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AXIAL COMPRESSION BEHAVIOUR OF COMPOSITE CONCRETE COLUMNS ENCASED WITH STEEL AND FRP TUBES

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Abstract: In recent years, researchers have paid attention to understanding the effectiveness of FRP materials in the construction field. However, to clear knowledge gap of understand the behaviour and effectiveness of FRP material under concrete filled columns under compressive loading. This study presents an investigation on the behavior of concrete filled tubular columns (CFT) using the finite element software ABAQUS. The comparison of steel infill columns and FRP infill columns under the axial compression is done by their stress strain curve. The steel tube or FRP tube provides lateral confinement to the concrete core which results in an increased concrete compressive strength and deformation capacity. CFT decrease the inward local buckling occur in the hollow tubular sections. The axial load bearing capacity of CFT is higher than the summation of axial load-bearing capacities of the concrete core and the hollow steel tube.

***Index Terms* – FRP, ABAQUS, concrete fill tubes, axial compression.**

I. INTRODUCTION:

Concrete filled tube (CFT) comprise advantage of both confining material and infill material such as concrete. The hallow tubes are filled either with plain or reinforced concrete. It is main used for high rise building. There are more number of benefit in structural systems both in performance and easy construction pattern. Problems of buckling is constrained or delayed because of the presence of concrete presence as infill, the performance of concrete is increased from confinement effect from the outer steel cover. Concrete infill steel tubes in high raise structures has seen its raise nowadays, mainly due to its easy executing procedure, apart from its superior structural performance.

High strength concrete-filled FRP tubular (CFFT) columns have several properties, such as high stiffness, compression resistance, ductility and impermeability. This make them a sustainable choice for high rise buildings, earthquake resistant structures. The high bearing capacity of a compact cross-section allows for greater floor space, despite the slenderness of the columns. The ductility of concrete is improved by the external casing of fibre in the underwater construction due to the resistance of permeability. Local buckling of the tube is restricted by the concrete fill core. The even filling of concrete in the tube is achieved by the self-compacting concrete and external vibrator. The failure response of concrete in the core is transmitted through the tube. During the construction of underwater large trenches are used for casting the piers, the removing of framework is difficult. The concrete is permeable in nature to protect the reinforcement inside the concrete FRP tubes are externally cased.

II Advantages:

- The strength of concrete is increased due to confining effect provided from the FRP tubes.
- Strength deterioration is not "*very severe*", since the concrete spalling is prevented by the tubes.
- *Dry shrinkage and creep* of concrete are much smaller than the ordinary reinforced concrete.
- *Form works and reinforced bars* are omitted, which leads to saving of manpower, construction cost and time.
- The *high bearing capacity* for a compact cross-section allows for greater story space and increase the floor area
- *local buckling* and ductility of the tube is restricted by the core concrete.

III Finite Element Modeling Details

3.1 Materials

Three main types of materials are considered in the proposed Finite Element modeling; a nonlinear compression and tension concrete infill, elasto-plastic confining steel tube and fibre reinforced polymer tubes. The concrete infill is modeled using solid elements whereas the steel tube is modeled using shell elements.

3.1.1 Confined Concrete

M30 grade of self-compacting concrete is used to infill the tube. The Materials used in SCC are the same as in conventional concrete except that an excess of fine material and chemical admixtures are used. Polycarboxylate ether based super plasticizer of Auro cast 100 will be required because slight variations in the quantity of water and the powdered content of silica fume is added by 20%.

In order to define the concrete behavior in the FE model, a stress-strain diagram for the confined concrete should be established first. The equivalent stress–strain diagram for confined concrete under compressive loading as shown in Figure is used in the proposed FE model.

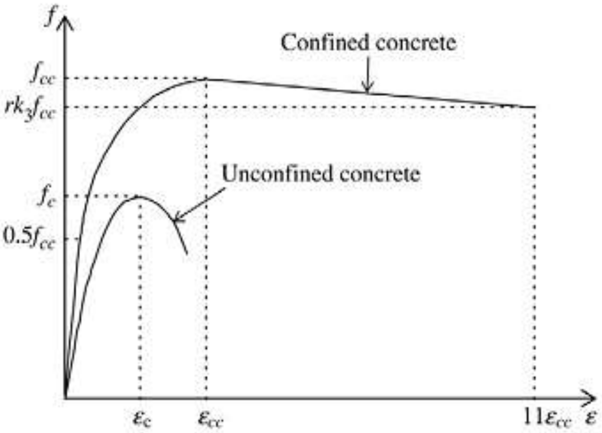


Figure 1: stress–strain diagram for unconfined and confined concrete uniaxially loaded

