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Web crippling tests of Rivet Fastened Rectangular Hollow Flange Channel Beams under Two Flange Load Cases

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ABSTRACT

Recent research on hollow flange beams has led to the development of an innovative rectangular hollow flange channel beam (RHFCB) for use in floor systems. The new RHFCB is a mono-symmetric structural section made by intermittently rivet fastening two torsionally rigid closed rectangular hollow flanges to a web plate element, which allows section optimisation by selecting appropriate combinations of web and flange widths and thicknesses. However, the current design rules for cold-formed steel sections are not directly applicable to rivet fastened RHFCBs. To date, no investigation has been conducted on their web crippling behaviour and strengths. Hence an experimental study was conducted to investigate the web crippling behaviour and capacities of rivet fastened RHFCBs under End Two Flange (ETF) and Interior Two Flange (ITF) load cases. It showed that RHFCBs failed by web crippling, flange crushing and their combinations. Comparison of ultimate web crippling capacities with the predictions from the design equations in AS/NZS 4600 and AISI S100 showed that the current design equations are unconservative for rivet fastened RHFCB sections under ETF and ITF load cases. Hence new equations were proposed to determine the web crippling capacities of rivet fastened RHFCBs. These equations can also be used to predict the capacities of RHFCBs subject to combined web crippling and flange crushing conservatively. However, new capacity equations were proposed in the case of flange crushing failures that occurred in thinner flanges with smaller bearing lengths. This paper presents the details of this web crippling experimental study of RHFCB sections and the results.

1. Introduction

In steel construction, cold-formed steel (CFS) Hollow Flange Channel Beams (HFCB) are innovative products that represent a modern light weight building technique (Fig. 1). HFCBs are thin-walled structural members designed with two rectangular hollow flanges. This is unique from other commonly used open CFS sections such as C-, Z-, or hat-shaped sections. HFCBs have no unstiffened elements (no free edges), hence reducing the local buckling effect in the flanges. They are also designed to have the hollow flanges away from the neutral axis, making them structurally efficient as beams. In doing so, this combines the stability found in hot-rolled sections with the high capacity-to-weight ratio found in cold-formed sections.

In 2005, OneSteel Australian Tube Mills (OATM) introduced the first HFCB known as LiteSteel beam (LSB), primarily for use as flexural members in residential and light commercial/industrial applications (see Fig. 1(a)). LSB was manufactured from a single strip of high strength steel using a combined cold-forming and dual electric resistance welding process. The structural behaviour of LSB has been investigated by many researchers in the past [1–12], which led to the use of LSB in many applications in buildings. Despite this, the OATM discontinued LSB production in 2012. However, LSBs have remained increasingly popular due to their improved structural performance and light weight. Hence an equivalent rectangular hollow flange channel beam (RHFCB) was proposed using an intermittently rivet fastening process without the need for the expensive dual electric resistance welding (see Fig. 1(b)).

The rivet fastened RHFCB can be easily manufactured using a cold-forming and rivet fastening process. The independent method of joining the web and flange plate elements of the section allows greater optimisation by choosing appropriate combinations of web and flange plate thicknesses. For example, the use of thicker web plate elements will increase the lateral distortional buckling capacity of RHFCB flexural members. The rivet fastened RHFCB also has additional lips, possibly contributing to increased rigidity and strength. Table. 1 shows the nominal dimensions of rivet fastened RHFCB sections used in this research. However, only limited research has been conducted on the structural

