Parametric Analysis on Stress Concentration Factors of Concrete-filled Steel Tubular (CFST) T-joint under In-plane Bending in the Brace

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1 Introduction

CFST trussed arch bridge is a main type of CFST arch bridges in China. The arch ribs are composed of concrete-filled chord and hollow brace connected each other generally with full penetration butt welds to form CFST joint. The joint is the weak part in the whole structure. In fact, fatigue damage at the weld toe of the chord-brace intersection has been observed in existing bridges. The hot spot stress (HSS) at the weld toe around the intersection, which should be used for the fatigue design of the joint, is mainly influenced by geometric parameters of CFST joint. However, their influence on HSS has not been formulated yet for CFST joint.

Therefore, in this study, finite element (FE) models of CFST T-joint (see Fig. 1) were developed first. After validating them by comparison with existing test results [1, 2], they were provided for parametric analysis to reveal the influences of three non-dimensional geometric parameters, i.e. diameter ratio (β = d/D), diameter to thickness ratio of chord (2γ = D/T) and thickness ratio (τ = t/T) on HSS of CFST T-joints under the in-plane bending in the brace.

2 Validation of FE models

2.1 FE modelling

The FE models were developed by the general-purpose FE software MSC.Marc, which were applied for the numerical investigation of HSS distribution of test specimens under in-plane bending in the brace. The dimensions, boundary conditions and linear elastic material properties of the FE models were in accordance with those of the test specimens [1, 2]. The material properties same as steel tube were assigned to the weld bead. For the sizes of full penetration butt weld bead, an average weld size at the brace and chord of t and $0.5t$, respectively, was used in the modelling of the test specimens. The linear full-integration 8-node hexahedron solid element with "assumed strain" was used for the whole model, i.e. steel tube, concrete and weld bead. Since the mesh size needs to be small enough to get the accurate HSS, 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 [3].

The behavior of the interface between chord tube and in-filled concrete was simulated by "Touch" functions. "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 = 0.3 was used for this study. The FE model and local mesh around the intersection are shown in Fig. 2.

2.2 HSS and stress concentration factor (SCF) calculation

The HSS around the intersection was obtained by linear extrapolation in the test. The region of positions of two picked nodes for HSS calculation is listed in CIDECT Design code [3]. The positions of picked nodes are arbitrarily determined in this region. The positions of 1st and 2nd nodes are approximately $0.4T$ (but $\geqslant$ 4 mm) and $1.0T$ away from the weld toe, respectively.

The SCF is generally defined as the ratio between the HSS at the joint and the nominal stress in the member due to the basic member load which causes this HSS [3]. Therefore, the nominal stress of the brace caused by in-plane bending was determined based on beam theory. The nominal stress was descripted using a simple formula (σ_n = M / W), where M is the applied bending moment (obtained as a product of the applied load at brace end and the distance from the loading point to the chord-brace intersection)

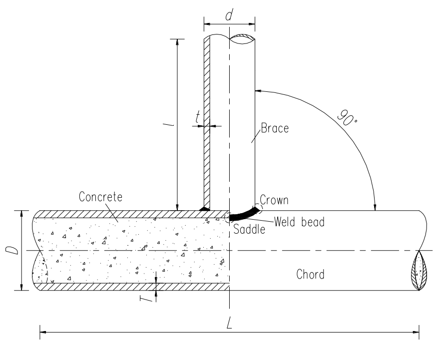
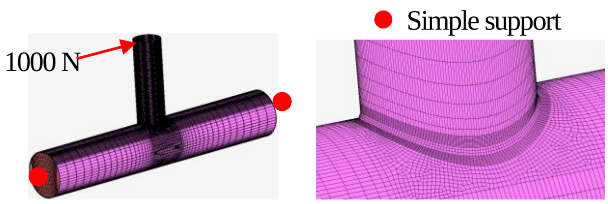


Fig. 1 Geometric parameters of CFST T-joints



(a) FE model　(b) Local mesh

Fig. 2 FE model and local mesh of CFST T-joint

and W is the elastic section modulus of the brace member.

2.3 Validation of FE models

For CFST T-joints under in-plane bending in the brace, the maximum SCFs are expected to occur at chord crown (CC) or brace crown (BC). Therefore, the comparisons of SCFs at four locations (location CC and BC in tensile and compressive sides) between FE analysis (SCF_{FEA}) and test (SCF_{Test}) are shown in Fig. 3 for all specimens. The averages of the SCF_{FEA} to the SCF_{Test} ratio of the location CC at tensile and compressive sides are 1.16 and 1.05, location BC at tensile and compressive sides are 1.03 and 1.03, respectively. These results show the good agreement between the SCF_{Test} and the SCF_{FEA}. Therefore, it can be concluded that the developed FE models can accurately predict the SCF distribution of CFST T-joints under in-plane bending in the brace.

