Influence of Shear Connectors In Concrete Encased Steel Rectangular Column Under Axial Compression

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Abstract- *Concrete encased steel tube (CEST) columns, which are a new type potential to be widely used in buildings. To reduce the steel rod and cost consumption, a thin-walled steel tube with longitudinal shear connectors may be adopted. This paper studies the experimental behavior and theoretical analysis of load carrying capacity of concrete encased steel tube (CEST) stub columns under axial compression. Shear connectors are used to enhance the load carrying capacity and test is conducted with specimens with and without shear connectors. Shear connectors are placed at different spacing from top and bottom at all four sides. A total of 24 specimens (12 specimens with 100% river sand, 12 specimens with 50% river sand and 50% M sand) are tested. Out of 12 specimens, 6 are with shear connectors at different spacing, 3 are without shear of composite columns, have high load carrying capacity and the connectors and 3 are with conventional (RCC). The results are compared and studied. The results concludes that specimens with partial replacement with shear connectors placed at 50mm from both ends are found to be effective and has more load carrying capacity.*

Keywords- Composite column, partial replacement, shears connectors, steel tube.

I. INTRODUCTION

A simple definition of structural system in context with building is, “A system of connected members to support the load that results from the usage of building or only presence of building to the ground”. There are several structural systems according to purpose, size, scale and loading to which the building is subjected to. Concrete and steel are pioneer materials amongst these. The choice of material depends upon numerous factors like type and purpose of building, size of building, availability of materials, and topography of land, climatology and budget. RCC and steel frames have been the most common frame systems for long times whereas composite frame system has also emerged as popular system for high rise buildings for few decades. Multi-storey composite frames are generally composed of structural steel members made composite with concrete.The use of concrete encased steel tubes in building construction has seen renaissance in recent years due to their numerous advantages, apart from its superior structural performance making a typical composite frame structure. Their usage as columns in high-rise and multi-story buildings, as beams in low-rise industrial buildings and as arch bridges, has become widespread in countries like China and many other countries in last few decades with abundant examples. But, their usage in India is a new concept.

A column is a compression member which transmits the weight of the structure above to the other structural elements below. The main types of column are concrete column and composite column (steel rod reinforced and steel tube reinforced column). A steel concrete composite column is a compression member comprising of either concrete with reinforced rods or steel tubes encased with concrete. The steel tubes maybe of different sections such as rectangular, square, circular, I, rolled steel, etc. A shear connector is a steel projection provided on the sides of steel tubes to provide necessary shear transfer between the steel and concrete to enable composite action. These are designed to provide static strength and fatigue loading.

Qihan Shen et.al(1) done axial compressive performance of circular CFST columns partially wrapped by carbon FRP to explore the axial compression property and failure mechanism of concrete filled steel tubular columns partially wrapped by carbon fibre reinforced polymer, a series of tests using carbon FRP strengthened circular CFST stubs and slender columns imposed with axial loads were conducted. Circular steel tubes and CFRP are used. In terms of stub composite columns, the ultimate axial load carrying capacity was enhanced by the increased steel stress and number of carbon FRP layers. The experimental and numerical data demonstrated that wrapping carbon-FRP strips on the steel tube in a reasonable scheme could yield a distinct strengthening effect on the load carrying capacity, compared with the carbon-FRP fully wrapped circular CFST stub column. For slender composite columns, the ultimate axial load carrying capacity primarily increased with decreasing slenderness ratio. X. Yu et.al(2) done axial compression tests on sea water and sea sand concrete-filled double-skin stainless steel circular tubes this paper presents an experimental study on sea water and sea sand concrete filled double skin stainless steel tubes under axial compression. Stainless steel tubes are used. Ultimate stress of confined concrete in a CFDST is mainly affected by its confinement factor, which is similar to fully-filled tubes. The influence of void ratio and inner tube slenderness ratio are not obvious. Zhi-Bin Wang et.al(3) studied axial compressive behavior of concrete-filled double tube stub columns with stiffeners this paper studies the behavior of concrete-filled stiffened double-tube (CFSDT) stub columns under axial compression. Circular steel tube, square steel tube and stiffeners are used. A total of 14 stub columns were tested under axial compression. The test results indicate the inner circular CFST component can be used to effectively improve the strength and ductility of thin-walled CFSDT columns. The CFSDT columns have very high strength and deformation capacity.

