Micro Study Of Slender Concrete Filled Aluminium Tubular Columns Under Axial Compression

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Abstract: This study aims at utilizing industrial wastes and mineral admixtures to improve the strength in single layer concrete filled aluminium tubular columns. This study also focuses on the effective ways of utilizing copper slag as fine aggregate replacement of 10% thereby reducing the pollution as well as meets the increasing demand of river sand for concrete. This experimental investigation indicates the compressive strength characterization at 28 days and the impact of mineral admixtures like metakaolin and GGBS in properties of concrete as a binder replacement of 5%, 10%, 15% and 20% respectively. The results obtained showed that the hybridization of natural minerals in combination with copper slag replacement can be incorporated in concrete to improve their mechanical strength of tubular columns.

Keywords: Short columns, aluminium tubes, metakaolin, GGBS, copper slag, compressive strength

1. INTRODUCTION

Concrete filled hollow section (CFHS) columns can carry important loads and therefore are used extensively in the construction of high-rise buildings. It is well known that concrete-filled steel composite columns have the advantages of high-bearing capacity and ductility, easy construction and cost saving. Similarly, aluminium tube columns filled with concrete can effectively take advantages of materials to provide both high strength and high stiffness.The need to focus on the innovative materials as replacements for fine aggregates is increasing day by day due to the pressure of incorporating sustainable aspects in the construction industry. Moreover the high amount of the energy associated with the production of cement demands the use of mineral or pozzolanic admixtures to solve the technical and environmental problems. Mineral admixtures mostly obtained from the industrial by-products are rich in alumina and silica and can function as effective cement replacements. Metakaolin is a highly reactive mineral admixture that possesses high pozzolanic activity and can contribute significantly towards the strength improvement of concrete. Several studies have seen significant enhancement in the properties of concrete due to the incorporation of metakaolin both at the hardened and the fresh state. The inclusion of the GGBS has also been found to reduce the bleeding of concrete due to their comparatively high water demand. The strength improvement in concrete due to GGBS addition may be attributed not only to their cementation material but also to their particle size which is finer when compared to the cement. Similarly copper slag also improved the strength of the concrete due to their filler effect and particle packing capacity. The beneficial utilization of metakaolin and GGBS in concrete and their combined effects with copper slag has been well documented by several researches. A comprehensive understanding is necessary when replacements to cement and fine aggregate is done at the same time and this study is an effort to glean the effect of replacement of fine aggregate by copper slag and cement by metakaolin with GGBS on the strength and stability of concrete filled aluminium tubular columns.

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2. RESEARCH OBJECTIVE

The primary objective of the research work is to investigate the effect of cement and fine aggregate replacements on the strength in concrete filled aluminium tubular columns. Following are the specific objectives of the study:

- Investigate the ultimate strength of the sample using compression testing machine
- Evaluate the relation between various grades of concrete at partial replacement of natural minerals and byproducts.
- Examine the behaviour of composite reaction between the concrete filled aluminium tubular section and partially concrete filled aluminium tubular section
- Assessing the failure pattern of various composite sections.

3. MATERIAL USED

3.1 Tubular section

The rectangular hollow aluminum tube confirming to IS 4923-1997 having a dimension of 101.60mm x 4.75mm x 1.35mm is used in this study. The Table.1 listed below states the mechanical properties of rectangular hollow aluminium tubes.

Table.1.*Properties of Aluminium tube*

Parameter	Value	Unit
Height of the section (H)	101.60	mm
Width of the section (B)	44.75	mm
Thickness of the section (T)	1.35	mm
Cross sectional area (A)	387.90	mm^2
Weight per metre (W)	1.013	Kg/m

Mass (M)	16.00	kg
Second moment of inertia (I_{XX})	521249.156	mm^4
Second moment of inertia (I_{YY})	145945.625	mm^4
Section modulus (S_{XX})	10260.811	mm^3
Section modulus (S_{YY})	6522.709	mm^3
Radius of gyration (r_x)	36.66	mm
Radius of gyration (r_y)	19.398	mm
COG distance in x direction (X_{cog})	22.375	mm
COG distance in x direction (Y_{cog})	50.80	mm

3.2. Cement
Ordinary Portland cement conforming to IS 1489-1991 was chosen as the main binder. OPC of 53 grade having specific gravity of 3.15.

