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RESEARCH ARTICLE

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BEHAVIORS OF RECTANGULAR AND D-END SHAPE OF THIN-WALLED GFRP COMPOSITE TUBED RC SHORT COLUMNS UNDER AXIAL COMPRESSION TEST

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ABSTRACT

FRP composite tubes are a potential use of new column construction in the form of concrete-filled tubes. This paper presents an experimental study on the behaviors and modes of failure of thin walled rectangular and D-End shape tubed RC columns subjected to axial compression test. The thickness of the GFRP tube is 3mm. A total of twelve specimens, including three tubed rectangular RC specimens and three tubed D-End RC specimens, were tested and it to be compared to as slenderness ratio 3 , 4 and 5 . The load carrying capacity is increases in D-End tubed RC column than Rectangular tubed RC column. The axial compressive capacity of tubed D-End RC column has a linear elastic behavior than tubed rectangular RC column and also increase in axial load capacity. The comparison of rectangular and D-End plain RC column like 20.02%, 20.00% and 20.00% and tubed RC column 33.97%, 33.02% and 33.01% as slenderness ratio 3, 4 and 5. The least value of slenderness ratio is more efficient to the higher value of slenderness ratios.

Key Words—tubed RC column, Rectangular tubed column, D-End tubed column, slenderness ratio, axial compression test.

INTRODUCTION

In many experiments have been conducted in order to investigate the compressive behavior of circular and rectangular concrete members confined with FRP. The concrete- filled tubes are new in column construction. This type of tubed column has more beneficial qualities. They are (1) high strength-to-weight ratio than other conventional concrete, (2) high deformability and load carrying capacity. The concrete-filled FRP tube is a one type of rare composite column and it comprises the combination of M20 grade of concrete and GFRP tube. This GFRP tube is made up of Glass fiber and Vinyl Ester resin. This type of tubed column has high uniformity of confining pressure and ductility.

In recent years, the compressive behavior of FRP-confined concrete has been studied. It is well known that lateral confinement can significantly enhance the both the strength and deformability of composite concrete columns. These studies have proven that substantial improvement of axial load-carrying capacity of columns. It is based on corner radius of tubes and tube thickness of tubes has an ultimate strain of confined concrete

(T.Ozabakkaloglu et al 2007). Existing studies of steel tube composite column has an approximately 60 to 70 percent of their axial compressive capacity and failure mode is depending from thickness of steel tubes (S.Seangatith and Thumrongvut, 2011). Experimental investigation of aluminum hollow section is deals with the effect of L/D in lowering the ultimate capacity of the columns becomes very less of higher values in D/t (Gopinatha Nayak et al., 2014). Existing experimental investigation of FRP wrapping for RC columns with varying corner radii deals that which column having higher corner radius of RC column is performed superior than other RC columns (Sushil S.Sharma et al., 2013). The slenderness effect on reinforced concrete column has energy absorption and deflection ductility is increases for least slenderness ratio of column (J Saravanan et al., 2013). Hollow sections of steel square tubed short columns are significant increases in ultimate strength and energy absorption under the large axial deformation (M.R.Bambach and M.Elchalakani 2007).

Experimental program

Test specimens

This paper presents the results of an experimental investigation of axially loaded concrete-filled Rectangular and D-End FRP tubes, where a total of twelve specimens were tested. The Rectangular tubed column cross section of 300 mm × 200 mm. D-End tubed column is new in revolution of construction. D-End shape describes that the rectangular cross section and the addition of bulging as provided to half of the shorter dimension in shorter direction of rectangular section.

These shapes of corresponding dimensions of molds were prepared in suitable material and then the outer surface of mold should be very smoothening. The PVA were applied at outer surface of mold and one layer of E-glass woven roving's mat 610gsm was wrapped on the mold after that cobalt accelerator, promoter and MEKP catalyst were mixed with vinyl ester resin and it sprayed on a layer of E-glass fiber. The paddle rollers were used to release the entrapped air in the lay-up. The procedure was repeated that the thickness of GFRP tubes. After curing for 24 hours, and the respective molds were released. Fiber to resin ratio of 1:0.90 was maintained at complete fabrication of GFRP tubes. After that the GFRP tubes were filled in M20 grade of concrete and use of Fe415 grade of reinforcement. And the slenderness ratio varies at 3, 4 and 5.

