Thin-Walled Structures 116 (2017) 180–193

Contents lists available at ScienceDirect

Thin-Walled Structures

journal homepage: www.elsevier.com/locate/tws

Full length article

Compression tests of built-up cold-formed steel hollow flange sections

Sivakumar Kesawan, Mahen Mahendran*, Yomal Dias, Wen-Bin Zhao

Queensland University of Technology (QUT), Brisbane, Australia

ARTICLE INFO

Keywords:
Cold-formed steel structures
Built-up sections
Screw fastened
Rivet fastened
Hollow flange sections
Direct strength method
Effective width method

ABSTRACT

Cold-formed steel hollow flange sections are structurally efficient compared to the conventional open channel sections. They can be of different forms including hollow flange I- and channel sections, which are generally fabricated by first cold-forming a single sheet to form the desired shape and then connecting their flange and web elements by continuous welding. Instead of welding, intermittently screw/rivet fastened or spot welded connection can also be used. A detailed investigation is currently under way on the structural performance characteristics of such intermittently screw/rivet fastened steel hollow flange sections. This paper presents the details of an experimental study performed to investigate the behaviour of built-up cold-formed steel hollow flange sections in compression, where more than 45 stub columns were tested. Both hollow flange I- and channel sections built-up using either single steel sheet or three steel elements were tested. Tests also included built-up hollow flange channel sections with stiffened web elements. Test results including the failure loads, load versus axial deformation plots and failure characteristics are presented in this paper. Test failure loads are compared with the predictions based on both effective width and direct strength methods to verify their adequacy in predicting the section compression capacity of built-up hollow flange sections. This paper has shown that although hollow flange I-sections made of three elements with a 100 mm fastener spacing can perform similar to continuously welded sections, hollow flange channel sections undergo premature failures even with a 50 mm fastener spacing, and the reasons are discussed.

1. Introduction

The usage of cold-formed steel structures in the building construction industry is rapidly increasing due to their potential benefits including high strength to weight ratio, rapid constructability and ease of transportability. To date, open Z-, unlipped or lipped channel sections are the most commonly used cold-formed steel sections. The open and thin-walled nature of these sections makes them suffer from local and distortional buckling effects, which ultimately reduce their ultimate capacities and moreover result in complex capacity calculations. Recently many attempts have been made to eliminate the occurrence of such buckling modes and improve the load carrying capacities of cold-formed steel members. The hollow flange section is one of the outcomes of such attempts.

In early 1990s, a hollow flange section with two triangular flanges (Fig. 1(a)), known as Hollow Flange Beam (HFB), was first introduced in Australia. This section has improved buckling capacities due to its unique shape where its distortional buckling is eliminated by the torsionally rigid hollow flanges while its local buckling capacity is improved due to the absence of free edges and reduced web width. This cold-formed steel section is considered to have the advantages of both hot-rolled I-section and conventional cold-formed C- and Z-sections [1]. However, it was discontinued due to its complicated manufacturing process involving simultaneous cold-forming and electric resistance welding [2].

LitesSteel Beam (LSB) is the recently invented hollow flange channel (HFC) steel section developed by OneSteel Australian Tube Mills (OATM) using an improved cold-forming and dual electrical resistance welding process (Fig. 1(b)). This section was extensively used in Australia since 2002, and is on average 40% lighter than the traditional hot-rolled structural sections of equivalent bending strength. Kesawan and Mahendran [3–5] and Jatheeshan and Mahendran [6,7] demonstrated the improved fire performance of Light gauge Steel Frame (LSF) wall and floor systems when these cold-formed and fully welded HFC sections/LSBs were used as load-bearing studs and joists. However, LSB has also been discontinued recently, due to the changes in OATM's business operations and expensive welding process. Instead of the continuous electric resistance welding used to connect the web and flange elements, other techniques such as spot welding or rivet/screw fastening can be adapted to form hollow flange sections. Fig. 2(a) and (b) show the new rivet/screw fastened or spot welded rectangular hollow flange I-sections (HFI) while Fig. 2(c) and (d) show the hollow flange channel (HFC) sections. However, the structural behaviour of these built-up hollow flange sections has not been investigated adequately.

* Corresponding author.

http://dx.doi.org/10.1016/j.tws.2017.03.004
Received 26 August 2016; Received in revised form 22 December 2016; Accepted 5 March 2017
Available online 28 March 2017

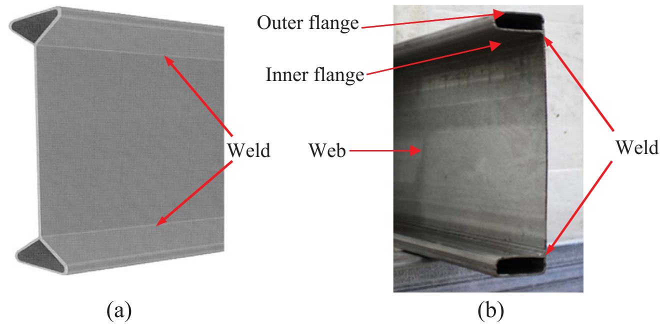

Fig. 1. Welded hollow flange sections, (a) Hollow Flange Beam (HFB), (b) LiteSteel Beam (LSB).