The concrete material behavior can then be defined in ABAQUS by defining the following three main sections:

- General: In this section the concrete density is required to be defined. From the tested concrete cubes the average density of concrete was 2.45x 10^{-6} Kg/mm^3. Note that this section is not needed if the standard analysis is used, but for our explicit model it is essential.
- Elastic: the linear segment of the confined concrete's stress-strain curve is defined in this section. The Young's modulus of confined concrete as 42304.2 MPa and the confined concrete's Poisson's ratio as 0.2 are defined in this part.
- Plastic: There are several material definition algorithms provided by ABAQUS for the nonlinear behavior of concrete materials. The damage Plasticity model is utilized in this study. The parameters defined in this section are shown in Table. A detailed description of the function of each of these parameters is defined in ABAQUS help as:

Table 1: parameters of concrete:

Dilation Angle	Eccentricity	$\frac{\sigma bo}{\sigma co}$	K_c	Viscocity Parameter
80°	1	1.12	0	0

3.1.2 Steel Tube

The elasto-plastic stress-strain diagram for the steel tube is utilized to define the steel in ABAQUS. It is mandatory to define three main segments for the ABAQUS to model the steel behavior which are:

- General: In this section the steel density is necessary to be defined. From the tested tubes the average density of steel was7.85 x 10^{-6} Kg/mm^3. Note that this section is not needed if the standard analysis is used, but for our explicit model it is essential.
- Elastic: The linear segment of the steel's stress-strain curve is defined in this section. The Young's modulus of steel is 2 x 10^5 MPa and its Poisson's ratio as 0.3 are defined in this part.
- Plastic: The nonlinear part of the stress-strain curve is defined in this section. $\varepsilon_{pl} = \varepsilon_{total} - (\sigma / E)$

Where the values of the stress taken after the yield point of the steel. The true stress can be calculated using:

$$\varepsilon_{true} = \varepsilon_{eng}\ (1+ \varepsilon_{pl\ eng})$$

While the true plastic strain can be calculated using:

$$\varepsilon_{pl\ true} = \ln(1+ \varepsilon_{pl\ eng})$$

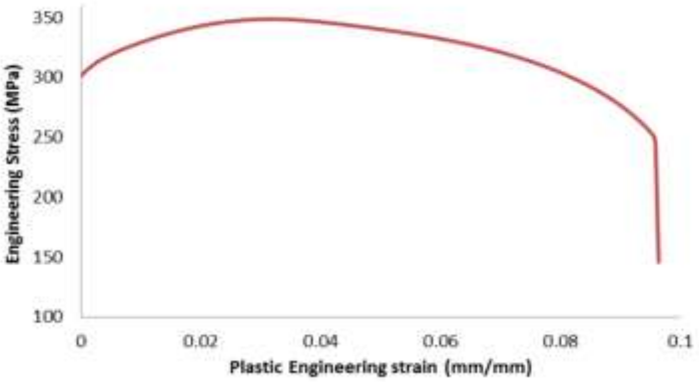


Figure 2: Plastic engineering strain from coupon test.

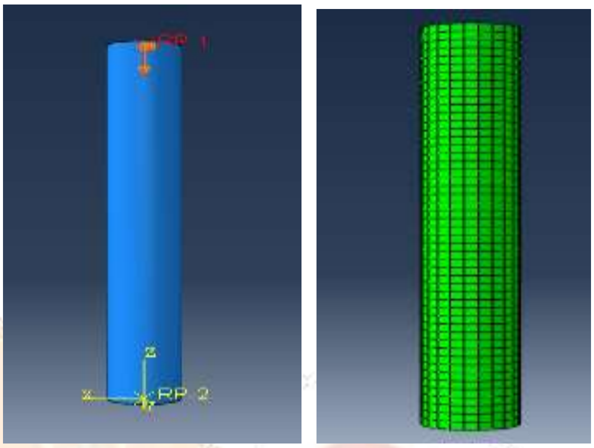
Keep in mind that the ABAQUS does not accept any decreasing set of data, thus the definition of these curves end around the ultimate stress limit state. Thus, the data post ultimate true stress is discarded.

