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Research on Reinforced UPVC Pipes as Structural Member

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Abstract

Different materials can be arranged in an optimum geometric configuration, with the aim that only the desirable property of each material will be utilized by virtue of its designated position. The material should be chosen in such a way that, it will not compromise with all parameters that an original member possesses, and there should not be any problems in the availability of this material. It will be an added advantage if the materials being used are the waste products. Here UPVC tubes that are in the market are being taken and concrete of lower grade is used by providing reinforcement. The testing of concrete filled UPVC tubes is tested under UTM to calculate the compressive strength. Aim of this study was to investigate the behaviour of CFUTs as structural members. Various parameters to be studied were therefore: (a) To study the axial load behavior of the sample CFUTs (b) To find out amount of confinement achieved using UPVC tubes and predict in strength with varying amount of fly ash (c) To study the effects of fly ash on the strength on CFUTs.

Keywords: *UPVC Pipes, Concrete Filled Tubes, Structural Member.*

1. Introduction

CFT tubes are now being using worldwide because of its advantages and several countries have made codes, and much of the study was being restricted to Concrete Filled Steel Tubes (CFST). CFT are generally used as columns and now the studies are extending to beam members. A lot of technical data is also available on CFST. As concrete filled steel tubes (CFST) are not resistant to corrosion, so these cannot be used as piles. The other problems include regarding the availability and their higher price. So the usage of Unplasticised Poly Vinyl Chloride or Poly Vinyl Chloride (UPVC/PVC) is covering all these drawbacks of CFST.

In this paper we are studying the compression behavior of UPVC tubes (Unplasticised Poly Vinyl Chloride) commonly known as PVC tubes as CFTs and Class F fly ash is used (as lime is <10%). As the ACI 211.4R-93 says to use fly ash content in between 15% to 25%, in this case we have taken 20% according to limits and 30% which is not as per the limits. So we studying the difference in the strength parameters and the loading is applied in UTM at the rate 1KN/sec. It also includes the study of the effect of confinement on the compression properties of CFTs.

1.1 Concrete Filled Tubes

Concrete filled tubular (CFT) columns have been increasingly used in many modern structures, such as dwelling houses, tall buildings, and arch bridges. The composite tubular columns have better structural performance than that of bare steel or reinforced concrete structural members. Steel hollow sections act as reinforcement for the concrete. Steel concrete composite members have advantageous qualities such as enhanced strength, ductility and stiffness. Concrete filled steel tubes are an economical column type, as the majority of the axial load is resisted by the concrete, which is less expensive than steel.

A number of additional economic benefits stem from the use of CFTs. These decreases labour and material cost. In moderate to high rise construction, the building can ascend more quickly than a comparable reinforced concrete structure since the steel work can precede the concrete by several stories. The cost of the member itself is much less than steel and roughly equivalent to reinforced concrete on a strength per rupee basis for low to medium strength concrete. When compared to steel moment resisting frames, in unbraced CFT frames, the amount of savings in steel tends to grow as the number of stories increases. On the other hand, relatively simple beam to column connection detail can be utilized for rectangular CFT members. This also results in savings for the total cost of the structure and facilitates the design process. In addition, the steel tube and concrete act together to provide natural reinforcement for the panel zone, which reduces the material and labour costs of the connections. With the use of high strength concrete, CFTs are stronger per square meter than conventional reinforced concrete columns.