3.3. Coarse Aggregate
Machine crushed well graded angular granite aggregate of nominal size 10 mm confirming IS 383-1970 from local source are used. The specific gravity is 2.84. It is free from impurities such as dust, clay and organic matter.

3.4. Fine Aggregate
The fine aggregate used in this study is natural river sand which conformed to zone 2 of IS 383-1970. The specific gravity is 2.47

3.5. Metakaolin
Meta kaolin is not a by-product. It is obtained by the calcinations of pure or refined Kaolinite clay at a temperature between 650^0 C and 850^0 C, followed by grinding to achieve a finesse of 700-900 m^2 /kg. It is a top notch pozzolonic material, which is mixed with concrete so as to improve the strength of concrete. At the point when utilized in solid it will occupy the void space between concrete particles bringing about a progressively impermeable concrete. The specific gravity of metakaolin is 2.50.

3.6. GGBS
It is a by-product from the blast-furnaces recycled to create iron. Blat furnaces are sustained with exact blend of iron-metal, coke additionally limestone, and worked at a temperature of about 1,500°C.The specific gravity of GGBS is 2.88.

3.7. Copper Slag
Copper slag is an industrial by-product material delivered from the way toward assembling copper. For each ton of copper creation, about 2.2 huge amounts of copper slag are produced. It has been assessed that around 24.6 million tons of slag are created from the world copper industry. The specific gravity of copper slag is 3.29

3.8. Water
Fresh portable water is free from concentration of acid and organic substance is used for mixing the concrete and curing.

3.9. Superplasticizier
Poly-carboxylate Ether Super plasticizer obtained from Chemcon tech SYS was used. It conforms to IS 9103 – 1999 and its specific gravity of 1.2. The superplasticizer dosage was fixed as 2% to attain required workability.

4. DESCRIPTION OF MIXES
Three series of concrete mixes M30, M40 and M50 grades are produced with water-binder ratios as shown in table 2.The water cement ratio has been fixed depending upon the compaction factor test, keeping medium workability. The workability of the fresh concrete mixes were investigated as per the procedure stated in IS 1199-1959.

***Table.2**. Mix ratio, proportions, % replacement of binder and fines*

Mix ID	Grade of concrete	w/b	Mix Ratio	% by wt of cement	% by wt of cement	% by wt of sand
				Meta kaolin	GGBS	Copper Slag
M1A0	M30	0.45	1:1.74:2.90	0	0	0
M1A1				5	5	10
M1A2				10	10	10
M1A3				15	15	10
M1A4				20	20	10
M2A0	M40	0.40	1:1.65:2.92	0	0	0
M2A1				5	5	10
M2A2				10	10	10
M2A3				15	15	10
M2A4				20	20	10
M3A0	M50	0.35	1:1.47:3.04	0	0	0
M3A1				5	5	10
M3A2				10	10	10
M3A3				15	15	10
M3A4				20	20	10

5. RESULTS AND DISCUSSION

5.1. Specimen fabrication
The 450 mm height rectangular hollow aluminum tubes were machined from 6 m length hollow section. To get the level surface, the two parts of the aluminium tubes were surfaced by the surface pounding machine. Inside part of the hollow steel tubes were altogether wire brushed to evacuate the rust and free space is introduced. At that point the hollow aluminium tube samples were filled up with concrete and the each layer of cement completely compacted by a needle vibrator to guarantee the solid liberated from defects or air holes. To dispense with the

spillage of slurry during compaction, a steel plate was put at the base preceding filling concrete. At that point the concrete was permitted to cure for 28 days.

5.2. Slender columns

Fifteen samples are planned to tested with five concrete mixes are prepared. Slenderness ratio (λ) is defined as

$$\lambda = L_e / i \geq 50$$

Where L_e is the effective length of a column;
$i = \sqrt{Isc/Asc}$, is the section radius of gyration,
Where Isc and Asc are the second moment of area and area of the CFT composite cross-section respectively. Therefore, the slenderness ratios for the composite columns with different cross-sections can be determined by

$$\lambda = 2\sqrt{3}L_e/B \text{ (square or rectangular column)}$$

Where D is the overall diameter of a circular column, and B is the overall width of a square or rectangular column.

