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Short- and long-term performance of wood based panel products subjected to various stress modes

Zaijun Yu [a], Mizi Fan [b,*]

[a] Longyan University, Longyan, Fujian 364000, PR China

[b] Nano-cellulose and Bio-composites Research Centre, College of Engineering, Design and Physical Sciences, Brunel University London, UB8 3PH, UK

HIGHLIGHTS

- Five stress modes were investigated for four major commercial wood composites;
- Stress modes had significant effects on short-/long-term performance of materials;
- Wood based composites had a much higher edge than plane load bearing capacity;
- The findings provided most constructive database for the design and application.

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ABSTRACT

This paper presents the findings from comprehensive studies for enhancing efficiency and competitiveness of wood based panels for uses in furniture and other building construction industries. Five stress modes, which are encountered in the design and applications of wood based panels, were investigated, i.e. flat-bending, edgewise-bending, panel shear, planar shear and concentrated load stresses. Four commercial board types, namely plywood (PW), particleboard (PB), medium density fibreboard (MDF) and oriented strand board (OSB), were examined to evaluate the different responses to the various stresses. Results showed that stress modes had a significant effect on both short- and long-term performance of wood based panels: 1) wood based panels had a much higher capability to carry the stresses applied along the edge than plane of the panels, 2) the maximum failure load under planar shear was 10–16 times that under flat bending load and 2–3 times that under concentrated load, and the maximum failure load under panel shear was 3–9 times that under pure edgewise bending load, 3) for the materials tested, PW had a higher capability to carry both pure edgewise bending load and concentrated load, and MDF had a higher capability to carry pure flat bending load, and panel and planar shear load, 4) stress modes had a more significant effect on deflection under creep loading than short term test, with the ratio of deflection under flat bending, concentrated load and planar shear being 23:6:1 for PW under short term test, while 205:20:1 for PW and 507:72:1 for PB under creep loads, 5) theoretically calculated deflection was higher than the measured for short term tests but lower than the measured for creep tests, 6) the effect of stress modes on relative creep varied among the materials tested. These findings provide most constructive database for designing and using wood based panels in various industrial sectors.

1. Introduction

The use of structural wood composite panels in furniture and building construction industries continues to increase annually because of reliance on smaller sized logs and because quality is decreasing in the wood resource base. Products, e.g. oriented strand board (OSB), continue to take a larger share of the wood component market from timber because their manufacturing processes have less restrictive stipulations on wood furnish size and quality. Constituents and structures vary considerably among various types of wood based panels. The purpose of the deviation of constituents is to construct a new material that will retain the advantages of its constituents but not their disadvantages, and such to tailor the material to the exact needs of the structure under design, for example, the strands of OSB are orientated in the longitudinal direction, while fibre boards within which fibres are nor-

* Corresponding author at: Department of Civil and Environmental Engineering, Brunel University London, UB8 3PH, UK.

E-mail address: mizi.fan@brunel.ac.uk (M. Fan).

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mally distributed randomly, leading to well known fact that the mechanical performance of OSB determined in the parallel direction is higher than that in other directions e.g. [42,33,1]. However, like other materials, wood based panels are subjected to various stress modes in their wide field of uses. Wood based panels would have different responses to various stress modes due to the variation of their constituents and structure. It has been reported that the compressive and tensile loadings along the longitudinal (0°), diagonal (45°) and transverse (90°) directions of OSB plates had very different stress-strain relationships and failure modes [8].

