Second International Conference on Nexgen Technologies
Sengunthar Engineering College, Tiruchengode, Namakkal Dist. Tamilnadu (India)
8th - 9th March 2019 www.conferenceworld.in ISBN : 978-93-87793-75-0

NUMERICAL STUDY ON CONCRETE-FILLED STEEL TUBULAR STUB COLUMNS WITH INNER FRP TUBE

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ABSTRACT

An numerical study into the axial compressive behaviour of concrete-filled circular steel tubular stub columns with internal fibre reinforced polymer(FRP) tubes is presented in this paper. In this paper the finite element analysis software ABAQUS 6.14 is used for numerical study. An axial loaded column of length 820mm and diameter of 273mm is taken for finite element study. The steel tube and FRP tube is created as shell element whereas the concrete is created as solid. The produced finite element analysis result is verified with experimental result done by previous researcher Y. L. Long . It shows that the finite element results are in good agreement with the experimental data.

Keywords- Column, finite element analysis, CFST, FRP tube, concrete damage plasticity model

I. INTRODUCTION

The concrete filled steel tubular column is widely used in high rise buildings and long span bridges due to their high strength and ductility. The mechanical performance of circular concrete- filled steel tubular (CFST) column are demonstrated experimenally [1-5]. In these studies, it was shown the confinement to the concrete in circular CFST column brings substantial benefit in terms of load- bearing capacity. [6] deals with elasto-plastic analysis of circular concrete-filled steel tube stub columns. [7] gives a detailed study about finite element modeling for CFST columns with rubberized concrete. [7,8,9] presented paper on modeling of concrete and steel tube in ABAQUS software.

In recent years, the strength of steel tube confined square column is improved by fibre reinforce polymer (FRP) wrapping [10]. The structural performance of circular CFST column is enhanced by using fibre reinforce polymer (FRP) jackets[11-17]. It provides additional confinement to the concrete and delaying the occurrence of local buckling of steel tube. However, the external FRP jackets may not be ideally suited for building construction due to limitations on their fire resistance. Therefore Y. L. Long proposed a new type of circular CFST column with an inner FRP tube[18]. Such circular CFST column with an inner FRP tube is modeled in ABAQUS. Fig 1 shows Circular CFST column with an inner FRP tube

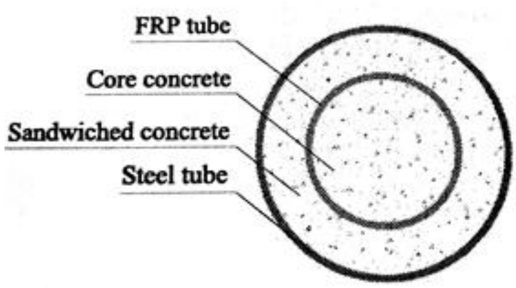

Fig. 1Circular CFST column with an inner FRP tube

II. Finite Element Analysis

In this paper, the general-purpose finite element program ABAQUS version 6.14 was used to study the behavior of concrete filled steel tubular columns. The various steps in Finite element analysis is discussed below:

2.1 Part Module

This is the first step in Finite Element analysis. In this step the various parts of CFST columns like outer steel tube , inner FRP tube , concrete between steel tube and FRP tube and concrete core are created individually. The created column has a diameter of steel tube and FRP tube is 273mm and 100mm respectively and length of 820mm. The thickness of steel tube and FRP tube are 61.mm and 2mm respectively.

2.2 Property Module

Under axial compression, the concrete core expands laterally and is confined by the steel tube. This confinement is passive in nature, and can increase the strength and ductility of concrete. This mechanism is well understood and is often referred to as "composite action" between the steel tube and concrete (Han et al., 2007 [5]). It is believed that the confined concrete is in a tri-axial stress state and the steel is in a biaxial state after interaction between the two components occurs. Thus concrete damage plasticity and steel tube constitutive model is used for concrete and steel material modeling respectively.

1.2.1 Concrete Damage Plasticity Model

The concrete damaged plasticity model available in ABAQUS was used for modeling concrete. The concrete damage plasticity is providing uni-axial stress strain for concrete unconfined, uni-axial, compressive strength and predicting confinement using damage plasticity model. The default values for various damage plasticity parameters like dilation angle(φ), eccentricity(e), ratio of compressive strength under biaxial loading to uniaxial loading( ), ratio of the second stress invariant on the tensile meridian to that on the compressive meridian( ) and viscous parameter are ,0.1, 1.16,0.667 and 0.1 respectively.

ISBN : 978-93-87793-75-0

1.2.2 FRP Tube Model

The elastic modulus, ultimate tensile stress and ultimate rupture strain for FRP are 87GPa, 2714Mpa and 0.0312 respectively are assigned to FRP tube.

