Experimental Study on Behaviour of Steel Tubular Composite Column Filled with Recycled Waste

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Abstract— Over the past few decades, developments of new techniques are seen in all the industries and activities. In such a case Concrete Filled Steel Tubular (CFST) column has become popular and plays an eminent role in constructions. This popularity is owing to its structural behaviour like excellent seismic resistivity properties like high ductility, high stiffness and large energy absorption capacity. The intentions of thiswork is to study the behaviour of CFST columns in-filled with concrete mixed with recycled coarse aggregate(RCA) and paper by partial replacement of coarse aggregate, which is subjected to axial loading. Since construction and demolition waste(C&D) and paper waste causes considerable environmental impact, these materials should be recycled in all possible way. The load carrying capacity, stress-strain behaviour is studied on the CFST columns of length to diameter ratio 4 and thickness of 4.8mm. The grade of concrete used is M_{20}. The paper is made into papercrete before mixing into the concrete mix. The optimum percentages of recycled coarse aggregate and paper were found from the compression and split tensile strength tests. That particular proportion is mixed with concrete and filled in the steel tubular column. The CFST column is tested for studying load carrying capacity and stress-strain behaviour.

Keywords—CFST column,paper,recycled coarse aggregate

I. INTRODUCTION

Concrete-filled steel tubular (CFST) columns have been progressively used in many upcoming modern structures (8). This is due to the fact that CFST columns have high strength, high stiffness, that is, the steel tube resists any tensile forces, bending moments and shear forces, and offers confinement to the concrete (1).This confinement acts as both longitudinal and lateral reinforcement and subjected to biaxial stresses of longitudinal compression and hoop tension. The concrete core can also restrain local buckling of the steel tube under different loading history. At the same time, it is stressed tri-axially (5).

1.1 COMPOSITE COLUMN

These composite columns are very important application of composite constructions. The use of composite column can result in significant savings in column size, which lead to significant economic savings. The size of CFST column is smaller than that required for RC columns to support same loads. Because of its high resistance for a small cross sectional area, it maximizes the useable floor area. The need of longitudinal reinforcement, transverse reinforcement and formwork are satisfied with the structural behavior of steel tube and it tends to rapid construction and prevents excessive concrete spalling. From the past study it is mentioned that, on the concentric compression behavior of CFT columns, the ultimate axial strength of CFT columns is considerably affected by the thickness of the steel tube, as well as by the shape of its cross section.

1.2 SCOPE

Currently, civil engineers have been challenged to convert the industrial wastes to useful building and construction materials. Since the usage of natural aggregate is getting more and more intense with the advanced development. We ought to change the practice of using natural aggregate by recycled aggregate. The troubling information of CO_2 emission is, it is mainly produced from the construction industries which leads to global issues, On the other hand, people's longing to live eco-environment. This desire is continuously increasing. In order to resolve these kinds of matters, this study carried out by reusing coarse aggregate and paper waste as partial replacement for coarse aggregate in the concrete of CFST column and suggest this system in future prefabrication industries. Further theoretical investigation is done on load carrying capacity of CFST column by Eurocode 4.

II. INVESTIGATION APPROCHES

After a general views on CFST columns and necessity on reusing the waste in all possible ways. A series of laboratory tests were carried out to assess fresh and hardened concrete properties using different proportions of recycled coarse aggregate and paper. About 100 specimens of concrete cubes and cylinders with 15 different mixes were casted and tested for compression and tensile strength. By observing the results, the optimum % of recycled coarse aggregate with paper by replacing coarse aggregate is designated.

III. NEED FOR THE PROJECT

- To get innovative materials in construction and prefabrication industry.
- To compensate and reduce the pollution by recycling the waste in construction field.
- Effective use of recycled materials without any adverse effect on the society.

IV. CONCRETE PROPERTIES

Concrete of design strength of 20 MPa was produced by using commercially available materials and recycled waste (recycled aggregate and paper) with mixing using simple curing techniques. The paper is made into pulp before mixing into the dry concrete mix. Mix design of grades was carried out in accordance to the IS 10262 (Table 1 shows the mix proportion)

Table 1: Mix proportion for M_{20} concrete

Water cement ratio(w/c)	cement	Fine aggregate	Coarse aggregate
0.5	1	1.81	3.04

Initially mix batch is done by 100% natural aggregate. Later it is replaced by 10% of RCA and 5% of paper and in each mix the replacement is increased by 10% of RCA and 5% of paper. This series is preceded for 50% of RCA and 15% of paper as shown in Table 2. A total of 45 cubes and 45 cylinders are casted and tested for compression and split tensile strength.