3.1.3 Fiber-reinforced polymer (FRP) tubes:

Fiber-reinforced polymer (FRP) composite materials have developed into economically and structurally viable construction materials for buildings and bridges over the last 20 years. FRP composite materials used in structural engineering typically consist of glass, carbon, or aramid fibers encased in a matrix of epoxy, polyester, vinyl ester, or phenolic thermosetting resins that have fiber concentrations greater than 30% by volume. Two most widely used reinforcements in FRP are carbon fiber and glass fiber. Carbon fiber reinforced polymer (CFRP) composites are much stiffer than glass fiber reinforced polymer (GFRP) composites, but CFRP composites are also more expensive. The material properties are taken from the manufacturing company's manual.

3.2 Parts

The proposed FE model consists of two main parts; steel tube or FRP tube and concrete infill. Each part is meshed separately after assigning the corresponding section in which the concrete solid sections while the steel is a shell-based element. Note that the mesh of the steel section is preferred to be finer than the concrete for analysis.



(a) (b)

Figure3: part and meshed section respectively

3.3 Interaction

Interaction properties were defined in this model: *concrete-steel*. The first is used between the concrete solid and the steel tube. The tangential behavior is defined as penalty with a friction coefficient 0.3.

3.4 Boundary conditions and Loadings

Bottom end of the column is fixed in all directions that is Δx=0, Δy=0, Δz=0. Top surface of the column is restrained in X and Y-direction (Δx=0, Δy=0) and allowing displacement in Z-direction. A fixed supports is assumed in the proposed Finite Element modeling using ABAQUS/Explicit time step. The specimen is loaded by applying an axial displacement of 20mm vertically downwards at one end and other end is consider as resistance tor rotation and translation.

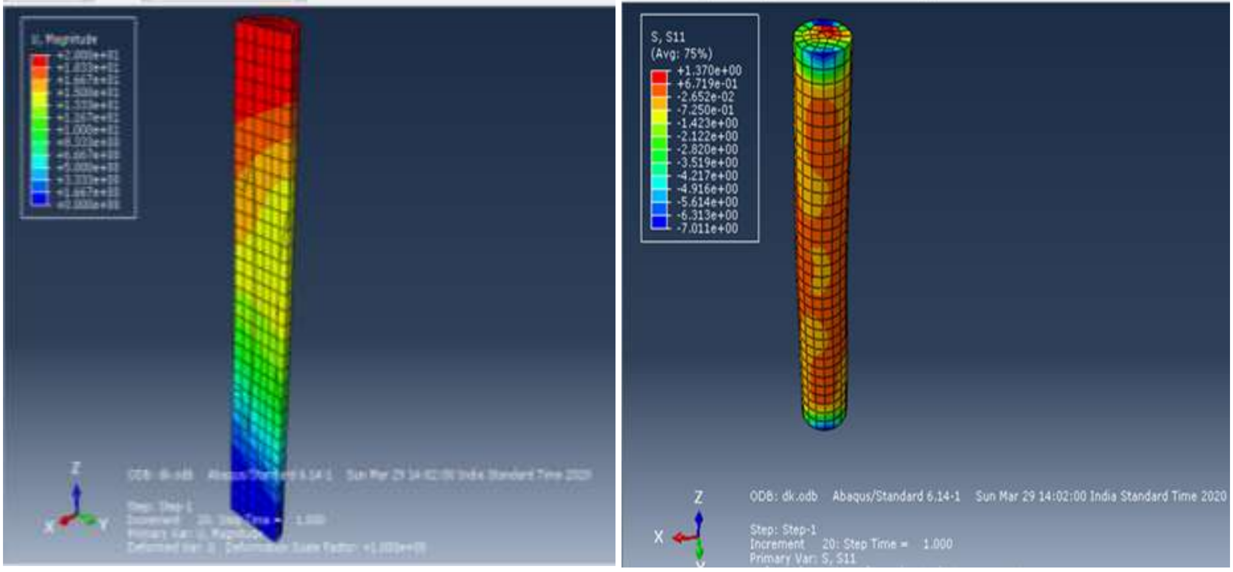
IVResults and Discussion:

The results obtained from the previously described testing program are used to verify the finite elements model of this study. The main aspects of the model's results is to determine the modes of failure, axial load-shortening results, and the stress-strain diagram of the column.