Figure1. Fabricated GFRP tubes

Material properties

In these GFRP tubes were filled in Fe-415 grade of steel and M20 grade of concrete. The properties of Fe-415 grade of steel shown in table 1 and proportion is indicated in table 2. Test results were found that

Table 1 Typical values of Fe-415 grade of steel

Grade of steel	Yield strength (N/mm^2)min	UTS (N/mm^2)min	% Elongation (min)
Fe-415	415	445	12.5

Table 2 Proportion of M20 grade concrete

Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Water-Cement ratio
1	1.08819	2.36638	0.4

The properties of the bidirectional glass fiber WRM 610gsm used to manufacture the FRP tubes are shown in table 3. The tensile properties of the FRP formed from these glass fiber sheets and vinyl ester resin were determined from flat coupon tests in accordance with ASTM standards.

Table 3 Typical values of GFRP composites and vinyl ester resin

S.No	Material properties	Value
1	Longitudinal modulus of elasticity (E_1)	27.519 MPa
2	Transverse modulus of elasticity (E_2)	22.759 MPa
3	Shear modulus (G_{12})	2631 MPa
4	Ultimate tensile strength	368 MPa
5	Shear strength	50 MPa
6	Major Poisson's ratio (γ_{12})	0.22
7	Ultimate strain (ε_{ult})	0.014
8	Gel time of resin	19 min

9	Heat distortion temperature (HDT)	130̊C
10	Peak exothermal of resin	119̊ C

Instrumentation and testing

GFRP tubed RC concrete are tested in the test set-up as shown in Figure 3. The columns were instrumented with using unidirectional strain gauges. The GFRP tubed RC concrete was fixed in perpendicular to the axial compression load. A patch load was applied (Figure) using a hydraulic jack of 2000 KN capacity. A two steel plate of size of 700 mm × 300 mm was kept above and below the ram of the jack and the load from the ram was distributed on the column through the steel plate. These unidirectional strain gauges were monitored in each incremental load. The columns were initially loaded gradually up to 10KN and then the load was released.

Figure 2 Experimental set-up

Specimen designation

The columns were labeled as follows: In FRP tubed columns, letter Rec for Rectangular and D-E for D-End shape of column was followed by the slenderness ratio S and respective slenderness ratio value of the column was described and then finally L for Length of the column and respective length to be mentioned and also followed by tubular thickness of TT.

test results and discussion

All of the tubed columns are failed in rupture. Once failed the tube, the concrete core was no longer able to sustain the axial load. The D-End is superior to rectangular column. Because of the bulging was reducing in premature failure. The ultimate performance is noticeable in table . The deflections for short columns with higher slenderness ratios were more than those for the columns with lower slenderness ratios.

Axial stress – strain behaviors of Rectangular plain and tubed RC column

The stress-strain behaviors of GFRP tubed column has an increased at ultimate stage than those yield stage. The ultimate point and yield point was marked at failure stage of short columns. Then, the axial strains and axial stress reached by the columns with more slenderness turned to be lower than those reached by columns with lower slenderness.

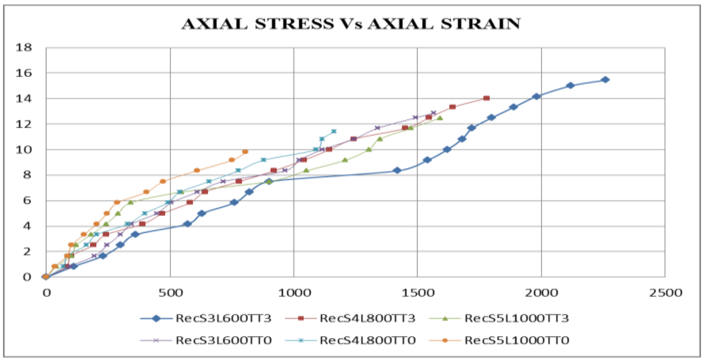

Figure 2 Axial stress-strains for Rectangular plain and tubed columns

The tubed Rectangular concrete column was increase than plain concrete column. The outer surface of the confinement is reducing to the failure modes. The load increases as slenderness ratio 5, 4 and 3 like as 16.83%, 18.76% and 21.50%.

