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An experimental study into the capacity of cold-formed steel truss connections

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ABSTRACT

This paper presents an experimental study on the behaviour of cold formed steel truss connections. Eighteen full scale cold-formed steel truss connections were tested. Of particular interests are the specimens maximum load capacity and the load-deformation behaviour. The study also looks at the failure modes of the connections. The behaviours exhibited by the connections are discussed and the design capacities calculated from the current CFS design standards are compared to the experimental results of the connections. This study investigates the main factors contributing to the ductile response of the CFS truss connections in order to suggest recommendations for connection designs, and improvements so that the connections respond plastically with a significant drift and without any risk of brittle failure. Also, a number of alternative fasteners are chosen and investigated for comparison with those that are currently specified for trusses' connections.

1. Introduction

The use of cold formed steel (CFS) structures in residential construction has become increasingly popular all over the world in recent decades; and is now a highly competitive alternative to traditional structural system. The increase in the CFS construction is due to the ongoing development and improvements in the field, the consequential availability of more cost-effective solutions, and the broad recognition of the advantages of cold formed steel framing. Some of the widely acknowledged advantages of CFS framing are: lighter weight, reduces transport and handling costs, and ease of prefabrication and mass production.

The optimal design of cold formed steel framing systems is important in ensuring they can produce a cost-effective solution which is competitive with other alternative structural systems in the housing industry. The improvement of the framing connections, in particular, could increase the capacity of the existing CFS framing system without changing the framing materials. This research study is aimed to conduct comparative evaluations for the optimisation of one of the currently in use CFS truss connections (lockbolt) in Australia and New Zealand. A number of alternative fasteners are chosen for comparison with those that are currently specified for trusses' connections.

The evaluation of the different connection types for the truss investigations is based on capacity testing of full-size connection specimens. The capacities reported are based on the maximum load which was resisted by the connection; and three types of fasteners are included.

2. Failure modes of cold formed steel connections

The main failure modes for bolted connections are tear-out, bearing failure of sheet material, tension failure of net section, shear failure of bolts, and combinations of two or more of these failures [1]. These failure modes are illustrated in Fig. 1 and described in more detail below.

Tear-out failure occurs most in connections where the bolt is near the edge of the plate, or the distance between adjacent bolts parallel to the line of force is small. The plate tears from a bolt hole to the edge of the plate or to another adjacent bolt hole (see Fig. 1). To prevent this type of failure, design guidelines specify minimum edge and spacing distances for bolted connections. Hancock et al. [1] suggest that when the edge and spacing distances are large enough to avoid tear-out failure, bearing failure of the sheet could occur. Bearing failure often produces stretching of the hole on one side of the bolt, while the sheet material is bunched together on the other side of the bolt. Rogers and Hancock [3] have proven through experimentation that the use of washers under the bolt head and nut can significantly increase a connection resistance against bearing failure, and propose that this is due to the commonly low thicknesses of CFS.

When the stresses in the net section of the connected sheet are large enough, failure of the sheet can occur across the bolt hole. This type of failure occurs at the connection because it is often the cross-section of the sheet with the lowest net area, and hence it is the weakest section of the sheet. The stresses in the net section depend on the spacing

