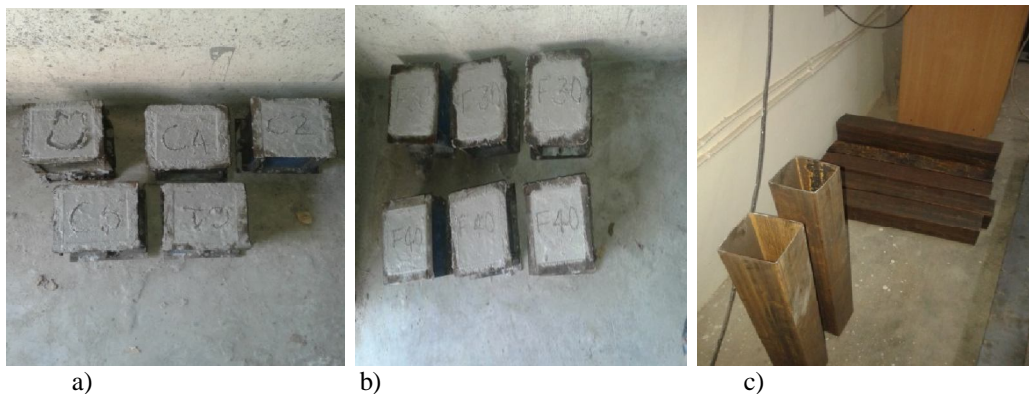


Figure1: a) control cubes, b)fly ash cubes c) hollow steel column

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	380	33
2	100	2	700	380	35.5
3	100	2	700	380	38.8
4	100	2.5	700	380	33

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 1 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 fly ash concrete columns with 2 mm thick steel tube

The stress versus axial strain behaviour and load versus elongation for the control column and shown in figure. The curve gradually increases, then sudden drop of curve takes place after the ultimate load is reached. Typical failure mode for hollow steel tube infilled with M30 grade of concrete was local outward folding failure mechanism in bottom of the column

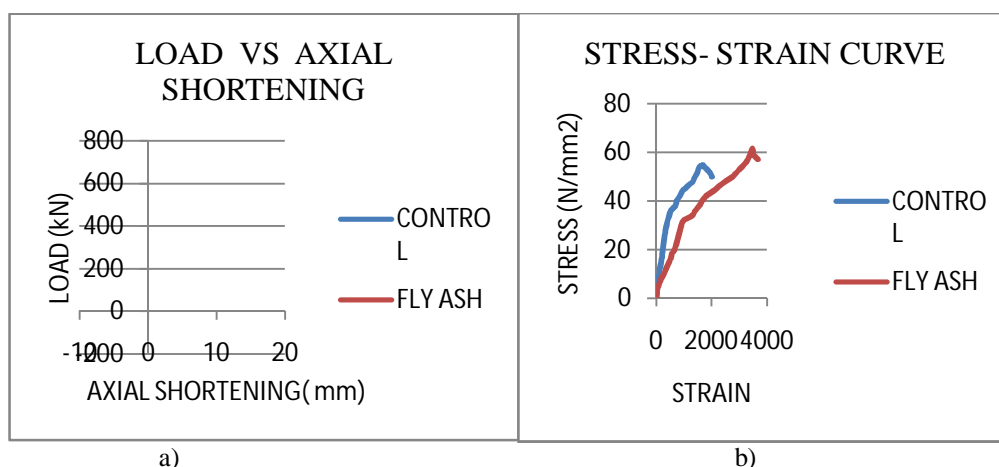


Figure 2: a)&b) behaviour of control and fly ash concrete columns

By comparing the results of control specimen and fly ash concrete specimen it is found that the load carrying capacity of control concrete is 547 Kn and that of fly ash is 614 kn. Ie,12.3% increment in strength even after the removal of 40% cement by fly ash. Strain corresponding to ultimate load is 0.014 for control concrete and 0.035 for fly ash concrete specimen.

