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Experimental study of the section moment capacity of cold-formed and screw-fastened rectangular hollow flange beams

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ABSTRACT

This paper presents the results of an experimental study on the section moment capacity of cold-formed steel beams with rectangular hollow flanges. The new Rectangular Hollow Flange Beam (RHFB) is fabricated using a unique manufacturing process in which two cold-formed rectangular hollow flanges are screw fastened to a web plate. It possesses unique stress-strain characteristics and initial imperfections that are different from conventional open cold-formed steel sections and welded hollow flange beam sections. In this study, the section moment capacity of RHFBs was investigated using a series of full scale bending tests. Twenty two section moment capacity tests of RHFBs were conducted on short span flexural members with simply supported end conditions for three steel grades G300, G500 and G550 and varying thicknesses. Test capacity results were compared with the capacities predicted by the current design rules in the Australian and North American steel design standards, AS 4100, AS/NZS 4600 and AISI S100, to verify their applicability to RHFBs. The results show that although the current design rules based on effective width principles predicted the section moment capacities of RHFBs slightly unconservatively in comparison to test results, they can be used for RHFBs provided a suitable screw spacing is used. However, the Direct Strength Method (DSM) based design rules are found to predict the section moment capacity of this new screw-fastened hollow flange beam section conservatively in most cases. This research shows that the DSM based design rules including the new inelastic reserve bending capacity provisions in AISI S100 can be used to predict the section moment capacities of both screw-fastened and welded hollow flange beam sections conservatively.

1. Introduction

The use of thin-walled, cold-formed high strength steel products in the building industry has significantly increased in recent years. These products are being widely used in various applications such as purlins, girts, portal frames and steel framed housing. With the availability of advanced technologies and very thin (< 1 mm) and high strength steels G500 and G550 with minimum yield strengths of 500 and 550 MPa, cold-forming process has become simple, efficient, economical and environmentally friendly, capable of producing a variety of efficient sections including rectangular and circular hollow sections compared to the conventional and more expensive hot-rolled sections. Hollow sections have a high torsional rigidity and thus give greater buckling strengths. Dempsey [1] states that the basis of the development of Hollow Flange Beam (HFB, Fig. 1(a)) in Australia in the 1990's was its higher torsional rigidity due to two closed triangular flanges. The HFBs combine the stability of hot-rolled steel sections with the high strength-to-weight ratio of conventional cold-formed steel sections, and are therefore considered superior than conventional sections. They have the hollow flanges away from the centre, making them more efficient flexural members than equivalent hot-rolled or welded I-sections. However, there were some shortcomings in the manufacturing and applications of HFBs. The manufacturing of HFBs incurred high cost due to combined cold-formed and electric resistance welding process whereas their applications had restrictions due to connection difficulties. This resulted in the discontinuation of HFB manufacturing by late 1990s.

The HFB manufacturer then developed a new hollow flange channel section known as the LiteSteel Beam (LSB) using an improved combined cold-formed and dual electric resistance welding manufacturing process. The LSB (Fig. 1(b)) comprises duo steel grades with nominal flange and web yield stresses of 450 MPa and 380 MPa, respectively. Since its inception LSB section has been thoroughly researched in many aspects, lateral torsional and distortional buckling [2–5], section moment capacity [6], shear behaviour [7,8], and flexural behaviour with and without web openings [9]. The welded LSB has therefore been

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(a) HFB (b) LSB

Fig. 1. Hollow flange sections. (a) HFB, (b) LSB.

highly researched particularly due to its ability to provide capacities that are more typically associated with hot-rolled, than cold-formed steel members. However, no such comprehensive investigations have been undertaken to develop and investigate the behaviour and strength of screw-fastened hollow flange beams.

The new Rectangular Hollow Flange Beam (RHFB) introduced in this study (see Fig. 2) is expected to address some of the shortcomings present in the cold-formed and welded HFBs and LSBs. A simple screw fastening method is proposed for the manufacturing of the new RHFBs by connecting the two cold-formed rectangular hollow flanges to a web plate. This will reduce the fabrication cost of this light weight steel section and make the manufacturing process simpler. Also unlike the HFBs and LSBs, this new RHFB section can be made using different combinations of flange and web thicknesses that allows structural optimisation to suit various applications. The use of a thicker web can eliminate or delay the critical lateral distortional buckling failure usually associated with HFBs and LSBs.

