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Behaviour of Steel Concrete Composite Columns under Lateral Load

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Abstract- *Nowadays, Composite sections of the steel and concrete have been utilized and considered around the world, yet filled tubular columns require more consideration. Broad examination work has been done in Japan in the most recent 15 years on this. This present attempt shows a trial study on the performance of Concrete Filled steel Tubular columns (CFT).The present research work depicts about signifying the utilization of Concrete Filled steel Tubular columns (CFT) instead of Reinforced Columns & to determine the conduct of composite columns. For this purpose sixteen numbers of columns with various cross area and different thickness of steel tube (8 short columns and 8 long columns) is subjected to external axial prestress and lateral loads. The circular and square composite columns are casted with different L/D apportion and wall thickness. The concrete used is M20.It is observed that Circular composite columns has less deflection and high load bearing capacity with deferred buckling while compared to the square composite columns.*

Keywords:- *Concrete Filled steel Tubular columns,Eurocode-4,Lateral buckling, External Prestress.*

I. Introduction

A steel-concrete composite segment is a compression member, involving either a concrete encased hot-rolled steel segment or a concrete filled tubular segment of hot-rolled steel and is for the most part utilized as a load bearing member in a structural composite frames. Typical cross-sections of composite columns with completely and halfway concrete encased steel segments are delineated in Fig. 1 indicates three typical cross-segments of concrete filled tubular segments. Note that there is no necessity to give extra reinforcing steel for composite concrete filled tubular areas, with the exception of prerequisites of fire resistance where appropriate. In a composite column both the steel and concrete would oppose the outside stacking by communicating together by bond and friction. Supplementary support in the concrete encasement averts extreme spalling of concrete both under ordinary load and fire conditions. In composite development, the exposed steel sections bolster the underlying construction loads, including the heaviness of structure amid development. Concrete is later thrown around the steel segment, or filled inside the tubular areas. The concrete and steel are joined in such a fashion, to the point that the benefits of both the materials are used viably in composite column. The lighter weight and higher quality of steel allow the utilization of smaller and lighter foundations. The ensuing concrete expansion empowers the building casing as far as possible the sway and horizontal deflections.

II. Theoretical Design by EUROCODE-4

EUROCODE-4 is the most recently completed international standard in composite construction. EUROCODE-4 covers concrete - encased and partially encased steel sections and concrete-filled sections with or without reinforcement. EUROCODE-4 considers confinement effects for circular sections when relative slenderness has value less than 0.5. EUROCODE-4 uses limit state concepts to achieve the aims of serviceability and safety by applying partial safety factors to load and material properties. It is the only code that treats the effects of long-term loading separately. The ultimate axial force of a circular column is,

$$PP = Aa * \eta 2\ \text{þ}a + Ac \left(* \ \text{þ}Ck * \quad 1 + \eta 1 * \{ t / d \} * \{ fy / fck \} \right)$$

Where,

$\eta 1 = \eta 10\ [\ 1 – \{10e / d\}.$

$\eta 2 = \eta 20 + \{ 1 - \eta 20 \} * \{10e / d\}.$

$\text{þ}a = \{ fy / \Upsilon a \}.$

$\text{þ}Ck = \{ fck / \Upsilon c \}.$

PP – plastic resistance of columns.

Aa & Ac - Area of the steel and concrete (mm^2).

t – thickness of steel (mm).

d – outer diameter of the columns (mm).

fy & fck – yield strength of steel and concrete (N/mm^2).

ϒa & ϒc - partial safety factor for steel and concrete.

$$Pcr = \pi^2 * \{ (EI)e / l^2 \}$$

Where,

(EI)e = Ea Ia + 0.8 EcdIc.

Ecd = { Ecm / ϒc }

$$Ecm = 5000\ (fck)^{1/2}$$

(EI)e - Effective elastic flexural stiffness of the composite columns.

Ia & Ic – second moments of area of steel and concrete(mm^4).

Ea & Ec - modules of elasticity of steel and concrete.

ϒc - partial safety factor concrete is reduced to 1.35 as per EUROCODE – 4.

