Construction and Building Materials 73 (2014) 311–319

Contents lists available at ScienceDirect

Construction and Building Materials

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

Thin-walled timber structures: An investigation

Benoit P. Gilbert [a,*], Steven B. Hancock [a], Henri Bailleres [b], Mohammed Hjiaj [c]

[a] *Griffith School of Engineering, Griffith University, Australia*
[b] *Salisbury Research Facility, Department of Agriculture, Fisheries and Forestry, Queensland Government, Australia*
[c] *Structural Engineering Research Group/LGCGM, INSA de Rennes, France*

HIGHLIGHTS

- Innovative thin-walled timber structures are discussed and presented.
- Stub-column tests of the thin-walled timber profiles are presented.
- The efficiency of the studied thin-walled timber profiles are compared to cold-formed steel structures and discussed.
- A FEA model of the thin-walled timber profiles is presented and compared to the experimental tests.

ARTICLE INFO

Article history:
Received 22 July 2014
Received in revised form 15 September 2014
Accepted 25 September 2014

Keywords:
Thin-walled timber structures
Lightweight structures
Composite timber structures

ABSTRACT

This paper presents an investigation on the structural potential of thin-walled timber structures compared to cold-formed steel and aluminium structures. The paper shows that manufacturing thin-walled timber profiles is possible. The manufacturing process is introduced herein. Specifically, short composite thin-walled timber Cee-sections (500 mm long) were fabricated by gluing together thin softwood (*Araucaria cunninghamii*) veneers (1 mm thick). Two types of Cee-sections were considered, one with an intermediate web stiffener to increase the local buckling capacity of the profile and one without. The profiles were tested in compression and the test results are presented and discussed in the paper in terms of structural behaviour and performance. A Finite Element model was also developed. Non-linear geometric analysis was carried out, with assumptions on observed delaminated areas, and the model was found to match the test results with reasonable accuracy. Further research directions are proposed in order to provide efficient and lightweight sustainable structural products to the construction industry.

1. Introduction

Due to their efficiency, lightweight, ease of erection and low cost, steel and aluminium thin-walled (cold-formed) structures have become very popular in the construction industry over the past few decades [1]. The worldwide market for these products is significant and estimated at more than two billions dollars. Typical industrial and civil engineering applications include roof and wall systems (purlins and girts), steel storage racks and composite concrete and steel slabs. Typical cold-formed steel profiles are shown in Fig. 1.

Due to the nature of the manufacturing process, consisting of bending a thin sheet of metal to a desired cross-sectional shape, open profiles such as Cee- or Zee-cross-sections are generally used. The effectiveness of these structures lies in their cross-sectional shapes which enhance their strength by controlling the three fundamental buckling modes: local, distortional, and global (see Fig. 2). The section capacity for local buckling is typically enhanced by adding intermediate stiffeners to walls having significantly large width-to-thickness ratios (see Fig. 1). Changing the cross-sectional shape, mainly by adding lip stiffeners, usually enhances the section capacity for distortional buckling.

However, despite the attractiveness of these types of profiles, steel and aluminium are greenhouse gas intensive materials and do not produce sustainable structural products [2]. Manufacturing profiles similar to the ones shown in Fig. 1 in timber is possible, but to the authors' best knowledge, has not yet been investigated in the published literature. Yet, Aicher and Stritzke [3] recently investigated composite floor panels (up to 380 mm deep) manufactured with 4.8 mm S-shape plywood webs.

This paper presents the first step of a study aiming at developing extra light and structurally sound timber profiles for applications including amongst others (i) emergency shelters which can

* Corresponding author.
E-mail address: b.gilbert@griffith.edu.au (B.P. Gilbert).

http://dx.doi.org/10.1016/j.conbuildmat.2014.09.070
0950-0618/

be rapidly assembled and disassembled, (ii) purlins for major timber buildings, as a substitute to steel purlins currently used and (iii) wall stubs.

Short composite thin-walled timber Cee-sections (500 mm long) were fabricated by gluing together thin softwood (Hoop pine – *Araucaria cunninghamii*) veneers (1 mm thick). Two types of Cee-sections were considered, namely one with an intermediate web stiffener to increase the local buckling capacity of the profile and one without. The steps involved in the manufacturing process are presented in this paper. The sections were tested in compression and the test results are presented and discussed in the paper in terms of structural behaviour and performance. Before testing, initial geometric imperfections were measured and introduced into a Finite Element model of the profiles. The numerical results are compared to the test results herein. Further research directions are also proposed in this paper in order to provide efficient and lightweight sustainable structural products to the construction industry.

