CALCULATION FORMULAE OF STRESS CONCENTRATION FACTORS FOR CONCRETE-FILLED STEEL TUBULAR T-JOINTS UNDER OUT-OF-PLANE BENDING IN THE BRACE

Nagasaki University Student Member ○Jian ZHENG
Nagasaki University Member Shozo NAKAMURA
Nagasaki University Member Toshihiro OKUMATSU
Nagasaki University Member Takafumi NISHIKAWA

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 since the axial stiffness of the brace is much bigger than the radial stiffness of the chord. 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, this study carried out parametric analysis to reveal the influences of four non-dimensional geometric parameters on HSS of CFST T-joints under the out-of-plane bending in the brace. It includes diameter ratio ($\beta = d/D$), diameter to thickness ratio of chord ($2\gamma = D/T$), thickness ratio ($\tau = t/T$) and relative chord length ($\alpha = 2L/D$), the parameters are shown in Fig. 1. The calculation formulae of stress concentration factors (SCFs) were proposed for them by multiple regression analysis based on the results of parametric analysis.

2. OUTLINE OF THE PARAMETRIC ANALYSIS

2.1 FE modelling

The FE models were developed by the general-purpose FE analysis software MSC.Marc, which were applied for the numerical investigation of HSS distribution of test specimens under in-plane bending in the brace. Young's modulus of steel tube and concrete were set to 2.05×10^5 MPa and 3.45×10^4 MPa, and their Poisson's ratio were set to 0.3 and 0.2, respectively. 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 element layers in the tube thickness direction were determined based on the edge length ratio of elements around the intersection is approximately 1, the mesh size of approximately 2 mm was used for the elements around the intersection.

The behavior of the interface between chord tube and concrete was simulated by "Touch" functions. "Touch" function allows that contact bodies can touch and separate each other 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 boundary conditions are shown in Fig. 2. The chord is simply supported and the torsion of the chord is fixed. In addition, ranges of non-dimensional parameters for the parametric analysis are β = [0.3, 0.6], 2γ = [40, 80], τ = [0.4, 1.0] and α = [8, 16].

2.2 HSS and SCFs calculation

The HSS around the intersection was obtained by linear extrapolation in the test. The positions of 1st and 2nd nodes are approximately 0.4T (but ≥ 4 mm) and 1.0T away from the weld toe, respectively.

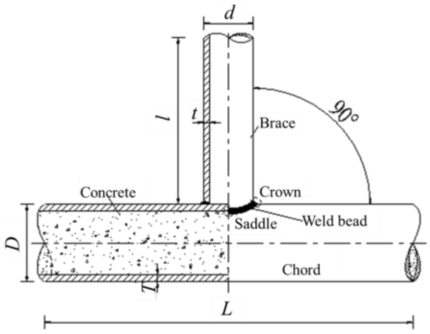
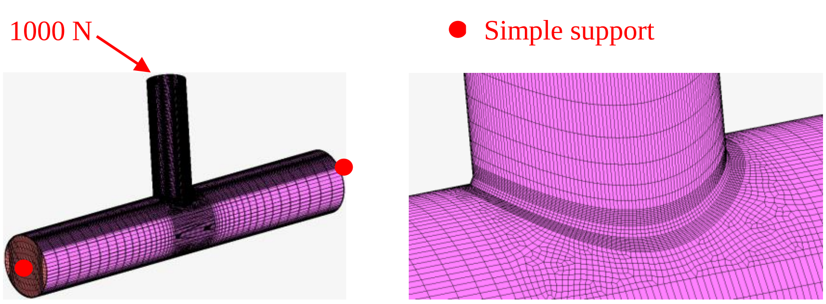


Fig. 1 Geometric parameters of CFST T-joints



(a) FE model (b) Local mesh

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

Keywords: Concrete-filled steel tubular structure; T-joint; Hot spot stress; Finite element analysis.
Contact address: 1-14, Bunkyo-machi, Nagasaki, 852-8521, Japan. Tel: 095-819-2613.

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 (Zhao 2001). Therefore, the nominal stress of the brace caused by bending was determined by a simple formula ($\sigma_n = M / W$), where M is the applied bending moment around the intersection and W is the elastic section modulus of the brace member.

3. PARAMETRIC FORMULAE OF SCF AND ITS VERIFICATION

According to the results of multiple regression analysis, the formulae for determining SCFs of CFST T-joints under out-of-plane bending in the brace are given in **Eqs. (1)-(4)**.

