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Medium Scale Experimental Investigation of Bending for Thin-walled Veneer Beams with Foam Filling

Katarzyna Jeleniewicz [1], Wojciech Gilewski [2]

[1] Warsaw University of Life Sciences, Faculty of Civil and Environmental Engineering, Nowoursynowska Str. 159, 02-776 Warsaw Poland
[2] Warsaw University of Technology, Faculty of Civil Engineering, Lecha Kaczynskiego Av. 16, 00-637 Warsaw, Poland

katarzyna_jeleniewicz@sggw.pl

Abstract. The purpose of this research is to examine the innovative concept of veneer-foam beams in bending. The beam consists of two very thin veneer sheets with open cross-section with polyurethane foam filling for extension of stiffness and shape stabilization. A series of medium scale preliminary experimental investigations have been done in the Water Centre of Warsaw University of Life Sciences. Simply supported beams of the length 60 cm and 80 cm with concentrated load were considered. The results are promising for future analysis of veneer-foam elements as secondary beams for glulam grillages.

1. Introduction

Steel or aluminium thin-walled (cold-formed) structures are relatively popular over a few decades with ever-advancing technology in the construction industry for residential and low-rise buildings. Typical civil engineering applications are roof, ceiling, floor and wall systems.

Open profiles are applied due to the nature of manufacturing process. However, despite of the attractiveness and advantages, the metal thin-walled structures are not sustainable structural products and several disadvantages can be also defined. A number of valuable literature for theoretical [1], analytical and numerical [2], as well as for experimental [3] studies is available. Timber as a similar structural material looks attractive if it would be possible to develop a thin-walled cross section in the civil engineering scale. Stabilization of the cross-section shape seems to be a crucial aspect for timber thin-walled structural elements. Structural foam panels (engineered sandwich or laminate plates with a solid foam core of 10 cm to 20 cm and structural facing or sheathing on each side [4]) are applied for building walls, ceilings, floors and roofs in the recent years. The polyurethane foam is used not only for insulation but also as a structural component.

The idea of the authors is to combine the advantages of thin-walled timber structure and the stabilization as well as stiffness of compression foam features to create efficient lightweight secondary beam elements.

The present paper is an introduction to developing very light and structurally efficient veneer-foam profiles for applications as secondary beams in bending for ceilings and roofs. The elements can be combined together with main glulam beams to make the structure stiff as well as light.

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2. Timber/Veneer thin walled structures

Efforts on the application of timber/veneer thin-walled elements is not popular and is limited to the tension elements [5, 6]. The offer of veneer sheets is very wide on the market (Figure 1).

The results presented in [5] are dedicated to tension of 5-layer veneer timber "C" profile with total thickness 5 mm, glued on dry. Tension strength of 50 cm specimens is equivalent to the strength of cold-form steel profile. The timber profile is lighter than the steel one.

Different solution was proposed in [6] with the 2-layer veneer profile glued on wet with the polyurethane foam filling. The results for tension elements of the length from 40 cm to 100 cm are on the level of 5000 N. The experiment is in progress.

(a) 

(b) 

Figure 1. Veneer sheets: market offer (a), single sheet (b).

The author's idea in the present paper is to apply the wet glued open profiles (Figure 2a) for beam bending. The profiles can be applied as secondary beams joined with main glulam beams (Figure 2b).

The profiles are open and consists of two very thin veneer sheets (2 x 0.6 mm) glued on wet, with the polyurethane foam filling as a stabilization and extension of strength. The proposed dimensions are medium scale 100 mm x 42 mm of a single profile cross section. Two profiles are proposed for a beam cross-section.

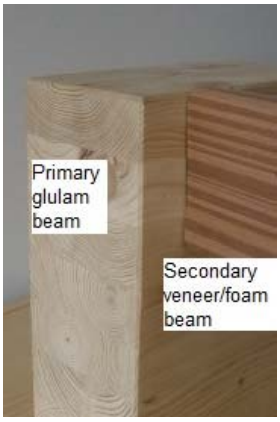
(a) 
(b) 

Figure 2. Veneer profiles with foam (a), Glulam-Veneer/foam grillage (b).