1.2 Unplaticised Poly Vinyl Chloride

The design of PVC-FRP confined concrete members requires accurate evaluation of the performance enhancement due to the confinement provided by PVC-FRP tube. Based on the study (Feng Yu and DitaoNiu 2010) the static equilibrium condition and the yield criteria of concrete and PVC-FRP tube, presented a calculating model of the load carrying capacity of PVC-FRP confined concrete column. The influences of the hoop spacing of FRP strips and equivalent confinement effect coefficient on load-carrying capacity were well considered. According to the ingression of experimental data, a calculating formula of the ultimate axial strain is also put forward. A bilinear stress-strain model of PVC-FRP confined concrete column in axial and lateral directions is established. The comparison between experimental and numerical results indicates that the model provides satisfactory predictions of the stress-strain response of the columns. For reinforced concrete column, the confining stress of steel spirals to concrete keeps constant after steel spirals yielding. But for PVC-FRP confined concrete column, the confining action of PVC-FRP tube to concrete is different. In the beginning load stage, the confining action of PVC-FRP tube to concrete is still not activated due to small lateral deformation of core concrete. In the vicinity of ultimate compressive strength of unconfined concrete, the confinement of PVC-FRP tube is activated and starts to be obviously enhanced. In the final stage, the confining action continuously increase with the increment of axial load, and the load-carrying capacity and axial deformation has been greatly improved before the failure of PVC-FRP tube. The load carrying capacity and ductility of PVC-FRP confined concrete column can be obviously improved by the confinement of PVC-FRP tube to concrete. The mechanical behaviour of PVC-FRP confined concrete column is different from that of reinforced concrete or concrete filled steel tube, so it is not proper to apply the existing stress-strain model of reinforced concrete or concrete filled steel tube to directly predict the stress-strain relationship of PVC-FRP confined concrete column.

2. Experimental Program

The objective of mix design is to find the proportions in which concrete ingredients-cement, water, fine aggregate and coarse aggregate should be combined in order to provide specific strength, workability and durability and possibly meet other requirements as listed in standards such as IS: 456-2009.

3. Concrete Mix Design

M40 Grade Concrete Mix Design Using IS 10262:2009 by 20% replacement of fly ash.

UPVC tubes were filled with concrete mix of M30 grade and M40 grade. The aim was to study the effect of confinement on concrete and enhancement of its strength. M30 and M40 grade of concrete were chosen to compare the strength values with varying amount of fly ash, as M30 and M40 grades are commonly used in multi-storey buildings as columns.

The pressure holding capacity is 0.6MPa as specified by maker. The tubes with L/D ranging from 3.93 to 3.94 were selected allowing the studies on short tubes. The D/t ratios selected were between 28 and 31

i. Stipulation for Proportioning

Grade designation: M40
Type of cement: OPC-43
Type of mineral admixture: FLY ASH
Maximum nominal size of aggregate: 10 mm
Minimum cement content: 320 kg/m3
Maximum water cement ratio: 0.45
Workability: 100 mm
Exposure condition: severe
Method of concrete placing: manual
Degree of supervision: good
Type of concrete: crushed angular aggregate
Maximum cement content (OPC): 450 kg/m^3
Chemical admixture type: super plasticizer

ii. Test data for materials

Cement used: OPC 43
Specific gravity of cement: 3.15
Fly ash: conforming to IS 3812(part 1)

Specific gravity of cement: 2.12
Specific gravity of admixture: 1.21
Specific gravity of coarse aggregate: 2.67
Specific gravity of fine aggregate: 2.60
Water absorption of coarse aggregate: 0.50%
Water absorption of fine aggregate: 1%
Free moisture for coarse aggregate: Nil
Free moisture for fine aggregate: Nil
Sieve analysis for fine aggregate: Zone III

iii. Target strength for mix proportioning:

f' = fck+1.65 s
= 40+ (1.65×5)
= 48.25 N/mm2

iv. Selection of water cement ratio:

From table 5 of IS 456 the maximum water cement ratio = 0.40
So let us adopt 0.40<0.45, hence O.K

v. Selection of water cement

From Table 2 maximum water content for 10 mm aggregate = 208 liters (for 25 to 50mm slump range)
Estimated water content for 100mm slump = 208+ (0.06×208)
= 220.48 liters
As super plasticizer is used the ater content can be reduced by 30%
So final water content=220.48×0.70
= 154.34 liters