5.3. Compression Strength Test

Compression test on concrete cubes has been carried out confirming to IS 516:1999. All the concrete cube specimens were tested in a 2000kN capacity compression testing machine. The crushing strength of concrete cube is determined by applying compressive load at the rate of 140kgf/cm^2/min till the specimen fail. After the 28 days, of curing, the specimens were then allowed to become dry for few hours before testing. Plane surfaces of the specimen were between platens of the compression testing machine and subjective to loading.

Table 3. *Compression Strength at 28 days (N/mm^2)*

SL.No	Type of sample	Compressive Strength at 28 Days (N/mm^2)	Average Compressive Strength at 28 Days (N/mm^2)
1	M1-A0	55.91	49.95
2	M1-A0	46.13	
3	M1-A0	47.82	
4	M2-A0	53.42	51.32
5	M2-A0	49.51	
6	M2-A0	51.02	
7	M3-A0	57.69	57.57
8	M3-A0	56.80	
9	M3-A0	58.22	

5.4. Split Tensile Strength Test

The test on tensile strength of concrete at simple to and gives more uniform results than other tensile tests. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter.

Table 4. *Split Tensile Strength at 28 days (N/mm^2)*

SL.No	Type of sample	Split Tensile Strength at 28 Days (N/mm^2)	Average Split Tensile Strength at 28 Days (N/mm^2)
1	M1-A0	15.83	15.39
2	M1-A0	15.05	
3	M1-A0	15.29	
4	M2-A0	18.33	17.00
5	M2-A0	17.53	
6	M2-A0	15.14	
7	M3-A0	18.21	18.15
8	M3-A0	17.26	
9	M3-A0	18.99	

From the compressive and split tensile strength of the concrete we can know the characteristics of concrete but it depends on many factors such as water-cement ratio, cement strength, quality of concrete material, curing method etc so that, here compressive and split tensile strength test have been conducted as per IS 516-1959 for M30, M40, M50 grade specimens of designed mix ratio and the 28 days compressive strength has checked.

5.5. Compression Strength Test on Specimens

Table 5. *Compressive strength of concrete filled tubular columns at 28 days (N/mm^2)*

Mix ID	Load (KN)	Average Strength of Composite Section (N/mm^2)
M1-A0	191.4	42.10

M1-A1	196.3	43.18
M1-A2	209.3	46.03
M1-A3	210.9	46.39
M1-A4	205.2	45.13
M2-A0	193.5	42.56
M2-A1	185.2	40.73
M2-A2	197.6	43.46
M2-A3	236.5	52.02
M2-A4	217.6	47.86
M3-A0	192.1	42.25
M3-A1	161.1	35.43
M3-A2	196.5	43.22
M3-A3	218.8	48.12
M3-A4	162.8	35.81

6.0. GRAPHICAL REPRESENTATION OF RESULTS

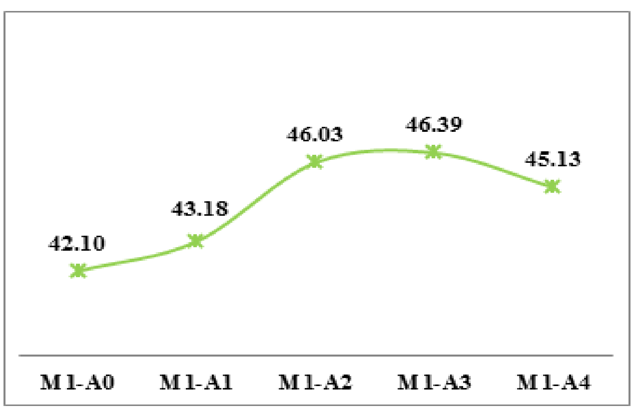

Fig.1.*Ultimate capacity of M30 grade tubular column*

This graphical representation denotes that the ultimate capacity of M30 grade aluminium tubular column gradually increased up to the replacement of MK 15%, GGBS 15% and copper slag 10%. Dramatically there has been a decrease at the replacement of MK 20%, GGBS 20% and copper slag 10%.