- Comparison between control ,fly ash concrete infilled short column with 2.5 mm steel tube

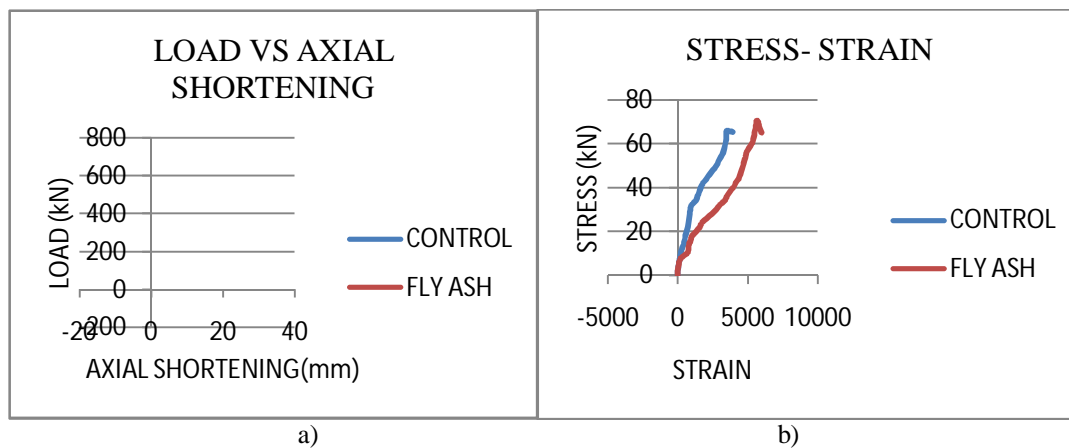


Figure 2: a)&b) behaviour of control and fly ash concrete columns

With increase in thickness of the steel tube the load carrying capacity of control specimen get increased to 659 kn. a net increase of 112 kn due to the higher confining effect of steel on concrete. Ultimate load for fly ash concrete is found to be 705 kn. 7% increment in failure load for fly ash concrete short columns than control specimen. By increasing the thickness, strain carrying capacity of both the specimen get increased. 53 % more strain can sustain fly ash concrete specimen at ultimate load than control column.

- Comparison of 2 and 2.5mm steel tubular short column behaviour

1) control concrete columns

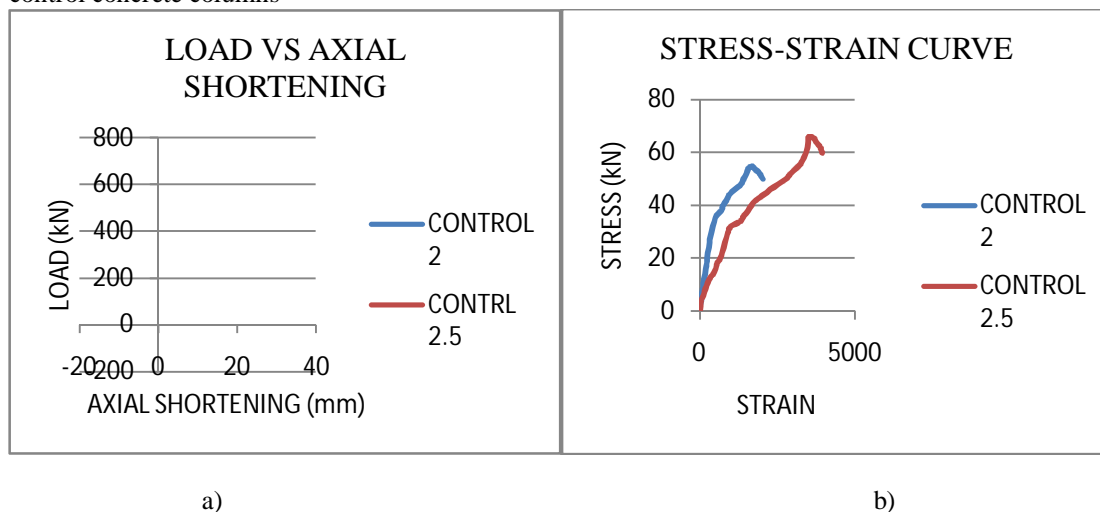


Figure3: a) &b) behaviour of control concrete columns with 2 and 2.5 mm thick steel tube

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 increased 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% .