Non – Dimensional Slenderness

$$\lambda = (PP/PCR)^{(1/2)}$$

Reduction Factor

$$Xx = 1/ \{ \Phi x + (\Phi x^2 - ʎ^2)^{(1/2)} \}$$

Where , $\Phi x = 0.5 [1 + ^{\mu} (ʎ - 0.2) + ʎ]$

The values calculated for circular columns by this method are listed in table . Although the values are a bit conservative, even they are to some extent accurate for both circular columns. The incorporation of confinement effect adds up to the estimation of ultimate capacity of circular columns.

III. Design for square columns:

Load carrying capacity of square columns with reinforcement.

P=Aa*fy/ϒa +αc * Ac *fck / ϒc+ Asfck/ ϒs.

Where,

P - ultimate axial force of columns.

Aa ,Ac &As **-** Area of the steel , concrete & reinforcement. **fy & fck –** yield strength of steel and concrete.

ϒa & ϒc - partial safety factor for steel and concrete.

Design for 110 diameter with 2mm thickness column

Step -1 datas:

Inner diameter = 110mm Outer diameter = 112mm

Height of the columns = 2000mm fck = 20 $N/mm^{2,}$ fy = 250 Assumed date:

λ = 0.3, e = 0

Step -2 Calculation of ultimate axial force of a circular column :

As per code for λ = 0.3 $^{\eta}10$ = 0.88, $^{\eta}20$ = 0.99 Aa = $(\pi/4)(D^2-d^2)$

$= 348.7mm^2$

$A_c = (\pi/4)(d^2)$

$= (\pi/4)(110^2)$

$= 9503.3\ mm^2$

$^{\eta}1 = {}^{\eta}10$ [1 – {10e /d} = 0.88 [1 – {10*0 /62}] = 0.88

$^{\eta}2 = {}^{\eta}20$ + { 1 - $^{\eta}20$ } * {10e / d} = 0.90 + { 1 – 0.90} * {10* 0 /62} = 0.99

PP = Aa* $^{\eta}2$ þa + Ac * þCk * 1 + $^{\eta}1$* { t / d } * { fy / fck }

PP =348.7* (0.9 * (250/1.15)) + (9503.3 * (20/1.5) *

[1 + 0.88 * { 2 /112 } * {250/20 }]

= 219824.08N

Step – 3 Calculation of critical load:

$$Pcr = \pi^2 * \{ (EI)e / l^2 \}$$

(EI)e = Ea Ia + 0.8 EcdIc.

Ecd = { Ecm / ϒc } = [5000(20) $^{(1/2)}$] / (1.35) =16563.4

Ia = $(\pi/64)*(D^4-d^4)$

= $(\pi/64)*(112^4-110^4)$

= 537111 mm^4

Ic = $(\pi/64)*(d^4)$

= $(\pi/64)*(110^4$

= $7.1 * 10^6$ mm^4

(EI)e = Ea Ia + 0.8 EcdIc.

= $(2*10^5)*(537111) +0.8*(1.65*10^4)*(7.1 * 10^6)$.

= $2.01*10^{11}$ N mm^2

Pcr = π^2 *{ (EI)e / l^2 }

Pcr = π^2 *{$2.01*10^{10}$ / 2000^2 }

Pcr = 4.9 * 10^4 N

Table 1: Ultimate Axial Load carrying capacity of composite columns
(with reinforcement)

SECTION	THICKNESS(mm)	AXIAL LOAD (N)	
		EUROCODE-4	TEST VALUE
SQUARE	2	$2.0*10^4$	$2.20*10^4$
	4	$2.6*10^4$	$2.9*10^4$
CIRCULAR	2	$1.2*10^4$	$1.33*10^4$
	4	$4.8*10^4$	$4.96*10^4$

Table 2: Ultimate Axial Load carrying capacity of composite columns
(without reinforcement)

