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Square Compression Member Containing UPVC Tubes

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***Abstract*: Concrete-filled-tubular (CFT) compression members have been investigated by several researchers in recent years. Further, CFTs reported have been mainly with circular sharpen experiment investigation has been carried out to evaluate the effectiveness of the square compression member with inside UPVC Pipe in concrete columns. Compression behaviour with a tubular core of UPVC pipe at central axis has been investigated. The work consisted of casting and testing of reinforced column specimens of size 100mm x 100mm x 380 mm with hollow as well as filled UPVC Pipe. Column specimens have been casted with 20mm and 40mm diameter UPVC pipe at centre. All columns have longitudinal reinforcement consisting of 4 deformed bars, 12mm diameter Fe 500bars. In addition, 8mm diameter bars @150 mm lateral spacing have been used as ties.**

Keywords: UPVC (Hollow/filled), Confinement, H/D ratio, Ductility ratio, Energy absorption, Energy ratio.

I. INTRODUCTION

Concrete filled tubular (CFT) columns have been increasingly used in many modern structures such as dwelling houses, tall buildings. The tubes are used to confine the concrete, whereas, the ordinary longitudinal reinforcing bars are still needed for providing flexural strength of the columns. The tubes can be used as formwork during construction and their after as an integral part of column. Literature suggests that confinement through tubes significantly enhances the axial load carrying capacity and energy absorption capacity of compression members. In initial times, steel tubes were used. However, in recent times, the use of UPVC tubes is also getting acceptance due to being a non-corrosive material. UPVC pipes are readily available in market and it is cheaper than steel tubes and also provides durability, reliability and integrity of the housing/building. Columns are considered as critical members in moment-resisting structural systems. Columns are structural elements which transfer whole building load to foundation, so they have to be designed and detailed adequately. Design of columns need to address many issues. General practice is to use transverse reinforcement to confine the concrete.

II. REVIEW OF LITERATURE

[1] Dr. R Kumutha et al. (2016)studied the PVC confinements in concrete columns. The strength characteristics of the plain and reinforced concrete columns under axial compression with and without external confinement using PVC pipes were studied. They concluded that the external confinement of concrete columns by PVC pipes results in enhancing compressive strength, ultimate load and energy absorption capacity. Their test results also indicated that as the thickness of PVC pipes increases, the confining pressure also increases which in turn increases the compressive strength of concrete. This increased compressive strength leads to an enhancement in ultimate load carrying capacity of reinforced concrete columns.

[2]Nameer A. Alwash et al (2013) investigated behaviour of self-compacting concrete Filled Steel Tube (CFST) stub columns strengthened by Carbon Fibre Reinforced Polymer (CFRP) laminates.They casted fourteen specimens with circular cross-sections (100x300) mm and another fourteen specimens with square cross-sections (100x100x300) mm, and each fourteen specimens can be classified into three categories: three hollow steel tube columns, three plain SCC columns, and eight SCC filled steel tube columns, figure2.2 show strengthening system for circular and square columns respectively. They observed that the longitudinal CFRP is more effective than transverse CFRP in square hollow or filled column, vice versa in circular ones and also the ductility of hollow and filled specimens of circular section was much larger than that of the specimens of square section.

[3] Pramod Kumar Gupta (2013) [4] studied the effectiveness of UPVC tube for confinement of concrete columns. UPVC tubes having 140 mm, 160 mm and 200 mm external diameters were used to confine the concrete having compressive strength 20 MPa, 25 MPa and 40 MPa. It is found that the predicted capacities of columns using different models are within ±6% of the experimental capacities. It is found that UPVC tubes can be effectively used for confinement of the concrete columns and to enhance their load capacity, ductility as well as energy absorbing capacity.

[4] Sheikh et al. (1993) studied the ductility and strength for confined concrete and they concluded that ductility is more sensitive, than the strength, to amount of transverse steel, and the increase in concrete strength due to confinement was observed to be between 2.1 and 4 times the lateral pressure. For the cases of both active and passive confinement gives a description of the constitutive formulation of the model.

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III. OBJECTIVE OF THE WORK

An experimental investigation is carried out on Square Compression Member Containing UPVC Tubes to determine the energy absorption capacity of the reinforced concrete column with hollow UPVC tube 20mm dia. and with 40mm diameter UPVC tube. The above one is also compared with unconfined columns for determining the energy absorption capacity of the reinforced concrete column with filled UPVC tube 20mm dia. and with 40mm diameter UPVC tube.

