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Experimental Investigation on Double Skin Tubular Short Columns

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ABSTRACT

In this research, Investigation on FRP-cement mortar infilled-steel double-skin tubular member is carried out with emphasis on lateral and vertical load resistance located at seismically active regions. In this new structural member, three constituent materials are optimally combined. The outer tube is made of fibre-reinforced polymer (FRP), the inner tube is made of steel, and the space in-between is filled with cement mortar. These members are highly useful when they are used as columns in scaffolding. These members are cyclically loaded to their Ultimate load to study the behaviour of Double skin tubular short columns (DSTSCs) under increasing d/t ratio by parametric optimization approach using DOE (Design of Experiments). From this experimental research, following conclusions were drawn; As the length of the tube or column increases, load carrying capacity decreases for every particular D/T ratio. As D/T ratio increases, for a particular length of tube ultimate load decreases. As cement mortar ratio increases the ultimate load for d/t =10 &13.5 decreases but for the d/t 17.667 ultimate load decreased and suddenly shot up. As Gap (between the inner steel tube and outer frp) increases the ultimate load for each cement ratio decreases.

Introduction

Columns occupy a vital place in the structural system. Weakness or failure of a column destabilizes the entire structure. Strength & ductility of steel columns need to be ensured through adequate strengthening, repair & rehabilitation techniques to maintain adequate structural performance.

Recently, composite columns are finding a lot of usage for seismic resistance. In order to prevent shear failure of RC column resulting in storey collapse of building, it is necessary to make ductility of columns larger.

Columns are considered as critical members in moment-resisting structural systems. Their failure may lead to a partial or even a total collapse of the whole structure. Therefore, it is important to improve the ductile deformation capacity and energy dissipation capacity of columns so that the entire structure can endure severe ground motions and dissipate a considerable amount of seismic energy. In recent years, composite concrete-filled steel tubes (CFSTs) have become increasingly popular as columns in braced and unbraced frames, as they have the advantages of ductile behaviour as a result of confinement to concrete by the steel tube and delayed local buckling of the steel tube due to the support from concrete, improved damping behaviour in comparison to traditional steel frames, ease for construction as the steel tube serves also as the permanent form, and a high strength-to-weight ratio. Fibre reinforced polymer (FRP) is composed of stiff fibres embedded in a resin matrix. As a new construction material, it has gained its popularity over the past decade as a jacketing material in the retrofit of existing RC columns to achieve improved seismic resistance . FRP jackets (or wraps) have been shown to significantly enhance the shear and flexural strengths, ductility, and energy dissipation capacity of columns. The application of FRP tubes in new construction has also been explored by many researchers (Fam and Rizkalla 2001; Mirmiran and Shahawy 1997). In particular, FRP tubes are used as the stay-in form for constructing concrete-filled FRP tubular columns, with or without an inner void. Such FRP tubes generally have both axial fibres to provide longitudinal reinforcement and hoop fibres to provide confinement to concrete. Concrete-filled FRP tubes (CFFTs) have almost all the advantages of concrete-filled steel tubes in resisting seismic loading. In addition, FRP tubes are very light and do not suffer from the corrosion problem of steel tubes. Concrete-filled FRP tubes also have their own disadvantages, including the high material cost of FRP, a low modulus-to strength ratio and poor fire resistance.

A variation of the concrete filled tubular column is the double-skin tubular column (DSTC), consisting of two generally concentric tubes with the space between filled with concrete. To the best knowledge of the authors, such double-skin tubes were first reported in late 1980s (Shakir-Khalil and Illouli 1987). Since then, much research has been conducted on these columns, both on doubleskin steel tubular columns (Shakir-Khalil 1991; Wei et al. 1995; Yagishita 2000; Zhao et al. 2002; Tao et al. 2003) and double-skin FRP tubular columns (Fam and Rizkalla 2001). The inner void reduces the column weight without significantly affecting the bending rigidity of the section and allows the easy passage of service ducts but in this experiment cement mortar has been used instead of concrete due to very less gap between the two tubes.