4.1 failure modes:

4.1.1 failure mode of concrete:

Unconfined concrete column fails through crushing. The cracks in columns is developed in concrete columns visible in the figure4 shown below. The spalling of concrete in the confined column is prevented by the encased tubes. The first crack is developed in the mid-section due to buckling of columns.

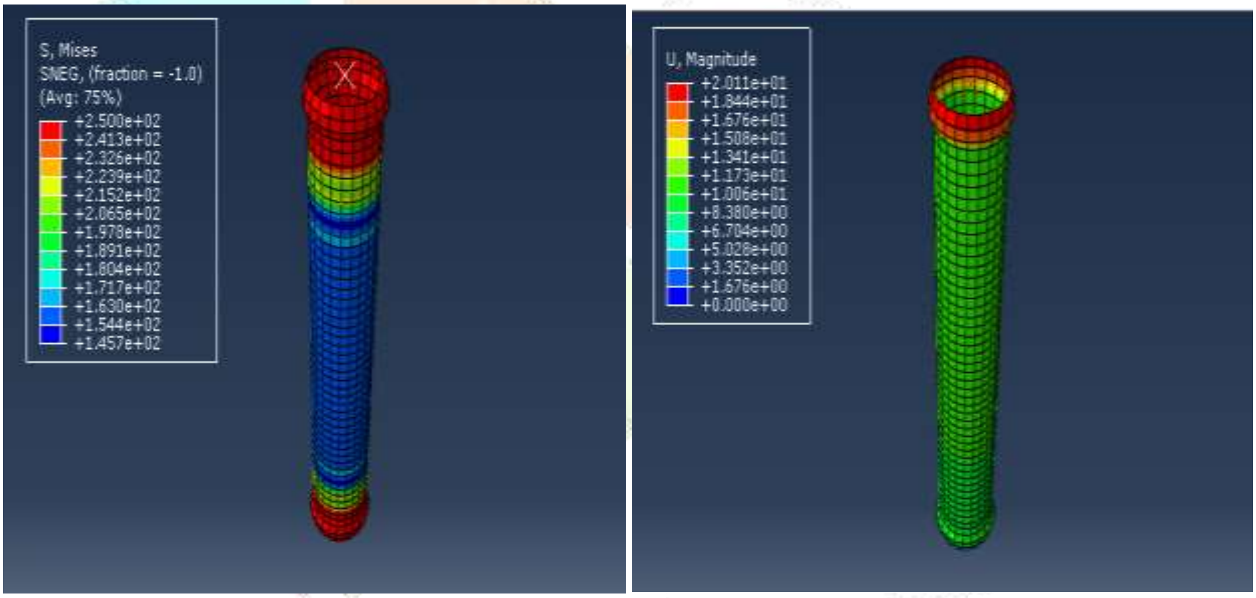


(a) (b)

Figure 4: Deformation and Stress diagram of concrete column respectively.

4.1.2 Failure mode of hollow tube:

The failure modes observed in the Finite Element analysis of the steel tube column is locally buckled at the ends. High amount of stress is developed at the end compare to the mid-section. From the abaqus analysis the tube at the mid portion are stress equally but the ends are highly buckled.

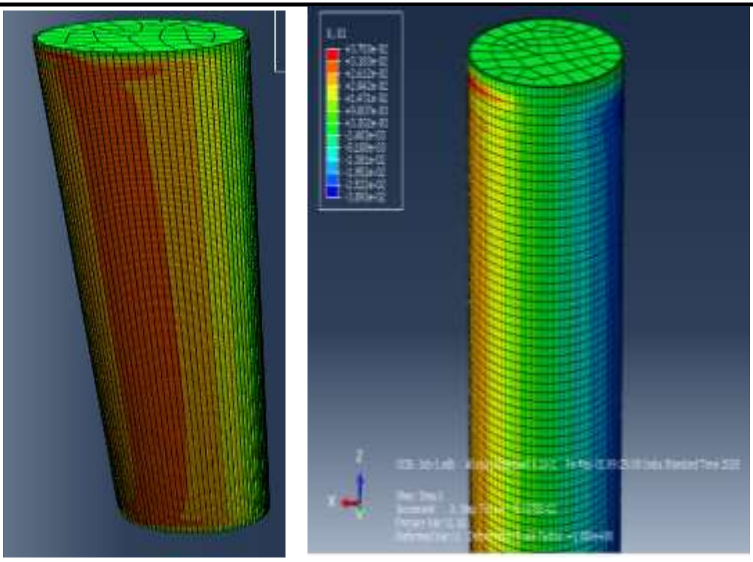


(a) (b)

Figure 5: Deformation and Stress diagram of hollow FRP column respectively.