Fa-xing Ding et.al(4) done behavior of CFRP-confined concrete-filled circular steel tube stub columns under axial loading this paper presents an experimental and theoretical study of CFRP-confined columns, which aims at investigating the effects of different numbers of CFRP layers and concrete strengths on the mechanical performance of CFRP-confined CFT stub columns. Circular steel tubes are used. The experimental results showed that the ultimate capacity increases linearly with the increase in the number of CFRP layers in the specimens. Fei-Yu Liao et.al(5) done Experimental investigation on sea sand concrete-filled stainless steel tubular stub columns this paper studies the behavior of sea sand concrete-filled stainless steel tube (CFST) stub columns under axial compression through experimental investigations. A total of 48 specimens including circular and square stainless steel tubes filled with three types of core concrete such as natural river sand concrete, desalted sea sand concrete and natural sea sand concrete are used. Sea sand CFST specimens showed excellent ductility during the axial compression tests. The strength and strain development results indicated that the confinement effects of stainless steel tube on sea sand concrete were as reliable as those on conventional river sand concrete.

M.F. Hassanein et.al(6) studied behavior and design of hexagonal concrete-filled steel tubular short columns under axial compression an experimental and analytical study is carried out on the behavior of hexagonal concrete filled steel tubular short columns under axial compression and it is designed using FEA modeling. Circular, rectangular, elliptical and polygonal steel tubes are used. The results indicate that slender cross section CFST columns benefit more from the composite action. This is because the buckling capacity of the steel tube decreases significantly when making the steel cross section more slender. Huan-Peng Hong et.al(7) done axial capacity of steel tube-reinforced concrete stub column this study aims to investigate the axial capacity of the ST-RC stub column by means of modified superposition method. Circular steel tube and reinforcement rods are used. By comparing the results predicted by the current method with a large number of specimens from different sources, it was found that the predicted results filled strongly with the test results. Weiqiang Wang et.al(8) studied behavior of concrete-encased concrete-filled FRP tube (CCFT) columns under axial compression a composite column named concrete-encased concrete filled fibre reinforced polymer tube (CCFT) column has been proposed in this study. An analytical model has been developed to predict the axial compressive behavior of CCFT columns. 16 concrete stub columns which are divided into 8 groups (one group of plain concrete columns, two groups of FRP confined concrete columns, and five groups of CCFT columns) are used. The conclusions in this paper are based on the experimental investigations of 16 concrete stub columns. Therefore, more experiments need to be conducted to fully validate the observed behavior of CCFT columns.

Biao Yan et.al(9) done behavior of circular tubed steel-reinforced-concrete slender columns under eccentric loading, the structural behavior of circular tubed steel-reinforced-concrete columns subjected to eccentric compression is experimentally and analytically studied. The specimens were tested to investigate the effects of load eccentricity, diameter to thickness ratio of steel tube and use of shear connectors on steel sections. Circular steel tubes, I sectional reinforcement tube and shear connectors are used. The ultimate strength and flexural stiffness of the specimens decrease with increase of load eccentricity, while the change of ductility is generally opposite. The tube confinement decreases with the increasing slenderness of the columns. Yu-Feng An et.al(10) in 2015 Performance of concrete-encased CFST box stub columns under axial compression a finite element analysis model is developed to predict the full range of concrete-encased CFST box stub columns under axial compression. Steel tubes of various sections and reinforcement rods are used. Generally good agreement is obtained between the predicted and measured results. When column reaches its ultimate load, the outer RC component has reached its ultimate load, and the inner CFST component is approaching its ultimate strength.

