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Comparative experimental investigation on steel staggered-truss constructed with different joints in fire

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ABSTRACT

A total of three fire tests have been conducted to compare the mechanical performance of the steel staggered-truss (SST) exposed to pool fire constructed with welded joints and gusset plate connections. The data of temperatures and deflections of typical members were recorded during the three tests. The experimental results showed that the performance of the connections had a significant influence on the mechanical behavior of the structure under elevated temperatures. The truss constructed with gusset plate connections (TRG) possesses better fire performance than the truss adapted with welded joints (TRW) because the gusset plate connection has better resistance capacity in fire than the welded joint does. Particularly, a chain of destruction might be aroused in the TRW due to local buckling and joint fracture, and then the progressive collapse of the whole structure might be induced. However, better coordination of the truss members is shown in the TRG because the gusset plate connections possess better hinged performance in fire, and the instantaneous damage of the structure was not induced; though the failure of some specific members was observed. The difference in the manifestation of the local buckling between the TRW and TRG was also found through the tests. That is, in-plane local buckling was observed in the TRW, while either in-plane or out-plane local buckling might be induced in the TRG.

1. Introduction

The steel staggered-truss system, which was developed at MIT in the 1960s under the sponsorship of the U.S. Steel Corporation, has many advantages over the conventional steel framing structure [1]. Generally speaking, the SST system is simple to construct because the trusses are prefabricated in the shop and then bolted to the columns directly. Besides, with the columns only on the exterior walls, the structural concept could provide a full width of column-free area. What's more, the staggered arrangement of the trusses allows an interior floor space of twice the column spacing to be available for freedom of floor arrangements. Since the SST system has numerous advantages, the system has been applied in practice for several times [2–4]; for example, the Baruch College Academic Center in New York City built in 2000, the Shangri-La Hotel in Seoul built in 2004 and the Staybridge Suites Hotel in Chicago built in 2008, etc.

At present, many researches on the SST system are mainly concentrated on the static behavior, economic performance and seismic performance at ambient temperature. For example, Kim et al. [5] evaluated the inelastic behavior of SST by pushover analysis. In addition, Zhou et al. [6] conducted a series of experimental and numerical analysis on the seismic behavior of the SST, and the influence of the typical parameter (e.g. height–width ratio, truss span–depth ratio and open-web panel length, etc.) was also studied. However, since the structural steel is a kind of heat sensitive material, fire load needs to be taken into account when designing and constructing these steel structures [7]. In particular, joints are critical members in steel structures since how the joints behave has critical influence in controlling progressive collapse of the structure under accidental fire attacks. For example, the critical influence of joints on structural behavior in fire has been painfully highlighted by the collapse of the World Trade Center twin towers [8]. Another notable case is the Cardington fire tests, through which the global structural behavior of steel-framed building and joints behavior under realistic fire conditions were studied carefully [9,10]. Thus, a large amount of authoritative bodies have since called for more research studies to be conducted to develop better understanding of the influence of joint performance on the structural behavior in fire [11]. Wang et al. [12] performed a series of fire tests to study the structural behavior and robustness of different types of steel joint in restrained steel frames. Yu et al. [13,14] conducted a series of experimental and numerical researches on the behavior of fin plate and web cleat connections in fire. Mao et al. [15] investigated the fire response of steel semi-rigid beam–column moment connections. AI-Jabri et al. [16] presented an artificial neural networking model to predict the behavior of semi-rigid bare-steel joints at elevated temperatures. Ding and Wang [17] carried out an experimental study of structural fire behavior of steel beam to concrete filled tubular column assemblies with different types of joints. Yu et al. [18] investigated the mechanical behavior of an impacted steel tubular T-joint in fire. Dai et al. [19] studied the effects of partial

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