2) Fly ash concrete columns

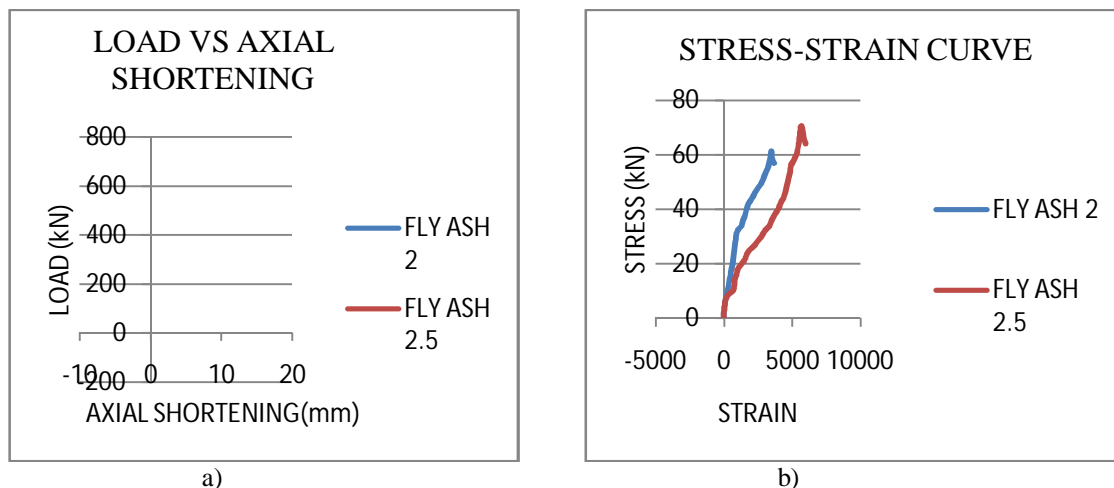


Figure3: a) &b) behaviour of control concrete columns with 2 and 2.5 mm thick steel tube

In case of fly ash concrete column also considerable increase in both load carrying capacity and strain with increase in thickness. Ultimate load carrying capacity and strain get increased to 15% and 71% respectively. When the load reaches ultimate stage the curve gradually decreases. In this case, after reaching around 88% of ultimate load ,first bulging occurred gradually at the bottom. When ultimate load reached 95% bulging took place at the top also.this failure was due to the higher load carrying capacity compared with control concrete. When the concrete withstood more load the steel reached yield first and then the concrete. So bulging in the outward direction took place in both the ends.

IV. THEORETICAL INVESTIGATION

- Strength index

A strength index is defined to quantify the section strength

$$SI = Nue/Nuo$$

$Nuo = A_s * f_y + 0.85 * A_c * f_c$,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

$$DI = \epsilon_{85} / \epsilon_{ue}$$

ϵ_{85} =strain when the load falls to 85% of the ultimate load

ϵ_{ue} = experimental ultimate strain

Table 2: Material properties, section capacities and ductility index

specimen	D(B) Mm	t(mm)	Fy	Fck	Nue	SI	ϵ_{ue}	DI
control	100	2	380	33	547000	1.08	1500	0.8
Fly ash	100	2	380	35.6	615000	1.18	3500	0.86
control	100	2.5	380	33	659000	1.15	3500	0.914
Fly ash	100	2.5	380	35.6	705000	1.95	5800	0.96

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 1: 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	657	612	547.8
2.5mm	100	975	9025	736.56	691.9	659

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, fly ash 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
- In case of column infilled with fly ash concrete, the bulging of the column occurred at the bottom at 85% of the ultimate load, then at the top when the ultimate load reached 95%. 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.
- 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 40% fly ash, it can save economy, reduce environment impact by reducing the heat of hydration.
- By comparing experimental and theoretical values, theoretical ultimate load by Euro code and ACI method gives almost equal values, which is comparatively same as that of experimental results
- And can also reduce size of the structural elements to carry high loads because of the usage of composite members.

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