Kuranovas.A et.al(11) done experimental and analytical investigation on behavior of concrete filled steel tube (CFST) columns the structural behavior of concrete filled steel tube (CFST) columns has been investigated. The effect of concrete compressive strength, thickness of steel tubes, stiffeners and longitudinal reinforcement were considered. 16 square samples with dimensions of 150x150x300mm and 15 circular samples of 150mm diameter and 300mm height are used. CFST columns show higher ductility after maximum load, especially for reinforced and stiffened columns. The ultimate load carrying capacity for two cross stiffened columns is more than for one cross stiffened CFST columns and more than for unstiffened columns. Lin-Hai Han et.al[12] done performance of concrete-encased CFST stub columns under axial compression the behavior of concrete encased concrete filled steel tube stub columns under axial compression is studied. A finite element analysis modeling is developed to analyze the behavior of the composite columns. Circular and square steel tube sections and reinforcement rods are used. Ultimate strength increases as outer concrete strength, core concrete strength, longitudinal bar ratio, steel ratio of CFST and D/B increase, but decreases as stirrup space increases. Nameer A.Alwash et.al[13] studied experimental Investigation on Behavior of SCC filled Steel Tubular Columns Strengthened with CFRP In this paper, experimental studies have been devoted to investigating the behavior of self compacting concrete filled steel tube (CFST) stub columns strengthened by carbon fibre reinforced polymer (CFRP). 28 stub columns (14 specimens with circular cross section 100x300mm and 14 specimens with square cross section 100x100x300mm) are used. Each 14 specimens can be classified into three categories as hollow steel tube columns, 3 plain SCC columns and 8 SCC filled steel tube columns. The main conclusion is that longitudinal CFRP is more effective than transverse CFRP in square hollow as filled column and vice versa in circular. Ductility is more in circular than in square. CFRP composites are more effective in enhancing load-carrying capacity of circular plain concrete stub columns and circular filled steel stub columns than in square ones.

Aparna.V et.al[14] conducted experimental Investigation on Steel Concrete Composite Column for Varying Parameters In this study, experimental investigation on steel tubes filled with different types of concrete are presented. Steel tubes filled with fibre reinforced concrete using lathe waste and steel tube wire concerned confined with steel mesh were investigated. Axial compression test to examine the resisting capacity of the columns and push out test for noting the bond strength were performed. Coupon test were also conducted to determine the mechanical properties of steel. 4 concrete filled steel tube combinations were made with tubes of diameter 100mm with wall thickness 1.6mm and a height of 300mm. Cement, aggregate, steel sheets (1.6mm thickness), lathe waste of length 25mm and diameter 0.3mm are used. It was observed that steel tube filled fibre reinforced columns possessed better bond strength and resistance to axial load. Santhosh kumar.D et.al[15] done experimental Investigation of Composite Steel-Concrete Column in this paper describes an investigation on the ultimate strength behavior on cold formed channel and hot rolled steel I section subjected to axial compression. 4nos of cold formed channel sections (40x20mm and dia 80mm), 4nos of hot rolled I sections (ISMB 125x75mm), both of height 600mm are used. Laboratory experiments gave the ultimate load capacity of the column. This investigation has shown the further research is needed with more number of specimens and more variation with stud and size of column will give better result to choose the better section.

To study the influence of shear connectors in concrete steel encased rectangular column under axial compression. To determine and compare the load carrying capacity of concrete steel encased rectangular columns and conventional reinforced concrete columns.

II. MATERIAL AND ITS PROPERTIES

A. Cement

The cement used for this study is Ordinary Portland Cement (OPC) of 53 grade conforming to IS code 12269. The properties of cement are tabulated in Table 1.

Table 1: Properties of cement

S.NO	DESCRIPTION	RESULT
1	Specific gravity	3.14
2	Fineness	4.67%
3	Standard consistency	32%
4	Initial setting time	30 minutes
5	Soundness	soundness

B. Fine Aggregate

The sand used for the experimental works was locally procured sand conformed to grading zone III. Sieve Analysis of the Fine Aggregate was carried out in the laboratory as per IS 383-1970. The properties of fine aggregate are tabulated in Table 2.

Table 2: Properties of Fine Aggregate

S.NO	DESCRIPTION	RESULT
1	Fineness modulus	3.196%
2	Specific gravity	2.32

C. M-Sand

M sand is a by-product of the crushing process which is a concentrated material to use as aggregates for concreting purpose especially as fine aggregates. In quarrying activities, the rock has been crushed into various sizes; during the process the dust generated is called quarry dust and it is formed as waste. The properties of M Sand are tabulated in Table 3.

Table 3: Properties of M Sand

S.NO	DESCRIPTION	RESULT
1	Fineness modulus	3.674%
2	Specific gravity	2.75

D. Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20 mm was used in the present work. Sieve. According to IS 383:1970, maximum 20mm coarse aggregate is suitable for concrete work. But where there is no restriction 40mm or large size may be permitted. In case of close reinforcement 10mm size also used. The properties of Coarse Aggregate are tabulated in Table 4.