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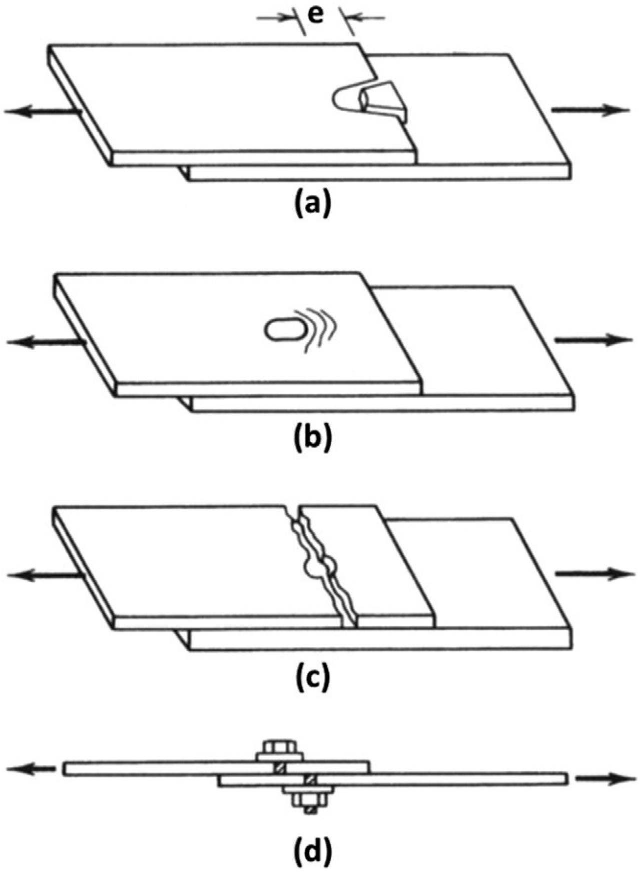

Fig. 1. Failure modes of bolted connections: a) tear-out failure of sheet, b) bearing failure of sheet, c) tension failure of net section, d) bolt shear failure [2].

arrangements, and the total number of bolts at a connection. The spacing arrangements usually determine the net section, particularly in solid sheets without perforations additional to the bolt holes. Bolt shear failure occurs when the grade of bolt used does not have shear strength high enough to resist loads beyond the load capacity of the sheet and/or the load capacity of the connection arrangement as a whole. The bolt can fail in double or single shear depending on the connection arrangement. In this case the failure is brittle and therefore is undesirable. Designers should design so that this type of failure is very unlikely.

It is necessary to mention that the screwed connections and riveted connections can fail in one mode or a combination of the aforementioned bolted connection failure modes in addition to some other failure modes including: tilting, pull-out, and pull-over. Tilting failure usually occurs when two materials of the same thickness are connected with screws, or when the thicker material is against the screw head. As the two sheets move over each other the screws can become tilted, and when the tilting angle becomes large, pull-out failure can occur. This type of failure is illustrated by Hancock [4] as shown in Fig. 2.

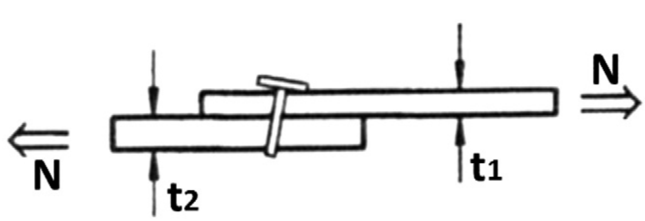

Fig. 2. Tilting failure of screwed connections [4].

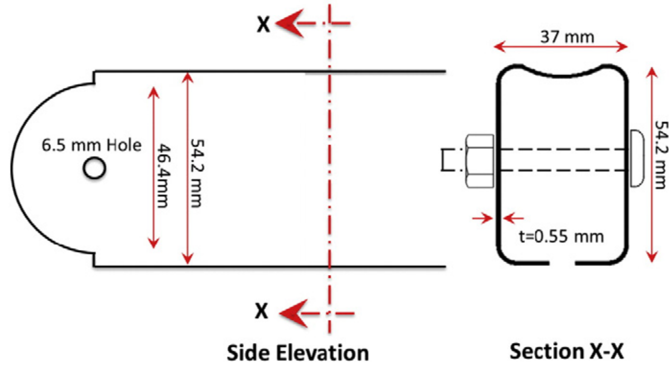

Fig. 3. Truss framing section.

Pull-out failure involves the screw(s) being 'pulled out' of the supporting sheet material under load, as a result of the axial tensile forces in the screws due to the rotated position of the screws relative to the direction of load in the connection [5]. This type of failure is often associated with tilting failure. Pull-over failure involves the

Fig. 4. Lockbolt truss connection, testing machine set-up.