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Experimental Investigation on Double Skin Composite Tubular Column

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Abstract: ***RCC and steel frames have been the most common frame systems for long times whereas composite frame system has also emerged as popular system for high rise buildings for few decades. Multi-storey composite frames are generally composed of structural steel members made composite with concrete. The use of Double-Skin Tubular columns in building construction has seen renaissance in recent years due to their numerous advantages, apart from its superior structural performance making a typical composite frame structure. Fiber reinforced polymers (FRPs), a relatively new class of non-corrosive, high-strength, lightweight material, have over the past approximately 15 years emerged as practical materials for a number of structural engineering applications. FRP has become one of the most popular methods in the repair and rehabilitation of concrete infrastructure due to its ease of application and the special physical characteristics. This paper focus to determine the compressive strength of columns in different type of specimens under Axial load.***
Keywords: Double Skin Tubular Columns, Concrete Filled Steel Tube.

I. INTRODUCTION

Concrete-filled steel tubes (CFST) are known as structural composite members, wherein the voids of steel tubes are filled with concrete to enhance stiffness and load-bearing capacity. The inter-boundary stresses of structural members are key to engineering advanced composites. Thus, the inherent engineering properties of such materials have earned them the global application as a state-of-the-art technique in the construction industry. In such a design pattern, structural members are combined, such as the case in concrete-filled steel tubes, to provide unprecedented structural properties as solutions to a focused situation. Concrete filled steel tubes have numerous benefits, several advantages over ordinary structural steel, and normal reinforced concrete applications. The infill of concrete is restrained by the steel tube, resulting in producing a tri-axial limit state of compression that up surges, which causes a hike in the strain and strength capacities of the infill of concrete. The concrete restrains the steel tubes from both global and local buckling. Consequently, the distortion capacity of a CFST compares favorably with those of hollow tubes. Further, the composited strength of both the concrete and steel offers outstanding compressive axial load and stiffness capacity. This makes the composite highly suitable for compressive structural applications, such as in columns. Concrete-filled steel tubes is also permitted a fast construction since the steel tube abolishes the formwork and reinforcement related to concrete infill and reinforced concrete construction, which is quickly filled and formed. The constituents of HPC contribute most efficiently to different structural requirements including strength, toughness, energy absorption capacity, durability, corrosion resistance, and damage tolerance when subjected to large deformations in structural members. RCC and steel frames have been the most common frame systems for long times whereas composite frame system has also emerged as popular system for high rise buildings for few decades. Multi-storey composite frames are generally composed of structural steel members made composite with concrete. The use of Double-Skin Tubular Beams and columns in building construction has seen renaissance in recent years due to their numerous advantages, apart from its superior structural performance making a typical composite frame structure.

A. Composite Columns

Composite columns of steel and concrete, especially in steel hollow sections filled with concrete, manifest a number of major architectural, structural and economic advantages, which are very much appreciated by modern designers and building engineers. They have been used in the structural buildings for quite a few decades, although their application has increased substantially in recent times. Some of these qualitative aspects leading to special preferences by the architects and structural people are listed below:

1) The concrete filling lends to the steel hollow sections a still higher rigidity and load bearing strength, so that the aesthetic slender columns can bear higher loads without any increase in their external dimensions. This can be further enhanced by means of reinforcing bars.
2) Steel allows a pretentious architectural design with various colorings. The painting costs as well as the costs for corrosion protection, eg. spray, paints, etc., are low due to small external surface area of the columns.

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3) There is seldom any problem with respect to the joints due to the highly developed assembly technique in structural engineering today. This permits prefabrication in workshop and a quick and dry assembly on site.

The composite column has higher ductility than the concrete column and connections may be constructed following the experience of steel constructions. The concrete filling not only leads to a bearing capacity which is much higher than that of steel columns but it also promotes resistance against fire.

As far as ductility and rotation capacity are concerned, concrete filled steel tubular columns show the best seismic behavior compared to other types of composite columns. The concrete is held by the steel profile and cannot split away even if the ultimate concrete strength is reached. The research work in the field of composite columns with concrete filled hollow sections has a long tradition in various parts of the world.

