MODELING OF AXIALLY LOADED CFT USING MIXED 3D-RIGID BODY SPRING MODEL AND GEOMETRICALLY NONLINEAR SHELL

Nagoya University ASCE Regular Member ○Rodolfo Mendoza Jr
Nagoya University Regular Member Yoshihito Yamamoto, Hikaru Nakamura, Taito Miura

1. INTRODUCTION

Several experimental tests have been conducted to evaluate the behavior of concrete-filled tubes (CFTs). In most cases, formulations of computational models were also proposed to simulate experimental observations in larger scale. These studies, however, highlight observations of steel tube behavior with few documentations of concrete behavior. Current finite element software cannot capture concrete failure mechanism in CFTs i.e., strain softening behavior including localized deformation of concrete in compression, thus an alternative formulation is necessary to address such limitations. In this study, a numerical method that that aims to evaluate CFT behavior under axial compression is presented. The method combines three-dimensional Rigid Body Spring Model (RBSM) to model the concrete core and shell Finite Element Method (FEM) to model the steel tube to form the CFT composite. The proposed formulation provides an emphasis on its ability to capture the localization behavior of concrete within the CFT composite such as crack initiation and propagation.

2. NUMERICAL MODELS

In this study a geometrically nonlinear shell formulation was developed in order to model the steel tube. The shell formulation consists of a four-node element with five degrees of freedom. The formulation uses degenerated 3D shell element which allows large displacement-large rotation effects. The method of selective reduced integration was employed in order to avoid shear locking of the element. The element uses an elasto-plastic constitutive model based on von Mises yield criterion with isotropic hardening. Shell validation was performed using cantilever with shear end force with studies of Jeon et al. (2015) and Sze et al. (2004). Result of validation is presented in Fig. 1.

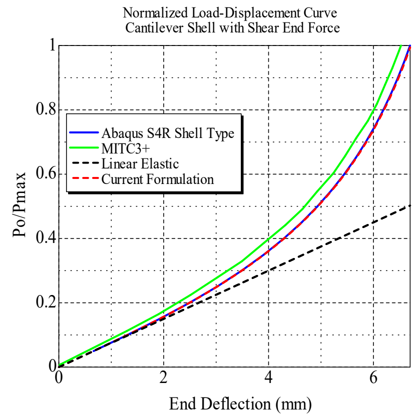

Fig. 1 Shell element validation

The concrete core is modeled using 3D RBSM based on the formulation of Yamamoto et al. (2008). 3D RBSM has been proven to be an effective tool in modeling the multi-axial compression and localization behavior of concrete such as its ability to capture crack initiation and propagation. In RBSM, concrete is modeled as an assemblage of rigid particles interconnected by springs along their boundary surfaces. Cracks initiate and propagate through the interface boundaries and thus is strongly affected by the mesh design. To address this, random geometry of rigid particles is generated using Voronoi diagram. The response of springs provides an insight into the interaction among the particles instead of internal behavior of each particle based on continuum mechanics. Rigid particles consist of six degrees of freedom i.e., three translation and three rotations, defined at an arbitrary point within the particle called the nuclei (computational point).

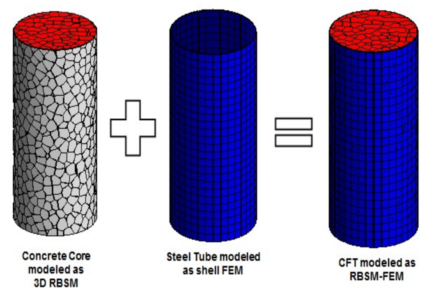

Fig. 2 RBSM-FEM CFT model

A simplified link element is utilizes to model the interaction between steel tube and concrete core. The linear elastic element consists of one normal and two rotational springs. The zero-size links bond the shell element nodes and concrete RBSM elements thus providing load-transfer mechanism.

3. NUMERICAL SIMULATION

To present the proposed numerical model, individual behavior of unconfined concrete cylinder and bare steel tube are first presented. Axial compression simulations were performed on unconfined cylinder modeled using 3D RBSM and bare steel tube modeled using shell FEM. Then, a CFT composite is subjected to axial compression simulation using the proposed RBSM-FEM formulation. Graphical presentation of the proposed formulation is shown in Fig. 2. Material and geometric parameters of the models are presented in Fig. 4. Results of respective load-strain curve are shown in Fig. 3. Post-peak behavior at a strain of 0.03 for unconfined concrete cylinder, bare steel tube, CFT and concrete inside

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Contact address: 〒464-8603 Nagoya University, Chikusa, Nagoya, Tel: 052-789-5690

the CFT are shown in Fig. 4. Confinement effect of steel tube on concrete is evident as can be observed from the post-yield behavior of CFT with lesser cracks observed in concrete inside CFT compared to unconfined concrete cylinder behavior.