Table 2 Replacement % of paper and RCA

Paper%	RCA%				
5	10	20	30	40	50
10	10	20	30	40	50
15	10	20	30	40	50

Usage of RCA lower environmental impact achieved through reduced carbon dioxide emission and reduced natural aggregate extraction from quarries. The major advantage is based on the environmental gain. According to CSIRO, construction and demolition waste makes up to around 40% of the total waste each year (estimate around 14 million tones) going to land fill. Through recycled these material, it can keep diminishing the resources of urban aggregated. Therefore, natural aggregate can be used in higher grade applications and the amount of waste materials used for landfill and amount of quarrying will be reduced. Therefore this will extend the lives of natural resources and also extend the lives of sites that using for landfill.

In addition to this RCA, paper is added as papercrete. Paper is principally wood cellulose. Cellulose is natural polymer as shown in Fig 1.

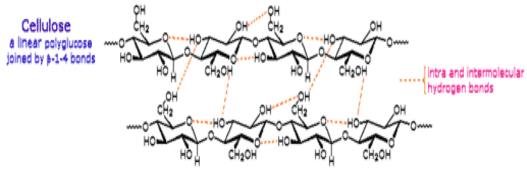

Fig 1 links of cellulose bonds.

Fig.2 shows the network of cellulose fibres and smaller offshoots from the fibres called fibrils. In this, fibres and fibrils network forms a matrix, which becomes coated with Portland cement. When these networks of fibres and fibrils dry, they intertwine an with the power of hydrogen bond which encases the fibres for extra strength.

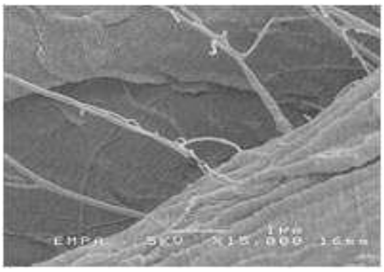

Fig 2 network of cellulose fibres

V. EXPERIMENTAL STUDIES (CONCRETE)

5.1 SLUMP TEST

Slump value (mm) for different mix is shown in Table 3. The results shows that the slump value get reduced with increasing RCA and paper content which indirectly represent the workability characteristics. The Fig 3 shows slump value for conventional mix which is higher than those replacement mix.

Table 3: slump value for the replacements

Paper (%)	Recycled coarse aggregate RCA (%)				
	10	20	30	40	50
5	79	85	82	88	77
10	74	73	69	66	61
15	58	54	60	59	55

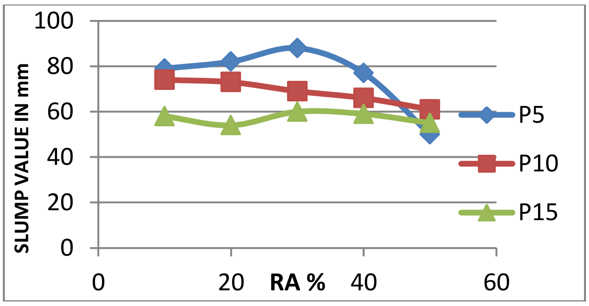

Fig 3: slump value for the replacements

5.2 COMPRESSIVE STRENGTH TEST

The Compression test was carried out on cube specimens of 150mm size which shown in Fig 4. The specimens are not to be allowed to cure for 28 days and dried before testing. The bearing surfaces of the testing machine were wiped clean the other materials, which may come in contact with the compression plates. While placing the cubes in the machine, care was taken such that the load was applied to opposite sides of the cubes as casted and not to the top and bottom. The axis of the specimen was carefully aligned with the centre of thrust of the spherically seated plate. As the Spherical-seated block is to bear on the specimen, the movable portion was rotated gently by hand, so that uniform seating was obtained. The maximum load applied to the specimen was recorded and any usual appearance in the type of failure was noted. The compressive strength values for various replacements are shown in Fig 5.