Location CS at tensile side,

$$\mathrm{SCF}_{\mathrm{CS,T}} = 2.102\gamma^{0.396}\tau^{0.904}[1.145 - 6.927(\beta - 0.434)^2] \tag{1}$$

Location CS at compressive side,

$$\mathrm{SCF}_{\mathrm{CS,C}} = 7.737\gamma^{-0.671}\tau^{0.914}\beta^{-0.928} \tag{2}$$

Location BS at tensile side,

$$\mathrm{SCF}_{\mathrm{BS,T}} = 1.082\gamma^{0.447}\tau^{0.259}[1.141 - 6.761(\beta - 0.451)^2] \tag{3}$$

Location BS at compressive side,

$$\mathrm{SCF}_{\mathrm{BS,C}} = 0.655\gamma^{0.324}\tau^{0.504}\beta^{-0.948} \tag{4}$$

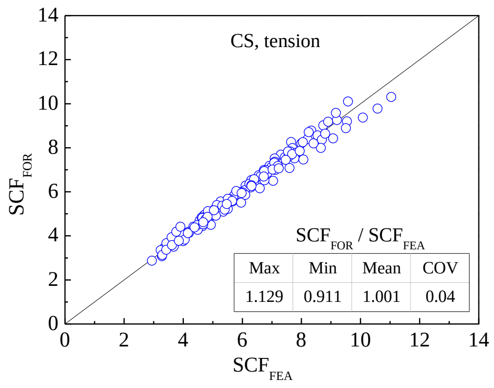
A comparison between the SCFs of formulae calculation ($\mathrm{SCF_{FOR}}$) and $\mathrm{SCF_{FEA}}$ was carried out to verify the accuracy of SCF formulae at location CS and BS, as shown in Fig. 3. It shows good agreements between them. Hence, It can be concluded that the proposed SCF formulae accurate and reliable for CFST T-joints under out-of-plane bending in the brace.

4. LAST REMARKS

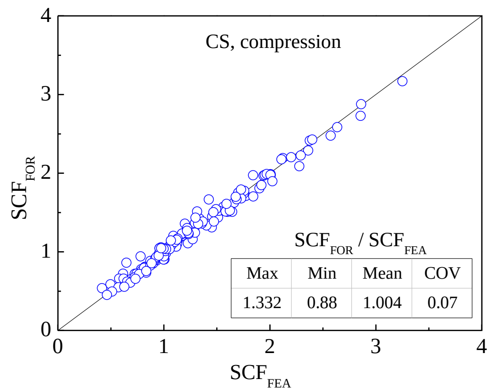
In this study, calculation formulae of stress concentration factors (SCFs) were proposed and their validity was confirmed. In the future, the fatigue experiments of CFST T-joints will be carried out and the calculation method of fatigue life will also be proposed.

REFERENCES

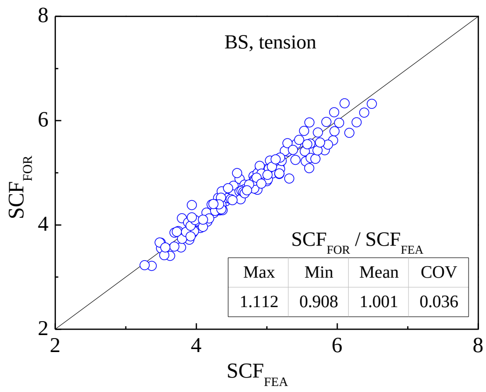
Zhao, X. L., Herion, S., Packer, J. A. and Puthli, R., et al.: Design Guide for Circular and Rectangular Hollow Section Joints under Fatigue Loading, CIDECT, TUV, 2000.



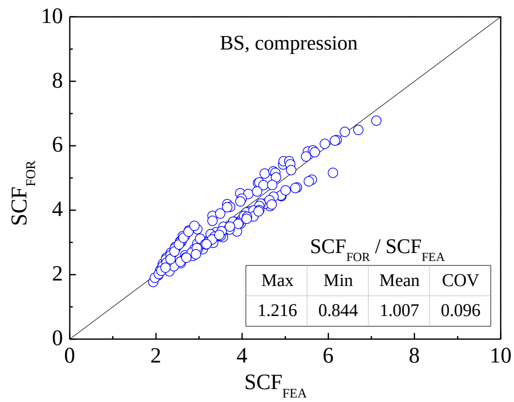
(a) Location CS (tension)



(b) Location CS (compression)



(c) Location BS (tension)



(d) Location BS (compression)

Fig. 3 Comparison of $\mathrm{SCF_{FOR}}$ with $\mathrm{SCF_{FEA}}$