3. Experimental investigations of beam bending

The first stage of works is the production of a thin-walled profile. Veneer samples are produced on the assembly table (Figure 3a), using wooden moulds (Figure 3b), according to the following scheme:

- Cutting the veneer to the requested dimensions;
- Soaking the veneer in water until softened – from 2 to 24 hours;

- Delicate veneer drying;
- Gluing of two layers of wet veneer to each other with polyurethane adhesive (Figure 4a);
- Applying glued veneer layers to the internal form that gives shape to the sample;
- Inserting veneer with filling into the external mould;
- Wait 24 hours for the glue to dry completely;
- Removal of the internal mould from the formed veneer, inserting the veneer back into the outer mould;
- Filling the moulded veneer with PUR foam by holes in the upper cover of the outer mould (Figure 4b).
- Wait 24 hours for the foam to fully expand and dry;
- Removing the finished sample from the mould.

Before filling with foam, the moulded veneer sample is wrapped with foil so that the foam did not stick too much to the mould. The finished samples are shown in Figure 4c.

(a)  (b) 

Figure 3. Details of the experiment: working table (a), timber boxes (b).

(a)  (b)  (c) 

Figure 4. Veneer profiles: empty profile (a), profile with foam (b), selection of profiles (c).

Two lengths of medium scale specimen of 60 cm and 80 cm are considered. Concentrated load bending experiments (Figure 5a) with the width of supports of 50 cm and 70 cm (Figure 5b) of double profiles were done with the use of Instron machine (Figure 6) with Blue Hill software an external camera

in the Water Centre of Warsaw University of Life Sciences. The sample before applying load in the Instron is presented in Figure 7.

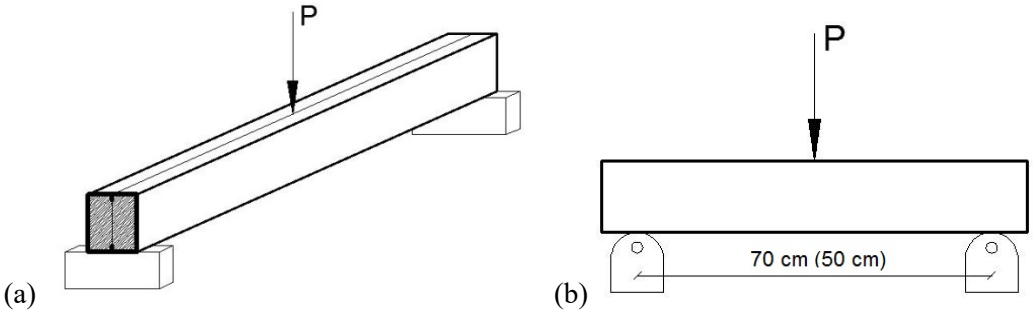


Figure 5. Details of the experiment: axonometry (a), side view (b).

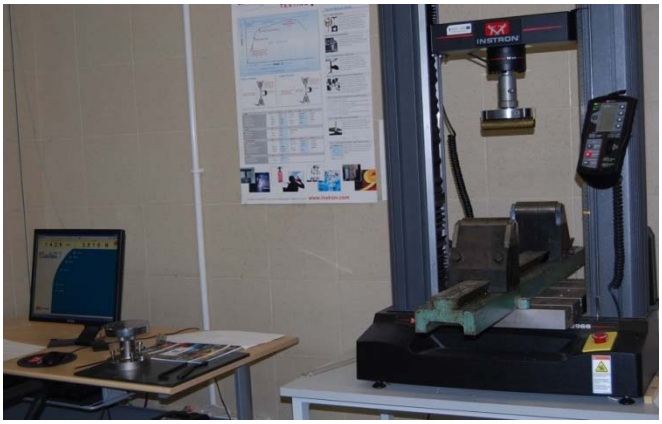


Figure 6. Instron machine with the workstation.



Figure 7. Veneer/foam beam in bending.

Local damage of the sample (approximately of 15 mm, Figure 8a, 8b) was observed at 900-1000 N for the spacing supports 50 cm (Figure 9) and at 550-700 N for the spacing of supports 70 cm (Figure 10).

(a) 

(b) 

Figure 8. Damage of the beam: general view (a), detail view (b).