B. Glass Fiber Reinforced Polymer (GFRP) Sheet

Glass Fiber-reinforced polymer (GFRP)-concrete-steel double-skin tubular column (DSTC) is a new type of composite columns which consist of an outer FRP tube and an inner steel tube, with concrete filled in the space between the two tubes. The composite column can be optimally designed to obtain several advantages over existing forms of columns which include high ductility, excellent corrosion resistance, and what's more, lightweight due to the hollow cross-section.

To give full play to the lightweight potentials of DSTC, the most obvious approach is to reduce the weight of concrete sandwiched between the two tubes.

This paper thus develops a new type of DSTCs that is filled with full lightweight aggregate concrete (FLAC) and reports a systematic study on the compression performance of the FLAC-filled DSTCs at the first time. The results indicate that FLAC in between the FRP and steel tubes is effectively confined, resulting in an excellently ductile behavior in compression and that the ultimate strength and strain of FLAC filled DSTCs are increased by a factor of 1.7 and 3, respectively. The void ratio has limited effect on the ultimate strength of FLAC-filled DSTC while the impact on the ultimate strain is significant. On the basis of the stress-strain model developed for FRP-confined FLAC, a stress-strain model for FLAC-filled DSTC is proposed, which provides a satisfactory agreement with the experimental results.

C. Objectives

1) Comparative study of Double Skin Tubular Columns (DSTC) members with Reinforce Cement Concrete (RCC).
2) To determine the axial load capacity of the double skin composite tubular column with Glass Fiber Reinforced Polymer Sheet (GFRP) wrapping.
3) Also Comparative study on Double Skin Tubular Columns (DSTC) members with Concrete Filled Steel Tube (CFST).

II. LITERATURE REVIEW

1) Yingwu Zhou, Xiaoming Liu, Feng Xing, Dawang Li, Yaocheng Wang, Lili Sui.(2016). Behavior and modeling of FRP-concrete-steel double-skin tubular columns made of full lightweight aggregate concrete. In this paper, the behaviors of FLAC-filled DSTC under axial compression are experimentally studied.
2) Silvana De Nardin, Ana Lucia H. C. B Debs (2007). Axial load behavior of concrete-filled steel tubular columns. This paper reports and experimental study of concrete-filled steel tubular columns. Results showed that the ductility of high-strength concrete increases when confined by a steel tube, but the load-carrying capacity remains the same.
3) Pengfei Li, Tao Zhang, and Chengzhi Wang (2018). Behavior of Concrete-Filled Steel Tube Columns Subjected to Axial Compression. The behavior of concrete-filled steel tube (CFST) columns subjected to axial compression was experimentally investigated in this paper. In addition, a numerical comparison between the ultimate load and the theoretical value calculated from the relevant specifications shown that the ultimate load in generally considerably greater than the theoretical calculation results.
4) Zhong Tao, Lin-Hai Han, Xiao-Ling Zhao (2003). Behavior of concrete-filled double skin (CHS inner and CHS outer) steel tubular stub columns and beam-columns. In this a series of tests on concrete filled double skin steel tubular (CFDST) stub columns and beam-columns were carried out. Both outer and inner tubes were circular hollow sections (CHS). The main experimental parameters for stub columns were the diameter-to-thickness ratio and hollow section ratio, while those for beam-columns were slenderness ratio and load eccentricity.

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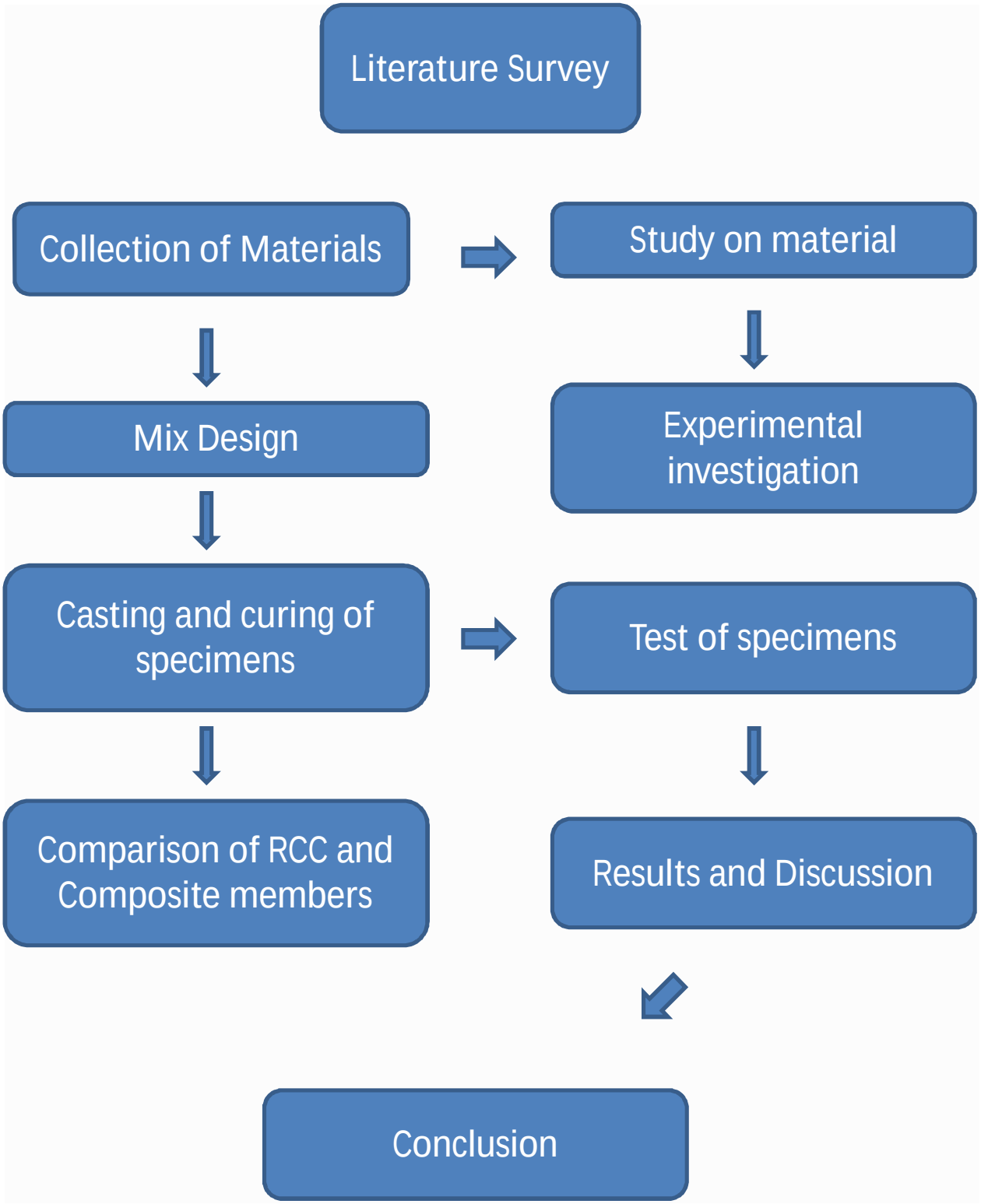
III. METHODOLOGY



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IV. DESIGN OF DOUBLE SKIN TUBULAR COLUMNS AND REINFORCED CONCRETE COLUMNS

A. Specification

Table: 4.1 Details of the Specimen

TYPE		SIZE (mm) (outer)	SIZE (mm) (inner)	LENGTH (mm)
Reinforced Concrete Column	RC 1	100 x 100	-	300
	RC 2			
	RC 3			
CFST Column	CFST 1	100 x 100	-	300
	CFST 2			
	CFST 3			
DSTC Column	DSTC 1	100 x 100	50 x 50	300
	DSTC 2			
	DSTC 3			
DSTC Column FRP wrapped	DSTC 1	100 x 100	50 x 50	300
	DSTC 2			
	DSTC 3			

B. Mix Design

Stipulations For Proportioning
Grade Designation: M25
Type of cement : PPC 43 conforming to IS1489 (Part 1)
Maximum nominal size of aggregate: 20mm
Minimum cement content : 300kg/m^3 (From Table 5&6 IS456:2000)
Maximum water cement ration: 0.5
Workability: 100mm (slump)
Exposure condition: severe (for reinforced concrete) (Table 3&5 of IS 456)
Method of concrete placing: pouring
Degree of supervision: Good
Type of aggregate: crushed angular aggregate
Maximum cement content : 450 kg/m^3
Chemical admixture type : Super-plasticizer conforming to IS 9103

C. Test Data For Materials

Specific gravity of cement : 3.14
Specific gravity of fine aggregate : 2.7
Specific gravity of coarse aggregate : 2.81
Specific gravity of Chemical admixture : 1.145
Water absorption

- Coarse aggregate : 0.5 percent
- Fine aggregate : 1.0 percent

Moisture Content of Aggregate
[As per IS 2386 (Part 3)]

- Coarse aggregate : Nil
- Fine aggregate : Nil

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1) Step 1: Target Strength For Mix Proportioning

f'ck = fck + 1.65 S

f'ck = fck + X whichever is higher.

Where,

f'ck = target average compressive strength at 28days,

fck = characteristic compressive strength at 28days,

S = standard deviation, and X = factor based on grade of concrete.

From IS 10262:2019, Table 2, standard deviation, S = 4 N/mm^2

Therefore, target strength using both equations,

f'ck = fck + 1.65 S = 25 + 1.65 x 4 = 31.60 N/mm^2

Or

f'ck = fck + 5.5 = 40 + 5.5 = 30.50 N/mm^2

The higher value is to be adopted.

Therefore, target strength will be 31.60 N/mm^2 as 31.60 N/mm^2 > 30.50 N/mm^2.

2) Step 2: Approximate Air Content

From IS 10262:2019, Table 3, the approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is 1.0 percent for 20mm nominal maximum size of aggregate.

3) Setp 3: Selection Of Water-Cement Ratio

From IS 10262:2019, Fig. 1, the free water-cement ratio required for the target strength of 31.60 N/mm^2 is 0.46 for OPC 43 grade curve. (For PPC, the strength corresponding to OPC 43 grade curve is assumed for the trail).

This is lower than the maximum value of 0.55 prescribed for 'severe' exposure for reinforced concrete as per Table 5 of IS 456:2000.

0.46 < 0.5, hence O.K.

4) Step 4: Selevtion Of Water Content

From IS 10262:2019, Table 4, water content = 186 kg (for 50 mm slump) for 20 mm aggregate.

Estimated water content for 100 mm slump = 186 + 6 x 186/100 = 197.16 kg

As super-plasticizer is used, the water content may be reduced. Based on trail data, the water content reduction of 23 percent is considered while using super-plasticizer at the rate 1.0 percent by weight of cement.

Hence the water content = 197.16 x 0.77 = 151.8 kg

5) Step 5: Calculation Of Cement Content

Water-cement ratio = 0.46

Cement content = Water Content / Water – cement ratio

= 151.8 / 0.46 = 330 kg/m^3

From Table 5 of IS 456:2000,

Minimum cement content for 'severe' exposure condition = 300 kg/m^3

Therefore, 330 kg/m^3 > 300 kg/m^3, Hence, O.K.

6) Step 6: Proportion Of Volume Of Coarse Aggregate And Fine Aggregate Content

From IS 10262:2019, Table 5, the proportionate volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 = 0.60. In the present case water-cement ratio is 0.46. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.04, the proportion of volume of coarse aggregate is increased by 0.01 (at the rate of -/+0.01 for every +/- 0.05 change in water-cement ratio).

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ration of 0.48 = 0.60 + 0.01 = 0.61.

Volume of fine aggregate content = 1 – 0.61 = 0.39

For pump able concrete these values should be reduced by 10 percent.

Therefore, volume of coarse aggregate = 0.39 x 0.9 = 0.351.

Volume of fine aggregate content = 1 – 0.351 = 0.649.

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7) Step 7: Mix Calculations

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = $1m^3$

b) Volume of entrapped air in wet concrete= 0.01 m^3

c) Volume of cement = Mass of cement / (Specific gravity of cement x 1000) = 330 / (3.14 x 1000) = 0.105 m^3

d) Volume of water = Mass of water / (Specific gravity of water x 1000) = 151.80 / (1000) = 0.152 m^3

e) Volume of chemical admixture = Mass of chemical admixture / (specific gravity of admixture x 1000) (super-plasticizer) (@1.0 % by of cementitious material) = 3.3 / (1.145 x 1000) = 0.0029m^3

f) Volume of all in aggregate = (a-b) – (c+d+e) = (1-0.01) – (0.105+0.152+0.0029) = 0.730 m^3

g) Mass of coarse aggregate = f x Volume of coarse aggregate x specific gravity of aggregate x 1000
= 0.730 x 0.351 x 2.81 x 1000 = 720.01 kg

h) Mass of fine aggregate = f x Volume of fine aggregate x specific gravity of fine aggregate x 1000
= 0.70 x 2.7 x 0.649 x 1000 = 1279.18 kg