Numerous researches have been carried out in the field of wood based panels with emphasis on their basic mechanical properties e.g. bending strength and modulus) and the models used to predict them e.g. [29,11,4,5,26,30,24,28]. However, the bulk of the work is concerned with the controversial constitution effect e.g. [25,10,40,3,34,37,23,27,32]. A research on the effect of stress conditions on the long term performance of wood based panels concluded that there is a closed relationship between stress conditions and long term creep behaviour of wood based composites [22]. A single stress condition may also result in a combination of behaviour, for example, a concentrated static load may give rise to both flexural and shear components of deflection [41,9,35]. In addition, the effect of stress modes is also related to the type of panels as the orientation of constituents within the panels varies considerably between types of wood based panels [22]. Wood based composites in use may also be subjected to loads in all three directions. In addition to conventional flat loading, a method has been developed to determine the edgewise bending strength and modulus of elasticity of wood based panels by using semi-size test pieces without laminating the test pieces [21]. The method has been employed to evaluate the edgewise bending performance of commercial particleboard (PB), oriented strand boards (OSBs), medium density fibreboards (MDFs) and plywood (PW) to achieve correct bending failure modes, and consistent and repeatable results. The edgewise characteristics are considered important for engineering designs, such as frame system of furniture or webs of I-Beam. A method for calculating the punching shear capacity of oriented strand board from its planar shear strengths, such as materials in flooring and roofing systems, has also recently been proposed [36]. It was concluded that the knowledge of punching shear capacity assessment under long-term loading is scare and further testing and validation should be carried out to realise potential benefits in panel design and applications.

Little attention has been paid to a systematic research on the performance of commercial panel products under various stresses. The volume of data available from long term performance tests is even sparser. These have prohibited an accurate development of characteristic values for correct design and uses of wood based composites. Moreover, when it comes to other forms of loading, there is an assumption that one characteristic value is appropriate to all stress types, for example, the characteristic values estimated for bending stress are used for concentrated load, and panel and planar shear loads. Given the different stress forms and failure modes induced by the various forms of loading and the non-isotropic nature of wood based panels, it is unreasonable to expect that the same characteristic values would be appropriate in all cases.

This present paper sets out the results from studies on the performance of wood based panels in use. Four types of commercial wood based panels, namely plywood (PW), particleboard (PB), medium density fibreboard (MDF) and oriented strand board (OSB), were studied. Five different stress modes, which encounter in the composite designs, were used. They include:

- Edgewise bending load
- Flat bending load
- Concentrated load
- Planar shear load
- Panel shear load

2. Theoretical considerations

2.1. Bending loading

Wood based panels in service are generally subjected to flexural loading, and the bending test along the fibre/longitudinal direction of the panels is considered highly desirable in the characterization procedure. More specifically, the four point bending test is commonly selected as means of mechanical evaluation because that the portion of the test piece within the load span is subjected to pure bending (Fig. 1A). Under four point bending, there are three possible failure mechanisms (flexural tensile, flexural compressive and shear) operating at different locations of the test piece at the same time. The failure mode of a bending test piece depends on which stress will exceed first.

A maximum flexural stress occurred at the outmost surface in the load span. That is,

$$\sigma_{\max} = \frac{3FL_2}{bh^2} \tag{1}$$

where, F = maximum failure load, L_2 = distance between loading head and support, b = width of test piece and h = depth of test piece.

A peak shear stress occurred at the mid-thickness in the outward span close to the two loading heads. That is,

$$\tau_{\max} = \frac{3F}{4bh} \tag{2}$$

Combining Eqs. (1) and (2) yields:

$$\sigma_{\max} = \frac{4L_2}{h}\tau_{\max} \tag{3}$$

For both edgewise and flat bending tests in this study, normally $4L_2 >> h$. Therefore, the flexural stress dominates the deformation and failure of test pieces. It should be noted that for edgewise bending, b means the thickness of board and h means the width of test pieces.

Deflection under bending loading can be expressed as:

$$def = \frac{FL^3}{Ebh^3}\left[\frac{3L_2}{4L} - \left(\frac{L_2}{L}\right)^3\right] \tag{4}$$

where, L = span between supports, E = modulus of elasticity.

2.2. Shear loading

There are two distinct shear properties for wood based panels for structural uses: interlaminar shear (called planar shear) and shear through-the thickness (called panel shear) (Fig. 1B and C). The shear due to the force applied along the plane of the panel is called the planar shear. The shear properties associated with the force applied along the edge of the panel are called panel shear. The deformation of square shaped element loaded with a shear force can be derived using the energy balance between the strain energy in shear and the work done by the external force [2] (Fig. 1D). The shear strain can be expressed as:

$$r = k\frac{F}{G.b.h} \tag{5}$$

where, k = coefficient which value ranges from 1.2 to 1.5 and G = modulus of rigidity.

Therefore, for the panel shear test, the deflection can be expressed as: