Validation of Finite Element Model of Concrete-filled Steel Tubular (CFST) T-joint for Hot Spot Stress Calculation

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1. Introduction

CFST trussed arch bridge is a main type of CFST arch bridges in China. The CFST joint between chord and brace is the weak part in the bridge. In fact, fatigue damages at the weld toe of the chord-brace intersection have been observed in existing bridges. However, the stress concentration factor (SCF) at the weld toe of intersection has not been formulated yet for CFST joint. In this study, the numerical simulation of CFST joint was carried out, and its results were compared with the existing experiment to verify the finite element (FE) model for calculating SCFs around the intersection.

2. Experiment of CFST T-joints (Wang 2011)

The test of a total of 10 CFST T-joints with different geometric parameters was carried out in Tongji University, China. The test specimen and loading method are given in **Fig. 1**. The two ends of chord were bolted connection with counterforce devices. The axial compressive or tensile force was applied to the brace fully welded at a right angle to the continuous concrete-filled chord. The static tests within elastic range were performed to obtain the hot spot stress at weld toe of the specimens subjected to the axial force in the brace.

3. FE Models

The general FE software MSC.Marc was applied for the numerical investigation on SCFs distribution of CFST T-joint under axial force in brace. The weld bead was also modelled to attain the accurate hot spot stress. The material properties of all members were assumed as linear elastic. The boundary condition of the chord ends was defined as simple support.

3.1 Element Type

If the steel tube was modeled by shell element, it becomes difficult to model the weld bead and make good contact behavior between steel tube and concrete. Therefore, the linear full-integration eight-node hexahedron solid element was used for whole model, i.e. steel tube, concrete and weld bead.

3.2 Mesh Generation

Since the mesh size needs to be small enough to get the accurate hot spot stress, fine mesh was used around the intersection. The mesh size of focused areas required depends on the thickness of the tube (t), i.e. 2 mm for $t \leq$ 8 mm, 3 mm for $t <$ 16 mm and 4 mm for $t \geq$ 16 mm

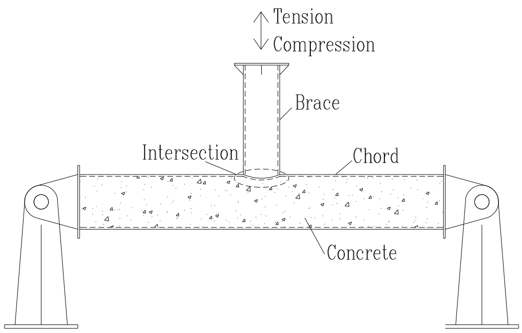
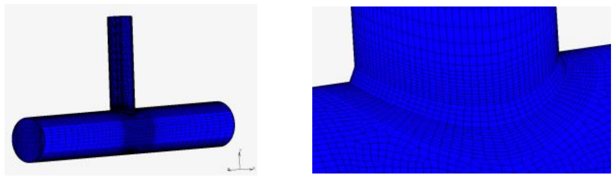


Fig. 1 Test specimen and loading method



(a) FEA model (b) Local mesh

Fig. 2 FE model and local mesh

(Zhao 2001). The mesh of concrete was the same as tube, and the tubes were divided into three layers of elements in the thickness direction.

3.3 Contact Relationships

The interface behavior between chord tube and concrete was simulated by "*Glue*" and "*Touch*" functions. "*Glue*" function assumes that contact bodies tie together without the relative slide. "*Touch*" function allows that contact bodies can touch and separate in normal direction and slide with the friction behavior in tangential direction. The friction coefficient (μ) between concrete and steel is 0.2-0.6 in general (Baltay 1990). The FE model and local mesh around the intersection are shown in **Fig. 2**.

4. Hot Spot Stress Calculation

In this study, the hot spot stress (HSS) around the intersection was obtained numerically by linear extrapolation. The position of two picked nodes for HSS calculation is shown in **Fig. 3**. The SCFs were defined as the ratio between the HSS and the nominal stress in the brace caused by the basic member that causes HSS. The nominal stress caused by the axial force F in the brace was determined using a simple formula ($\sigma = F/A$), where A = section area of the brace (Wang 2011).

5. Comparisons of Contact Relationships

The SCFs at crown under tensile force in brace of FEA

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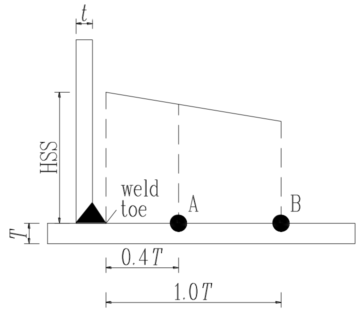


Fig. 3 Definition of HSS

results with "*Glue*" and "*Touch*" functions with different friction coefficient are compared with the test result of T4-joint specimen, as shown in **Fig. 4**. It shows that SCF calculated with "*Glue*" function is much lower than test result. However, the SCFs calculated with "*Touch*" function show good agreement with the test result and the friction coefficients have almost no influence on the SCF. The relative deformations between chord and concrete around the chord-brace intersection are shown in **Fig. 5**. It reveals that the difference between "*Glue*" function and "*Touch*" function, because total cross-section of chord and concrete bears the axial loading of brace with "*Glue*" function but "*Touch*" function allows separation around intersection between chord and filled-concrete. Therefore, "*Touch*" function with μ = 0.3 was applied for this study.

