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Experimental Investigation of Double-skinned Composite Stub Column

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Abstract— a steel-concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled steel and is generally used as a load-bearing member in a composite framed structure. In a composite column both the steel and concrete would resist the external loading by interacting together by bond and friction. Supplementary reinforcement in the concrete encasement prevents excessive spalling of concrete both under normal load and fire conditions. The simplest form of concrete-filled steel tubes consist of a single hollow steel tube filled with concrete with or without internal steel reinforcing bars, while a double skin tubular column consist of two generally concentric tubes with the space between filled with concrete. DSTC have higher bending stiffness, lighter weight, higher fire resistance capacity, high strength-to-weight ratios and good corrosion resistance. Hence In the present study double skin tubular columns (DSTC) are considered in which the strength criteria and failure pattern were studied. In the present study the DSTC specimen is made of outer FRP tube and inner steel tube for which the hollowness ratio is varied from 0.4 to 0.8 and slenderness ratio from 2 - 3.3 are being considered. Conventional concrete and Geopolymer concrete are used as infilling material for which the test results are being compared.
Key words: DSTC, Geopolymer Concrete, FRP Tube, Hollowness Ratio

I. Introduction

The most commonly used materials in high rise construction are steel and concrete. Most of the tallest buildings in the world are made from steel due to its speed of construction and relatively light weight. Steel's light weight also reduces the size and cost of structural foundations. Steel columns in tall buildings can have a 25% larger cross-section and weigh 80% less than concrete columns. Due to the strength of the material, steel columns are capable of carrying large axial forces. The material properties of steel alloys can be adjusted to achieve stronger, tougher, and more durable steel. Steel is also capable of being erected in all types of, weather. Concrete has proven to be an equally viable material in the construction of large buildings. Concrete has shown to be an inexpensive material for large columns and shear walls. Due to the high compressive strength of concrete a column of moderate size can carry an extremely large axial load, especially with the development of high strength concrete. Composite construction is utilized to take advantage of both steel and concrete properties and is becoming more widespread. Concrete contributes its inherent mass, stiffness, damping, and economy, while steel supplies its speed of construction, strength, long-span capabilities, and light weight.

Hybrid FRP-concrete-steel double-skin tubular stub columns (referred to as hybrid DSTSCs) are a new form of hybrid columns. A hybrid DSTSC consists of a layer of concrete sandwiched between an outer tube and an inner tube made of steel, FRP or any other material. In the present study the FRP is used for outer tube and steel is used for inner tube. In a hybrid DSTSC, the FRP tube offers mechanical resistance primarily in the hoop direction to confine the concrete and to enhance the shear resistance of the member; the steel tube acts as the main longitudinal reinforcement and prevents the concrete from inward spalling. The two tubes (i.e., the FRP tube and the steel tube) may be concentrically placed to produce a section form more suitable for columns, or eccentrically placed to produce a section form more suitable for beams. Hybrid DSTSCs may be constructed in situ or precast, with the two tubes acting as the stay-in-place form. Shear connectors should be provided between the steel tube and the concrete, particularly in situations in which bending dominates; such shear connectors are generally not needed between the concrete and the FRP tube if the FRP tube has only a small longitudinal stiffness. This new form of hybrid members represents an innovation that combines the advantages of all three constituent materials and those of the structural form of DSTSCs to deliver excellent structural and durability performance.

II. Double Skinned Composite Stub Column

A. General

Double skin tubular columns are a variation of the conventional concrete filled steel tubes which have been a common form of columns. The simplest form of concrete-filled steel tubes consist of a single hollow steel tube filled with concrete with or without internal steel reinforcing bars, while a double skin tubular column consist of two generally concentric steel tubes with the space between filled with concrete. The inner void reduces the column weight without significantly affecting the flexural rigidity of the section and allows the easy passage of service ducts. When compared to ordinary concrete filled tube (CFT), they have higher bending stiffness, lighter weight, higher fire resistance capacity, high strength-to-weight ratios and good corrosion resistance. This double skinned member has the following forms,

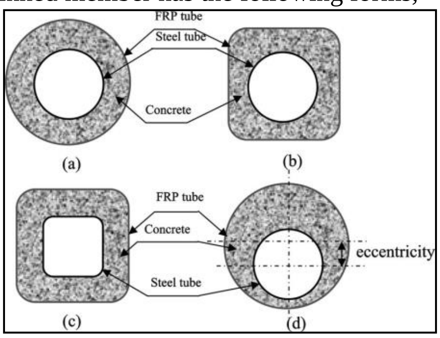

Fig. 1: This double skinned member

B. Advantages of DSTC

Compared to steel-concrete DSTC, the advantages of the new hybrid DSTC which is considered in the present study includes,

