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Structural behaviour of cold-formed thin-walled short steel channel columns at elevated temperatures. Part 1: experiments

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Abstract

Cold-formed thin-walled steel structures are increasingly being used as primary load bearing members. However, there is a lack of study of their performance in fire. This paper presents a detailed description of an experimental study of the axial strength of cold-formed thin-walled channel sections under ambient and uniform high temperatures. The objectives of this study are two-fold: to gain an insight into the physical behaviour and failure modes of this type of structure and to provide some experimental results for detailed numerical studies. A total of 52 strength tests were carried out on short cold-formed lipped channels with and without service holes and unlipped channels at ambient and various elevated temperatures. From these experimental studies, it has been observed that the failure mode of two nominally identical columns can be different even though the failure loads are close. Depending on the thickness of a channel and the location of the service hole, perforation can have an important effect on the strength of the channel, irrespective of the temperature. The companion paper will describe the results of design calculations and numerical studies.

Keywords: Thin-walled columns; Elevated temperature tests; Fire resistance; Perforated section; Cold-formed steel; Strength tests; Local buckling; Distortional buckling

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1. Introduction

Cold-formed thin-walled steel members provide a high strength to weight ratio and are also easy to construct when compared to thicker hot-rolled steel members. Because of these, cold-formed thin-walled steel sections as load-bearing structural components are widely used in domestic and industry buildings and in almost any imaginable location since it was first applied in building construction in about 1850 in USA. Its applications and our understanding of its behaviour have been further expanded in various fields by leaps and bounds since the first specification for cold-formed steel design was issued by the American Iron and Steel Institute (AISI) in 1946. However, one of the main disadvantages of cold-formed thin-walled steel as a structural material is its low fire resistance because of a combination of the high thermal conductivity of steel and the high section factor of the structural member, both leading to rapid steel temperature rises in fire. Nevertheless, despite increasing use, studies of the fire performance of cold-formed thin-wall steel members are rare and available information in the literature is scarce [1-8,12–,14,16,19,20].

There are a number of important differences between the fire behaviour of cold-formed thin-walled steel members and that of hot-rolled ones. Firstly, the mechanical properties at elevated temperatures are different. Cold-forming steel has a strengthening effect at ambient temperature, but this strengthening effect is reduced at elevated temperatures. Secondly, due to the nature of fire protection to thin-walled steel members and the fact that thin-walled members are usually exposed to fire attack on one side, temperature distributions in thin-walled steel members under fire attack are highly non-uniform and different from those in hot-rolled members. Thirdly, thin-walled steel members usually have more complex buckling behaviour, involving local, distortional, global buckling and their interactions. In addition, for easy installation of electrical wires and plumbing systems, pre-punched service holes are often introduced in the web of a thin-walled steel member. Although the effect of a web opening in a column at ambient temperature has been investigated by many researchers [9–,11,15,17,18,21], the effect of perforation under high temperatures is not clear and there are very few studies of the fire performance of cold-formed thin-walled steel columns with holes. As a result, no design method is available for this type of construction.

At present, fire resistant design of cold-formed thin-walled steel structures is often based on the results of manufacturers' standard fire tests. Not only is this expensive, but it also limits flexibility of the designer. In order to develop rational and general fire engineering design methods for cold-formed thin-walled steel structures, a study of the behaviour of cold-formed thin-walled steel structures in fire has been recently started in the Structures and Fire Research Group at the University of Manchester with financial support from the EPSRC. This paper reports the results of a number of tests on cold-formed thin-walled steel short columns with and without holes under ambient and uniform high temperature conditions. The objectives of these experiments are to study the failure modes of short thin-walled columns at elevated temperatures and to provide data for checking and validating design and numerical pre-