8) Step 8: Mix Proportions

Cement : 330 kg/m^3
Water : 151.8 kg/m^3
Fine aggregate : 1279.18 kg/m^3
Coarse aggregate : 720.01 kg/m^3
Water-cement ratio : 0.46

Table: 4.2 Mix Ratio

Cement	FA	CA	W/C ratio
1	3.87	2.18	0.46

V. RESULTS AND DISCUSSION

A. Compressive Strength Test

In order to validate the basic mechanical concepts of CFST columns and DSTC columns, 12 specimens will be tested under axial loading by Universal Testing Machine. In that, 3 RC column with size 100mm x 100mm, 3 square CFST column of size 100mm x 100mm with thickness 2 mm, 3 square DSTC column of size 100mm x 100mm with thickness 2 mm in outer and 50mm x50mm with thickness 2mm, and 3 square DSTC column of size 100mm x 100mm and 50mm x 50mm with thickness 2mm will be tested. Load will be applied axially to the column at an increment of 5 KN. All specimens will be subjected to load up to failure. The load will be applied gradually till the ultimate load.

Compressive strength of the specimen will be calculated by dividing the maximum load carried by the specimen during the test with the average cross-sectional area.

B. Results Obtained by Calculations

IS 456-2000 is used for calculations of RC column and Euro Code 4 is used for Calculations of Concrete Filled Steel Tube (CFST) columns.

$$\lambda = le / b$$

$$e = (le/500) + (b/30)$$

$$Pu = 0.4\ fck\ Ac + (0.67\ fy\ As / 1000)$$

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Table: 5.1 Result obtained by calculation for RC Column

Type	Size (mm)	Area (mm^2)	Length (mm)	Asc (mm^2)	% of Steel	Concrete Grade	Load Pu in KN
Reinforced Concrete Column	100 x 100	10000	300	92	0.92	M25	100.031

EC 4 and NBR 8800 methods
For Square sections
Npl.Rd = As fy + Ac fck
$Ne = \pi^2 (El)_e / le^2$;
$(El)_e = E_s I_s + 0.6 E_c I_c$;
$\lambda = \sqrt{(NpLr) / Ne}$;
$X = 1 / Ø + \sqrt{Ø^2 - \lambda^2} \leq 1.0$;
$Ø = 0.5 [1 + \alpha (\lambda - 0.2) + \lambda^2]$ $\alpha = 0.21$ (Curve a)
$N_{RD} = X N_{pl.Rd}$
$E_c = 22000. [(f_{ck} / 10)^{0.3}]$ to EC 4 and $E_c = 4760 \sqrt{f_{ck}}$ to NBR 8000 – (fck and E_C in MPa)

Table: 5.2 Result obtained by calculation for CFST Column

Type	Size (mm)	Length (mm)	Ac (mm^2)	As (mm^2)	Ic (mm^4)	Is (mm^4)	Npl.Rd in KN	X	N_{RD} in KN
CFST Column	100 x 100	300	10000	784	7.077 x 10^6	1.255 x 10^6	380.30	0.72	274.272

Table 5.3 Comparative Test results on RCC, Concrete Filled Steel Tube (CFST) and Double Skin Tubular Column Specimen (DSTC)

Type		Size (mm) (outer)	Size (mm) (inner)	Length	Grade of Steel	Concrete Grade	Load P in KN	Average Load in KN
Reinforced Concrete Column	RC 1	100 x 100	-	300	FE 500	M 25	145.80	157.02
	RC 2						170.35	
	RC 3						154.91	
CFST Column	CFST 1	100 x 100	-	300	FE 250	M 25	281.15	301.80
	CFST 2						305.34	
	CFST 3						318.91	
DSTC Column	DSTC 1	100 x 100	50 x 50	300	FE 250	M 25	309.25	303.24
	DSTC 2						298.14	
	DSTC 3						302.32	
DSTC Column (FRP wrapped)	DSTC 1	100 x 100	50 x 50	300	FE 250	M 25	132.10	135.65
	DSTC 2						138.54	
	DSTC 3						136.30	