IV. EXPERIMENTAL INVESTIGATION

In this study total 30 specimens were casted. The specimens were casted of 380mm in height having UPVC pipes with hollow and filled column specimens.

Table-1: Details of Specimens

Specimen	Outer Dia. UPVC PIPE (mm)	Inner Dia. UPVC PIPE (mm)	Thickness of UPVC Pipe(mm)	Height (mm)
HCCA1	25mm	20mm	2.5mm	380
HCCA2	25mm	20mm	2.5mm	380
HCCA3	25mm	20mm	2.5mm	380
HCCB1	46mm	40mm	3mm	380
HCCB2	46mm	40mm	3mm	380
HCCB3	46mm	40mm	3mm	380
FCCA1	25mm	20mm	2.5mm	380
FCCA2	25mm	20mm	2.5mm	380
FCCA3	25mm	20mm	2.5mm	380
FCCB1	46mm	40mm	3mm	380
FCCB2	46mm	40mm	3mm	380
FCCB3	46mm	40mm	3mm	380
HRCA1	25mm	20mm	2.5mm	380
HRCA2	25mm	20mm	2.5mm	380
HRCA3	25mm	20mm	2.5mm	380
HRCB1	46mm	40mm	3mm	380
HRCB2	46mm	40mm	3mm	380
HRCB3	46mm	40mm	3mm	380
FRCA1	25mm	20mm	2.5mm	380
FRCA2	25mm	20mm	2.5mm	380
FRCA3	25mm	20mm	2.5mm	380
FRCB1	46mm	40mm	3mm	380
FRCB2	46mm	40mm	3mm	380
FRCB3	46mm	40mm	3mm	380

Here 'CC' represents for Control column specimens, 'HCC' represents for Hollow concrete column 'FCC' represents Filled concrete column, 'RC' represents the reinforced concrete column, 'HRC' represents Hollow reinforced concrete column, 'FRC' represents Filled reinforced concrete column and 'A' represents 20mm diameter UPVC pipe and 'B' represents 40mm diameter UPVC pipe.

All materials and strength of samples were tested at materials testing lab of RTU, Kota. Test was performed as per IS 516:1959 to find out the compression strength of concrete after 28 days curing of concrete. At the time of testing, specimen removed from curing, surface water was wiped off by the cloth and any projecting fines removed.

The tests for compressive strength of cube specimens, unconfined and confined compression members, all were performed on a CTM (Compression Testing Machine) of capacity 2000 KN. The loading was applied continuously without a jerk load. Displacements were measured continuously by dial gauge positioned at the bottom platen of CTM.

Figure 1: Arrangement of Dial gauge with CTM

V. Experimental Results and Discussion

Table 2: Compressive Strength of Unconfined Specimens

Specimen	Compressive strength (N/mm^2)
CC1	46
CC2	45
CC3	44
CC4	46.5
CC5	45.55
CC6	47.87

Load and displacement values, for control specimens with energy absorbed (E) values of the ultimate and yield load are computed as the respective areas under the load displacement curve below in Table II.

Ductility Ratio:- The ratio of the total deflection to the deflection at elastic limit.

The deflection at elastic limit is the deflection at which strength behaviour can be assumed to change from elastic to plastic.

$$\mu_u = \frac{\Delta u}{\Delta y}$$

Energy Ratio:- The energy absorption or work done have been calculated at peak load, (P_u) by the following formula.

E = area under the curve

OR

E =load x displacement

ξu = Eu/Ey

Table 3: Observed Values of P and Δ for CC1 with E, μ and ξ (w/o reinforcement)

	Yield	Ultimate	90%of Ultimate	80%of Ultimate
P (kN)	100	130	-	-
Δ (mm)	4	5.5	-	-
E (Joule)	200	372.50	-	-
Ductility Ratios			**Energy Ratios**	
$\mu=\Delta_u/\Delta_y$	1.375		**$\xi_u=E_u/E_y$**	1.8625
$\mu_{90}=\Delta_{90}/\Delta_y$	-		**$\xi_{90}=E_{90}/E_y$**	-
$\mu_{80}=\Delta_{80}/\Delta_y$	-		**$\xi_{80}=E_{80}/E_y$**	-

