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Experimental buckling performance of scrimber composite columns under axial compression

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ABSTRACT

Wood, as a renewable and environmentally friendly building material, has gained much attention in sustainable building industry. In terms of mechanical and physical properties, wood-based composite normally has less inherent variability than the natural wood material. Thus, wood-based composite is considered as a promising material choice for timber constructions. A novel scrimber composite, which is manufactured from fast-growing wood, is introduced in this paper. Small clear specimens were sampled and tested to determine the mechanical properties of the scrimber composite. Experiments were then conducted to investigate the mechanical performance of 50 scrimber columns under axial compression. The failure modes with respect to various slenderness ratios are reported, and attempts were made through theoretical analysis to predict the buckling stress of the column specimens under both elastic buckling and inelastic buckling. The presented experimental results and analyses serve as fundamental knowledge for evaluating the mechanical performance of scrimber columns, thus supporting more applications of such composite material in practical engineering.

1. Introduction

Wood is a commonly used construction material in many parts of the world. With carbon storage and environmentally friendly characteristics, wood has gained more attention in green building industry nowadays. The various species of wood have a number of different mechanical and physical characteristics, which leads to variability in the performance of wood as a construction material. Therefore, a broad range of engineered wood-based composite materials were developed. These materials extract the best properties of wood and combine them with other materials (e.g. adhesives, plastics, etc.) to create new products that meet both structural and non-structural demands. During the manufacturing process of engineered wood composites, the wood is reconstituted to form large members from small pieces. Natural macro defects in wood are dispersed so that the variability in mechanical and physical properties are reduced when compared to those of solid swan lumber. The increase in uniformity lead to more efficient utilization of the fiber resources, thus higher characteristic strengths can be assigned for engineered wood composites while aiming to maintain the safety level in relation with other products.

During the past two decades, researches on the mechanical performance of innovative wood-based composites (e.g. wood-fiber reinforced polymer composites, wood-plastic composites) have been conducted [1–14]. In addition, the structural application of wood-based composites manufactured from unconventional raw materials has also attracted much research attention. An overview of the application of non-cutting technology to produce long strands with strict grain orientation was reported by Joscak et al. [15]. Results showed that long-strand products (e.g. Superposed Strand Timber, TimTek) were able to compete with the mechanical performance and production costs of existing engineered wood products. Yu et al. [16] investigated the feasibility of manufacturing scrimber from mulberry branches by using cold pressing method. The motivation of this research is to utilize the large amount of mulberry branches which are secondary products from the silk industry. The mechanical properties of the product were determined by small clear specimen tests, showing that the scrimber may serve as a possible material choice for timber constructions. The fabrication, material properties, and application of innovative bamboo scrimber and glued laminated bamboo have been reported [17,18]. Similarly with wood scrimber, the fabrication process of bamboo scrimber is found to be very materially efficient.

Scrimber, by definition, is a product made by reconstituting structural lumber from small-diameter timber. Previous attempts

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to reconstitute wood into structural products have required that either the wood be broken down in varying degrees or turned into veneer, then realigned and glued to form the desired section. In this paper, a novel veneer-based scrimber composite is introduced. The scrimber composite is manufactured from fast-growing wood (e.g. poplar), which has been planted in vast areas in China within the forest planting plan during the past three decades. Although the strength and modulus of elasticity (MOE) of fast growing wood itself are normally not sufficient for structural application, it can serve as a sustainable and relatively inexpensive source of raw material to manufacture scrimber composite for structural purposes. The present work investigates the mechanical performance of the scrimber composite to access its application as structural members.

2. Mechanical property

The production process of the scrimber, as shown in Fig. 1, mainly includes mechanical slicing, drying, thermal treatment, impregnation, cold molding and hot curing. Natural logs are firstly sliced circumferentially to form veneer lumber with a thickness of about 2 mm. The veneers, after going through the drying, and modifier/adhesive impregnation process, are squeezed and laminated into rectangular cross sections under specific temperature and pressure. Fig. 2 shows a typical cross section of the scrimber composite. Since the veneer lumber are laminated with the original size, the cross section of the scrimber composite is featured by curved thin laminates, which is quite different from existing veneer-based laminated products. The scrimber has an average density of 885 kg/m^3. Small clear specimens, with an average moisture content of 18%, were sampled and tested in accordance with Chinese standard JB/T 1927-1943 2009 [19] (Testing methods for physical and mechanical properties of wood) to determine the mechanical properties both parallel to grain and perpendicular to grain.