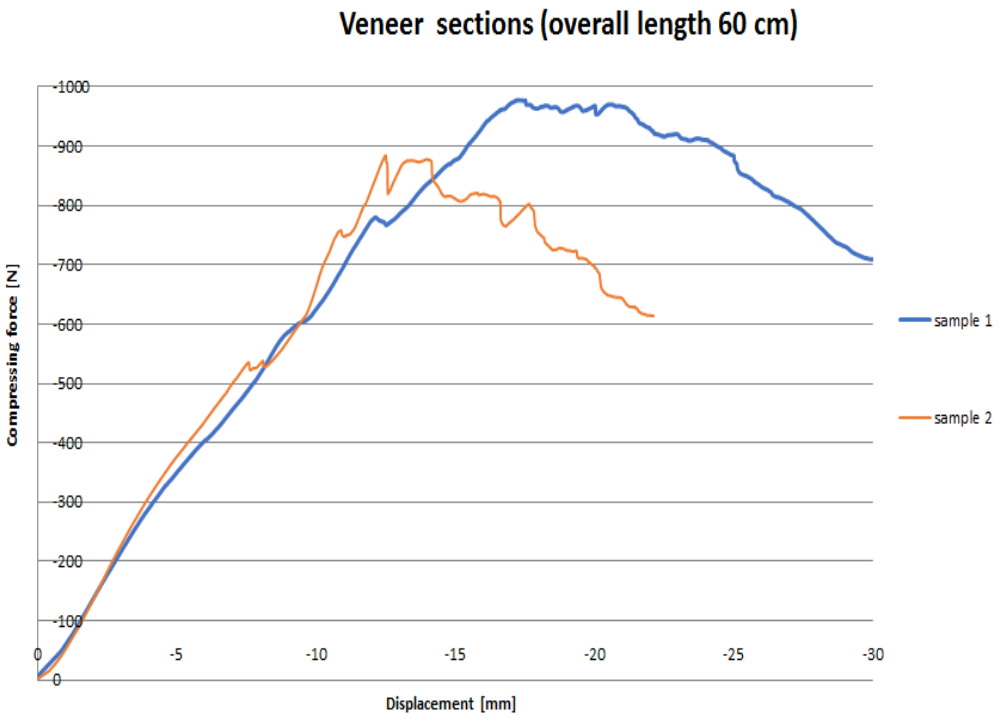


Figure 9. Displacement vs. force graph for the beam of 60 cm overall length.

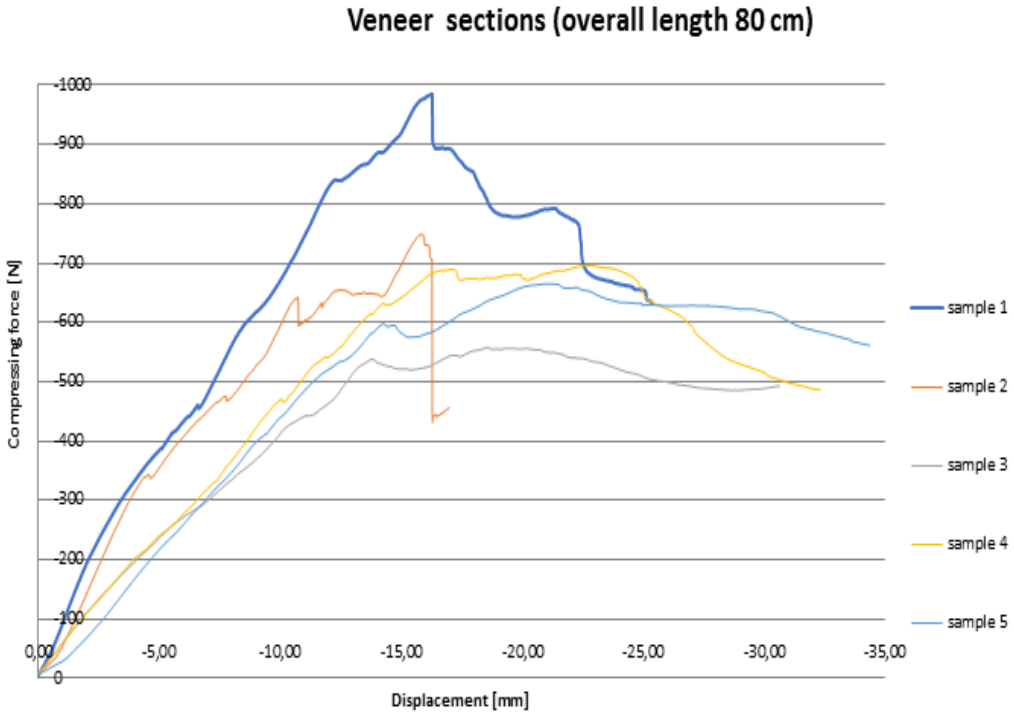


Figure 10. Displacement vs. force graph for the beam of 80 cm overall length.

4. Conclusions

The preliminary experimental studies are promising. The average limit concentrated force is approximately 80 N and local damage is observed. The profiles are extra light (7 times less than the respective steel profile), esthetical and greenhouse gas extensive products. Further investigations are recommended for uniformly distributed load and internal reinforcement of the profiles in the direction of successful application as secondary beams in timber celling grillages.

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