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Compression-bend-shearing performance of column-to-column bolted-flange connections in prefabricated multi-high-rise steel structures

X.C. Liu[a,b,c,*], X.N. He[a], H.X. Wang[a], A.L. Zhang[a,b,c]

[a] Beijing Engineering Research Center of High-Rise and Large-Span Pre-stressed Steel Structures, Beijing University of Technology, Beijing 100124, China
[b] Beijing Key Laboratory of Earthquake Engineering and Structural Retrofit, Beijing University of Technology, Beijing 100124, China
[c] Beijing University of Civil Engineering and Architecture, Beijing Advanced Innovation Centre for Future Urban Design, Beijing 100044, China

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ABSTRACT

The bolted-flange connection is used to connect rectangular HSS columns in prefabricated multi-story and high-rise steel structures. It may subject to coexisting axial compression, bending moments and shearing under the combination of dead, live, wind loads or earthquake action. The bearing performance is different from that of bolted-flange connections used in pipelines, towers and mast structures. To investigate the bearing performance of a connection subjected to coexisting compression, bending moments and shearing, static tests and a finite element analysis (FEA) were applied to 12 column-to-column bolted-flange connections with different flange thicknesses, bolt edge distances, flange edge widths and bolt hole diameters, as well as one column without connection. The effects of flange thickness, bolt edge distance, flange edge width, and bolt hole diameter on the stiffness and strength of connections, bolt tension levels, and contact forces between flanges were obtained as well as effects on the failure mode and mechanisms of the connections. Flange thickness was found to have a considerable impact on the performance of connections, while the bolt edge distance and flange edge width were found to have a lesser effect. The FEA results agree well with the test results, verifying the finite element model (FEM). Some performance results that could not be obtained through testing were obtained. Based on yield line theory and T-stub analogies, the load transfer mechanism of bolted-flange connections was obtained and formulas for yield-bearing capacity are proposed. The results obtained from the formulas agree well with the test and FEA results.

1. Introduction

Steel structures offer excellent levels of machinability and are suitable for industrial production and for connection to high-strength bolts. They are lightweight and easy to transport. Such characteristics render them typically suitable to be used for prefabricated structures [1,2]. Prefabricated steel structures can be constructed from a standardized design, through industrial production and via on-site bolted assembly, significantly reducing manpower costs and shortening construction periods [3–5]. Prefabricated steel structures have been used in many countries. From our review of the existing literature, to our knowledge, they are mainly used in low-rise buildings and less often in high-rise buildings [6–8]. Broad Sustainable Building Technology Ltd. and the Beijing University of Technology collaboratively developed a prefabricated high-rise steel frame structure system referred to as a prefabricated steel frame structure with inclined braces [9–15]. The T30 hotel and S30 apartment building and a series of multi-rise buildings were built in Hunan province, a 26-story office building was built in Shanxi province, a 25-story technology mansion was built in Ningxia province, and an 11-story office building was built in Shandong province in China using this structure. The structure of the S30 apartment was designed by the first author of the present paper. Bolted-flange connections were used to connect square HSS columns in these structures, but such connections bear less force due to the presence of inclined braces around connections. Connections without inclined braces can bear larger forces and can bear high levels of axial compression, bending moments and shearing simultaneously. Bearing performance and mechanisms of connection require further study [9–15]. Based on such studies, the authors of the present paper developed a new type of joint for connecting beams and columns with flanges and bolts in a prefabricated multi-storey and high-rise steel structure, and a two-story building was built from these joints. Square HSS columns were connected on-site using bolts rather than being welded together, significantly shortening the construction period. The joints performed well under coexisting axial compression, bending moments and shearing according to analyses and tests executed by the authors [16–20].

* Corresponding author at: Beijing University of Technology, Beijing 100124, China.
E-mail address: liuxuechun@bjut.edu.cn (X.C. Liu).

