Effect of axial force in main member on initial axial stiffness of tubular joints

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ABSTRACT

Initial stiffness of tubular joints plays considerable role in the global analysis of frames and trusses. Axial forces that occur in the chord can affect initial stiffness of joints, leading to noticeable redistribution of forces in members of structures. Generally, this effect is taken into account by chord stress functions. Currently many chord stress functions exist for resistance of joints; however, no function was determined for initial stiffness. Based on the comprehensive finite element analysis and the manual curve fitting approach, this paper develops a chord stress function for initial axial stiffness of square hollow section T joints.

INTRODUCTION

Rectangular hollow sections (RHS) joints combine high strength, simple end preparations and welding process (Wardenier, 1982), leading to nice appearance and good stiffness and resistance. Many researchers (Boel, 2010; Snijder et al., 2011; Haakana, 2014) have proved the initial rotational stiffness to play the key role in buckling of tubular truss members. Affecting the distribution of forces between members, axial stiffness is also known to be essential in the global analysis of frames and trusses. Therefore, the neglect paid to the role of axial stiffness of joints in current design rules is proved to be unreasonable, leading to collapses of structural elements, particularly in shallow Virendeel girders (**Error! Reference source not found.**).

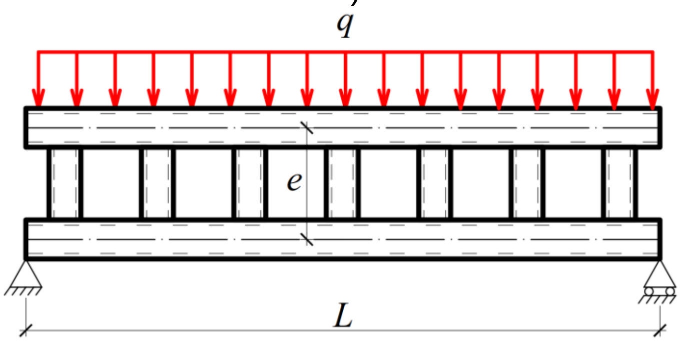

Figure 1. Shallow Virendeel girder.

Most of the publications and design guides for RHS T joints deal with the resistance of RHS joints (Yu, 1997; Cao et al., 1998; Zhao & Hancock, 1991; Packer et al., 2009; Zhao et al., 2010; Nizer et al., 2015). Initial stiffness of tubular joints was investigated by Mäkeläinen et al. (1988), Grotmann & Sedlacek (1998), de Matos et al., Neves (2004) and

(Weynand et al., 2015). However, none of these papers considers the effect of axial stresses in the chord on the initial axial stiffness of joints.

This paper, dealing with the axial stiffness of square hollow section T joints, develops the chord stress function, which defines the stiffness reduction produced by the axial forces in the main member. Investigation of the effect of the chord stresses is conducted with the FEM analysis. The final chord stress function is obtained via the approximation of the results using the linear and polynomial regressions. The chord stress function is determined by the following equation:

$$C = k_{sn,N} C_0 \,, \tag{1}$$

where C is the initial axial stiffness of the joints; C_0 is the initial stiffness of the joint with no axial force in the chord; $k_{sn,N}$ is the developed chord stress function.

RESULTS

The conducted FE simulation shows that axial forces in the chord significantly affect the initial axial stiffness of joints. Compressive loads lead to the maximum 65% reduction of the stiffness, while tensile loads increase it by maximum 30%. The observed influence is found to depend on chord width-to-thickness ratio $\gamma = b_0/2t_0$ (Figure 2a), brace-to-chord width ratio $\beta = b_1/b_0$ (Figure 2b) and the steel grade f_{y0} (Figure 2c).