Ductility and Energy Dissipation Capacity

Under seismic attacks, the ductility and energy dissipation capacity of a column are the major concerns. Confinement to concrete is an effective means of improving the ductility of a column in which concrete is a main material. It has been demonstrated by extensive research that concrete confined by a steel tube outside can exhibit much better ductility compared with unconfined concrete, either under monotonic loading or cyclic loading. Extensive research on FRP-confined concrete

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has shown that FRP tube confinement to concrete can also significantly enhance the strength and strain capacity of concrete, although the stress-strain behaviour of steel-confined concrete differs from that of FRP-confined concrete.

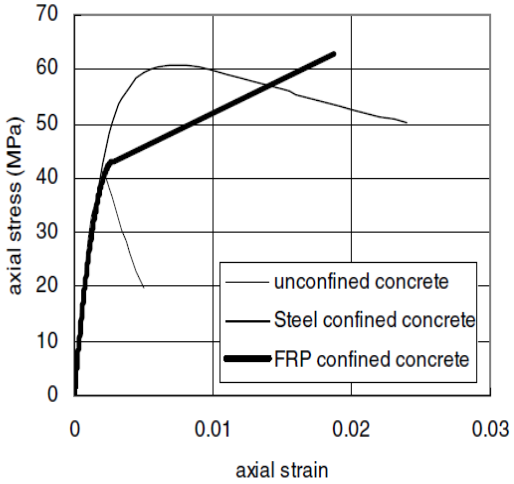


Fig 1

Some previous research has revealed that a concentric hole in the concrete section may decrease the confining effect of the FRP tube on the concrete (Fam and Rizkalla 2001). In the present hybrid DSTC, the steel tube inside provides compensation for the inner void, as indicated by the test results of Fam and Rizkalla (2001) for double-skin tubular FRP columns and Zhao et al. (2002) for double-skin tubular steel columns. In conventional CFSTs and CFFTs, the axial stiffness and strength of the outer tube are substantial and important. The considerable axial stiffness leads to a large axial compressive stress on the tube by either direct end loading or by friction between the concrete and the tube.

As the outer tube is generally loaded in hoop tension by the expansion of the concrete, the FRP tube is generally subjected to a combined tension-compression stress state. Lateral expansion of the FRP tube through the Poisson's effect reduces the effectiveness of confinement to the concrete, and in addition, local buckling of the outer tube becomes an important failure mode. In the new hybrid member, the inner steel tube acts as the longitudinal reinforcement, while the FRP tube outside is provided with fibres predominantly oriented in the circumferential direction to provide confinement only.

The FRP tube outside in the new hybrid member thus has a much lower axial stiffness and theeffect of Poisson's ratio on the lateral expansion of the FRP tube is almost negligible.

Experimental Program

Test Specimens

First set up: Outer FRP tube of 52mm Dia and thickness of 3mm, inner mild steel tube of 33.7mm Dia and thickness of 2mm Dia.

Second Set up : Outer FRP tube of 52mm Dia and thickness of 4mm ,inner mild steel tube of 33.7mm Dia and thickness of 2.6 mm

Third Set up : Outer FRP tube of 52mm Dia and thickness of 5mm ,inner mild steel tube of 33.7mm Dia and thickness of 3.2 mm Dia . 3 same specimens of each set up are taken and their gap is filled with cement mortar of ratio 1:3, 1:4 and 1:5

Material properties

Compressive strength of a cement mortar

Here the sand used is passed from 600 micron sieve and retained on 425 micron sieve, grade of cement used is 53 grade. Ratios taken are 1:3,1:4 and 1:5. This mix is placed and compacted in a mould of 75X75X75mm^3 and has been cured for 7 days and then compressive test of this cement mortar is done in CTM machine