Since the structural performance of this new RHFB made using intermittent screw fastening has not yet been investigated thoroughly, the fundamental knowledge and understanding of the complicated behaviour of RHFB section is inadequate. Anapayan et al. [3] showed that the LSBs were subjected to local buckling and then lateral distortional buckling and lateral torsional buckling as their spans increased. However, it is expected that the buckling behaviour of RHFB sections is more complicated than HFB and LSB sections due to the lack of continuity along the flange to web connections. Therefore the suitability of current design rules including those developed for the welded HFBs and LSBs is unknown for this type of sections due to its unique manufacturing process and material characteristics. Detailed investigations into the flexural behaviour and moment capacity of intermittently screw-fastened RHFBs are needed. In this research, the section moment capacity of RHFBs was investigated using an experimental study. Experimental data of commonly used hot-rolled and cold-formed steel sections are inappropriate for use as the basis for the development of design rules of RHFB sections. For example, the moment capacity results of conventional rectangular and square hollow sections [10–12] cannot be used for RHFB sections. The section moment capacity research on LSBs [6,7] is also not directly applicable since screw-fastened RHFBs do not have a continuous web to flange connection. In this research, four point bending tests of fully laterally restrained short RHFB sections were conducted to investigate their in-plane bending behaviour associated with local buckling effects and determine their section moment capacities. A total of 22 section moment capacity tests was undertaken with different parameter combinations. This paper describes the details of the section moment capacity tests of RHFBs, their capacity results and comparisons with predictions from the current design rules.

2. Section moment capacity tests

2.1. Test specimens

Since the flexural behaviour of RHFB sections has not yet been investigated thoroughly, it is important that the key parameters are selected precisely in the design stage of test program. A group of sections with different key parameters (i.e. section geometry, material thickness and yield stresses) were selected in this test program. Details of the 22 test specimens used in this test program are shown in Table 1. The cross-section and overall view of a typical RHFB test section is shown in Fig. 2.

All the test specimens were 1130 mm long and were fabricated by assembling two separately cold-formed rectangular hollow flanges to a single web plate using self- drilling screws of size 10 – 16 × 16 mm at 50 mm and 100 mm spacings. The rectangular hollow flanges of size 50 mm × 25 mm with 15 mm lips were formed by press-braking in the university workshop. The two flanges were then held together with the web plate and then screw-fastened at the selected spacing. The

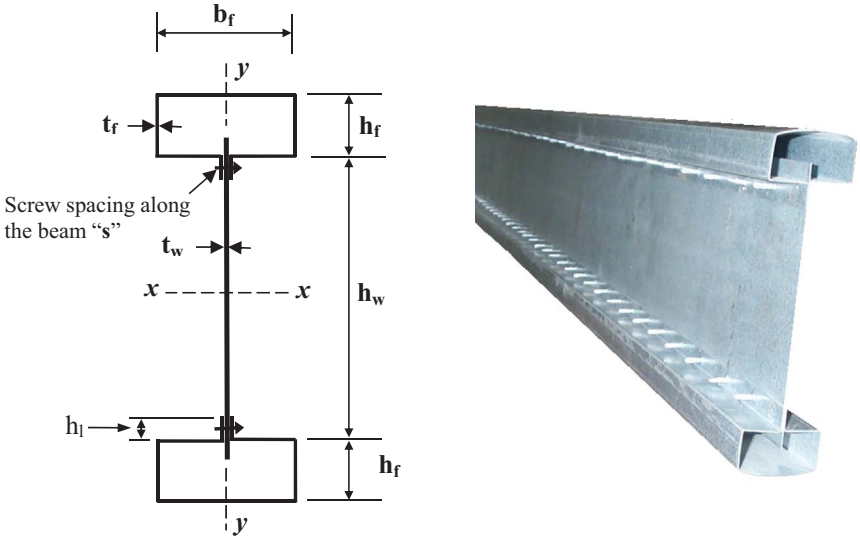

Fig. 2. Cross-section and overall view of RHFB.