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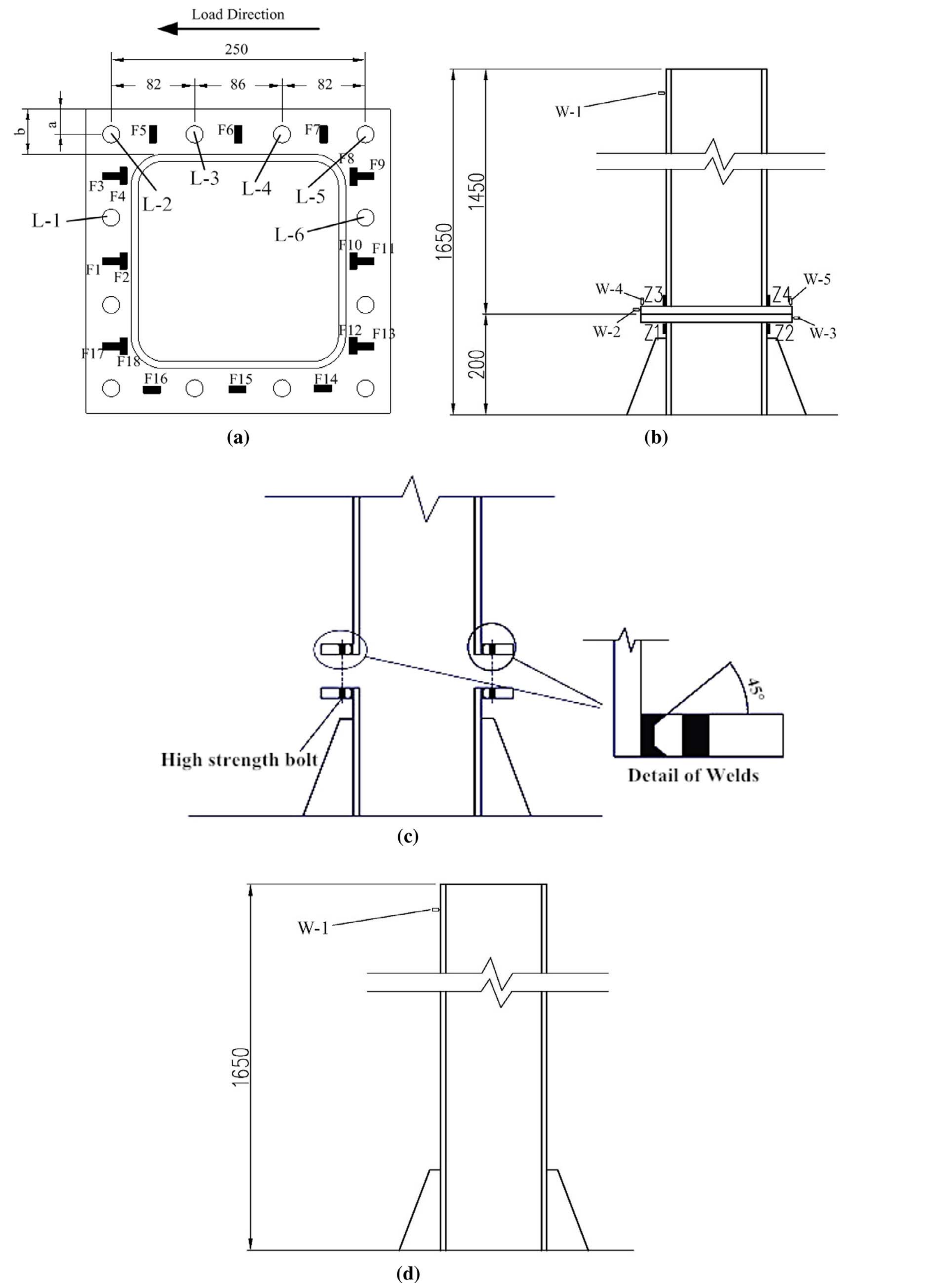

Fig. 1. Test specimens. (a) Plan view of the flange. (b) Elevation view of a flange-connected column. (c) Assembly diagram of a flange-connected column. (d) Elevation view of a column with no connections.