Casting of double skin tubular columns

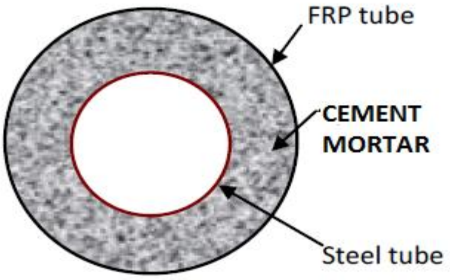


Fig 2

Cross section of a FRP-cement mortar-steel double skin tubular column

Fig 3

Double skin tubular coloumn before filling cement mortar in the gap

Fig 4

This image is taken after just casting cement mortar in the gap between outer dia of mild steel and inner dia of FRP , To avoid the entry of cement mortar into the inner dia of mild steel it is covered with cello tape as shown in figure

Experimental setup and instrumentation

Here we are using 200 ton cyclic loading machine Axial cyclic loading has been done to the specimens by the cyclic loading machine and also by using scada software

Components of this testing machine :

Hydraulic press for testing load comprising press frame; Hydraulic cylinder (dia 320Xdia250X250mmstroke); Hydraulic power pack 100 its with electric motor 5hp x 1440 rpm electrical control panel operating with PLC SCADA soft ware ,strain guage Sl-30 and strain indicator

Fig 5

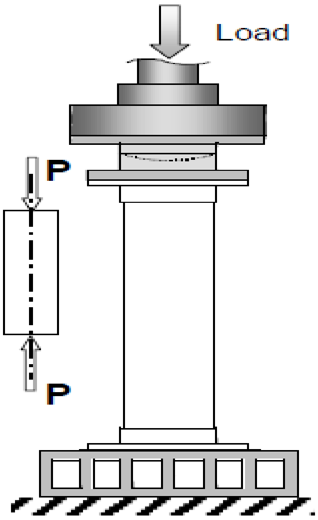
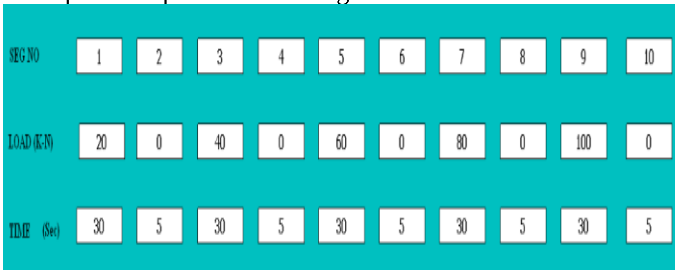


Fig 6

Picture of a 200 ton cyclic loading machine with specimen placed

Loading Schemes

Here all samples were cyclically loaded .Cyclic compression involving full unload/reloading cycles have been conducted , where the unloading of each cycle was designed to terminate at zero load and the reloading of each cycle was designed to terminate at the unloading displacement of the same cycle (i.e. where the unloading started) or after reaching the envelope curve picture of loading sheme from r.nd d lab



SEG NO	1	2	3	4	5	6	7	8	9	10
LOAD (K-N)	20	0	40	0	60	0	80	0	100	0
TIME (Sec)	30	5	30	5	30	5	30	5	30	5

Fig 7

Results And Discussions

Failure modes

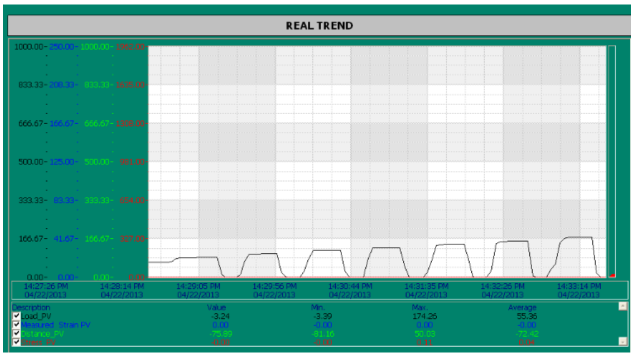
As expected, all the specimens failed by the rupture of the DSTSC at or near the midheight With obvious buckling deformation in the inner steel tube. The specimens after test are shown in Figure