SECTION	THICKNESS(mm)	AXIAL LOAD (N)	
		EUROCODE-4	TEST VALUE
SQUARE	2	$2.03*10^5$	$2.23*10^5$
	4	$3.4*10^5$	$3.7*10^5$
CIRCULAR	2	3.01*105	$3.40*10^5$
	4	$5.6*10^5$	$5.8*10^5$

Table 3: Shows the Section Details of Various Types Of Columns

SECTION	THICKNESS (mm)	LENGTH OF COLUMNS	
		FOR COMPRESSIVE TEST(mm)	FOR LATERAL LOAD TEST(mm)
SQUARE	2	650	1850
	4	650	1850
CIRCULAR	2	650	1850
	4	650	1850
	No. of specimens	**8**	**8**
	Total	**16**	

IV. Calibration of 12mm Rod by 10kN Proving Ring

Certified that proving ring No.PR.10kn.0795.fitted with dial gauge least count 0.002mm calibrated by compression and it is mentioned in Fig.1

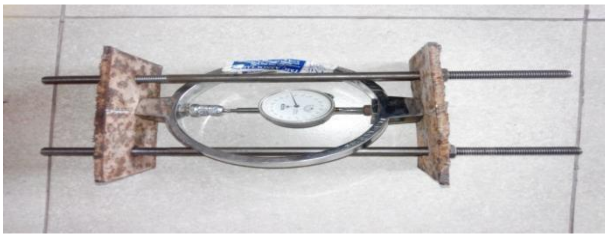

Fig.1 Arrangement of Proving Ring With Calibration Rod

Table 4: Calibrated Value of 12mm Rod

Turns	Trail-1	Trial-2	Average	Load By Turns
Half turns	24	21	22.5	(22.5*5)* 0.01=1.12 kN
Full turns	42	41	41.5	(41.5*5)* 0.01= 2.07kN

V. Experimental Setup For Lateral Load By Universal Testing Machine (UTM)

Fig 2 shows the experimental setup of lateral load in UTM. The length of columns is 1850mm and with thickness of 2 & 4 mm. The shape of the columns are circular and square. And the size of the columns were shown in table 6.1. the specimens setup is placed in UTM, which is 100ton capacity. In the specimens axial load of 34kN has been applied for the column behaviour. Dial gauge is placed in the midpoint of columns to find deflection of columns , which is least count 0.001mm.

Fig.2 Position of Columns For Lateral Load with Axial Load of 34kN

TABLE 5: Load and Deflection of Columns

Load (kN)	Deflection in mm							
	C2	C4P	C2RP	C4RP	S2	S4P	S2RP	S4RP
0	0	0	0	0	0	0	0	0
5	0	0	0	0	0.36	0.006	0.12	0.02
10	0.07	0	0	0.08	1.26	0.14	0.2	0.08
15	0.26	0.1	0.07	0.12	2.14	0.24	0.34	0.16
20	0.61	0.5	0.14	0.14	2.85	0.38	0.38	0.24
25	1.64	0.7	0.22	0.17	4.5	0.67	0.47	0.29
30	2.14	0.94	0.31	0.2	5.6	0.82	0.51	0.6
35	2.92	1.02	0.41	0.26	6.8	1.04	0.74	0.73
40	3.4	1.18	0.61	0.32	9.1	2.8	0.86	0.96
45	3.88	1.24	0.78	0.4		3.4	0.92	1.23
50	5.1	2.41	0.91	0.46		6.2	1.46	1.8
55	6.7	3.1	1.02	0.57		7.1	2.35	2.2
60	8.4	5.1	1.14	0.64		7.8	2.94	2.8
65			1.22	0.69				3.65
70			1.41	0.72				4.1
75			1.78	0.76				4.8

80			1.9	0.88				5.98
85				0.92				7.6
90				0.97				8.84
95				1.04				
100				1.09				
105				1.2				

TABLE 6: Lateral Load with External Axial Load Test Value

Columns	Load (kN)
C2	69.01
C4P	70.4
C2RP	86.45
C4RP	112.6
S2	45.01
S4P	70.50
S2RP	60.1
S4RP	105.01

Where,

C2 - circular columns with steel wall thickness of 2mm

circular columns with steel wall thickness of 4mm with external prestress.