Axial stress-strain behavior of D-End plain and tubed column

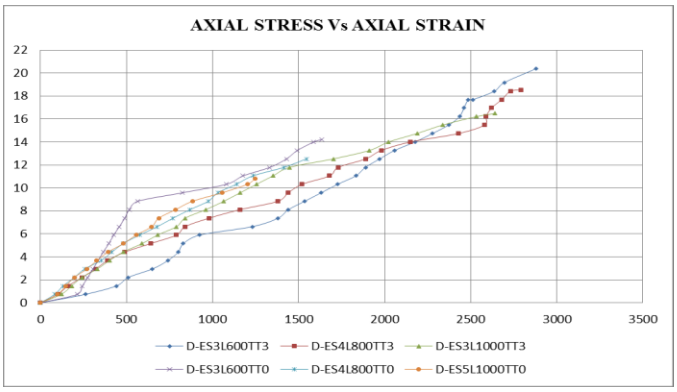

Figure 3 Axial stress-strain curve for D-End plain and tubed column

The tubed D-End concrete column was increase than plain concrete column. The outer surface of the confinement were resist the load carrying capacity. The load increases as slenderness ratio 5,4 and 3 like as 34.26%,31.98% and 30.30%.

Table 4 Test results for Rectangular and D-End plain and tubed columns

Name of Specimens	Ultimate load (KN)	Ultimate deflection (mm)	Ultimate axial stress (MPa)	Ultimate axial strain
RecS3L600TT0	771	3.994	12.85	1567
RecS4L800TT0	684	5.146	11.4	1162
RecS5L1000TT0	588	5.586	9.8	806
D-ES3L600TT0	964	4.538	14.21	1634
D-ES4L800TT0	855	5.848	12.60	1589
D-ES5L1000TT0	735	6.348	10.83	1248
RecS3L600TT3	927	5.684	15.45	2260
RecS4L800TT3	842	7.322	14.03	1780
RecS5L1000TT3	749	7.948	12.48	1590
D-ES3L600TT3	1383	6.358	20.38	2880
D-ES4L800TT3	1257	8.194	18.53	2790
D-ES5L1000TT3	1118	8.894	16.48	2640

The ultimate stress-strain behavior of rectangular and D-End shape of tubed and plain concrete column

In plain concrete column, the ultimate stress-strain behaviors are increased in D-End shape of the plain concrete column. The load was increases in 20.02%, 20.00% and 20.00% for slenderness ratio 3, 4 and 5 respectively.

In tubed concrete column, the ultimate stress-strain behaviors are increased in D-End shape of the tubed column. The load was increases in 33.97%, 33.02% and 33.01% for slenderness ratio 3, 4 and 5.

