Geometric Parameters Statistics of Concrete-filled Steel Tubular (CFST) K-joint in China

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

1 Introduction

CFST trussed arch bridge is a main type of CFST arch bridges in China. It accounts for 37.84% of 388 CFST arch bridges [1], The trussed arch ribs are composed of concrete-filled chord and hollow brace connected each other generally with full penetration butt welds to form K-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 is mainly influenced by geometric parameters of CFST K-joint. However, their influence on HSS has not been formulated yet for CFST K-joint.

In this study, the geometric parameters of CFST K-joints from 119 CFST trussed arch bridges in China are attained by literature review and website investigation, and analyzed to demonstrate their range for the parametric analysis of hot spot stress with finite element (FE) method.

2 Outline of studied bridges

Among 119 bridges, there are 16 deck bridges, 48 half-through bridges, 27 fly-bird bridges, 13 rigid-frame through tied bridges and 15 through arch-beam bridges. The cross-section of CFST trussed arch ribs is categorized into four-limbs, transverse dumbbell, two-limbs, three-limbs and six-limbs shown in **Fig.1**, and their distributions are illustrated in **Fig.2**. Four-limbs and transverse dumbbell are mainly used in CFST trussed arch bridges, which account for 83.2% of the total bridges.

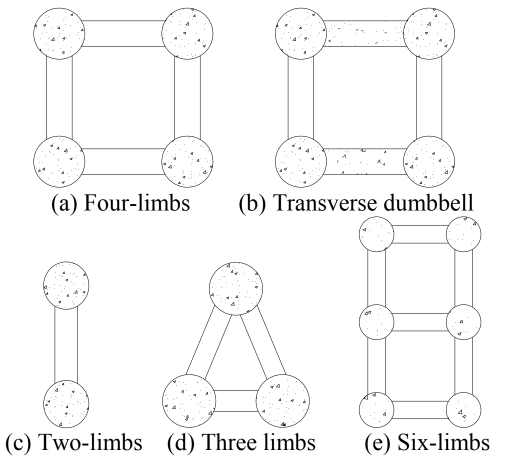

Fig.1 Cross-section of CFST trussed arch bridges

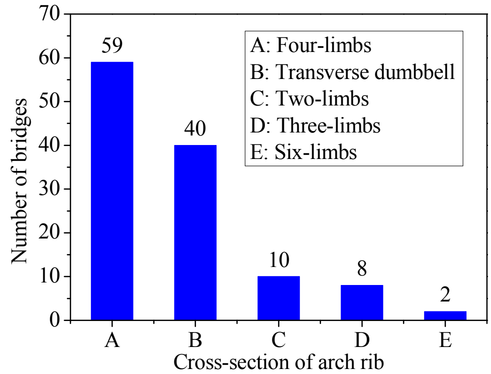

Fig.2 Cross-section distribution

3 Structural type of CFST K-joint

The structural type of CFST joint in all bridges is K-joint. Most of them has the brace and concrete-filled chord tube directly weld together, as shown in **Fig.3**. This type of joint accounts for 95.8% of the total. Therefore, the following section focuses on this joint type to demonstrate the range of geometric parameters.

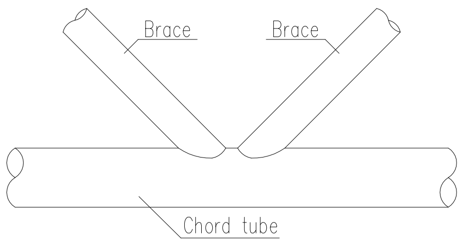

Fig.3 Structural type of CFST K-joint

4 Geometric parameters statistics

The hot spot stress of tubular joint is mainly influenced by external diameter (D) and thickness (T) of the chord tube, external diameter (d) and thickness (t) of the brace, and the angle between the axis of the chord tube and brace (θ). Stress concentration factors of uniplanar circular hollow section (CHS) tubular K-joint with no eccentricity and equal braces are formulated by using these parameters [2]. Moreover, the eccentricity (e) between the cross-point of the adjacent brace axis and the axis of the chord tube, and the gap (g) between crown toes of adjacent braces may also affect SCF value. Every geometric parameter of CFST K-joint is shown in **Fig.4**.

Statistical analyses of the geometric parameters are conducted on the basis of the dimensionless parameters, including the external diameter to thickness ratio of the chord tube ($\gamma = D/2T$), the thickness of the brace to the thickness of the chord tube ratio ($\tau = t/T$), the external diameter of the brace to the external diameter of the chord tube ratio ($\beta = d/D$), the eccentric ratio of the joint ($\rho = e/D$). $\rho > 0$ represents the cross-point of adjacent braces located under the axis of chord tube, $\rho = 0$ represents the cross-point of adjacent braces located at the axis of chord tube, $\rho < 0$ represents the cross-point of adjacent braces located above the axis of chord tube.