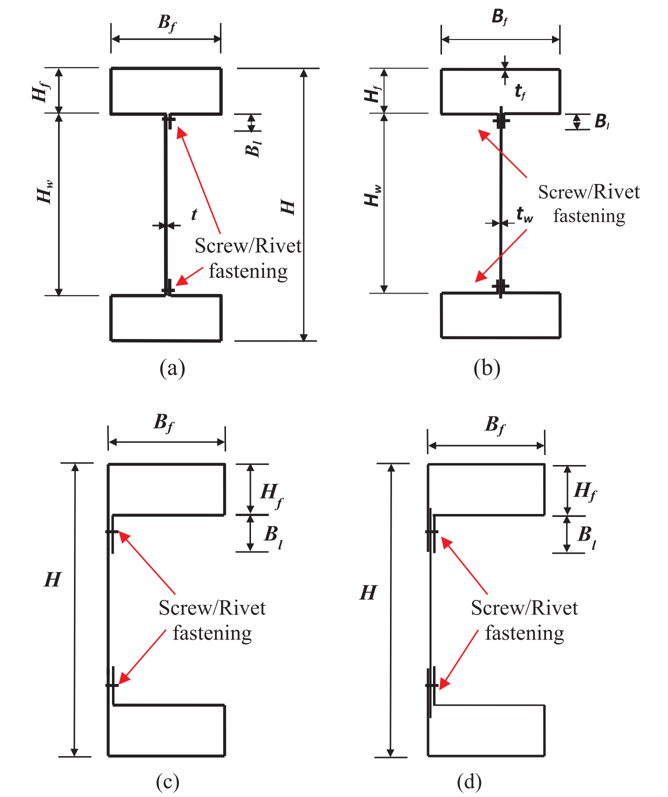

Fig. 2. Screw/Rivet fastened hollow flange sections, (a) HFI section made of single steel plate, (b) HFI section made of three steel elements, (c) HFC section made of single steel plate, (d) HFC section made of three plate elements.

*Note: B_f is the flange width, h_f is the lip length, H_w is the web depth, t_w is the web thickness, t_f is the flange thickness, B_l is the length of the outstanding element.

From the introduction of cold-formed hollow flange sections in the 1990s, many research studies have been undertaken, but they were limited to their bending and shear studies [8–10]. Yi and Wilkinson [11] and Kesawan and Mahendran [12] were the first to conduct an extensive investigation on the compression capacity of cold-formed steel hollow flange sections. Their tests were also limited to welded hollow flange channel sections (LSBs). Since reliable research data on the structural performance of built-up hollow flange sections is not available, detailed investigations are now being undertaken on their structural behaviour at the Queensland University of Technology. As part of these investigations, this study focuses on the section compression capacity of built-up hollow flange sections.

The built-up cold-formed HFI and HFC sections can be made using either single steel sheet or three steel elements. The manufacturing process of HFC sections using a single steel sheet is complex whereas they can be easily made of three steel elements with their two hollow flange elements connected to the web element through rivet/screw fastening or spot welding. The significant advantage of the built-up sections made of three steel elements is that the web and flange elements can be of different steel grades and thicknesses (Fig. 2(b) and (d)), for example, web element can be thicker than flange elements. Furthermore, different steel grades can be used for web and flange elements depending on the requirements. These enable the designers to choose from a variety of options based on their requirements, thus leading to an optimum design. However, it is critical to determine the required rivet/screw spacing to minimise any loss in the section capacity due to intermittent fastening. Although many studies [13–19] have been undertaken in the past on the structural behaviour of built up I- and box sections, no such attempts have been made on built-up hollow flange sections.

To obtain reliable structural performance data and to develop suitable design guidelines for built-up hollow flange sections in compression, an experimental study was performed where more than 45 stub columns were tested. This paper presents the details of this experimental study conducted to investigate the structural behaviour and capacity of built-up hollow flange I- and channel section stub columns subject to local buckling effects. The ultimate failure loads of tested columns were compared with the predictions based on the effective width and direct strength design methods in AS/NZS 4600 [20] in order to verify their applicability to built-up hollow flange sections.

Past research studies [21–24] and AISI S100 [25] recommend suitable connector spacing requirements for cover plated sections based on three criteria, (1) the connector should be able to transmit the shear forces between the connected parts, (2) connector spacing should be higher than $1.16t\sqrt{E/f_c}$ to avoid column like buckling behaviour of the plates, and (3) connector spacing should be higher than a spacing of three times the flat width of the narrowest unstiffened compression

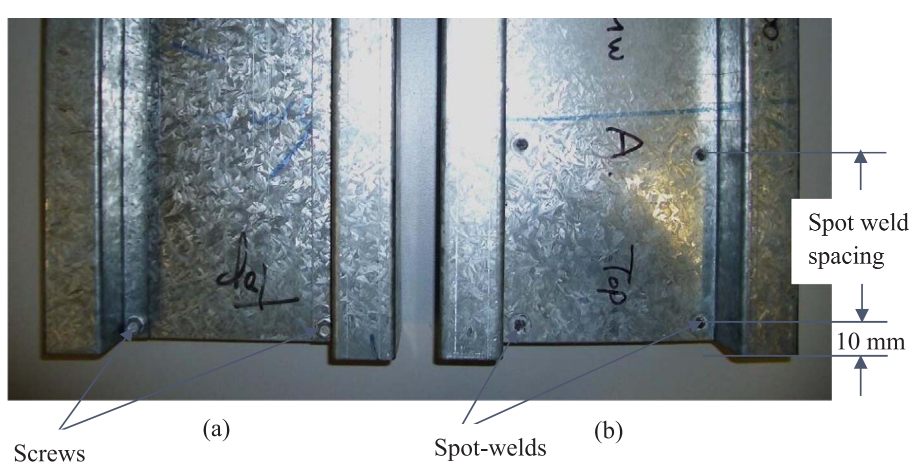

Fig. 3. Screw fastened and spot welded 1PHFIs (a) Screw fastened, (b) Spot welded.