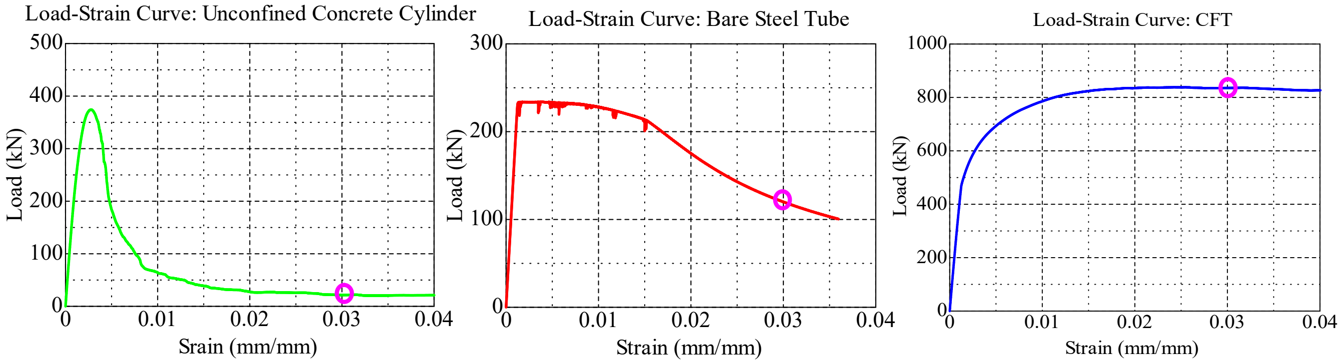

Fig. 3 Load-strain curves of unconfined concrete cylinder, bare steel tube, and CFT

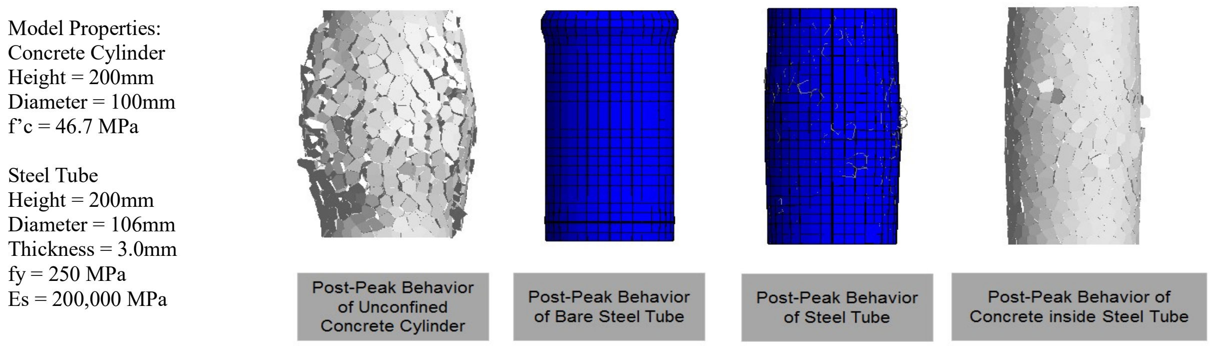

Fig. 4 Behavior of unconfined concrete cylinder, bare steel tube, CFT, and confined concrete

4. VALIDATION

Axial compression validation was performed with experimental tests conducted by Han et al. (2005). Tests' materials and geometric properties are available in aforementioned study. Two specimens were considered i.e., CA4-1 with Diameter/thickness (D/t) ratio of 107, and CC1-1 with D/t ratio of 30. As shown in Fig. 5, model for CA4-1 provides a good agreement with experimental result while model CC1-1 has slightly different initial stiffness with an evident disparity in their plastic behavior. This disparity may be attributed to the assumed constitutive model adopted for the link element.

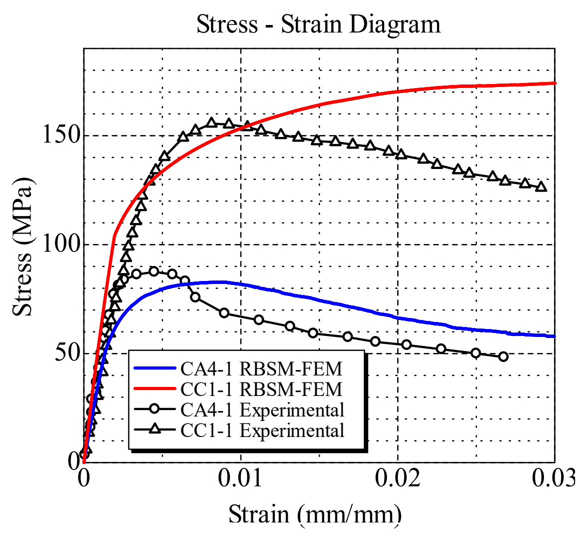

Fig. 5 Validation results for CFT RBSM-FEM model

5. CONCLUSION

The ability of the present formulation to capture localization behavior of CFTs provides an alternative evaluation method in understanding the behavior of CFTs with emphasis on concrete failure mechanism. Improvement in the proposed formulation includes the use of an accurate contact model between concrete core and steel tube.

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