Fig 4: compressive strength test

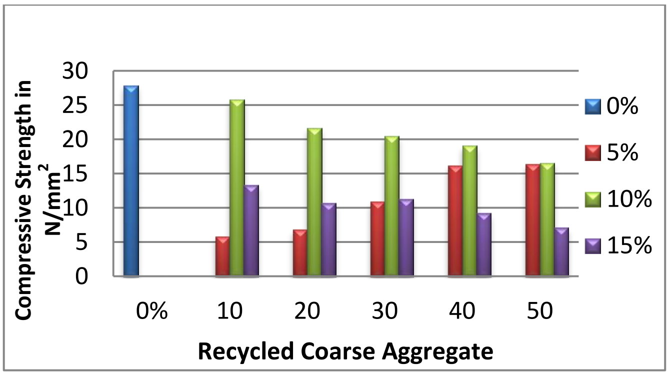

Fig 5 compressive strength value for replacements

5.3 SPLIT TENSILE STRENGTH TEST

The cylindrical specimens were tested for split tensile strength at an age of 28days (Fig 6).The dimension of the specimen is 150mmX300mm. The Split tensile strength values for various replacements are shown in Fig 7

Fig 6: split tensile strength test

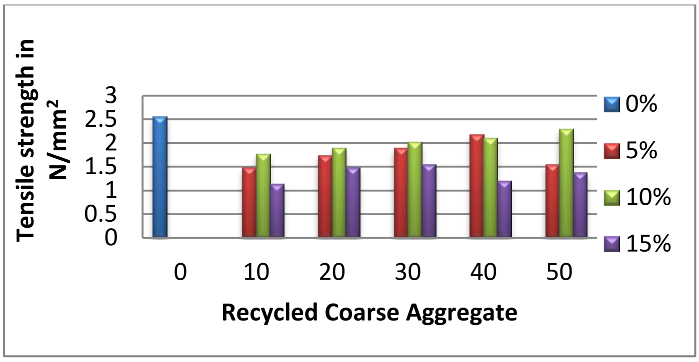

Fig 7: Tensile strength value for replacements

V. EXPERIMENTAL STUDIES(CFST)

From the above concrete strength test the mix which has optimum strength in compression is selected for composite action inside the confinement steel tubular column. The steel tubular column had thickness of 4.8mm and slenderness ratio of 4.Two specimens of circular tubular steel section are filled with conventional concrete and recycled aggregate concrete. (Table 4)

Table 4: specimen properties

Reference	PC	RAC
L(mm)	600	600
D(mm)	150	150
L/D	4	4
t(mm)	4.8	4.8
D/t	31.25	31.25
f_y(MPa)	250	250
f_{cu}(MPa)	27.9	25.82
f_{ct}(MPa)	2.56	2.29

Where, f_y= yield strength of steel
f_{cu}= compressive strength
` f_{ct}= tensile strength'

The specimens are fabricated in circular section and filled with conventional concrete and recycled aggregate concrete (recycled paper and coarse aggregate). The average yield and ultimate strength of steel are 260 and 320MPa respectively and modulus of elasticity is E_S is 2×10^5MPa. All the parameters are under practical limits as per Eurocode 4.

VI. TEST SET-UP AND PROCEDURE FOR COMPOSITE COLUMN

Each composite column was carried out under axial compression loading in a loading frame of capacity 2000 kN. The column was assembled under loading frame was centred by using plumb bob to avoid eccentric loading at the both end mild steel plate was provided as a simply supported end condition. Axial compressive load was applied. The test set-up of columns is shown in figure 9. A pre-load of about 50kN was applied to hold the specimen upright. Dial gauges were used to measure the lateral and longitudinal deformations of the columns. The load was applied in small increments of 20 kN by using hydraulic jack which is kept at the bottom of the column. At each load increment, the deformations were recorded.

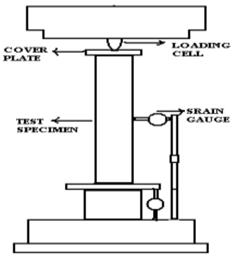

Fig 8: Line diagram Fig 9: Test set up

VII.RESULT AND DISCUSSION

Fig10 indicates of failure of CFST column with conventional concrete which shows the distribution of stress and Fig11 shows the indication of failure of CFST column with recycled aggregate concrete due to local buckling or crushing.