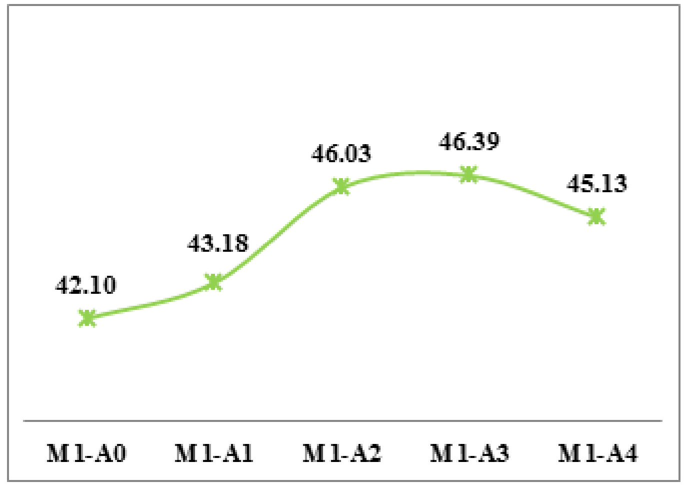

Fig.2*.Ultimate capacity of M40 grade tubular column*

At the replacement of MK 15%, GGBS 15% and copper slag 10% M40 grade of aluminium tubular column specimens also gets the highest ultimate capacity than other specimens.But here we can note that M2-A1 specimens ultimate capacity is less than the conventional specimens.

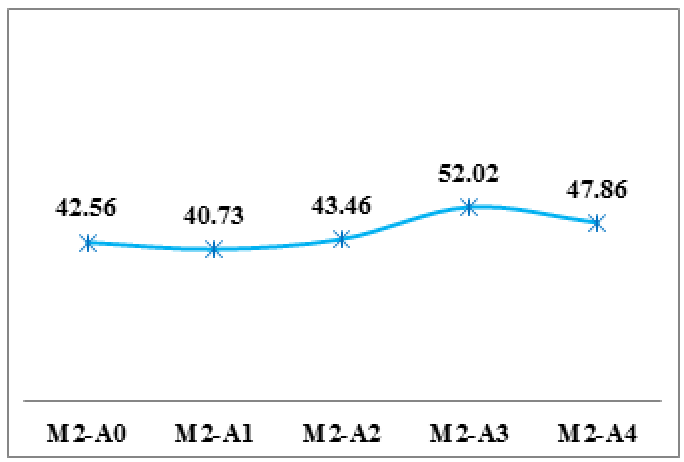

Fig.3*.Ultimate capacity of M30 grade tubular column*

M50 grade of aluminium tubular column gains 48.12 N/mm^2 ultimate capacity at the replacement of MK 15%, GGBS 15% and copper slag 10%. In this Grade of concrete specimens the replacement of MK5%, GGBS 5% and copper slag 10% specimens get the ultimate capacity less than conventional specimens like M40 grade.

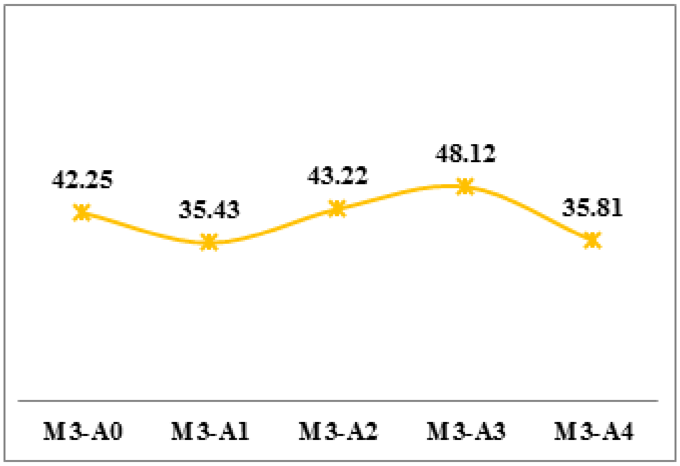

***Fig.4**.Comparision of partial replacement concrete for M30, M40 & M50.*

The grade of M30, M40 and M50 aluminium tubular concrete columns have 10.19%, 22.22% and 13.89% respectively the ultimate capacity more than the conventional concrete aluminium tubular column.