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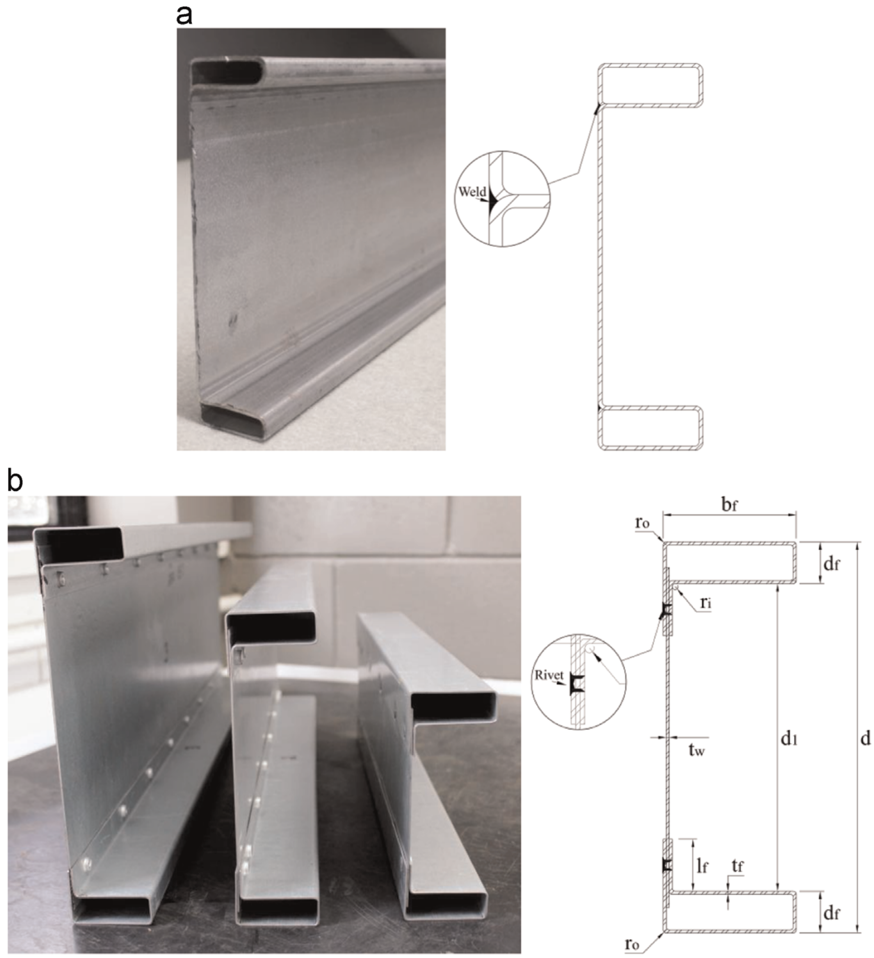

Fig. 1. Hollow Flange Channel Beams. (a) LiteSteel Beam (LSB) and (b) Rivet Fastened RHFCB.

Table 1
Nominal dimensions of rivet fastened RHFCB sections.

Rivet fastened RHFCB section ($dxb_fxd_fxt_fxt_w$)	d (mm)	b_f (mm)	d_f (mm)	t_f (mm)	t_w (mm)
150 × 53 × 18 × 0.95 × 0.95	150	53	18	0.95	0.95
150 × 53 × 18 × 1.15 × 1.15	150	53	18	1.15	1.15
150 × 53 × 18 × 1.15 × 1.50	150	53	18	1.15	1.50
150 × 53 × 18 × 1.15 × 0.70	150	53	18	0.70	0.70
150 × 53 × 18 × 1.15 × 0.95	150	53	18	0.95	0.95
200 × 53 × 18 × 1.15 × 1.15	200	53	18	1.15	1.15
150 × 53 × 18 × 1.20 × 1.20	150	53	18	1.20	1.20
200 × 53 × 18 × 1.20 × 1.20	200	53	18	1.20	1.20
250 × 53 × 18 × 1.20 × 1.20	250	53	18	1.20	1.20

d, b_f, d_f=external dimensions (see Fig. 1(b)), l_f=20 mm, and r_i=0.

performance of rivet fastened RHFCB sections.

Since the rivet fastened RHFCB is a thin-walled flexural member, web bearing/crippling instability may occur. Web crippling is a web buckling failure mode that is caused by concentrated loads or support reactions. Fig. 2 shows the web crippling failure of different cold-formed steel beams. Rivet fastened RHFCB joists and bearers that are unstiffened against this type of loading are also vulnerable to similar web crippling failures, but no research has been undertaken. Four different web crippling load cases are defined in AISI S909 [13], which are shown in Fig. 3: End-One-Flange (EOF), Interior-One-Flange (IOF), ETF and ITF load cases.

Suitable design equations are needed to predict the web crippling capacity of cold-formed steel sections subject to all four of the load cases listed above. However, the web crippling design equations in most cold-formed steel structural design codes are empirical, derived from experimental studies consisting of over 1200 tests of conventional cold-formed steel sections [14-25]. The current AS/NZS 4600 [26] and AISI S100 [27] web crippling design equations provide a unified web crippling capacity equation. However, it is not applicable to the rivet fastened RHFCB due to the presence of two rectangular hollow flanges. Unlike other open cold-formed steel sections, rivet fastened RHFCB can also be subjected to flange crushing, combined web crippling and flange crushing and lip failures.

Rivet fastened RHFCBs can be used as flexural members in steel building systems. For them to be used as flexural members, their flexural, shear and web crippling capacities must be known. However, no investigation has been conducted into the web crippling behaviour and strength of rivet fastened RHFCBs. In this research web crippling behaviour and strength of rivet fastened RHFCBs under ETF and ITF load cases was investigated using an experimental study. This paper presents the details of this experimental study, and the results. Experimental web crippling capacities are compared with the predicted capacities using the current design rules, based on which appropriate improvements are recommended.

2. Web crippling of cold-formed steel beams

Recent years has seen the development and introduction of different test methods and design equations for cold-formed thin-walled structures. The following section will review the current