Fig 8

Fig 9

Real Trend

Real trend image of the scada software while cyclic loading was going on for the first specimen frp 52mm ,thickness 3mm and inner MS tube of 33.7 mm of thickness 1.9 mm and cement mortar of ratio 1:3 is shown below



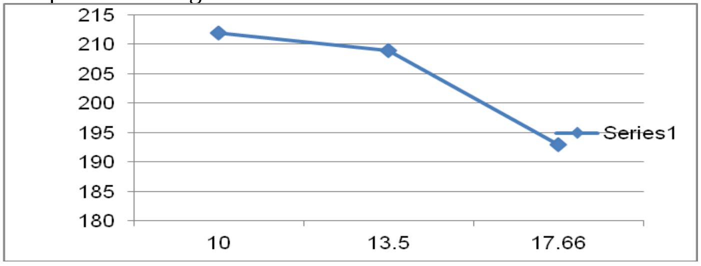
Description	Value	Min.	Max.	Average
☑ Load_PV	-3.24	-3.39	174.26	55.36
☑ Measured_Strain PV	0.00	-0.00	0.00	-0.00
☑ Distance_PV	-75.89	-81.16	50.03	-72.42
☑ Stress_PV	-0.00	-0.00	0.11	0.04

Fig 10

Main parameters and its experimental results

The main parameters choosen in our design of experiments are the D/T ratio, cement mortar and gap filling ,hence the behaviour of the specimens are studied with respect to these main parameters

(a)Since D/T ratio is taken as one of the main parameters graph of load vs D/T ratio is plotted in this experiment,the results show that as D/T increases ultimate load decreases for one particular length 400 mm



(b) the behaviour of the specimen to the ultimate load for varying cement ratio has been studied without varying the length (400mm).

	FRP	(outer tube)	MILD	STEEL(inner tube)		
Specimen	Dia (mm)	Thickness	Dia (mm)	Thickness	Cement mortar ratio	D/T ratio
1	52	3	33.7	2	1:3	17.667
2	52	3	33.7	2	1:4	17.667
3	52	3	33.7	2	1:5	17.667
4	52	4	33.7	3	1:3	13.5
5	52	4	33.7	3	1:4	13.5
6	52	4	33.7	3	1:5	13.5
7	52	5	33.7	4	1:3	10
8	52	5	33.7	4	1:4	10
9	52	5	33.7	4	1:5	10

Material	Density Kg/mm^3	Youngs modulus(E) MPa
FRP tube	2.61x10^-6	1.6X10^4
	2.26x10^-6	1.6X10^4
	1.93x10^-6	1.6X10^4
MS tube	2.01x10^-8	210
	1.98x10^-8	210
	1.97x10^-8	210

Ratio	Wt of cement (grams)	Wt of sand(grams)	Wt of the CM cube(kg)	Compressive strength of the mould (KN)
1:3	200	600	0.701	7.5
1:4	200	800	0.705	5.75
1:5	200	1000	0.710	4

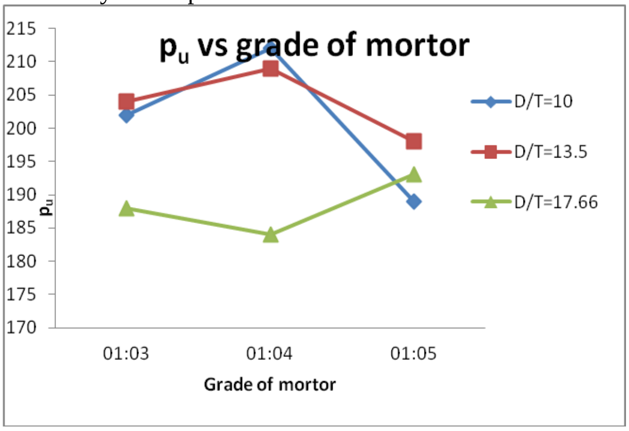
sl.no	D/T	P_U(KN)
1	10	212
2	13.5	209
3	17.66	193