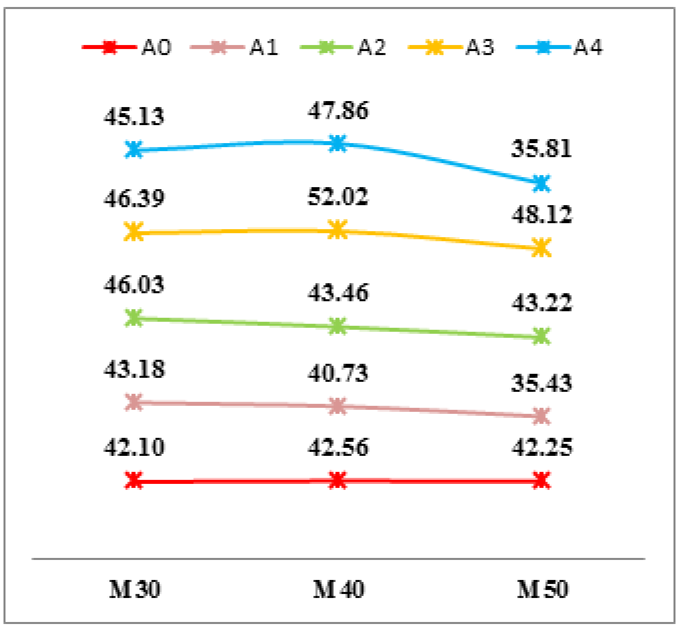

***Fig.5**.Comparision of Partial Replacement Concrete for M30, M40 & M50*

When compared the ultimate capacity of aluminium tubular column the replacement of MK 15%, GGBS 15% in weight of cement and copper slag 10% in weight of sand is effective in loading conditions. Here in all the grades of concrete filled aluminium tubular column the replacement of MK15%, GGBS 15% and copper slag 10% have been more effective than other replacements.

7 CONCLUSION

i) The concrete filled tubular sections when loaded are subjected to behave as a composite section.
ii) The strength of composite section is greater when the ingredients in the concrete inside is with 10% copper slag, 15% metakaolin, 15% GGBS in M40 grade concrete.
iii) When the ingredients of concrete are not replaced with minerals and by-products, the higher strength of composite section falls with M40 grade. This reveals that M40 grade concrete shows commonly higher composite action.
iv) When 10% copper slag, 5% metakaolin and 5% GGBS replaced, the section filled with M30grade concrete showed higher strength of 43.18 N/mm2.
v) The replacement with 10% copper slag, metakaolin and GGBS in M30 grade concrete matrix showed higher strength of 46.03 N/mm2 which is 5.6% and 6% greater than mixes with same replacement of materials in M40 and M50 grade concrete respectively. This shows that increase in metakaolin and GGBS increases strength of composite section.
vi) When replacing with 15% metakaolin and GGBS in M30 grade concrete shows a reduction in strength of composite section than in M50 grade concrete. This shows increase in metakaolin and GGBS increased strength and ductility that it holds good with limited water content or the other hand increased cement content.
vii) The replacement with 20% metakaolin and GGBS showed higher composite action in M40 grade.
ix) The section buckled at the bottom and teared off. This is due to thickness of the tube. This results that the increase in metakaolin and GGBS showed a decreasing line for M30 and M50 whereas the strength of composite section is stagnant higher in M40 grade concrete.
x) This inferred that the use of 5 to 10% metakaolin and GGBS in M30 grade and 15 to 20% in M40 grade to be used as infilling matrix to enhance composite action.
xi) It is also inferred that high strength concrete shows decrease in strength when 20% replacement of metakaolin and GGBS is used.

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