vi. Calculation of cement and fly ash content

Water cement ratio= 0.40
Cementitious material content= 154.34/0.40
= 386 kg/m3
Since 386 kg/m3 > 360 kg/m3 (minimum cement content)
Cementitious material content = 386×1.10
= 425 kg/m3
Water content= 154.34 liters
Water cement ratio= 154.34/425
= 0.36
Fly ash @ 20% of total= 425×0.20
= 85 kg/m3
Cemettitious material content Cement= 425-85
= 340 kg/m3
Saving cement by using fly ash = 386-340
= 46 kg/m3

vii. Proportioning of volume of coarse aggregate and fine aggregate content

Volume of coarse aggregate corresponding to 10mm size aggregate and fine aggregate for water cement ratio of 0.50=0.48
So volume of coarse aggregate= 0.48+0.02
= 0.50
So volume of fine aggregate = 1.0-0.50
= 0.50

viii. Mix calculation

The mix calculation per unit volume of concrete shall be as follows:
Volume of concrete= 1 m3
Volume of cement= (340/3.15)×(1/1000)
= 0.107 m3
Volume of fly ash= 85/2.12) × (1/1000)
= 0.040 m3
Volume of water= (154.34/1) × (1/1000)
= 0.154 m3
Volume of chemical admixture @2% by mass
= (7.72/1.21) × (1/1000)
= 0.006 m3
Volume of all aggregate
=(1-(0.107+0.040+0.154+0.006)
= 0.693 m3
Coarse aggregate mass = 0.693×0.50×2.67×1000
= 925 kg/ m3
Mass of fine aggregate= 0.693×0.50×2.60×1000
= 901 kg/ m3

ix. Summary of mix proportions 20FM40D190

Cement	FA	CA	Water	Fly ash	Admixture
340	901	925	154.34	85	7.72
1	2.65	2.72	0.45	0.25	0.022

x. Actual quantities required per bag of cement

Cement= 50 kg
FA= 132.5 kg
CA= 136 kg
Water= 22.5 liter
Fly ash= 12.5 kg
Admixture= 1.1 liter

xi. Concrete for 6 samples of 20FM40D190

Cement	FA	CA	Water	Fly ash	Admixture
43.18	114.43	117.45	19.44	10.80	0.94

(All quantities in kg)

xii. Concrete for 6 samples of 30FM40D190

Cement	FA	CA	Water	Fly ash	Admixture
36.23	112.65	115.67	19.45	16.06	0.97

4. Nomenclature of the Samples

Sr. No.	Nominal ext. dia. (mm)	Avg. length (mm)	Avg. external diameter (mm)	Avg. thickness (mm)	L/D ratio	D/t ratio
1	190	750	190.45	6.1	3.938	31.221
2	190	750	190.30	6.3	3.941	30.206
3	190	750	190.65	6.6	3,933	28.886
4	190	750	190.10	6.2	3.945	30.661

-20FM40D190: 20F stands for 20% fly ash and M40 stands for compressive strength of concrete and D190 stands for the diameter of the UPVC tube.
- 30FM40D190: 30F stands for 30% fly ash and M40 stands for compressive strength of concrete and D190 stands for the diameter of the UPVC tube.
6 bars of 12mm diameter was used as main reinforcement and 8mm diameter bars are used as ties at a spacing of 150mm center to center.

a. Casting of UPVC CFT

1. Six samples of each category are cast. A total of 24 specimens were cast.
2. Reinforcement is provided for all the samples with a clear cover of 40mm.
3. The concrete was cast in 3 layers each of 250mm for ensuring proper compaction.
4. Concrete filled UPVC tubes were cored for 28 days.

b. Testing

1. The load is applied at 1 KN/sec.

The load and displacement graph is plotted.