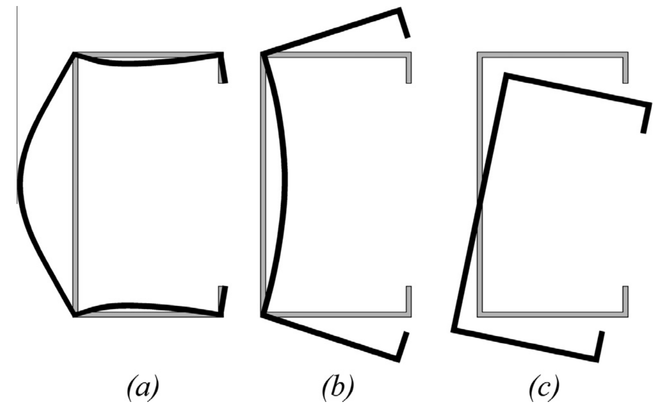

Fig. 2. Fundamental buckling modes for thin-walled open cross-sections in compression, (a) local, (b) distortional and (c) global.

2. Investigated cross-sections

2.1. General

Three sets of 210 mm deep × 105 mm wide Cee-sections (with 50 mm lip stiffeners) were manufactured and investigated. There were two cross-sections in a set and they were of different type. Type A cross-section had no intermediate web stiffeners and is shown in Fig. 3a. The cross-section was designed so local buckling of the web would govern the strength of the profile. On the contrary, a web stiffener was added to the second type of cross-section (Type B), as shown in Fig. 3b, so the local buckling capacity of the cross-section would significantly be enhanced. The nominal section properties of the cross-sections are given in Table 1.

Each cross-section was composed of 5 layers of nominal 1 mm thick Hoop pine rotary sliced veneers. The grain of the three inner layers was orientated along the member longitudinal axis, while the grain of the two outer layers was perpendicular to the inner layers and orientated in the member transverse direction (see insert in Fig. 3). In this configuration, the three inner layers mainly resist the compressive load while also providing resistance against bending of the walls in the longitudinal direction. The two outer layers mainly provide resistance against bending of the walls in the transverse direction, therefore enhancing the local buckling capacity of the profile.

2.2. Manufacturing process

Veneers were delivered in sheets of 1.2 m × 1.3 m and sheets with a minimum number of or with no natural defects (knots, holes, splits, resin veins, etc...) were selected. Different veneer sheets were used for each layer constituting a profile. Yet, all cross-sections in a set were manufactured from the same sheets, glued in the exact same order, allowing comparison between the two types of cross-sections in a set.

Each cross-section was manufactured as:

Step 1: Sheets were cut to size and veneers were soaked in water for 48 h.
Step 2: The veneers were laid flat on a bench, with the grain in the appropriate orientation (see Section 2.1), heated using a steamer and bent around a jig to form the cross-section.
Step 3: Each flat side of the cross-section was clamped to the jig, as seen in Fig. 4 for Type B cross-section.
Step 4: The jig was placed in an oven at 40 °C for about 12 h, till the bends were dried and held their shapes.
Step 5: The veneers were unclamped and removed from the jig, further left to dry in the oven for about 4 h, and stored in an air-conditioned room until their moisture content reached equilibrium.
Step 6: The veneers were glued around the jig at ambient temperature with Resorcinol formaldehyde structural adhesive. Similar to Step 3, each flat side of the cross-section was clamped to the jig. Rubber sheets were inserted between the veneers and the clamping plates to apply the pressure uniformly. As the sections had a tendency to warp when drying outside the jig, the glue was left to set for a minimum of 48 h before unclamping the cross-sections. This is about 4 times longer than the glue manufacturer recommendation.
Step 7: The excess wood in the lip stiffeners were cut to form the final cross-sections.

To simplify the manufacturing process, apply the pressure more uniformly and obtain more reliable products, the manufacturing process will be improved in the future. A vacuum press may be used along with structural polyurethane adhesive. Fig. 5 shows a photo of the final products.

To determine the mechanical properties of each set of cross-sections, flat panels were also manufactured using the same sheets as their associated cross-sections, glued in the exact same order

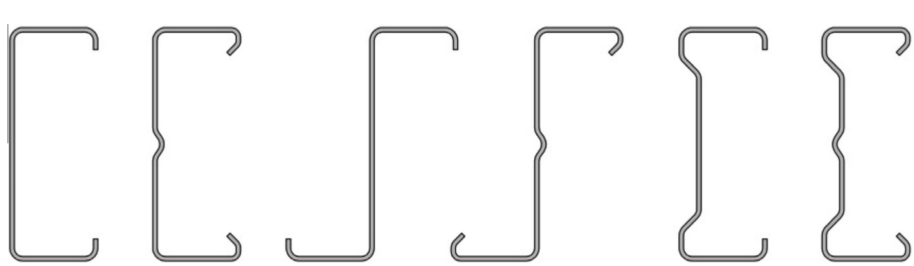

Fig. 1. Examples of cold-formed steel profiles, with and without intermediate stiffeners.