2.1. Compression

Sixty specimens, with the dimension of 20 mm × 20 mm × 80 mm, were prepared for the compression test. The specimens were divided into two groups. Thirty specimens were sampled and loaded in the parallel to grain direction, and the other thirty

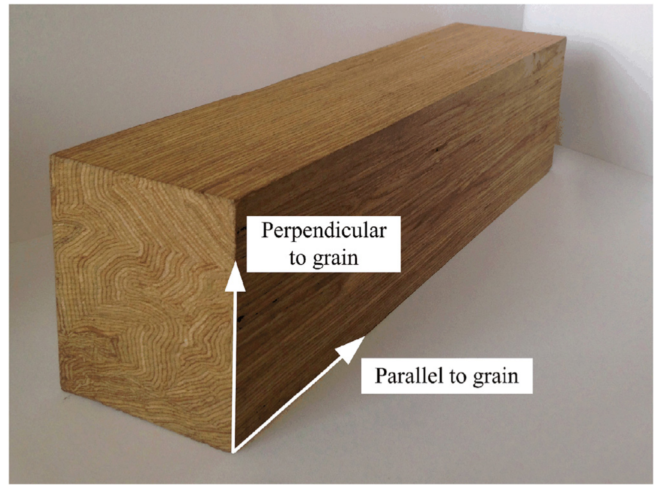

Fig. 2. Cross section of the scrimber composite.

specimens were sampled and loaded in the perpendicular to grain direction. Monotonic loading was applied at a rate of 5 mm/min Fig. 3(a) shows the test setup. For parallel to grain specimens, crushing was observed with the maximum load carrying capacity, as shown in Fig. 3(b). Moreover, splitting was also observed as failure mode with respect to their ultimate load carrying state in a few specimens, as shown in Fig. 3(c). However, for specimens loaded in the perpendicular to grain direction, splitting between the adjacent veneers, as shown in Fig. 3(d), was observed as the main failure mode. The load carrying capacity of the specimens dropped quickly after splitting occurred, resulting in a brittle failure mode. The strength data were also fitted to a normal distribution to get the 5 percentile characteristic strength value. Test results are listed in Table 1. The compressive strength parallel to grain has a mean of 101 MPa, which is about five times of the strength perpendicular to grain. The coefficient of variation (COV) of compression parallel to grain and that of compression perpendicular to grain are 9.9% and 14.3%, respectively. The axial modulus of elasticity (MOE) of the scrimber was obtained as 16,780 MPa for compression parallel to grain, and for compression perpendicular to grain, the MOE was obtained as 1242 MPa.

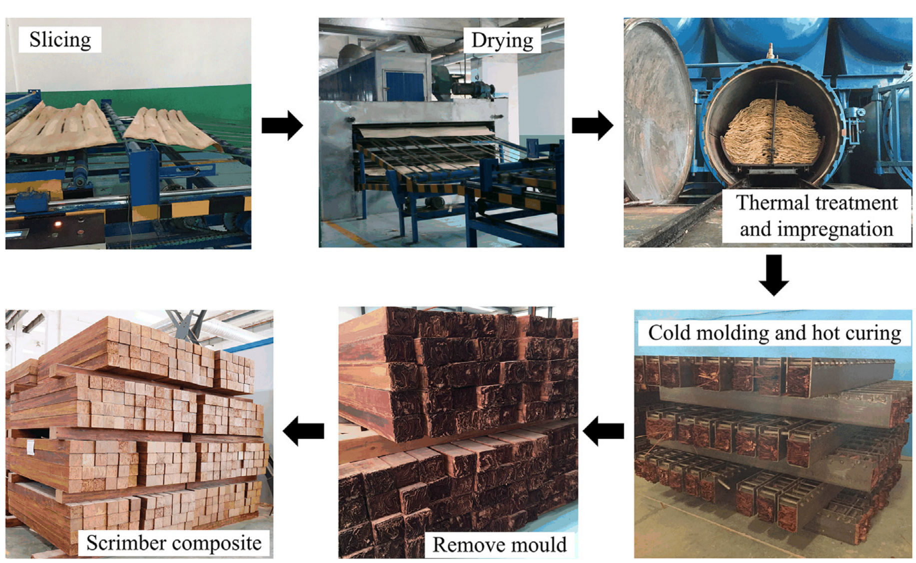

Fig. 1. Production of the scrimber composite.