4.1.3Failure mode of infill columns:

The local buckling or the hollow section is rectified by in-filling the concrete. It also increase the axial strength on compression. The mode of failure is by buckling in the steel tube and blasting failure in the FRP tube. The stress is developed in the one side of tube due to buckling of the columns. Fig.5 shows the failure by buckling of the columns by the lateral strain of the column.

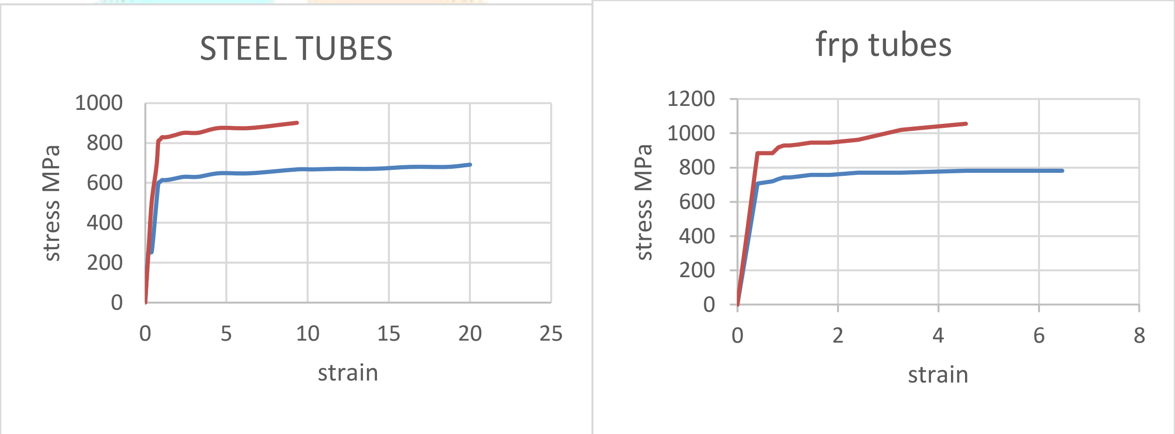


(a) (b)

Figure 6: failure mode of concrete filled tubes

4.2 Stress strain curve of concrete:

The deflection at various stages of loading are obtained from non-linear analysis. Based on the obtained results, load-deflection curve is plotted for the columns. Fig 7(a) shows the Steel tube has increases the strength of columns after filling the concrete in the tubes. Likewise FRP also increases the stress stress value.



(a) (b)

Figure 7: stress strain graph of steel and FRP tubes respectively

4.3 Load carrying capacity

The ultimate load carrying capacity of columns are analyzed by finite element model using the abaqus software. Fig 8 shows the load carrying capacity of the various columns.

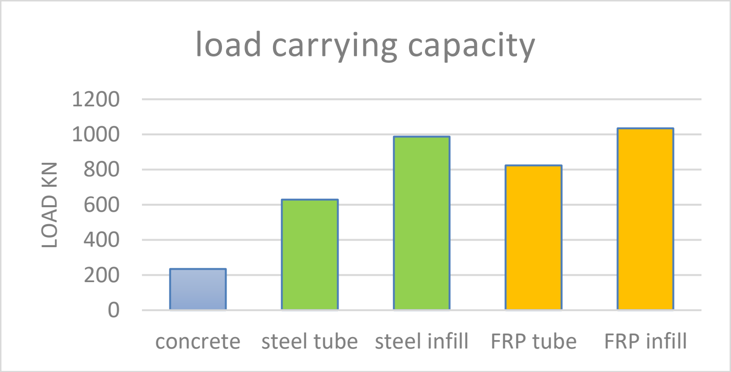


Figure 8 : load bearing capacity of columns

V Conclusion:

1. The strength of hollow column is less than concrete filled column. The hollow column fails due to inward buckling at lower load. Where as in concrete filled steel tube, concrete try to bulge and steel tube try to buckle

therefore due this opposite forces failure takes place after a long time results in increasing the capacity of column.

2. Hollow and concrete-filled FRP tubular members are extensively used in the construction industries due to their excellent material and geometric properties.
3. The hollow steel tube strength increased by 36.37% and FRP tube increased by 20.38% after filled by concrete. Steel columns increase the strength higher than FRP columns.

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