Construction and Building Materials 123 (2016) 365–371

Contents lists available at ScienceDirect

Construction and Building Materials

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

Experimental investigation on full-scale glued oak solid timber beams for structural bearing capacity

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HIGHLIGHTS

- Full-scale oak glued solid timber beams have been manufactured using MUF adhesive.
- Full-scale bending tests on glued solid oak timber beams have been performed.
- Influence of the finger-joint on the performance of glued beams has been highlighted.
- The relative structural performance of glued oak timber has been assessed.

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 2 March 2016
Received in revised form 1 July 2016
Accepted 4 July 2016

Keywords:
Glulam
Hardwoods
Adhesive joints
Finger-joints
Experimental
Timber construction

ABSTRACT

This paper presents an experimental investigation on full-scale glued solid timer beams made of oak timber, for structural purposes. Similar experimental work was previously presented by the authors using beech timber (Tran et al., 2012). Here, the results from the previous work were served for comparison purpose between the performances of the two hardwood species (oak and beech). The obtained results showed that the glued solid timber beams made of oak timber perform relatively more much better than their counterparts made of beech timber, which was explained by the weakness in the finger-joint due to a poor adhesion within the beech timber.

1. Introduction

Hardwoods with their availability and high mechanical performances, as compared to the most softwood species, may be appealing materials for users of modern timber constructions and buildings. Nowadays, demand for structural Engineered Wood Products (EWPs), such as glulam and cross laminated timber, particularly in large structural sizes, has dramatically increased and a far greater proportion of timber for construction is obtained from softwood species. In the last decade, hardwoods have gained increasing interest for use in modern timber construction as far as high strength timber structural elements are concerned. Incorporating EWPs made of hardwoods in buildings and achieve mechanical performance and safety while at the same time

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http://dx.doi.org/10.1016/j.conbuildmat.2016.07.002
0950-0618/

meeting future requirements, as stipulated in the European Building Standards, are truly challenging. In fact, the literature review shows that the almost of the existing studies on the subject are mostly dealing with softwoods and much less attention was paid to hardwoods. Consequently, very limited knowledges, in contrast to softwoods, in particular those related to the use of adhesive with hardwoods for structural purposes and full-scale performance of structural components as well. In addition, glued solid hardwoods are not even listed by most standards, as they could be, for structural uses.

This topic has been already approached experimentally by many authors but there is still a need for insight knowledge particularly at the structural adhesive joint level. The role of the finger-joints and bond lines in the structural performance of beams has long been recognized. The first investigators of beech hardwood for structural uses were Egner and Kolb [1,2], since fifty years ago, who clearly demonstrated its feasibility. Then, further investigations have been carried out in the mid-eighty by Gehri [3,4] who highlighted the potential high strength and stiffness properties of glulam beams made from beech. Experimental researches were continued until today to provide grading, strength and stiffness properties of glued beams made of beech timber.

The most popular investigations on beech glulam including grading of beech timber as well as strength and stiffness properties of beech glulam using large-scale bending tests were published by Glos and Lederer [5], Blaβ et al. [6], Frese [7] and Aicher [8,9]. Mechanical performance of fingerjoints, made of beech timber, under tension and bending tests have been performed by Aicher et al. [10], Méausoone et al. [11] and Tran et al. [12], among others. Other works have focused on the gluability of beech timber for a better understanding of the surface and interfacial adhesion aspects [13–19]. Works have focussed in studying the penetration of MUF adhesive into beech, the formation and curing of glue-lines as well as their integrity. In the last decade, numerical modelling using the finite element method has been also used to understand the stress distributions within the fingerjoints and to predict the failure mechanisms [20–26] with the aim of reducing expensive experimental procedures. All these works, however, consider beech timber and very much less attention was paid for oak hardwood, despite its availability and its high natural durability.