Fig 10: Stress Distribution Fig 11: Local buckling

COMPARISON OF LOAD CARRYING CAPACITY (YIELD LOAD)

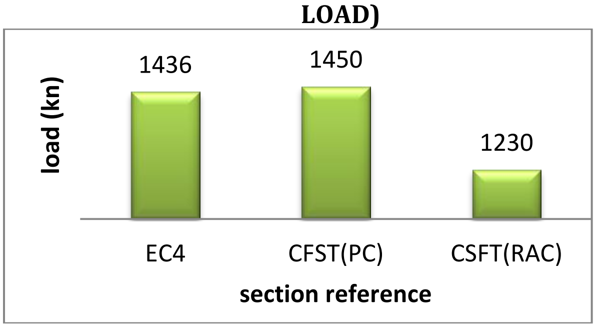

Fig 12: Comparison of load carrying capacity

Table 5: Comparison of load carrying capacity

Theoretical value (Eurocode 4)	1436KN
CFST column (PC)	1450KN
CFST column (RAC)	1230KN

- The load carrying capacity value which shown in Fig 12, shows the N_{PC}/N_{EC4} is 1.01 which is mostly equal and N_{RAC}/N_{EC4} is 0.86.
- Though the load carrying capacity of CFST (Recycled aggregate concrete) column is not much less when compare to CFST (conventional concrete) column. It can be proposed for composite action.
- Comparison of lateral and longitudinal deflection with load shown in Fig 13 & 14

COMPARISON OF LATERAL AND LONGITUDINAL DEFLECTION WITH LOAD (YIELD)

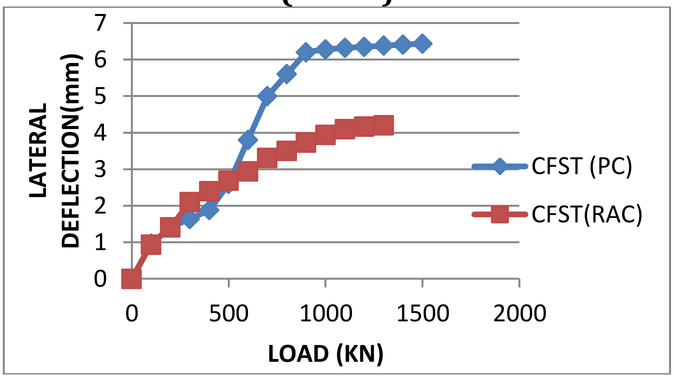

Fig 13: Lateral deflection

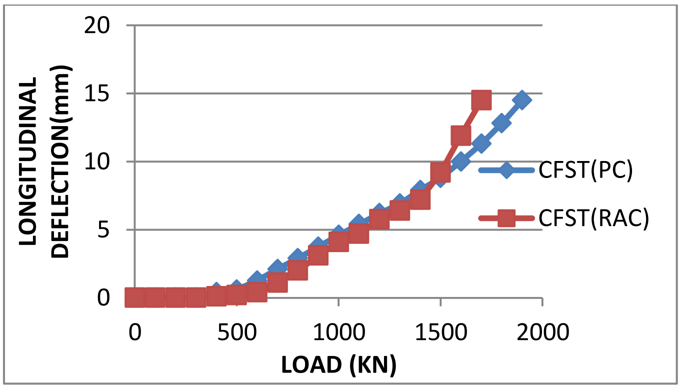

Fig 14: Longitudinal deflection

VIII.CONCLUSION

This paper study the behaviour of CFST columns with conventional and recycled aggregate concrete (made of recycled coarse aggregate and paper).from the experimental studies the following conclusion were drawn,

- The tubular section has certain advantages over other cross section, it distribute the load uniformly from the point of loading to the surface of the section. The thickness of the steel section plays an important role, the load carrying capacity increases with increasing the thickness.
- The result under loading shows that load carrying capacity of CFST (PC)is 1.18times the CFST (RAC).Though it is high over CFST(RAC),

CFST(RAC) reduces the CO_2 emission and pollution. It can be used in prefabricated industries with additional facilities and developments.

- Under lateral deflection the CFST (PC) shows higher deflection than CFST (RAC) for the same load and longitudinal deflection reach the same value for different loads.
- The failure pattern is observed on the CFST column, by local failure and crushing near the support as shown in above figures.

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