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DEVELOPMENT OF ENGINEERED BAMBOO

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ABSTRACT: Bamboo is one of the fastest growing plants and has mechanical properties similar to timber. Application of bamboo in construction is, however, limited to low cost housing and temporary structures due to a number of growth characteristics such as irregular shapes, hollow circular cross-sections, etc. To overcome these limitations in bamboo, an experimental study was undertaken to investigate the potential of developing an engineered bamboo product by cutting bamboo into smaller strips and gluing them together into rectangular cross-sections. Results of the tests showed that higher strength and stiffness and much lower variation in these properties, compared to natural bamboo, can be achieved when bamboo is fabricated into such an engineered product.

KEYWORDS: engineered bamboo, fabrication, strength, stiffness, variability

1 INTRODUCTION

Bamboo has been commonly used for many years as a traditional construction material for low rise houses, foot bridges, roofs and construction platforms, especially in Asia and Latin America (Chung and Yu 2002). The main reasons for the popularity of bamboo in construction can be attributed to its low cost, ease in availability locally and adequacy of local tools and skills for fabrication. In Australia, bamboo has mainly been put to architectural and decorative uses such as garden screens and hedges.

Tested mechanical properties of bamboo have been found to be comparable to sawn timber but bamboo possesses a number of features such as irregular and hollow cross-section and presence of nodes, which make it difficult to use bamboo as a construction material. A number of studies have highlighted the durability issues associated with bamboo. Bamboo is susceptible to environmental degradation when used for construction in its natural form (Lakkad and Patel 1980). Low resistance against fungal and insect attack, rapid absorption of water and susceptibility of starch present in bamboo to insect have been reported (Liese 1987).

Bamboo, however, also possesses number of unique properties which make it attractive for use as a construction material. (1) Bamboo takes only between 3 to 6 years to fully mature (Chung and Yu 2002) and can grow up to 100 cm per day (Liese 1987) (2) Bamboo does not require pesticides and only limited amount of fertilizers for growth and is therefore environmentally sustainable to grow (Liese 1987). (3) Bamboo plantations can act as a carbon sink for continuous sequestration of carbon. The carbon sequestration rate for bamboo is similar to that of hard-wood forest. (Janssen 2000). Above ground carbon storage of 61 tons per hectare has been reported for bamboo in North-East India (Nath et al. 2009). (4) Mechanical properties of bamboo are comparable to timber (Lakkad and Patel, 1980, Leise, 1987) (5) Metabolic processes in bamboo do not produce organic and inorganic by-products such as polyphenols, resins and waxes. This property of bamboo is quite beneficial, since such by-products influence physical properties like shrinkage, durability and gluability. (Liese 1992)

Therefore, bamboo has the potential for a use similar to timber in construction, provided some of the undesirable properties of bamboo can be overcome.

This paper presents an experimental investigation on development of an engineered bamboo product through a low tech, low cost method. Small beam specimens with rectangular cross-section were produced by gluing bamboo strips together. Such a manufacturing technique overcomes the presence of hollow core in natural bamboo and randomises the inter-nodes and other growth characteristics found in natural bamboo. Flexural properties of the manufactured engineered bamboo were then compared with natural bamboo.

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2 FABRICATION PROCESS

Bamboo species used for fabrication of the engineered bamboo was Australian grown Dendrocalamus Asper. The choice of this particular species was based on its superior mechanical properties. The fabrication process involved the following steps (i) bamboo was first cut into small strips and the inner and outer layers were then removed to achieve rectangular shaped strips (Figure 1) (ii) surface of these strips were coated with a layer of adhesive and were then laid out in a plywood formwork (Figure 2). Purbond® HB S109, which is one part polyurethane adhesive, was used for gluing the bamboo. (iii) Pressure was then applied to the formwork from the all sides using G-clamps (iv) the specimens were left to cure for a day, after which the formwork was removed. The manufactured bamboo had a dimension of 1600x40x40mm (Figure 3) but larger specimens can be fabricated using a similar process.

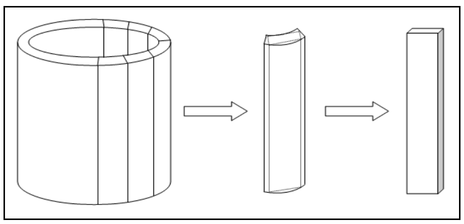

Figure 1: *Fabrication process – cutting into strips*

Figure 2: *Fabrication process – layout on formwork*

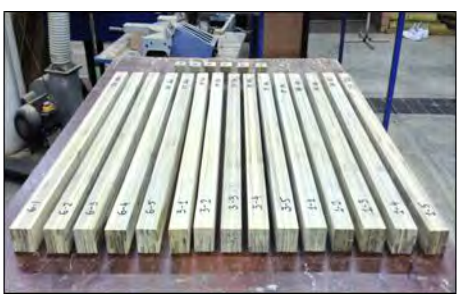

Figure 3: *Fabrication process – fabricated specimens*

3 EXPERIMENTAL INVESTIGATION

Flexural properties of the fabricated engineered bamboo samples were investigated using four-point bending tests.

3.1 Test Specimens

Ten samples (800x40x40 mm) were tested. Five of the samples were tested after curing of the glue while the remaining five were tested after being subjected to humidity cycles for 6 months. Each humidity cycle consisted of approximately six weeks of very wet condition (relative humidity close to 100%) followed by six weeks of normal lab conditions. Moisture content of tested samples was also measured for each set of tests using the oven-dried method as per AS/NZS1080 (1997).

3.2 TEST PROCEDURE

All specimens were tested under four-point bending load as per AS4063 (2010). The depth (d) of the specimens was approximately 40 mm and the distance between the two supports was 720 mm (18d) and with an overhang of 40 mm (d) at each support (Figure 4). Loads were applied at middle 1/3 span and mid-span deflection was recorded along with applied loads through a data-taker.

Figure 4: *Four-point bending test setup*

3.3 TESTS ON NATURAL BAMBOO

Flexural properties of natural bamboo were also tested as per ISO 22157 (2004). Ten randomly selected samples of Dendrocalamus Asper which were free of any natural defects were tested under four-point bending test.

4 RESULTS AND CONCLUSIONS

The modulus of rupture (MOR) and modulus of elasticity (MOE) for the fabricated engineered bamboo were compared with MOR and MOE for natural bamboo. Also, results from control and humidity exposed specimens were used to investigate the effect of humidity cycles on the properties of the fabricated engineered bamboo.

Results showed that higher strength and stiffness could be achieved for the engineered bamboo compared to natural bamboo while the coefficient of variation for both strength and stiffness results were much lower compared to natural bamboo. Such a result is attributed to the random distribution of natural "defects" and growth features in natural bamboo when manufactured into an engineered product. Results from tests on specimens subjected to humidity cycles showed no significant change in the MOE values but a reduction in strength by up to 30% was observed.