- A more ductile response of concrete as it is well confined by the FRP tube which does not buckle. The FRP tube is designed to have predominantly hoop fibre with its axial stiffness being nearly zero; by doing so, local buckling of the FRP tube due to axial compressive stresses, which is a commom problem for steel tubes, is unlikely to happen.
- No need for fire protection of the outer tube as the outer tube is required only as a form during construction and as confining device and additional shear reinforcement during earthquakes. The FRP tube with negligible axial stiffness contributes little to the load –carrying capacity of the member and is not expected to affect the structural resistance during a fire.
- No need for corrosion protection as the steel tube inside is well protected by the concrete and the FRP tube. Hence FRP has an excellent corrosion resistance.
- Better confinement of the concrete as a result of the increased rigidity of the inner tube. Ease for connection to beams due to the presence of the inner steel tube, which enables existing connection forms to be directly used.

C. Disadvantages of DSTC

Compared to the two primary modern structural materials, namely steel and concrete, FRP composites also have some disadvantages. These include their relatively high cost, linear-elastic-brittle stress- strain behaviour, low elastic modulus-to-strength ratio. And poor fire resistance.

III. METHODOLOGY

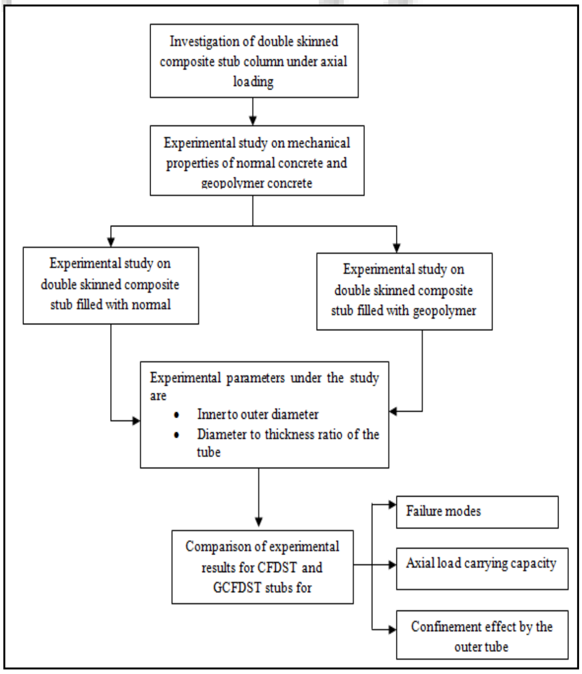

Fig. 2: Methodology adopted

In the present study, the hybrid double skinned tubular stub column is investigated for strength, stiffness and the failure modes. The Fibre Reinforced plastic (FRP) is used as outer tube and the steel is used for inner tube. The stub columns are in filled with normal concrete and geopolymer concrete and are tested for axial compressive forces and the results were compared. The following Fig.2 shows the methodology adopted.

IV. TEST SPECIMENS

A total of 12 double skinned stub column specimens were casted for compression test and cured. Out of 12 specimens, 6 DSTC specimens were prepared with plain cement concrete and remaining 6 DSTC specimens were prepared with geopolymer concrete. The geometric properties of outer FRP and inner steel tube section are shown in the figure below.

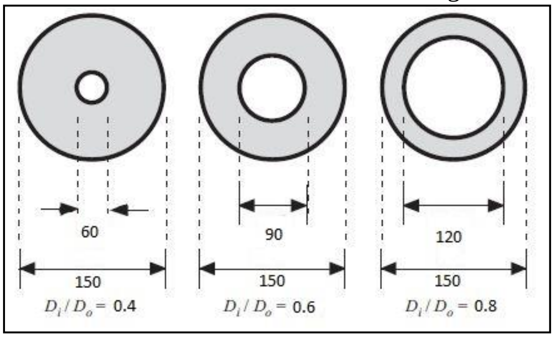

Fig. 3: Cross-section of the specimen

V. FABRICATION OF THE SPECIMEN

The effective length of the specimens are 300 mm and 500 mm, and the external diameter is 150 mm and internal diameters are 60 mm, 90mm and 120mm respectively. Mild steel, FRP, normal concrete of strength 40Mpa and geopolymer concrete of strength 27 MPa are used for the specimens. The specimens can be separated into 3 series: DS-N-60-300, DS-G-60-300, DS-N-60-500, DS-G-60-500, DS-G-90-300, DS-N-90-300, DS-N-90-500, DS-G-90-500, DS-N-120-300, DS-G-120-300, DS-N-120-500, DS-G-120-500. DS is for the double skinned columns, N stands for normal concrete sample and G stands for geopolymer concrete. Here the prime factor of variation is the hollowness ratio which has values from 0.4 to 0.8 respectively.