Table 4: Observed Values of P and Δ for RC1 with E, μ and ξ (with reinforcement)

	Yield	Ultimate	90%of Ultimate	80%of Ultimate
P (kN)	270	380	340	300
Δ (mm)	5.89	11.2	13	15.5
E (Joule)	753.20	2460	3108	3908
Ductility Ratios			**Energy Ratios**	
$\mu=\Delta_u/\Delta_y$	1.90		**$\xi_u=E_u/E_y$**	3.26
$\mu_{90}=\Delta_{90}/\Delta_y$	2.20		**$\xi_{90}=E_{90}/E_y$**	4.12
$\mu_{80}=\Delta_{80}/\Delta_y$	2.63		**$\xi_{80}= E_{80}/E_y$**	5.18

Table 5: Observed Values of P and Δ for HCCA2 with E, μ and ξ (w/o reinforcement)

	Yield	Ultimate	90%of Ultimate	80%of Ultimate
P (kN)	60	110	90	70
Δ (mm)	1.41	3.86	4.59	5.3
E (Joule)	45.55	264.4	337.65	398
Ductility Ratios			**Energy Ratios**	
$\mu=\Delta_u/\Delta_y$	2.73		**$\xi_u=E_u/E_y$**	5.80
$\mu_{90}=\Delta_{90}/\Delta_y$	3.25		**$\xi_{90}=E_{90}/E_y$**	7.41
$\mu_{80}=\Delta_{80}/\Delta_y$	3.75		**$\xi_{80}= E_{80}/E_y$**	8.73

Table 6: Observed Values of P and Δ for FCCA2 with E, μ and ξ (w/o reinforcement)

	Yield	Ultimate	90%of Ultimate	80%of Ultimate
P (kN)	80	160	140	130
Δ (mm)	1.98	5.2	7.2	7.98
E (Joule)	85.4	483.1	781.3	886.6
Ductility Ratios			**Energy Ratios**	
$\mu=\Delta_u/\Delta_y$	2.62		**$\xi_u=E_u/E_y$**	5.65
$\mu_{90}=\Delta_{90}/\Delta_y$	3.63		**$\xi_{90}=E_{90}/E_y$**	9.14
$\mu_{80}=\Delta_{80}/\Delta_y$	4.03		**$\xi_{80}= E_{80}/E_y$**	10.38

Table 7: Observed Values of P and Δ for HRCA2 with E, μ and ξ(with reinforcement)

	Yield	Ultimate	90%of Ultimate	80%of Ultimate
P (kN)	290	490	450	390
Δ (mm)	5.8	14.5	16.2	18.9
E (Joule)	781.90	4413	5212	6346
Ductility Ratios			**Energy Ratios**	
$\mu=\Delta_u/\Delta_y$	2.50		**$\xi_u=E_u/E_y$**	5.64
$\mu_{90}=\Delta_{90}/\Delta_y$	2.79		**$\xi_{90}=E_{90}/E_y$**	6.66
$\mu_{80}=\Delta_{80}/\Delta_y$	3.25		**$\xi_{80}= E_{80}/E_y$**	8.11

Table 8: Observed Values of P and Δ for HRCB1 with E, μ and ξ

	Yield	Ultimate	90%of Ultimate	80%of Ultimate
P (kN)	260	450	410	370
Δ (mm)	5.3	12.58	13.96	15.74
E (Joule)	761.30	3440.6	4034	4728.2
Ductility Ratios			**Energy Ratios**	
$\mu=\Delta_u/\Delta_y$	2.37		**$\xi_u=E_u/E_y$**	4.51
$\mu_{90}=\Delta_{90}/\Delta_y$	2.63		**$\xi_{90}=E_{90}/E_y$**	5.29
$\mu_{80}=\Delta_{80}/\Delta_y$	2.91		**$\xi_{80}= E_{80}/E_y$**	6.21