3 Results of parametric analysis

According to the Zheng's study [4], the practical ranges of each parameter is β = [0.3, 0.6], 2γ = [40, 80] and τ = [0.4, 1.0]. In these parameter ranges, one hundred and forty FE models with different combination of geometrical parameters were prepared and analyzed. Because of the nonlinear feature of stress distribution around the intersection, HSS was calculated by the quadratic extrapolation method for the parametric analysis. The influences of each geometric parameter to SCFs at the location CC (tension) are shown in Fig. 4. It shows that SCF_{CC} (tension) decreases linearly as the value of β increases at tensile and compressive sides, and increases as the value of 2γ or τ increases. The influence of geometric parameters (β, 2γ and τ) on SCFs for each hot spot location can be summarized in Table 1. It shows that the influence of τ is much larger than other two parameters.

4 Last remarks

The formulas of SCFs for CFST T-joints under in-plane bending in the brace will be developed by multiple regression analysis based on the results of parametric analysis in this study.

References

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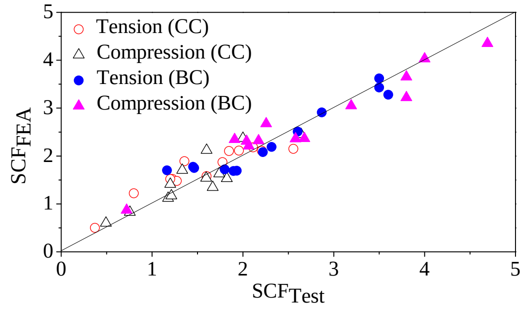
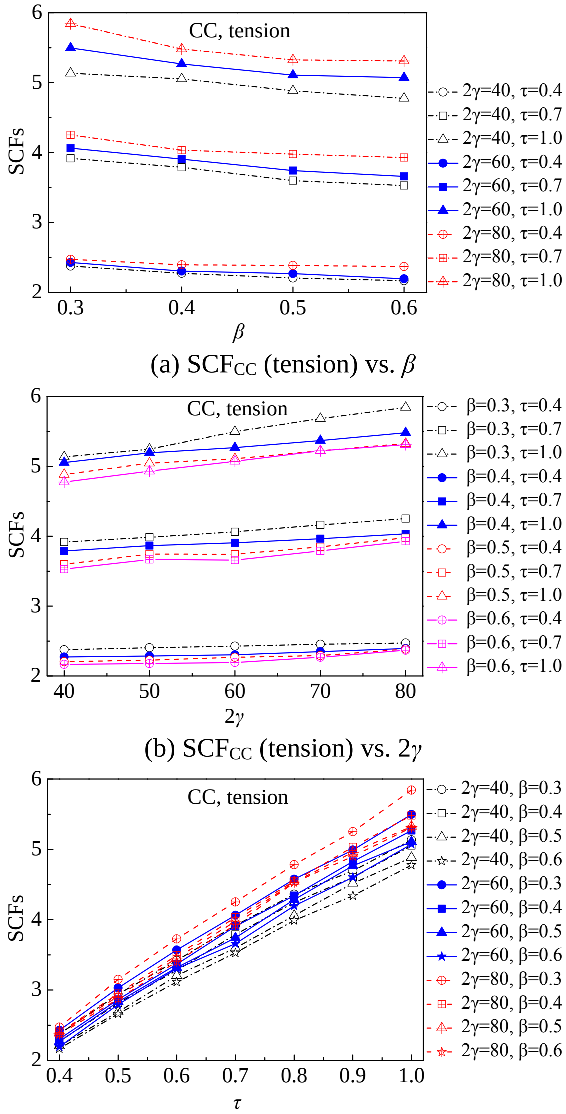


Fig. 3 Comparison on SCF_{FEA} with SCF_{Test}



(c) SCF_{CC} (tension) vs. τ

Fig. 4 Influence of each parameter on SCFs

Table 1 Influence of geometric parameters on SCFs

Parameters		CC		BC	
		Tension	Comp.	Tension	Comp.
β	0.3→0.6	↘	↘	↘	↘
2γ	40→80	↗	↘	↗↘	↗
τ	0.4→1.0	↗	↗	↗↘	↗

Where, "↗" represents increasing, "↘" represents decreasing, "↗↘" represents increasing first and then decreasing.