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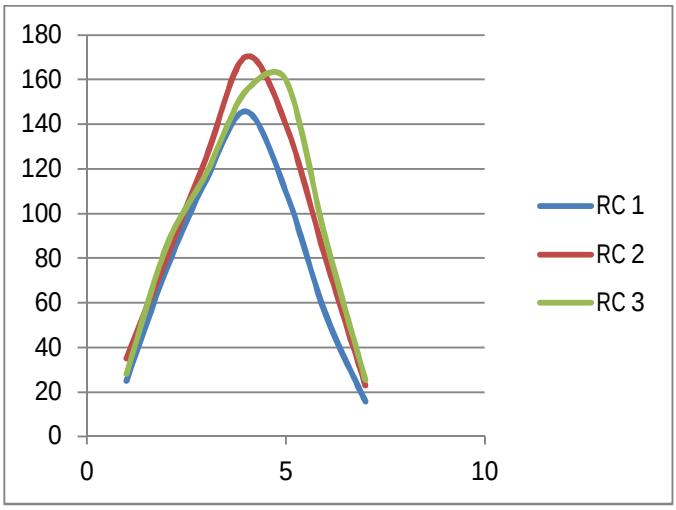

Fig5.5 Load (KN) vs Displacement (mm) Curve for RC Column

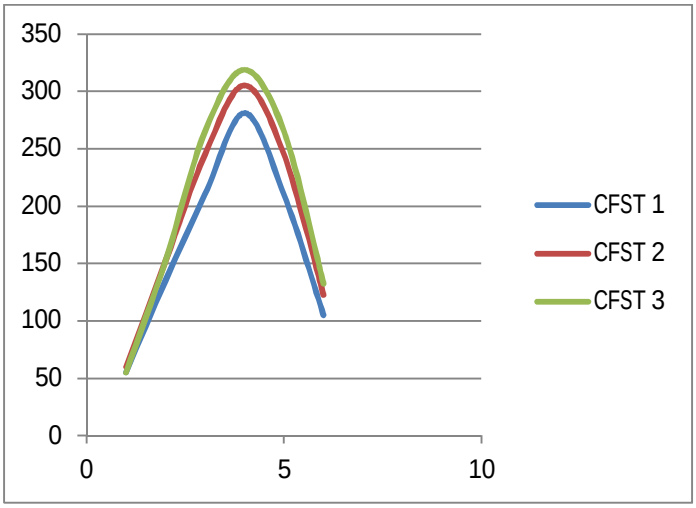

Fig5.6 Load (KN) vs Displacement (mm) Curve for CFST Column

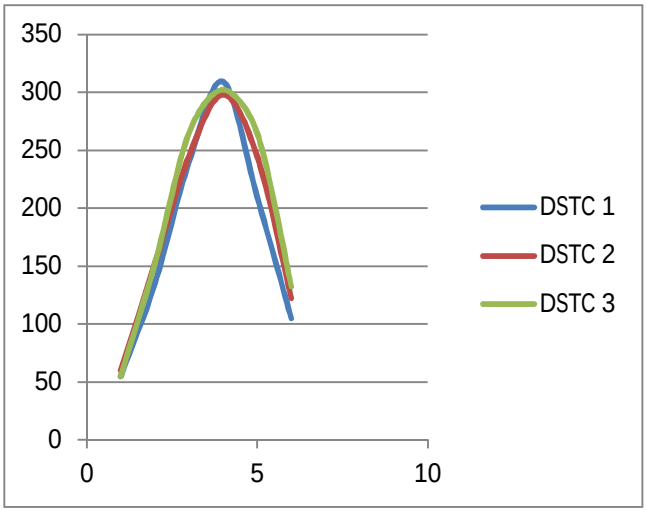

Fig5.7 Load (KN) vs Displacement (mm) Curve for DSTC Column (using Steel Tube)

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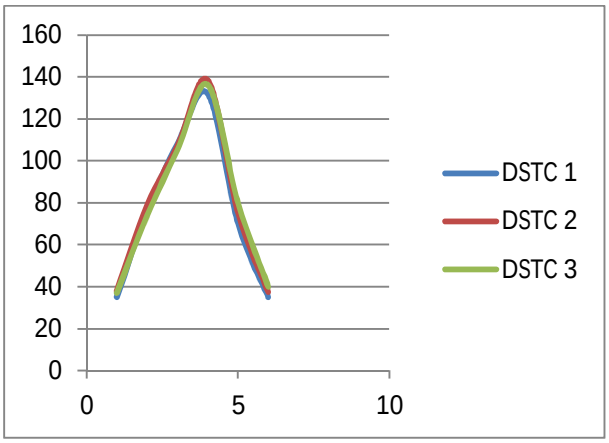