		Pu(KN)		
si no	CEMENT MORTAR RATIO	d/t=10	d/t=13.5	d/t=17.66
1	01:03	202	204	188
2	01:04	212	209	184
3	01:05	189	198	193

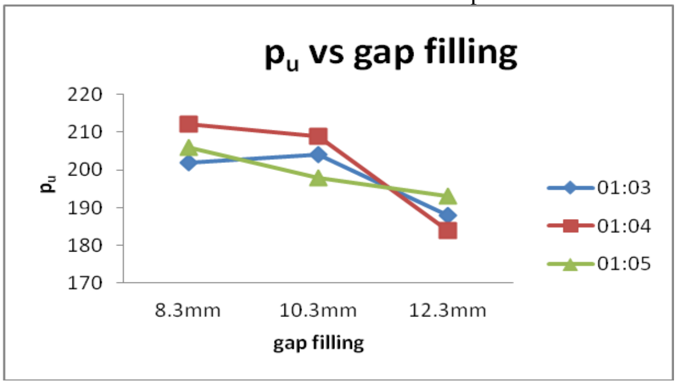
si no	Gap filling	p_u(1:3)	p_u(1:4)	p_u(1:5)
1	8.3mm	202	212	206
2	10.3mm	204	209	198
3	12.3mm	188	184	193

Length	P_U		
	D/T=10	D/T=13.5	D/T=17.66
400	212	209	193
450	204	201	186
500	191	189	172

As cement mortar ratio increases the ultimate load for d/t =10 &13.5 decreases but for the d/t 17.667 ultimate load decreased and suddenly shot up

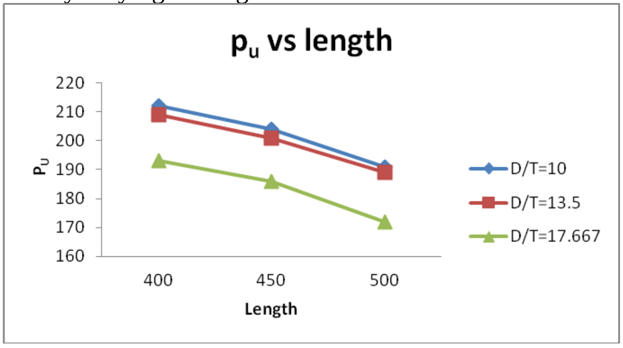


(c) Here the variation of ultimate load with respect to gap filling have been studied for a length od specimen 400mm Here the ultimate load variations for each set up of different ratio has been studied. As gap filling increases there was decrease in ultimate load for each ratio of different setup



Comparisons for varying length 400mm,450mm and 500mm

The behaviour of the specimens to the ultimate load is studied by varying its length for each D/T ratio has been studied



As the length of the tube or column increases, load carrying capacity decreases for every particular D/T ratio

Conclusion

- As the length of the tube or column increases, load carrying capacity decreases for every particular D/T ratio
- As D/T ratio increases, for a particular length of tube ultimate load decreases
- As cement mortar ratio increases the ultimate load for d/t =10 &13.5 decreases but for the d/t 17.667 ultimate load decreased and suddenly shot up
- Gap (between the inner steel tube and outer frp) increases the ultimate load for each cement ratio decreases
- This double skin tubular structural member possesses good ductility and good energy dissipation capacity. When subjected to cyclic compression, the cement mortar sandwiched between the two tubes may achieve significant enhancement in both strength and ductility over unconfined cement mortar.

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