5. Load v/s Displacement for 20FM40D190 AND 30FM40D190

In Fig 4.1 the load v/s displacement is plotted for M40 grade of concrete with the variation in the amount of fly ash and the following points are observed:

a) Both the graphs behave linearly until they peak load because the load is taken both by the concrete filled UPVC tube.
b) 20FM40D190 does not show signs of major displacement after peak load because the maximum load capacity is reached by the concrete filled UPVC tube. The initial cracking occurs when it reaches 97.80%of its total strength.
c) 30FM40D190 displays resistance at peak load so a straight line can be observed in the graph, so at this point resistance is offered by the UPVC tube which leads to displacement. Resistance is being offered only by the UPVC tube in this case because concrete fails at an early stage, due to the presence of extra fly ash. The initial cracking can be observed when it reaches 58.83% of its total strength.
d) For 20FM40D190 the cube strength achieved in this design shows enhanced strength in a UPVC tube because of confinement pressure.
e) For 30FM40D190 the cube strength achieved is lower than 20% fly ash replacement, but it show enhanced strength due to the presence of UPVC tube which exerts a confinement pressure.

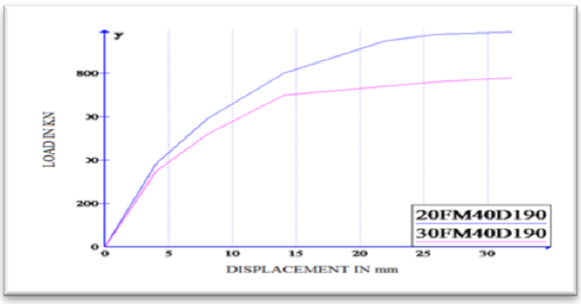

Figure 1: Load Vs Displacement of average of 20FM40D190 & 30FM40D190

Picture Various Failures Observed in Cfut's Samples

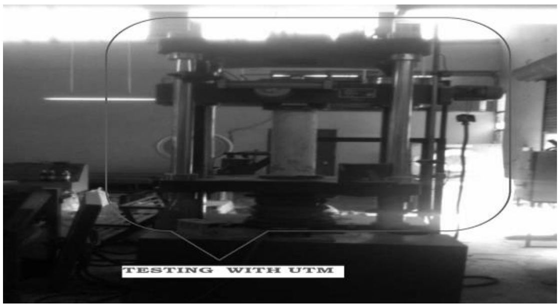

Figure 2: Testing with UTM

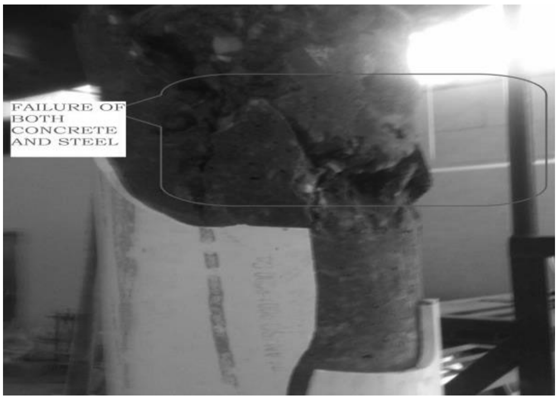

Figure 3: Failure of both Concrete and Steel

6. Conclusions

The following conclusions can be drawn based on the experimental research work presented in this dissertation:

1. The longitudinal steel bars provide significant dowel action, which delays the dilation of concrete core inside CFUT, thereby improving the ductility of CFUT columns.
2. It is found that most of the CFUT columns failed by local buckling and bulging of material radially in the out ward direction of the column which causes the failure of UPVC tubes.
3. The load-carrying capacity of the CFUT is considerably higher than the conventional RC columns.
4. The strength enhancement will depend on percentage of the stiffness of the UPVC tube in radial direction.
5. Local pipes fail by explosion and hence not preferred for low cost housing. The local pipes cannot be used for low cost housing; however the CFUT's can be used as piles, because the external pressure of the soil keeps the pipes intact preventing from an explosion.
6. Most of the samples are failing in shear failure with diagonal crack, resulting to an explosion.
7. Higher grade of concrete makes the CFUT's much brittle, because the breaking point of concrete is higher than the UPVC tubes.
8. The mode of failure of the CFUT columns was by local buckling and bulging of material radial outer ward direction of the column.

Higher fly ash content provides better strength in CFUT's than in RCC members.

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