Fig5.8 Load (KN) vs Displacement (mm) Curve for DSTC Column (using FRP Wrapping)

VI. CONCLUSION

A. In this investigation, the properties of materials and concrete were found out. Then the mix design of M25 is casted as respective specimens (RCC, Concrete Filled Steel Tube (CFST) and Double Skin Tubular Columns (DSTC) and made for the strength test.

B. The Ultimate Axial Load of RCC is 157.02 KN, Concrete Filled Steel Tube (CFST) is 301.80 KN and Double Skin Tubular Columns (DSTC) (both inner and outer using Steel Tube) 303.24 KN

C. Then FRP sheet wrappings are done and the results are analyzed will be comparative to the RCC and Concrete Filled Steel Tube specimens. After that the failure modes, Ultimate Compressive Load in Column 135.65 KN.

D. This experiment is exploring the strength capability of Steel composite Column with FRP wrapping and the hollow structure will made economic to the structure and it will reduces the Self-weight of the concrete structure.

E. Also the Double Skin Tubular Columns (DSTC) manifest a number of major Architectural, Structural and Economic advantages, which are very much appreciated by Modern Designers and the Building Engineers.

REFERENCES

[1] Behavior and modeling of FRP-concrete-steel double-skin tubular columns made of full lightweight aggregate concrete. by, Yingwu Zhou, Xiaoming Liu, Feng Xing, Dawang Li, Yaocheng Wang, Lili Sui (20 Feb 2017)
[2] Compressive test of GFRP-recycled aggregate concrete-steel tubular long Columns, by Lan Zeng, Lijuan Li, Zhi Su, Feng Liu (07 May 2018)
[3] Nonlinear concrete model for double-skinned composite tubular columns, by Taek Hee Han, J. Michael Stallings, Young Jong Kang (30 June 2010)
[4] Effect of ultra-high strength steel on mitigation of non-ductile yielding of concrete-filled double-skin columns, by Mojtaba Farahi, Amin Heidarpour, Xiao-Ling Zhao, Riadh Al-Mahaidi (26 April 2017)
[5] Behavior of circular concrete-filled double steel tubular slender beam-columns including preload effects, by Mizan Ahmed, Quan Liang, Vipulkumar Ishvarbhai Patel, Muhammad Hadi (23 June 2020)
[6] Responses of concrete-filled FRP tubular and concrete-filled FRP-steel double skin tubular columns under horizontal impact, by Zhilin Chen, Jun Wang, Jiye Chen, Hota GangaRao, Ruifeng Liang, Weiqing Liu (23 June 2020)
[7] Behavior of concrete-filled double skin (CHS inner and CHS outer) steel tubular stub columns and beams-columns, by Zhong Tao, Lin-Hai Han, Xiao-Ling Zhao, (18 November 2003)
[8] Behavior of concrete-filled double skin rectangular steel tubular beam-columns, by Zhong Tao, Lin-Hai Han (02 Nov 2005)
[9] Axial Compressive Behavior of FRP-Concrete-Steel Double-Skin Tubular Columns Made of Normal and High-Strength Concrete, by Togay Ozbakkaloglu and Butje Louk Fanggi (07 June 2013)
[10] Axial Behavior of Square Reinforced Concrete Columns Strengthened with Lightweight Concrete Elements and Un-bonded GFRP wrapping, by Andrin Herwig and Masound Motavalli, (21 May 2012)
[11] FRP Wrapping for RC Columns with Varying Corner Radii, by Sushil S. Sharma, Urmil V. Dave, Himat Solanki (31 Jan 2013)
[12] Hybrid FRP-Concrete-Steel Tubular Columns: Concepts and Behavior, by J.G. Teng, T. Yu, Y.L. Wong, S.L. Dong (29 Aug 2006)
[13] Effect of Steel and Concrete Thickness on Shear Strength of Square Concrete Filled Double Skin Tubular Beams, by Najeeb Ullah, Muhammad Usman, Syed H, Farooq, Wahab Ashraf, Asad Hanif (16 Dec 2020)
[14] Nonlinear finite elements analysis of double skin composite columns subjected to axial loading, by Suleyman Ipek, Esra Mete Guneylsi (27 Jan 2020)
[15] Study of Strength and Behavior of Concrete Filled Double Skin Tubular Square Columns under Axial Compressive Loads, by S.Karthika, M.Ranjitham (05 May 2016)