Table 9: Observed Values of P and Δ for FRCB3 with E, μ and ξ

	Yield	Ultimate	90%of Ultimate	80%of Ultimate
P (kN)	220	520	480	440
Δ (mm)	4.25	15.69	17.5	19.5
E (Joule)	541.30	5286.80	6191.80	7118
Ductility Ratios			**Energy Ratios**	
$\mu=\Delta_u/\Delta_y$	3.69		**$\xi_u=E_u/E_y$**	9.76
$\mu_{90}=\Delta_{90}/\Delta_y$	4.11		**$\xi_{90}=E_{90}/E_y$**	11.43
$\mu_{80}=\Delta_{80}/\Delta_y$	4.58		**$\xi_{80}= E_{80}/E_y$**	13.14

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Comparison of Ductility Ratio between Hollow and Solid Specimens

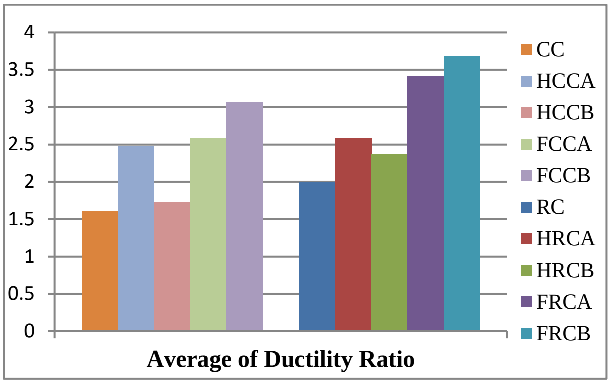

Figure 2: Average of Ductility Ratios at Ultimate load

Comparison of Energy Ratio between Hollow and Solid Specimens

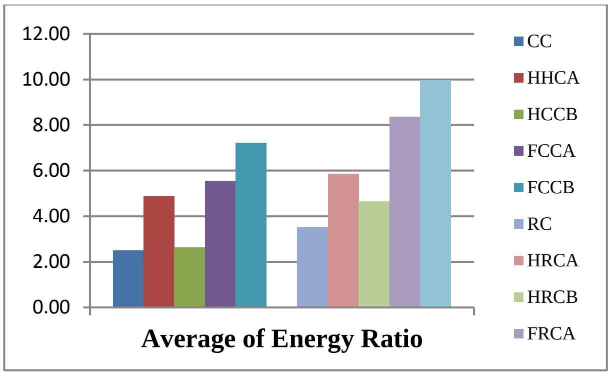

Figure 3: Average of Energy Ratios at Peak Load

Observation

Summary of Effect of using UPVC tubes in columns placed at central core.

Table 10: Observation Table

S.NO.	Properties	Dr. R. Kumutha [1]	Present Study
1.	Increase in ultimate load	152 mm ϕ, 3mm T - 56% ↑ 152 mm ϕ, 4mm T, 68.95% ↑ 178 mm ϕ, 3mm T - 20% ↑ 178 mm ϕ, 4mm T – 40% ↑	20mm ϕ, 2.5mm T - 30%↑ 40mm ϕ, 3mm T - 17%↑ 20mm ϕ, 2.5mm T - 38%↑ (with RCC) 40mm ϕ, 3mm T – 45% ↑ (with RCC)
2.	Deflection	Reduces	Reduces
3.	Increase in Ductility Ratio	–	89.06% (20mm filled without RCC) 188.67% (40mm filled without RCC) 70.5% (20mm filled with RCC) 83 .5% (40mm filled with RCC)
4.	Increase in Energy Ratio	152 mm ϕ, 3mm T, 164.7%↑ 152 mm ϕ, 4mm T, 194.12%↑ 178 mm ϕ, 3mm T, 265.22%↑ 178 mm ϕ, 4mm T,386.95%↑	122% (20mm filled without RCC) 189.25% (40mm filled without RCC) 137.78% (20mm filled with RCC) 182.67% (40mm filled with RCC)

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VI. CONCLUSIONS

Based on experimental test results, due to presence of filled and hollow UPVC tube kept inside central core of compression member with and without reinforcement, the following conclusions are drawn:

1. The ultimate load of compression members due to filled tubes gets enhanced by 30 % and 40 % for the UPVC tube diameter of 20 mm and 40 mm respectively.
2. The ductility ratio is found to increase upto 70.5% and 83.5% for 20 mm and 40 mm filled UPVC tube column.
3. The absorbed energy and energy ratios are observed higher with filled UPVC tube specimens than that of specimens containing hollow UPVC tubes.
4. The ductility ratio gets improved in the filled specimens with increase in thickness of the UPVC tubes.

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