Table 4: Properties of Coarse Aggregate

S.NO	DESCRIPTION	RESULT
1	Specific gravity	2.77
2	Fineness modulus	4.82%
3	Water absorption	0.41%
4	Aggregate impact value	39%

E. Slump cone test

Calculation of material used for slump cone test, for M20 grade concrete, the mix ratio is 1 : 1.5 : 3. By volume batching the mix ratio is 0.3 : 0.45 : 0.9 (m³). The Weight is tabulated in Table 5.

Table 5: Weight of materials

Materials	Volume (m^3)	Density (kg/m^3)	Weight (kg)
Cement	0.3	1440	432
Sand	0.45	1576	709.2
Aggregate	0.9	1487	1338.3

Volume of slump cone,

$$V = \frac{h\pi}{3}[R^2 + r^2 + Rr]$$

$= 5497.787\ cm^3$

$= 5.49 \times 10^{-3}\ m^3$

Therefore quantity of materials needed,

Cement = 2.37 kg.
Sand = 3.9 kg.
Aggregate = 7.36 kg.

Table 6: Water cement ratio

Cement content (kg)	Water-cement ratio	Quantity of water added (ml)	Slump (mm)
432	0.50	8.64	39
432	0.52	8.64	46
432	0.54	8.64	57
432	0.55	8.64	60

F. Mix design

For 60mm slump, by weigh batching the mix ratio is **394: 735: 1150 (kg)**

Table 7: Mix proportion

No. of specimens	Cement (kg)	River sand (kg)	M sand (kg)	Coarse aggregate (kg)	Water content (litres)
24	19.86	18.55	18.50	56.95	9.928

III. THEORITICAL ANALYSIS

A. Design equation

Load is acting at the centroid of the column is called as axially loaded column. As per Clause 39.3, IS456 – 2000, when the minimum eccentricity as per the previous equation does not exceed 0.05 times the lateral dimension, the member shall be designed as an axially loaded column.

Ultimate load carrying of a short axially loaded column,

$$P_{th} = 0.4\, f_{ck}\, A_c + 0.67\, f_y\, A_{sc}$$

Where,

P_{th} = theoritical axial load on the member
f_{ck} = characteristics compressive strength of the concrete
f_y = characteristics strength of the compression reinforcement
A_c = Area of concrete
A_{sc} = Area of longitudinal reinforcement for columns
For without shear connectors
Area of steel (A_{sc}) = 2 (L+W) t

Where,

L and W is cross sectional dimension of steel tube
t is thickness of steel tube

Area of steel (A_{sc}) = 2 (L+W) t
= 2 (60 + 40) 2

$= 400mm^2$

Area of concrete (A_c) = $A_g - A_{sc}$
= (100 x 80) – 400
= 8000 – 400
= 7600mm2

Ultimate load carrying of a short axially loaded column,

$P_{th} = 0.4\ f_{ck}\ Ac + 0.67\ f_y\ A_{sc}$

= (0.4 x 20 x 7600) + (0.67 x 240 x 400)

P_{th} = 125.12 Kn

For with shear connectors

Shear connector area (rivet) = (11.78 x 2.20) + (13.30 x 5.54)
= 99.59 mm2 (for 1 shear connector)

Cross sectional area of shear connector = 99.59 x 4
= 398.39 mm^2

Area of steel (A_{sc}) = 2 (L+W) t + cross sectional area of shear connector
= 400 + 398.39
(A_{sc}) = 798.39 mm2

Area of concrete (A_c) = $A_g - A_{sc}$
= (100 x 80) – 798.39
= 7210.61 mm2

Ultimate load carrying of a short axially loaded column,
$P_{th} = 0.4\ f_{ck}\ A_c + 0.67\ f_y\ A_{sc}$
= (0.4 x 20 x 7210.61) + (0.67 x 240 x 798.39)
P_{th} = 186.06 kN

For conventional reinforcement
No of bars required

$$n = \frac{2\,(L+W)\,t}{\frac{\pi}{4}(d)^2}$$

$$= \frac{2\,(60+40)\,2}{\frac{\pi}{4}(8)^2}$$

= 8 bars for one specimen
No of bars required for 3 specimens
= 24 bars
Total no of ties required = 9 (3 for each specimen)