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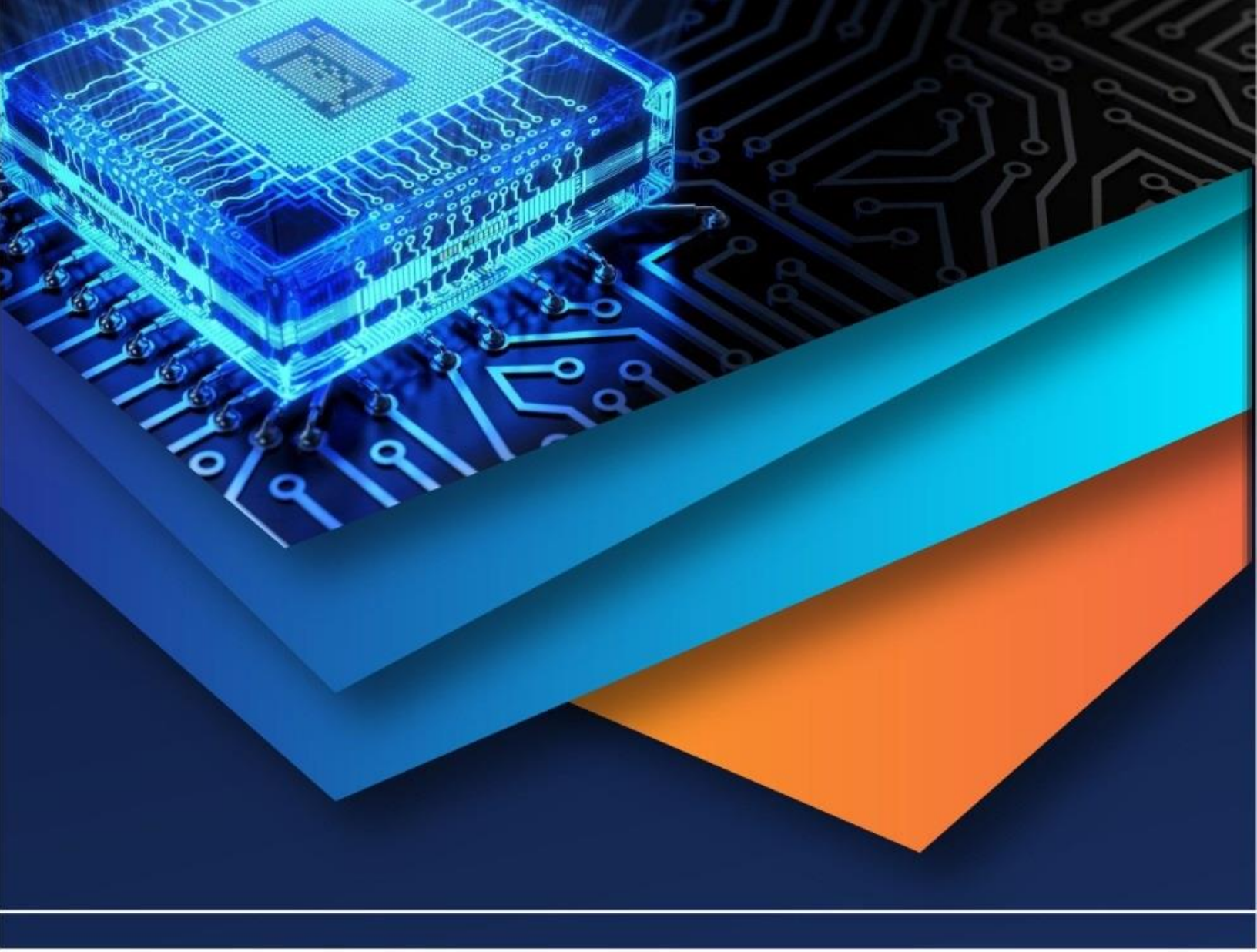

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