Journal of Constructional Steel Research 125 (2016) 252–262

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Section moment capacity tests of rivet fastened rectangular hollow flange channel beams

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ARTICLE INFO

Article history:
Received 12 April 2016
Received in revised form 23 June 2016
Accepted 23 June 2016
Available online 5 July 2016

Keywords:
Hollow flange beams
Cold-formed steel structures
Section moment capacity tests
Intermittent rivet connection
Direct strength method
Design rules
Local buckling

ABSTRACT

This paper presents the details of an experimental investigation on the section moment capacities of rivet fastened Rectangular Hollow Flange Channel Beams (RHFCB). The rivet fastened RHFCB is a new type of cold-formed steel section, an extension to the widely researched hollow flange beams, shown to have capacities more typically associated with hot-rolled steel beams. It is characterized by a unique geometry, consisting of two rectangular hollow flanges and a web. Unlike other cold-formed sections, the RHFCB has improved capacity due to its mono-symmetric shape and the absence of free edges. The RHFCB manufacturing involves fastening two hollow flanges to a web, utilizing inexpensive intermittent self-pierced rivet fastening. This enables designers to develop optimum sections with varying web and flange thicknesses, therefore delaying the onset of other buckling failures due to slender web element. Various researches have been carried out to investigate the behavior of continuously welded hollow flange beams but little is known on the behavior of RHFCBs. Hence this paper investigates the section moment capacities of rivet fastened RHFCBs. Fifteen section moment capacity tests were conducted to investigate the behavior of RHFCB flexural members. The reduction in section moment capacities from having continuous weld to intermittent rivet connection at its web-flange junction was also investigated. The ultimate moment capacities from the tests were compared with current steel design standards: AS/NZS 4600, AS 4100 and AISI S100. The paper also explores the suitability of the Direct Strength Method, with modification being proposed, from the results obtained from this investigation.

1. Introduction

The rivet fastened Rectangular Hollow Flange Channel Beam (RHFCB) is a new section in the category of cold-formed, hollow flange beams. It is made by rivet fastening two torsionally rigid rectangular hollow flanges to a web (Fig. 1) at ambient temperature. The proposed manufacturing method of RHFCBs, based on cold-forming and rivet fastening, provides designers the flexibility of using different combinations of flange and web thicknesses. This is likely to delay or avoid certain buckling modes that are commonly associated with the hollow flange beams such as lateral distortional buckling, which is mainly due to the presence of slender web elements. The detrimental effect of lateral distortional buckling on the moment capacity of hollow flange beams was investigated by Anapayan et al. [1] and Anapayan and Mahendran [2].

The structural application of cold-formed steel sections is increasing rapidly in residential, commercial and industrial buildings. Although cold-formed steel members are considered to be more cost efficient than hot-rolled steel members, they are subjected to complicated buckling modes due to slender sections that are also either unsymmetric or singly symmetric. For instance, conventional C- and Z-sections are subjected to distortional buckling due to the presence of free edges. With the advancement in the manufacturing technology and with the aim of introducing lighter and structurally efficient sections, several unique cold-formed cross-sections have been introduced in recent times. Most notable to this development are the hollow flange beams (Fig. 2) which were designed with minimum weight (therefore minimum cost) and maximum structural performance in their applications as flexural members [3]. This is made possible by incorporating torsionally rigid hollow flanges.

As shown by researchers in the past, the hollow flange beams (Fig. 2) are able to provide capacity more typically associated with hot-rolled steel beams, than other conventional cold-formed steel beams. Research on hollow flange beams [2,4–8] have demonstrated this through experimental and numerical studies. Keerthan and Mahendran [9,10] showed that LiteSteel beams (LSB) in Fig. 2(b) have higher shear capacities than the predictions by the Australian/New Zealand cold-formed design standard AS/NZS 4600 due to the presence of higher elastic shear buckling capacities caused by the additional fixity in the web-flange juncture, and the available post-buckling strength. The rivet fastened RHFCB is an extension of LSB, manufactured using intermittent rivet fastening, instead of continuous electric resistance welding used to manufacture the hollow flange beams shown in Fig. 2. However, limited research has been conducted on its behavior and moment capacity to date.

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http://dx.doi.org/10.1016/j.jcsr.2016.06.021
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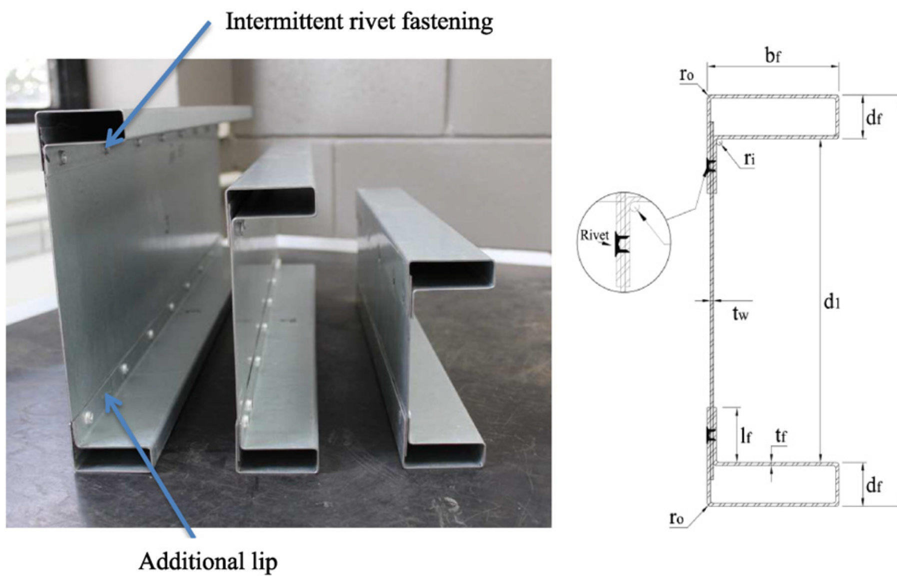