Area of steel (A_{sc}) = $\frac{\pi}{4}$ x (d)2 x no of bars
= $\frac{\pi}{4}$ x (8)2 x 8
= 402.12 mm2

Area of concrete (A_c) = $A_g - A_{sc}$
= (100 x 80) – 402.12
= 7597.88 mm2

Ultimate load carrying of a short axially loaded column,
$P_{th} = 0.4\ f_{ck}\ A_c + 0.67\ f_y\ A_{sc}$
= (0.4 x 20 x 7597.88) + (0.67 x 240 x 402.12)
P_{th} = 125.44 kN

Table 8: Theoritical results

S. No	Specimen		Ultimate load, P_{th} (kN)	Compressive strength (P/A) (N/mm^2)
1	With shear connectors	Type-1 (100mm)	186.06	23.25
		Type-2 (50mm)		
2	Without shear connectors		125.12	15.64
3	Conventional column		125.44	15.68

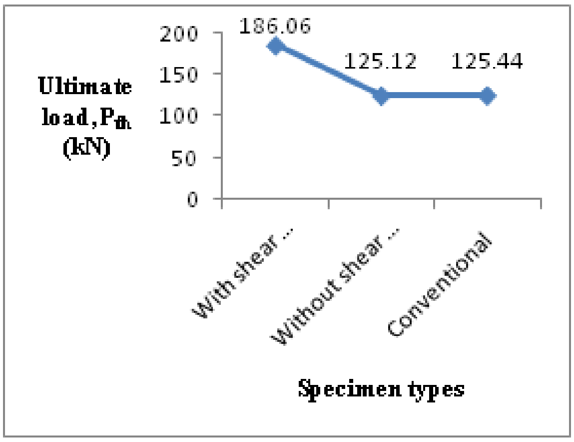

Figure 1: Theoritical result graph

From the above graph, it is found that composite column with shear connectors carry a more load than compared to both conventional column and composite column without shear connectors as shown in fig 1.

IV. EXPERIMENTAL INVESTIGATION

This study deals with experimental study on axial load in composite rectangular column without shear connectors and with shear connectors with two different spacing and also in conventional column. Comparison between the concrete reinforced column and concrete encased column is experimentally studied with and without partially replacement of M-sand.

A. Cutting of mild steel tube

Steel specimen of total length 19ft is cut into 20 specimens for every 30cm by using cutting wheel as shown in fig 2 and fig 3.

Figure 2: Cutting

Figure 3: Specimen after cutting

B. Filing of mild steel tube

The specimens are held in bench vice and the sharp edges are removed using filing tool as shown in fig 4. This process is called Filing.

Figure 4: Filing

Figure 5: Welding

C. Welding of specimen

The specimens are arc welded with shear connectors at different spacing on all four sides using 12 gauge welding rod as shown fig 5.

D. Red oxide coating

The specimens are coated with red oxide to prevent corrosion or exposure to atmospheric reactions as shown in fig 6.The specimens are kept undisturbed for 24 hours for the purpose of drying as shown in fig 7.

Figure 6: Red oxide coating

Figure 7: Drying

E. Batching and mixing

Batching is the process of measuring concrete mix ingredients such as cement, fine aggregates, coarse aggregate and water either by volume or by mass as shown in fig.8 Batched materials are thoroughly mixed in required proportions until the paste shows uniform color and consistency as shown in fig 9.

Figure 8: Batching

Figure 9: Mixing

F. Bar bending

Bar Bending is a process of bending reinforcing steel into rectangular shapes as per the requirement of the particular reinforced concrete work. In this 3 no's of 6mm dia bars is bended by using bar bending tool of required size as shown in fig 10 and 11.

Figure 10: 6mm ties

Figure 11: 8mm bars

G. Reinforcement details

The number of main bars and lateral ties are calculated as per the theoretical calculation in above chapter 4.The rod of 6mm dia is used as a lateral ties in reinforced column and 8 no's of 8mm dia rod is used as a main bar. Binding wire is used for binding the lateral ties and main reinforced bars at required spacing as shown in fig 12. This process is called reinforced binding.