C2RP - circular columns with steel wall thickness of 2mm with external prestress and reinforcement.

C4RP - circular columns with steel wall thickness of 4mm with external prestress and reinforcement.

S2- square columns with steel wall thickness of 2mm.

S4P – square columns with steel wall thickness of 4mm with external prestress.

S2RP – square columns with steel wall thickness of 2mm with external prestress and reinforcement.

S4RP – square columns with steel wall thickness of 4mm with external prestress and reinforcement.

Fig.3 Ending of Columns while Ultimate Load on Columns

Fig.4 Failure of Columns

Fig.5 Tested Column

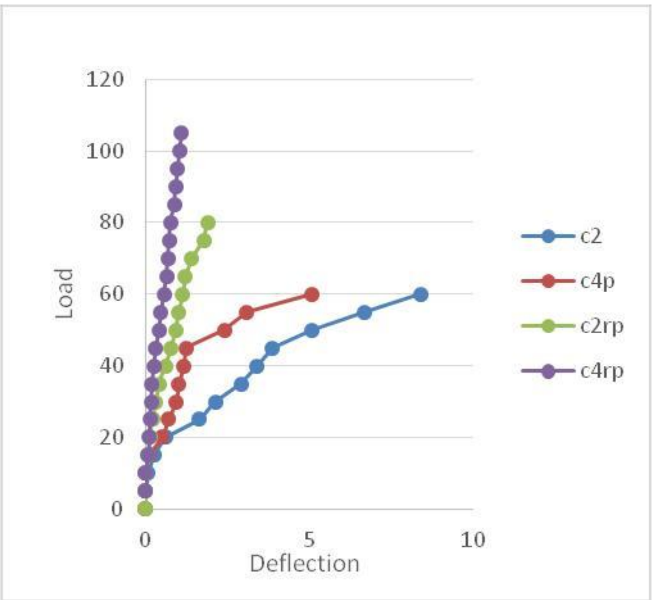

Fig.6 Deflection Vs Load of Circular Composite Columns

In the Fig.6 its clearly states that C4RP circular columns with steel wall thickness of 4mm with external prestress and reinforcement has more load bearing capacity (112.6kN) with minimum deflection of 1.2mm. The load bearing capacity is high and the lateral buckling is deferred in circular columns, since the circular columns are uniform throughout its circumference, so there is an impediment in lateral bulking.

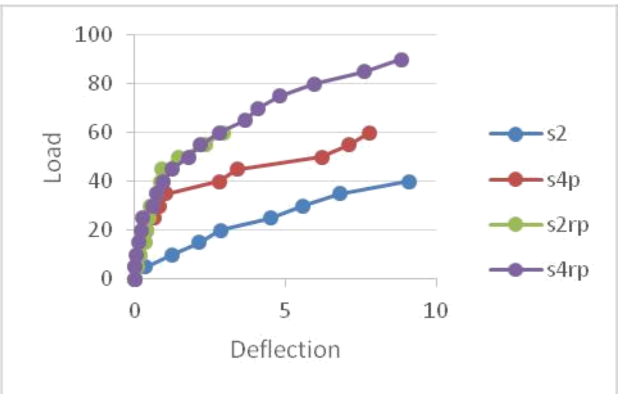

Fig.7 Deflection Vs Load of Square Composite Columns

In the Fig.7 its clearly states that deflection in S2,S4P,S2RP,S4RP is almost same and it is in the range of 5-8 mm, which shows that square column has less lateral buckling capacity compared to circular columns.

VI. CONCLUSION

Deflection is higher in square composite columns compare to circular composite columns. Max load carrying capacity occurred in C4RP columns and minimum deflection also occurred in the same columns of 1.2mm.

Lateral load carrying capacity of square columns is less than circular columns of 7.22%.

In square columns only local buckling occurs, but in circular columns cracks (crack width of 3mm) forms in the bottom of the columns.

By providing additional reinforcement gives improved lateral load capacity.

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