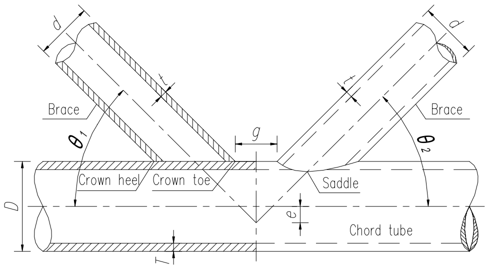

Fig. 4 Geometric parameters of CFST K-joint

Distributions of γ-value, τ-value and β-value of the 119 bridges are illustrated in **Figs. 5-7**, respectively. The serial number is numbered based on the above-mentioned five bridge structural types (deck type, half-through type, fly-bird type, rigid-frame through tied type and through arch-beam type) and their span length in sequence, respectively. Moreover, every geometric parameter of CFST K-joint in all studied bridges is listed as more as possible by the reason of that some certain geometric parameters were not provided in some literatures. The distributions of γ-value, τ-value and β-value are all irregular. They show that the maximum and minimum γ-values are 42.50 and 17.14, respectively; the maximum and minimum τ-values are 1.00 and 0.40, respectively; the β-value is mainly varied from 0.30 to 0.60, and the maximum and minimum β-values are 0.72 and 0.12, respectively.

For the range of θ- and ρ-values, they would be determined by relevant standard because they are not provided in the literatures. The θ-value and the angle between two axis of adjacent braces should be not less than 30° to prevent serious welding difficulties at crown heel location [3]. The maximum θ-value for which the parametric formula for CHS K-joint can be applied is 60° [2], thus the range of θ-value would be [30°, 60°]. In addition, the ρ-value would be [-0.55, +0.25] referring to the corresponding value of CHS K-joint [2].

5 Last remarks

This paper presents the geometric parameters statistics of CFST K-joints, based on the results of geometric parameters statistics, the value range of γ, τ, β, θ and ρ are [17.14, 42.50], [0.4, 1.0], [0.12, 0.72], [30°, 60°] and [-0.55, +0.25], respectively.

The numerical simulation of CFST K-joint will be carried out to verify the hot spot stress around the weld toe of intersection with the existing experiment of CFST K-joint. After the FE model is validated, the geometric parameters of CFST K-joint will be provided to carry out parametric analysis with FE method and reveal the influence to the hot spot stress around the intersection of CFST K-joint with parameter variations. Eventually, the formula of stress concentration factors for CFST K-joint will be presented based on a large number of parametric analysis.

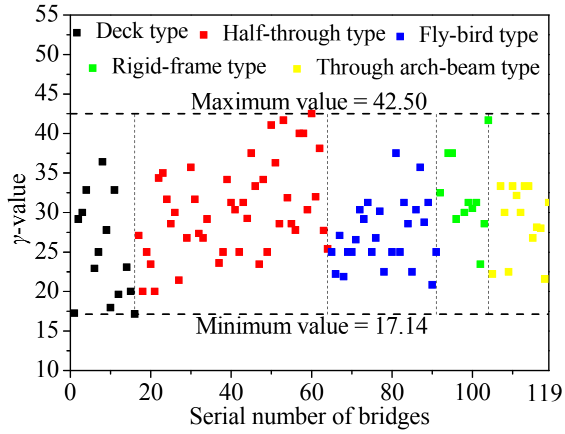

Fig.5 Distribution of γ-value

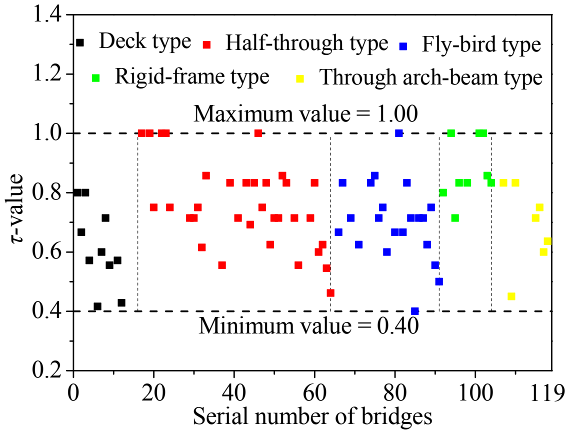

Fig.6 Distribution of τ-value

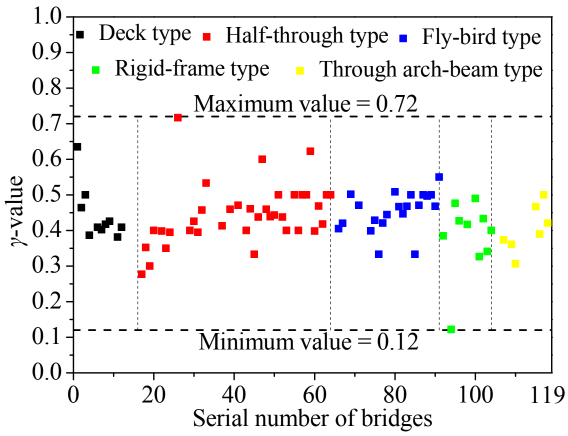

Fig.7 Distribution of β-value

References

[1] Wang, Q., Nakamura, S., Chen, K. M., Chen, B. C. and Wu, Q. X.: Comparison between Steel and Concrete-filled Steel Tubular Arch Bridges in China, Journal of JSCE, Vol. , pp. , 2016.

[2] Zhao, X. L, et al.: Design Guide for Circular and Rectangular Hollow Section Welded Joints under Fatigue Loading, TÜV-Verlag, 2001.

[3] Chen, B. C.: Concrete Filled Steel Tubular Arch Bridges. China Communications Press, 2007. (in Chinese)