Figure 12: Reinforcement details

H. Casting and compacting

Casting is a manufacturing process in which a mixed concrete paste is injected or poured into mould of dimensions 100*80*300 mm and cube size of 150*150*150 mm in layer by layer and compacted each layer with no of strokes with the tamping rod to avoid formation of honeycomb. Finish the top surface by trowel after compaction of last layer. Total 24 specimens of column is casted are classified into three category, 9 specimens of column with river sand (out of 9 specimens, 3 with shear connectors at 100 mm spacing i.e., type 1, 3 with shear connectors at 50 mm spacing i.e., type 2 and 3 with without shear connectors i.e., type 3), 9 specimens of column with partial replacement of M sand (3 with shear connectors at 100 mm spacing, 3 with shear connectors at 50 mm spacing and 3 with without shear connectors) and 6 specimen is conventional column (3 with river sand and another 3 with partial replacement of M sand). Each casted mould is kept undisturbed, after 24 hours specimen is removed from the mould. While removing the specimens from the mould take care to avoid breaking the edges. Code the cube with paint or marker

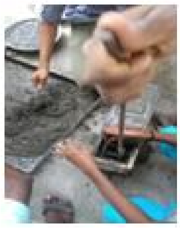

Figure 13: Compacting

Figure 14: Mould with concrete

I. Curing

Curing is process of submerging the casted specimen in clean water until the time of testing to gain the characteristic compressive strength at 28 days and to maintain the moisture content in the concrete. 18 specimens of rectangular column and 6 cube specimens are kept inside bag in water for 28 days as shown in fig 15.

Figure 15: Curing

Figure 16: Testing in CTM

J. Testing

After 28 days of curing, specimens is taken out from the curing tank and kept out for few hours for drying. Axial compression strength test were conducted on composite stub columns and cubes. Compressive strength is ability of material or structure to carry the loads on its surface without any crack or deflection. The material under compression tends to reduce the size. The specimen is kept in the compression testing machine in such a manner that the load is applied in vertical direction as shown in fig 16. The specimen is centrally aligned on the base plate of machine and movable portion is rotated gently by hand so that it touches the top surface of the specimen then load is applied gradually applied without shock and continuously till the specimen fails. The ultimate load at which specimen failed is noted.

V. RESULT AND DISCUSSION

The various specimens were tested in compression testing machine by providing axial load and the following results were obtained. The ultimate loads of cubes with river sand and partial replacement are discussed below.

Table 9: Ultimate loads of cubes with river sand

Specimens	Ultimate load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
1	324	14.40	15.54ss
2	373	16.57	
3	352	15.64	

Table 10: Ultimate loads of cubes with partial replacement of river sand with M sand

Specimens	Ultimate load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
1	506	22.48	20.01
2	434	19.21	
3	403	18.35	

From the tables 9 and 10, it is found that the cubes with partial replacement have the compressive strength of 20.01 N/mm^2. Compressive strength range is 20-26 N/mm^2. Hence partial replacement has the correct value.

The ultimate loads of rectangular specimens with river sand and partial replacement are discussed below.

Table 11: Ultimate loads of rectangular specimens

Specimen Name	Specimen size (mm)	Size of steel tube (mm)	Thickness of steel tube (mm)	L/d ratio	Ultimate load	
					P_{th} (kN)	P_{ex} (kN)
CCR.1	100 x 80	60 x 40	2.1	3.75	125.44	133
CCR.2						134
CCR.3						137
CCP.1						152
CCP.2						155
CCP.3						165
CER.1.1	100 x 80	60 x 40	2.1	3.75	186.06	134
CER.1.2						155
CER.1.3						167
CEP.1.1						260
CEP.1.2						207
CEP.1.3						235
CER.2.1	100 x 80	60 x 40	2.1	3.75	186.06	193
CER.2.2						228
CER.2.3						203
CEP.2.1						221
CEP.2.2						268
CEP.2.3						279
CER.3.1	100 x 80	60 x 40	2.1	3.75	125.12	156
CER.3.2						136
CER.3.3						154
CEP.3.1						209
CEP.3.2						194
CEP.3.3						210

*P_{th} – Theoretical ultimate load , *P_{ex} – Experimental ultimate load

Here, in the name CCR.1, CC refers to conventional column, R refers to river sand and the decimal refers to the specimen number. This is the same for other two specimens. In the name CCP.1, CC refers to conventional column, P refers to partial replacement of river sand with M sand and 1 refers to the specimen number. This is the same for other two specimens. In the name CER.1.1, CE refers to concrete encased, R refers to river sand, the first decimal refers to the type of shear connector placement and the second decimal refers to the specimen number. This is the same for other 8 specimens. In the name CEP.1.1, CE refers to concrete encased, P refers to partial replacement of river sand with M sand, the first decimal refers to the type of shear connector placement and the second decimal refers to the specimen number. This is the same for other 8 specimens.