6. Validation Analysis

The SCFs distribution was observed in FE models. For instance, the FEA results of T1-joint specimen were shown in **Fig. 6**. It shows that the both of SCF distribution and maximum SCF position by FEA results show good agreement with the test results.

The comparison on the maximum SCFs between the test and FEA results is shown **Fig. 7**. The averages of FEA value to test value ratio of tensile condition and compressive condition are 0.91 and 0.82, respectively. Moreover, their variances are 0.098 and 0.129, respectively. Therefore, it can be concluded that the established FE models can successfully predict the SCFs distribution of CFST T-joint under axial loading in brace.

7. Conclusions

The developed FE models of CFST T-joint were validated to have enough precision in this study. In the future, parametric analysis will be carried out to reveal the influence of geometric parameters on SCFs around the chord-brace intersection of CFST joint.

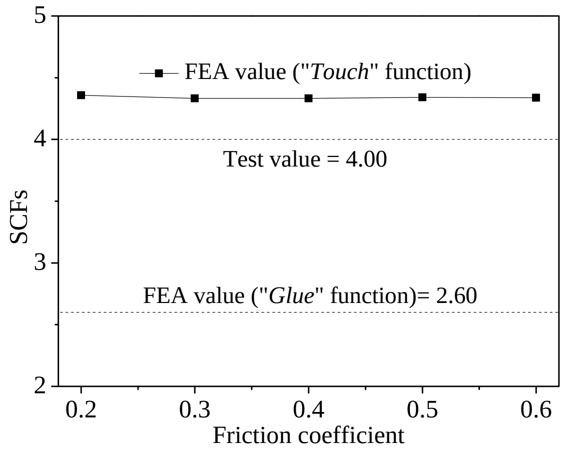
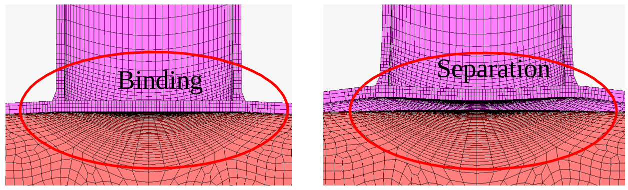


Fig. 4 Comparison on between contact relationships



(a) "*Glue*" function (b) "*Touch*" function

Fig. 5 Comparison on between contact relationships

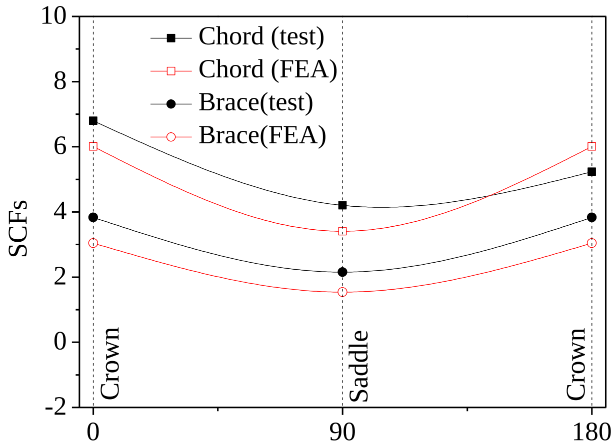


Fig. 6 SCF distribution under tensile force

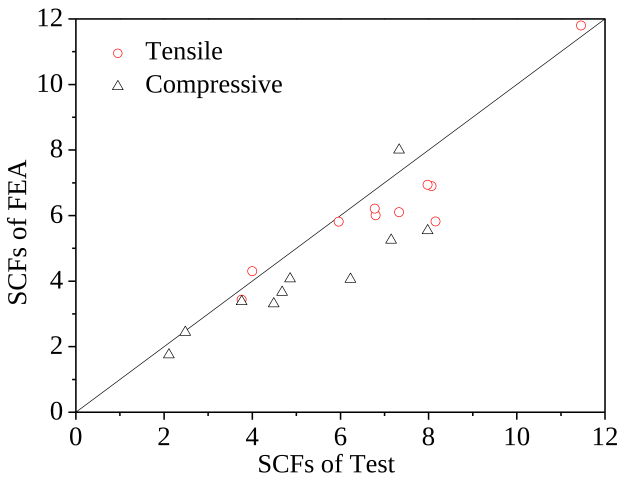


Fig. 7 Comparison of the maximum SCFs

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