1.2.3 Steel Tube Constitutive Model

In this method the response of the steel material simulation is established by using a multi linear stress-strain curve. By using the Equation ($= \frac{f_y}{\epsilon_y}$)the linear elastic part can be determined.

In this study modulus of elasticity of steel ( ) is assumed to be equal to 200000Mpa. Fig 2 shows the stress strain curve of steel tube

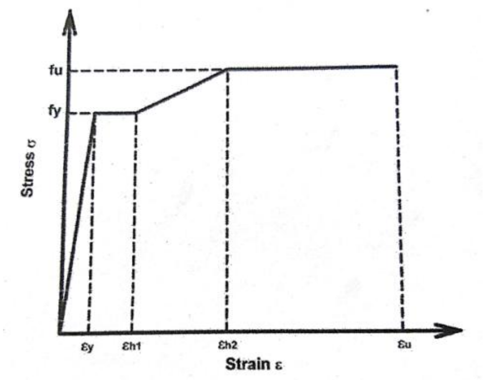

Fig. 2 Steel tube stress- strain curve

The strain (at the beginning of steel tube hardening is calculated using,

$$= \frac{f_y + 7100) \times \epsilon_y}{500} \quad \text{if} \quad <800\text{Mpa}$$

$$= 3 \times \epsilon_y \quad \text{if} \quad 800\text{Mpa}$$

When the ultimate strength is attained in the steel tube the strain at the point is ( ). It can be determined by the equation which is given below .

$$= \frac{f_y}{\times E_s}$$

The ultimate strength of the steel tube is being calculated by the equation which is given below, and that equation is being induced by Tao et al [8].

$$f_u = \left(1.6 - 2 \times 10^{-3} \times (f_y - 200)\right) \times f_y \quad 200 \le f_y \le 400$$

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$$f_u = \left(1.2 - 3.75 \times 10^{-4} \times (f_y - 400)\right) \times f_y$$

$400 < f_y \leq 800$

For more than 800 Mpa steel tube strengths can be included by the extension of this formula.

3 Load Module

Generally, for axially loaded column, the bottom is fixed and the load is applied at the top of the column. Therefore, the bottom end is restrained against all degrees of freedom and the upper end is restrained against all degrees of freedom except the one in the direction of the load application and axial load is applied at top of column. Fig 3 shows boundary condition and load application.

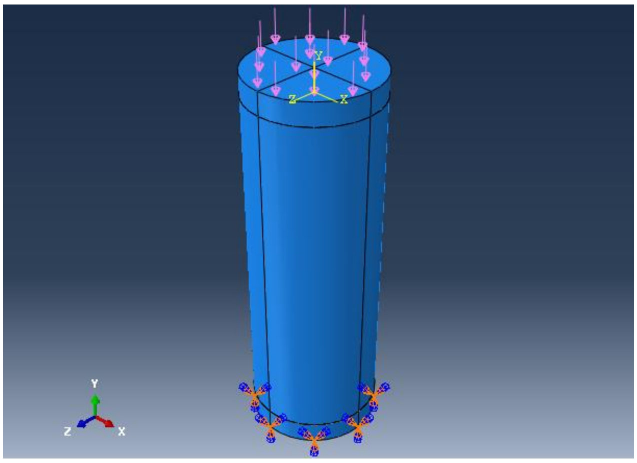

Fig. 3 boundary condition and load application

4 Mesh Module

For meshing, the model was discretized to obtain accurate result possible in lowest computing time. A typical specimen meshing has been conducted by generating 24 element along outer peripheral. Four-node shell elements with reduced integration (S4R) was used for steel tube and FRP tube and 8-node brick elements with three translation degrees of freedom at each node (C3D8R) was used for concrete core, respectively. Fig. 4 below shows meshing of specimen.

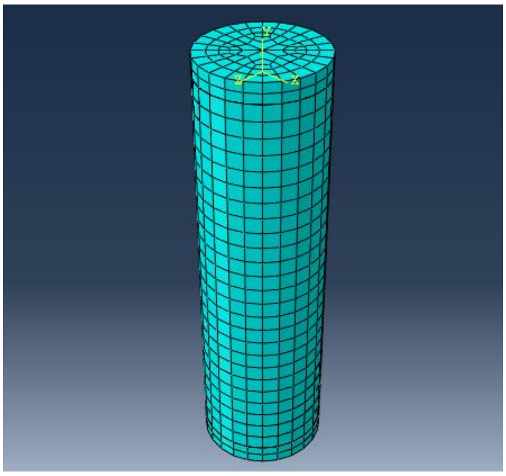

Fig. 4 Meshing of specimen

5 Interaction Module

After defining the property, the steel tube, sandwiched concrete between steel tube and FRP tube, FRP tube and concrete core are assembled together as a concrete filled steel tubular column with inner FRP tube. Surface to surface interaction were considered for the contact surface between concrete and steel tube. “Hard contact” in the normal direction can be specified for the interface, which allows the separation of the interface in tension and no penetration in compression. The tangent contact can be simulated by the Coulomb friction model and the friction coefficient is taken as 0.6 as suggested by Tao[8]. Tie constrained was adopted between FRP tube and concrete.