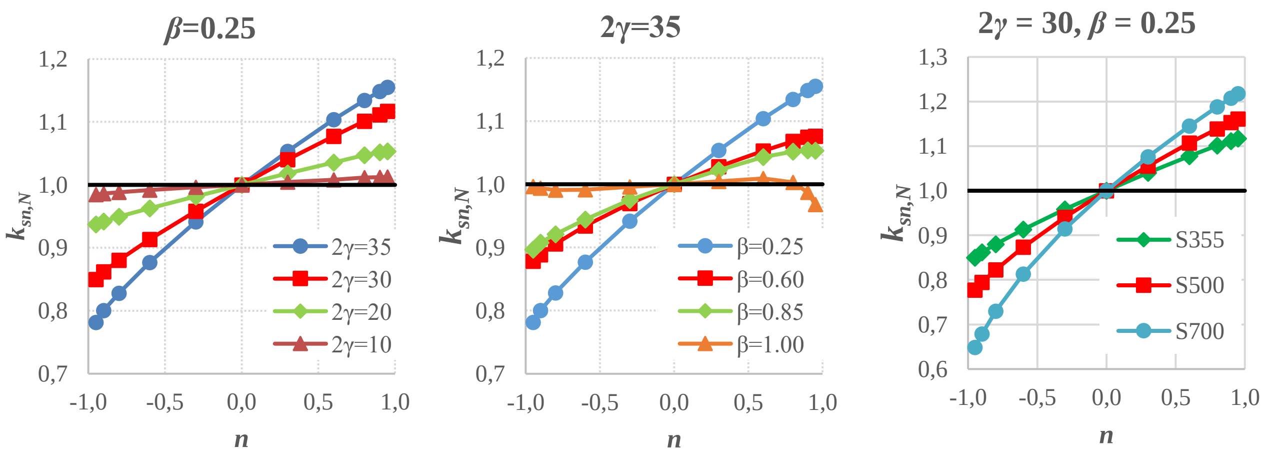

Figure 2. Dependence of the observed effect on γ (a), β (b) and steel grade (c).

Based on these observations, the following equation is proposed as a chord stress function:

$$k_{sn,N} = 1 + 10^{-5} \cdot f(\beta) \cdot f(\gamma) \cdot f(f_{y0}) \cdot n \tag{2}$$

where

$$\begin{aligned} f(\beta) &= -2\beta^2 + 1.6\beta + 0.3 \\ f(\gamma) &= 1.3\gamma^2 - 38 \\ f(f_{y0}) &= 0.02 f_{y0}^{\,1.4} \end{aligned} \tag{3}$$

Validation with an independent series of FE results shows that the proposed chord stress function provide good correlation with numerical results.

CONCLUSIONS

The conducted FE research has proved that axial forces in the main member significantly affect the initial axial stiffness of tubular joints. Based on the numerical results, a chord stress function is developed for initial axial stiffness of square hollow section T joints. When compared to numerical results, the proposed equation provides accurate results within the considered range.

However, it should be noted that this study was performed for square hollow section joints and further investigations are required to extend the proposed chord stress function to rectangular hollow section joints.

REFERENCES

Boel, H., 2010. *Buckling Length Factors of Hollow Section Members in Lattice Girders. Ms Sci thesis*, Eindhoven: Eindhoven University of Technology.

Cao, J.J., Packer, J.A. & Yang, G.J., 1998. Yield line analysis of RHS connections with axial loads. *Journal of Constructional Steel Research*, 48(1), pp. 1–25.

Grotmann, D. & Sedlacek, G., 1998. *Rotational stiffness of welded RHS beam-to-column joints. Cidect 5BB-8/98*, Aachen: RWTH-Aachen.

Haakana, Ä., 2014. *In-Plane Buckling and Semi-Rigid Joints of Tubular High Strength Steel Trusses. Ms Sci thesis*, Tampere: Tampere University of Technology.

Mäkeläinen, P., Puthli, R. & Bijlaard, F., 1988. Strength. stiffness and nonlinear behaviour os simple tubular joints. *IABSE congress report*, 13, pp. 635–640.

Neves, L.F. d. C., 2004. Monotonic and Cyclic Behaviour of Minor-axis and Hollow Section Joints in Steel and Composite Structures. *Doctoral Thesis, University of Coimbra*.

Nizer, A., de Lima, L.R.O., Vellasco, P.C.G. da S., de Andrade, S.A.L., Goulart, E. da S., da Silva, A.T. & Neves, L.F. da C., 2015. Structural behaviour of T RHS joints subjected to chord axial force. *Proceedings of the 15th International Symposium on Tubular Structures, Rio de Janeiro, Brazil, 27-29 May 2015*, pp. 371–378.

Packer, J.A., Wardenier, J., Zhao, X.-L., Vegte, A. van der & Kurobane, Y., 2009. Design guide for rectangular hollow section (RHS) joints under predominantly static loading. *CIDECT Design Guide No. 3, 2nd Edition, CIDECT, Geneva, Switzerland*.

Snijder, H.H., Boel, H.D., Hoenderkamp, J.C.D. & Spoorenberg, R.C., 2011. Buckling length factors for welded lattice girders with hollow section braces and chords. *Proceedings of Eurosteel 2011*, pp. 1881–1886.

Wardenier, J., 1982. *Hollow Section Joints*, Delft: Delft University of Technology.

Weynand, K., Jaspart, J.P., Demonceau, .J-F. & Zhang, L., 2015. *Component method for tubular joints. CIDECT Report 16F – 3/15*,

Yu, Y., 1997. *The static strength of uniplanar and multiplanar connections in rectangular hollow sections. Doctoral Dissertation*, Delft: Delft University of Technology.

Zhao, X.-L. & Hancock, G.J., 1991. T-joints in rectangular hollow sections subject to combined actions. *Journal of Structural Engineering*, 117(8), pp. 2258–2277.

Zhao, X.-L., Wardenier, J., Packer, J.A. & Vegte, G.J. van der, 2010. Current static design guidance for hollow-section joints. *Proceedings of the Institution of Civil Engineers - Structures and Buildings*, 163(6), pp. 361–373.