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Fire behavior of shear angle connections in a restrained steel frame

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ABSTRACT

Experimental results of double angle connections with thermally-induced loading are presented in this paper. Two beam assemblies were tested inside a furnace by simulating typical building fire conditions. These beams were connected to a restrained steel frame outside of the furnace with double angle connections. The test variables included fire scenario, load level and composite action arising from beam-slab effect. Data generated from the fire tests indicate that double angle connection exhibit inherent rotational rigidity in spite of being designed as simple shear connections and are capable of transferring thermally-induced moments. Despite undergoing permanent deformations, no failure occurred in the tested assembly, thus illustrating the ductile behavior of the double angle connections.

1. Introduction

Steel connections play a crucial role in transferring forces between members (beam to beam, girder or columns) in a structural framing system. Of various connection types, double angle connections are widely used because of their higher rotational ductility and tying capacity [1,2]. In current design practice, double angle connections are designed to be flexible (simple shear connections) but they exhibit some inherent rigidity [3]. Steel connections lose their strength and stiffness at a rapid rate when subjected to fire. Further, double angle shear connections experience additional axial forces and moments due to restraint against free thermal expansion of heated members. The nature of these fire induced forces change from compression, during the heating phase, to tension, during the cooling phase of fire [4,5]. Thus, the behavior and performance of connections is vital in determining the overall response of the structural system under fire conditions.

Design strategies for connections at elevated temperatures are based on fire tests of isolated connections that were not considered to be a part of the structural assembly. The nature and the effect of fire induced forces developed due to structural continuity cannot be fully captured when connections are tested in isolation. Hence, there is a need for generating test data on the true behavior of double angle connections under the effect of structural continuity, rigidity of the connected members (beams, columns, girders) and cooling phase of fire. Currently there are limited test data on the behavior of double angle connections under fire conditions and this paper fills some of that data-gap.

In order to develop a better understanding on the fire behavior of double angle connections, experimental studies were undertaken. A network of steel beams with double angle connections was designed, fabricated and tested under fire conditions. The tested assembly was designed in such a way that the double angle connection fails under fire. The results of the fire resistance tests on two assemblies under different fire exposure conditions and the presence/absence of slab are presented in this paper.

2. State-of-the-art

2.1. Experimental studies

Few experimental studies are reported in the literature on the fire behavior of connections in framed structures due to complexity and costs associated with fire tests. Most of the previous fire experiments [6–13] were aimed at generating moment-rotation characteristics of isolated end-plate connections at elevated temperatures, while a few tests examined fin-plate [14] (shear tab) connections and the global structural behavior of connections [15]. However, only a handful of these studies were specific to double angle connections.

Lawson [6] carried out tests on double angle connections to quantify the moment capacity of the connections by subjecting them to ISO834 standard fire exposure. Results from these tests indicated that the connections possess significant strength at elevated temperatures and were able to sustain large moments (up to two-thirds of ambient temperature moment capacity) under fire conditions. Lawson concluded that (a) the limiting (critical) temperature of bolts is be less than that of the beam indicating that the bolts are not susceptible to premature failure, (b) bolt temperatures generated under fire conditions are significantly lower than the beam lower flange, thus enhancing the fire performance of connections, (c) mesh reinforcement present in composite beams contribute to increasing moment capacity of the connections, and (d) moment transferred through the connections helps in reducing

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