A. Fabrication of FRP tube

After the mould is made ready for casting the concrete is poured in a PVC pipe mould. After this process the PVC mould is removed the next day and the outer surface is made to cure. The Epoxy resin and a hardener are mixed together and applied on the outer surface of the concrete and the FRP tape is wound tightly in 2 layers. Then a coat of the mix is applied on the outer surface of the wounded sample and when it hardens it forms a FRP tube.

B. Plain Cement Concrete

The required proportion of ingredients as obtained in the design mix was weighed separately. Then, gravel was spread in an even layer in the mixing pan followed by cement and sand respectively. Required amount of water as calculated by the design is mixed uniformly and then the fresh normal concrete is prepared.

C. Casting of geopolymer concrete

The required proportions of ingredients as obtained in the design mix were weighed separately. Then, gravel of 20mm and 14mm was spread in an even layer in the mixing pan followed by fly ash and sodium silicate & NaOH solution respectively. In order to increase the workability of the concrete required amount of super plasticizer as calculated by the design is mixed uniformly and fresh geopolymer concrete is prepared.

Fig. 4: Casting and forming of FRP tube

VI. EXPERIMENTAL SET-UP AND INSTRUMENTATION

For each hybrid DSTC specimen, three bi-directional strain rosettes (gauge length = 10 mm) have to be installed at the mid-height of the steel tube and four bi-directional strain rosettes (gauge length = 20mm) have to be installed at the mid-height of the FRP tube (Fig.5). In addition, three dial gauges were used to obtain the axial deformation of the middle region for each specimen. All test data, including the strains, loads, and displacements, were recorded simultaneously by a data logger.

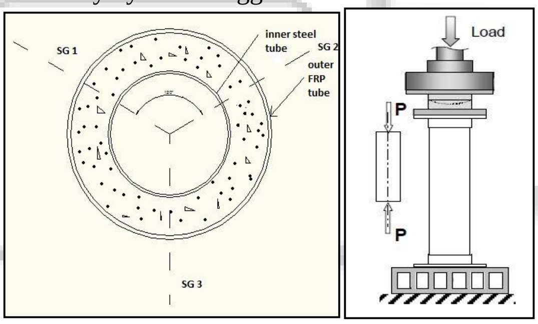

Fig. 5: Test set up

Test setup consist of three strain gauges and three dial gauges. The figure above shows the test setup.

VII. RESULT AND DISCUSSION

Specimen	Max load KN	Max deflection mm	Max Axial Strain	% Increase in strength
DS-N-60-300	324	1.2	0.0039	34.25 %
DS-G-60-300	435	1.8	0.0256	
DS-N-60-500	263	2.5	0.028	34.98 %
DS-G-60-500	355	3.9	0.0235	
DS-N-90-300	315	11.7	0.0301	51.11 %
DS-G-90-300	476	4.2	0.022	
DS-N-90-500	418	5.1	0.0242	8.13 %
DS-G-90-500	452	4.8	0.022	
DS-N-120-300	287	6.7	0.0291	4.52 %
DS-G-120-300	300	3.9	0.0254	
DS-N-120-500	253	3	0.0234	59.6 %
DS-G-120-500	404	1.8	0.0256	

Table 1: Results

From the experimental results, the above tabulated results were obtained. Fig.6-Fig.11 represents the load vs deflection curves for various specimens. The deflection of all the composite columns increased linearly with the applied load upto the yield point. Beyond that the DSTC showed a decrease in the deflection which was considered as the ultimate load of the specimen.