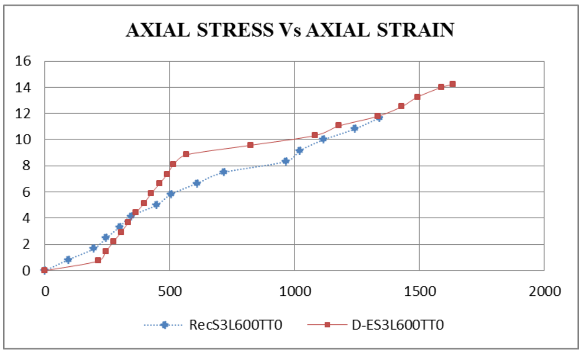

Figure 4 Axial stress-strain curves for RecS3L600TT0 and D-ES3L600TT0

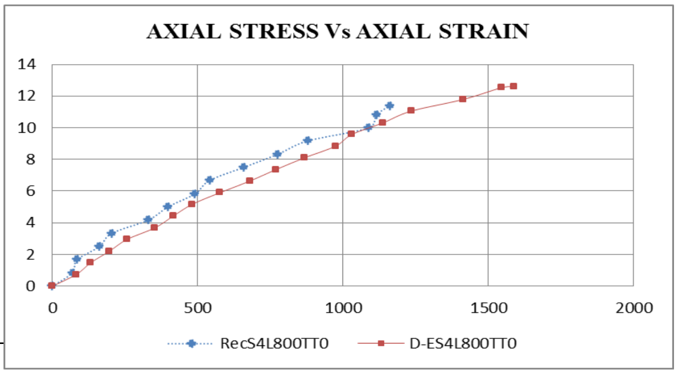

Figure 5 Axial stress-strain curves for RecS4L800TT0 and D-ES4L800TT0

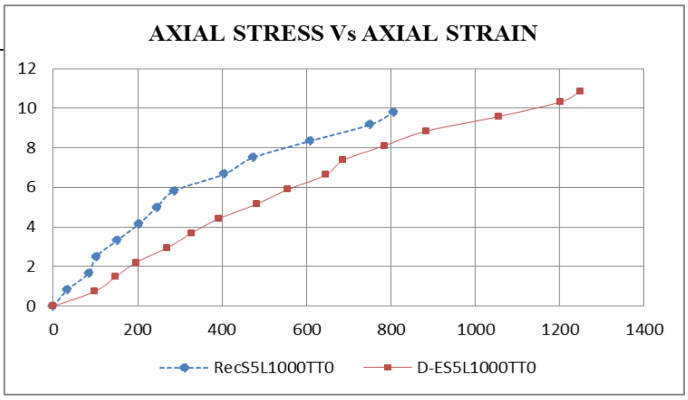

Figure 6 Axial stress-strain curves for RecS5L1000TT0 and D-ES5L1000TT0

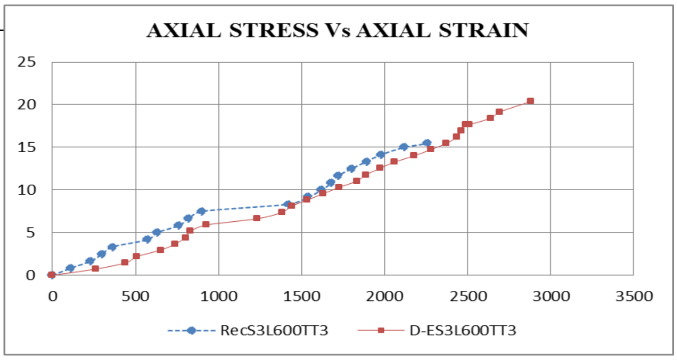

Figure 7 Axial stress-strain curves for RecS3L600TT3 and D-ES3L600TT3

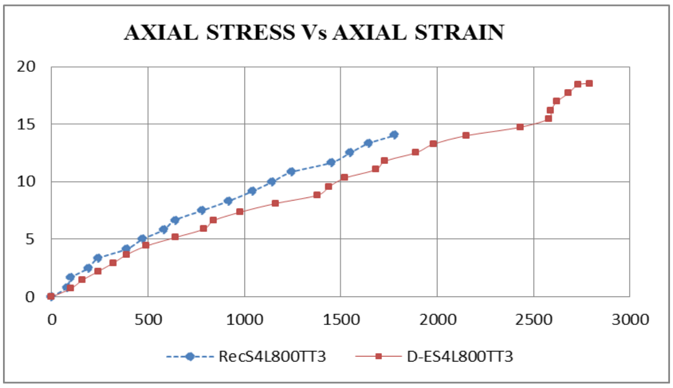

Figure 8 Axial stress-strain curves for RecS4L800TT3 and D-ES4L800TT3

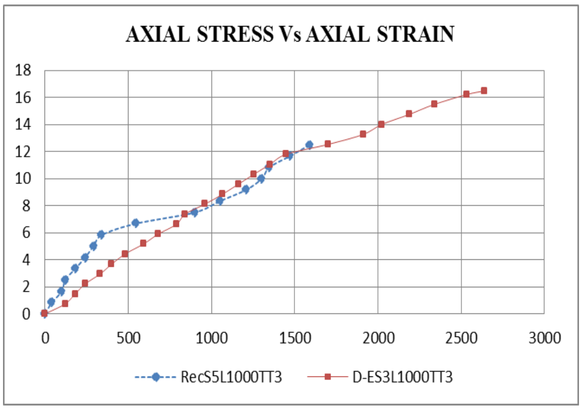

Figure 9 Axial stress-strain curves for RecS5L1000TT3 and D-ES5L1000TT3

Behaviors of load-deformation curves

The load deformation results are presented in figures 10 to 15 for all columns.The ultimate loads and strength increases of the GFRP tubed columns compared to the plain concrete columns. The least value of slenderness ratio has small amount of deformations. And to be compared this type of load-deformations are normalised in tubed columns than plain RC columns.