However, despite the aforementioned advantages of hardwoods some shortcoming of hardwood EWPs related to the mechanical performance of finger-joints and bond-lines exist. In principal, adhesively reconstituted softwoods work with improved stiffness and strength as compared to the equivalent solid wood because they present much less variability and defects. However, hardwoods EWPs are susceptible to exhibit a great loss in bending strength (MoR) caused by a premature failure of adhesive joints. Finger-joint is the most predominant failure zone [12,25]. These drawbacks can shorten the added-value of those products and limit their utilization. Therefore, the need for a thorough mechanical investigation arose to gaining new understanding on the behaviour of adhesively reconstituted hardwoods. This study is aimed to assess the strength of glued solid hardwoods at full-scale level. For this end, oak timber has been employed and the main flexural characteristics, such as the module of elasticity (MoE) and the module of rupture (MoR), were assessed using standardised tests according the EN 408 standard and compared to their corresponding values from equivalent solid hardwood. In addition, results from previous work by the authors [12,25] performed on beech timber are used here for comparison purpose.

2. Materials, specimen preparation and methods

2.1. Materials

The materials used in this study was oak, which was purchased from a local hardwood sawmill. Flat sawn boards were obtained and conditioned at ambient temperature of 20 °C and kiln-dried to an equilibrium moisture content which fluctuated from about 10 to 13% for both species. Before all, the density of the oak timber has been determined from free defects samples. The average density of the studied oak was 620 kg/m^3. Note that the density of beech timber studied in previous work was 720 kg/m^3.

The adhesive which was used to glue the beams was Melamineurea-formaldehyde (MUF) adhesive that fulfil current approval criteria for the use in load-bearing timber components. The mechanical strengths of the used MUF adhesive have been characterized in a previous work by the authors [12]. Before being used for gluing, the MUF was added a hardener Prefere 5035 (made by DYNEA) with the ratio of MUF/Prefere of 100/15.

2.2. Preparation of specimens

First, oak logs have been sawn into boards with thickness ranging from 42 mm to 47 mm. From the sawn boards, finger-jointed short-length lamellae have been manufactured by profiling cutterheads with 22 mm length, 6 mm pitch and 1 mm tip gap (Fig. 1), according to the EN 14080 requirements [27].

The applied end pressure to manufacture the finger-jointed boards was accomplished with a press and reached 10 MPa, and lasted 2 s. After the manufactured finger-jointed laminations were cut to the desired dimensions and planed to a desired uniform thickness, MUF adhesive was applied manually on the two sides of laminations, which were stacked on top of each other and pressed on an hydraulic press (Fig. 2) to form the desired layered beams.

Finally, two-layer and three-layer glued beams, with and without finger-joints, have been obtained in addition to solid single and finger-jointed laminations. Typical configurations of the manufactured beams are summarized in Fig. 3.

2.3. Methods

Prior to manufacturing of full-scale multilayered glued beams, grading of oak solid wood has been undertaken based on appropriate experimental procedures according to the EN 408 requirements [28].

After that, four-point bending tests were undertaken for all multi-layered beams with test arrangement according to the EN 408, as shown in Fig. 4.

All tests were conducted by displacement control with a crosshead speed set to 2 mm/min. Deflection was recorded with displacement transducers (LVDT) located at the mid-span of the specimen (Fig. 5) and recorded versus the total applied load.

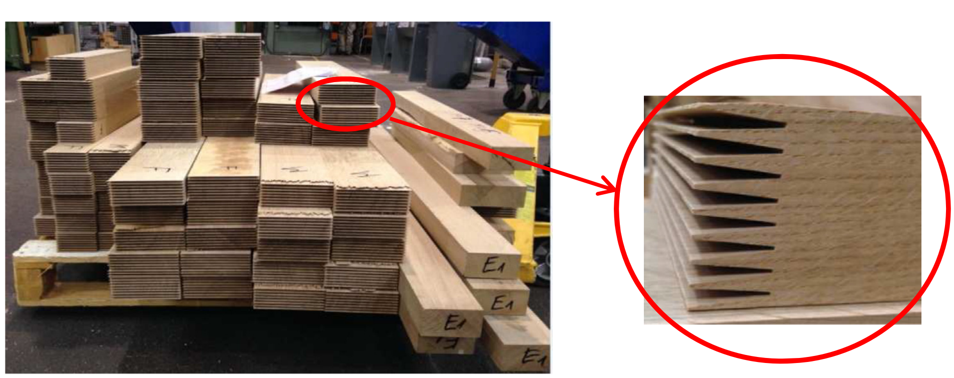

Fig. 1. Preparation of finger-jointed laminations.