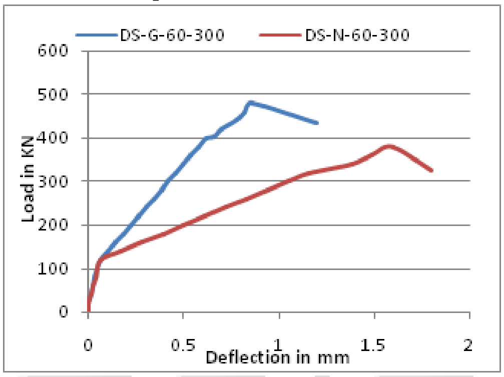

Fig. 6: Load vs Deflection curves for 60mm dia DSTC and 300 mm length

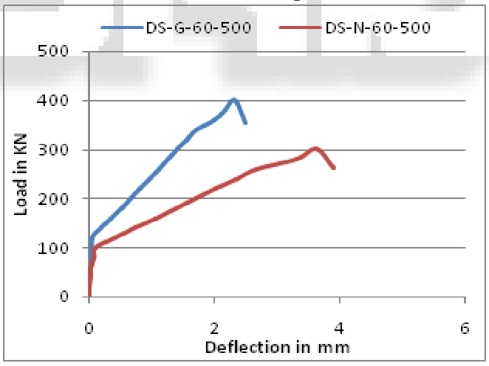

Fig. 7: Load vs Deflection curves for 60mm dia DSTC and 500 mm length

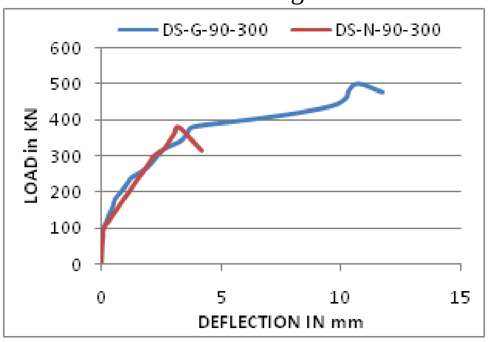

Fig. 8: Load vs Deflection curves for 90mm dia DSTC and 300 mm length

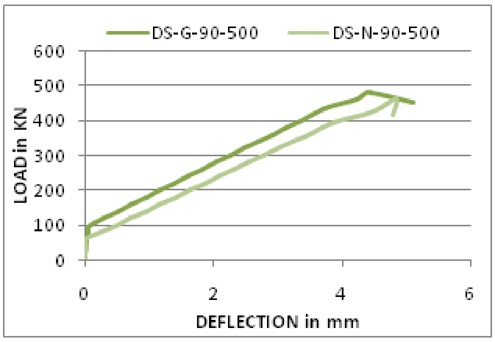

Fig. 9: Load vs Deflection curves for 90mm dia DSTC and 500 mm length

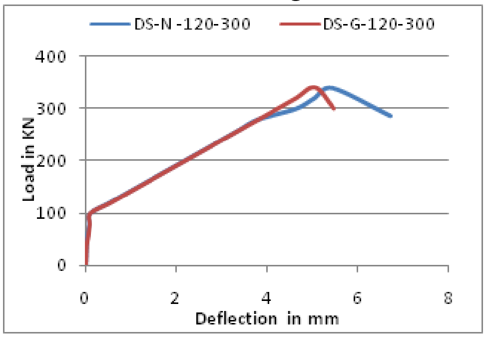

Fig. 10: Load vs Deflection curves for 120mm dia DSTC and 300 mm length

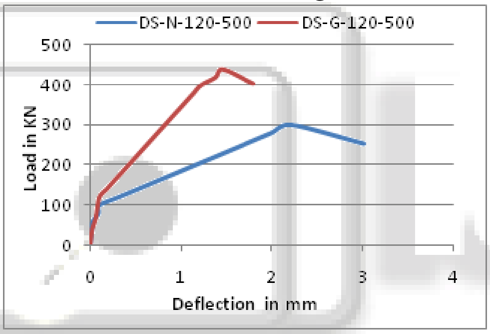

Fig. 11: Load vs Deflection curves for 120mm dia DSTC and 500 mm length

VIII. CONCLUSION

In the present study, the testing of the specimen were conducted and the behavior of double skinned composite stub columns from the study is noted as follows,

- For the double skinned composite stub column, in-filled with GPC shows higher percentage of increase in strength than conventional concrete specimen.
- The percentage increase in strength is from 4.52 % to 59.16 %.
- The load versus deflection curve was seen to be greater for geopolymer concrete than conventional concrete.
- Due to increased confinement effect the inner steel tube did not undergo large amount of buckling which kept the in-filled concrete to delay in failing.
- The failure of the specimen is occurred only due to rupture of FRP tubes.

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