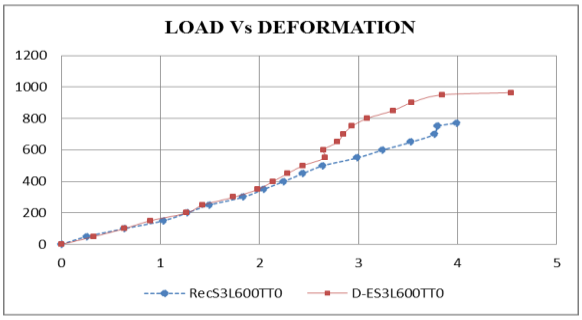

Figure 10 Axial load-deformation curves for RecS3L600TT0 and D-ES3L600TT0

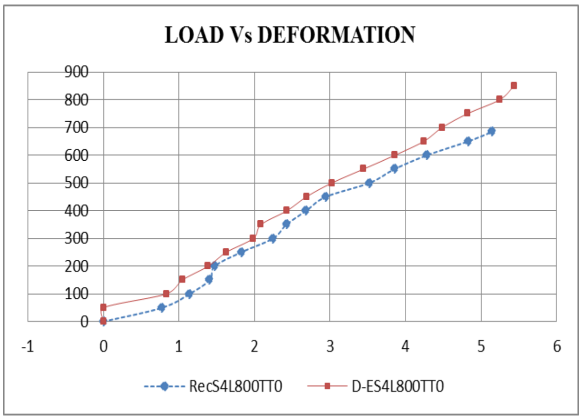

Figure 11 Axial load-deformation curves for RecS4L800TT0 and D-ES4L800TT0

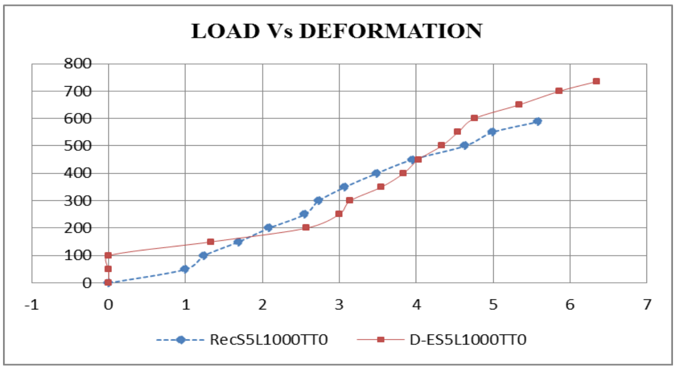

Figure 12 Axial load-deformation curves for RecS5L1000TT0 and D-ES5L1000TT0

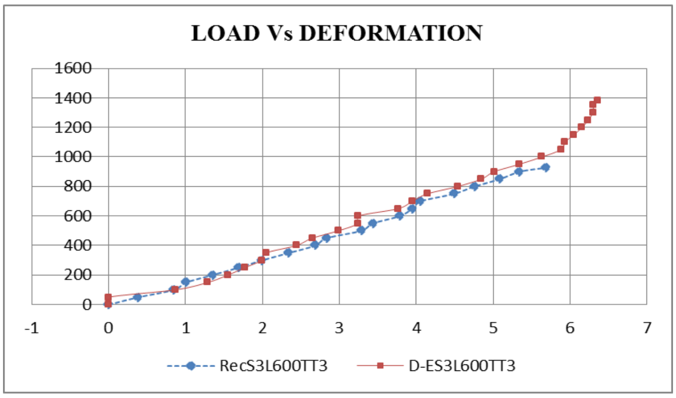

Figure 13 Axial load-deformation curves for RecS3L600TT3 and D-ES3L600TT3

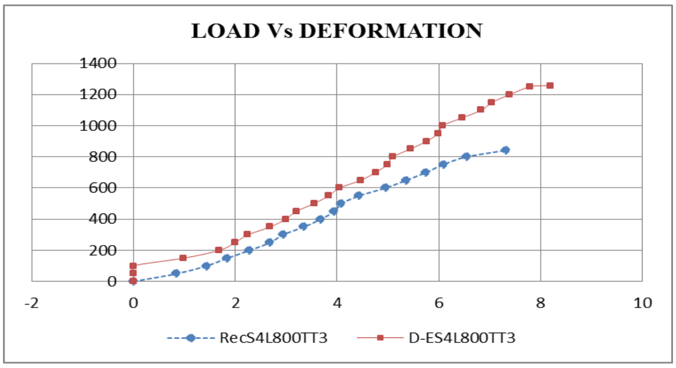

Figure 14 Axial stress-strain curves for RecS4L800TT3 and D-ES4L800TT3

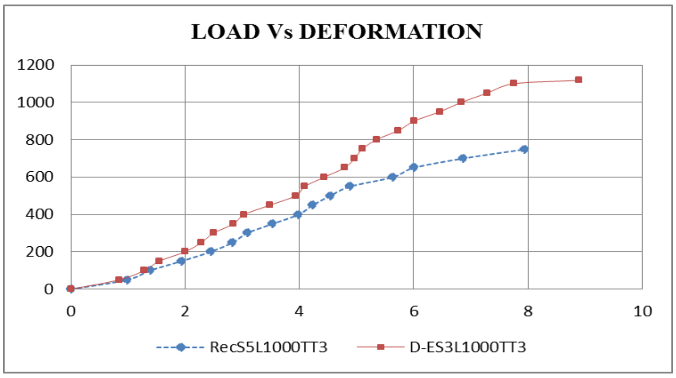

Figure 15 Axial load-deformation curves for RecS5L1000TT3 and D-ES5L1000TT3

Table 5 Deflection ductility and Energy ductility for tested Columns

Specimen designation	Load (KN)	Deflection ductility	Energy ductility
RecS3L600TT0	771	1.131	1.187
RecS4L800TT0	684	1.065	1.065
RecS5L1000TT0	588	1.016	1.046
D-ES3L600TT0	964	1.471	1.205
D-ES4L800TT0	855	1.114	1.069
D-ES5L1000TT0	735	1.006	1.016
RecS3L600TT3	927	2.007	2.06
RecS4L800TT3	842	1.274	1.202
RecS5L1000TT3	749	1.05	1.036
D-ES3L600TT3	1383	1.959	2.305
D-ES4L800TT3	1257	1.608	1.572
D-ES5L1000TT3	1118	1.052	1.015

The ductility of the columns was calculated based on deflection and energy absorption. The deflection ductility was calculated as the ratio between the deflection at ultimate point to the deflection at yield point. The energy ductility was calculated as the ratio of cumulative energy absorption at ultimate point to the cumulative energy absorption at yield point.

The deflection ductility ($\Delta_{d)}$ is defined as,

$$\Delta_{d} = \delta_u/\delta_y$$

The energy ductility is defined as,

$$\Delta_e=\int\sigma_{ult}\, d\varepsilon \;/\; \int\sigma_{yield}\, d\varepsilon$$

Behaviors of slenderness ratio on ultimate stress for Rectangular and D-End RC columns

Slenderness ratio is depending on the influence of the ultimate stress. The ultimate stress increased as the slenderness ratio was decreased. The plain rectangular columns with slenderness ratios of 3 and 4 showed increase in ultimate stress by 23.74% and 14.04% over the columns having slenderness ratio of 5. The tubed rectangular columns showed higher levels of increase in ultimate stress than the columns without use of GFRP tubes. The tubed rectangular columns showed 16.83% and 18.76% over the columns having higher slenderness ratio of 5.