Table 12: Average Ultimate loads

Specimen	River sand		Partial replacement	
	P_{u} (kN)	Average P_{u} (kN)	P_{u} (kN)	Average P_{u} (kN)
CC.1	133	134	152	137
CC.2	134		155	
CC.3	137		165	
CE.1.1	134	152	260	235
CE.1.2	155		207	
CE.1.3	167		235	
CE.2.1	193	208	221	256
CE.2.2	228		268	
CE.2.3	203		279	
CE.3.1	156	148	209	204
CE.3.2	136		194	
CE.3.3	154		210	

The results from the tables are shown in the chart below.

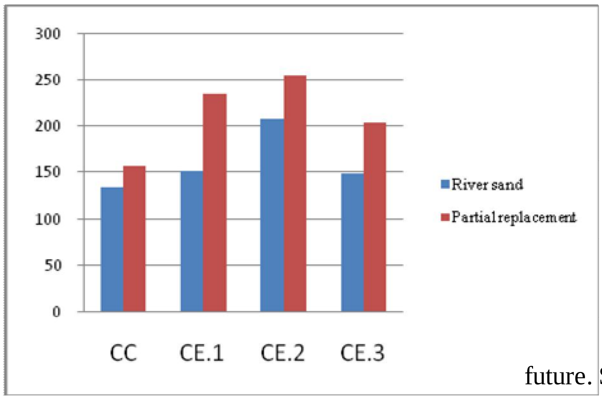

Figure 17: Comparison between ultimate loads of specimens in river sand and partial replacement

From the chart, the specimens with partial replacement have high load carrying capacity compared to specimens with river sand.

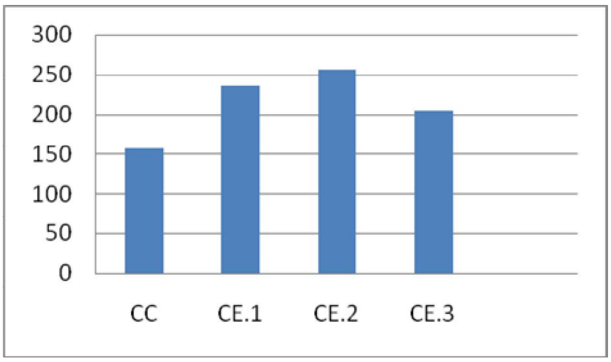

Figure 18: Comparison between ultimate loads of specimens in partial replacement

From the chart, the third specimen, i.e., specimens with shear connectors at 50mm from both ends has high load carrying capacity than the other specimens.

VI. CONCLUSION

A total of 24 specimens (9 with river sand, 9 with partial replacement of river sand with quarry dust and 6 with conventional) were tested under axial loads and following conclusions were drawn.

- In general, the specimens with steel tubes have more load carrying capacity than the specimens with conventional rods. This concludes that steel tube is much efficient than the conventional rods.
- In case of steel tubes, the load carrying capacity of specimens with partial replacement is higher than the specimens with river sand.
- In partial replacement, out of three types, the type 2 i.e., specimens with shear connectors at 50mm from both ends found to have high load carrying capacity than the other two types.
- Thus the specimens with partial replacement with shear connectors at 50mm from both ends is found to be effective than the other types.

VII. SCOPE FOR FUTURE STUDIES

The composite structures have many applications in future. Some of them are discussed below

- Preparation of miniature specimens for testing may be thought of to avoid costly experimentation generally carried out on full size models to know the exact behavior of steel-concrete composite structural elements. A numerical analysis of the same will also be highly desirable to correlate the data and result.
- The wind analysis of multi-storied composite structure can be carried out and charts can be prepared for various wind pressure.
- The earthquake response of steel and composite building structures is a subject of much interest; therefore there is much scope for research on the use of composite structures in seismic areas.
- In future, studies can be carried out with biaxial loading also.
- Composite structures are used in bridges. In future it can be implemented in residential structures also.

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