Fig. 1. Rivet fastened rectangular hollow flange channel beam.

Today, much research has been carried out on the unique behavior of cold-formed steel sections (CFS). Distortional buckling is common in the conventional C- and Z-sections due to the presence of open edges. Local buckling is prevalent in CFS sections as they are typically thin-walled. At the same time, local buckling in CFS sections provides beneficial post-buckling reserve that is included in design. As shown by Shifferaw and Schafer [11], significant inelastic reserve capacity is available for CFS sections in bending. Yener and Peköz [12,13] developed design rules to determine the inelastic bending capacity of CFS sections based on the recommended ratio of compressive strain to yield strain (C_y) as a function of the b/t ratio of compression elements, which have been adopted in the Australian/New Zealand Standard for cold-formed steel structures AS/NZS 4600 [14] and the North American Specification AISI S100 [15]. However, they cannot be used for predicting the capacity of hollow flange beams as they do not meet the two criteria including the web slenderness limit.

Anapayan et al. [6] conducted 20 section moment capacity tests of LSBs using a four point loading arrangement. Their test results revealed that the section moment capacities of compact and non-compact LSB sections were greater than their first yield moments. They concluded that AS/NZS 4600 is conservative in predicting the section moment capacities of LSB sections as it did not consider the available inelastic bending capacities. Their research did not suggest an improved design method and also did not explore the suitability of the Direct Strength Method for predicting the section moment capacity of LSB or other hollow flange beams in general.

In terms of design, two design methods exist for the design of CFS structural beams. They are the Effective Width Method (EWM) and the Direct Strength Method (DSM). However, the iteration process in EWM becomes cumbersome as the section becomes complicated. The DSM allows the moment capacity prediction of any general cross-section, requiring only the elastic buckling and first yield moments. However, the DSM has been calibrated to cover only the pre-qualified sections specified in AISI S100. Pham and Hancock [16] tested plain C and SupaCee sections in pure bending for the extension of the DSM to include channel section beams with complex stiffeners. Wang and Young [17] proposed modified DSM equations to include cold-formed steel channels with stiffened webs subjected to bending as the current DSM is conservative, especially in the case of local buckling. Shifferaw and Schafer [11] investigated the inelastic bending capacities of plain C- and Z-sections and developed methods for inelastic capacity, which have since been included in the DSM provision of the North American Specification (AISI S100). Therefore, this study also looks into the suitability of the current DSM on predicting the section moment capacities of rivet fastened RHFCBs.

This paper presents the details of an experimental study on the buckling and ultimate strength behavior of the new intermittently rivet fastened RHFCBs. Fifteen rivet fastened RHFCBs were tested under a four-point bending arrangement about the major axis of the sections. The ultimate moment capacities obtained from the experiments were compared with design code predictions where the suitability of currently used design rules including DSM was investigated. Finally, suitable modifications were made to the use of DSM that takes into account the reduction in moment capacity with increasing rivet spacing.

2. Experimental investigation

2.1. General

The section moment capacity (M_s) of a steel cross-section accounts for its yielding and local buckling effects. For cold-formed steel sections, due to their thin plate elements with a high plate slenderness ratio (b/t) ratio, they are often subjected to local buckling effects which reduce their section moment capacities. The Australian hot-rolled design

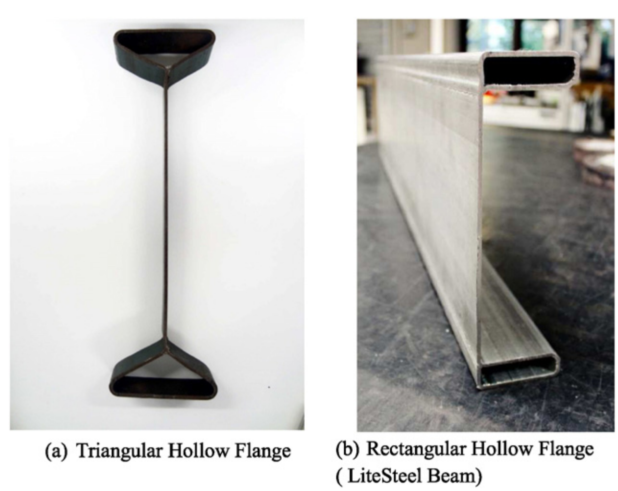

Fig. 2. Hollow flange beams.