6 Solution Procedure

The load was applied incrementally using static Riks method. The increments are established automatically by the program. Then, the job is created and submitted to run the analysis. The output gives deflection diagram and stress distribution diagram of concrete filled steel tubular column. Fig. 5 shows the deflection diagram of CFST column with inner FRP tube.

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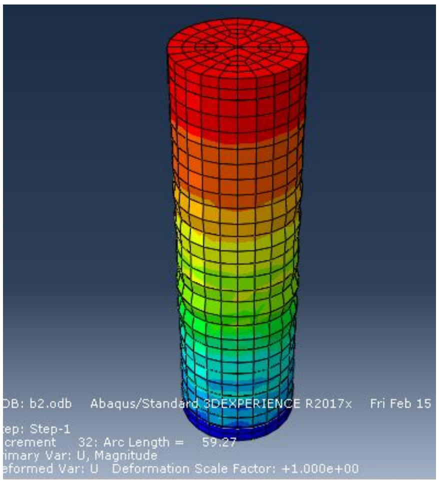

Fig. 5 Deflection diagram of CFST column

II. RESULT AND DISCUSSION

The load Vs strain curves for the CFST column with inner FRP tube specimen obtained from the result of analytical modeling using ABAQUS software is presented in Fig. 6. The peak load taken by the column specimen modeled in ABAQUS is 4850 kN and the experimental peak load obtained by Y.L. Long [18] is 4734 kN

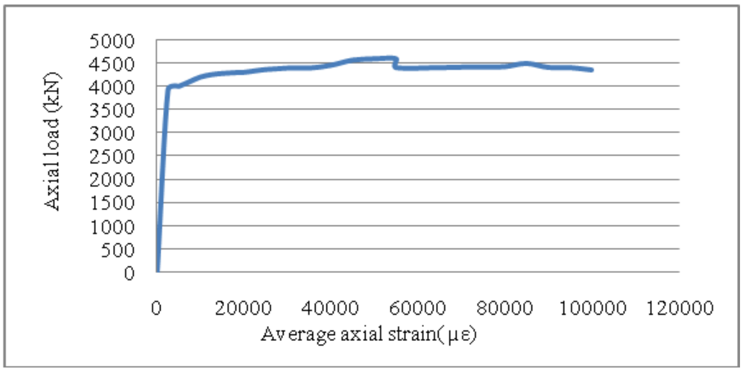

Fig. 6 Analytical Axial load Vs Average axial strain of CFST column with inner FRP tube

The current Finite element result is compared against experimental result done by Y. L. Long[18]. Fig. 7 shows comparison of experimental and analytical axial load Vs average axial strain

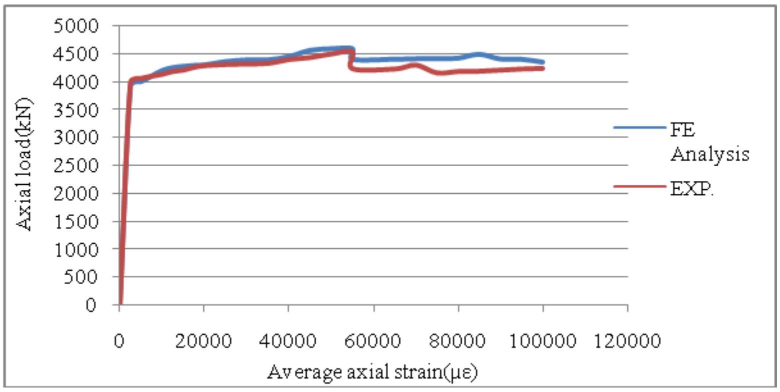

Fig. 7 Comparison of Experimental and Analytical Axial load Vs Average axial strain curve of CFST column

IV. CONCLUSION

The circular concrete filled steel tubular column was modeled using ABAQUS software in which element type of shell S4R and C3D8R was used for steel tube, FRP tube and concrete respectively. It was found that this element represents the behavior of column very well and it is observed that the current finite element model results are in a good agreement with its experimental counterparts. The load- shortening curves shows that the current model was able to predict the confinement offered by the steel tube.

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