The plain D-End columns with slenderness ratios of 3 and 4 showed increases in the ultimate stresses by 23.755% and 14.04% over the columns having slenderness ratio of 5.the tubed D-End columns showed higher levels of increase in ultimate stress than the columns with use of GFRP tubes. The tubed D-End columns showed 19.16% and 11.06% over the columns having higher slenderness ratio of 5.

Behaviors of slenderness ratio on ultimate lateral strain for rectangular and D-End RC columns

The ultimate strain attained by the plain rectangular RC concrete columns was 48.56% and 30.64% for RecS3L600TT0 and RecS4L800TT0. The ultimate strain increased by 29.65% and 10.67% over the columns having higher slenderness ratio to the use of GFRP tubes.

The ultimate strain attained by the plain D-End RC column has 23.62% and 21.46% for D-ES3L600TT0 and D-ES4L800TT0. The ultimate strain increased by 8.33% and 5.38% over the columns having higher slenderness ratio to the use of GFRP tubes.

Conclusions

Based on the results obtained through the experimental investigation

1) The plain rectangular RC concrete column with slenderness ratio 4 and 3 are showed increase in ultimate stress by 23.74% and 14.04% over the columns having slenderness ratio of 5.
2) The plain D-End RC concrete column with slenderness ratio 4 and 3 are showed increase in ultimate stress by 23.755% and 14.04% over the columns having slenderness ratio of 5.
3) The comparison of rectangular and D-End plain RC concrete column the ultimate stress increases in D-End RC plain concrete column as 20.02%, 20%and 20% of slenderness ratio as 3, 4 and 5.
4) The tubed rectangular RC concrete column with slenderness ratio 4 and 3 are showed increase in ultimate stress by 16.83% and 18.76% over the columns having slenderness ratio of 5.
5) The tubed D-End RC concrete column with slenderness ratio 4 and 3 are showed increase in ultimate stress by 19.16% and 11.06% over the columns having slenderness ratio of 5.
6) The comparison of rectangular and D-End plain RC concrete column the ultimate stress increases in D-End RC plain concrete

column as 32.97%, 33.02%and 33.01% of slenderness ratio as 3, 4 and 5.

7) The D-End is more superior to rectangular column and the least value of slenderness ratio is more strength to the higher value of slenderness ratios.

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