Assessment of the impact on boron treatment for finger-jointed Pine (Pinus caribaea) wood by impregnation method

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Abstract

Timber material could be considered as a leading environmental friendly construction material. Timber stores as much as 15 times CO_2 released during its manufacture whereas Aluminium and steel store negligible amounts. Finger joint is a sustainable, eco-friendly and economically valuable concept for timber industry. It ensures the sustainable utilization of small wood cut pieces which removed as waste. Chemical protection of wood is performed with preservatives, such as fungicides, insecticides, fire retardants and UV protective finishes that are applied for wood materials. Softwood timber species are subjected to easily deteriorate by the actions of wood destroying agents. Thus preservation is needed to enhance the durability of such wood. Major objective of this study is to evaluate of the impact on Boron treatment for finger-jointed Pine wood specimens and enhanced the durability of Pine wood timber planks. Specimens with 19 mm finger joint length of Pine wood were used for this study. Average tensile strength values of treated and untreated finger-jointed Pine specimens are higher than the recommended minimum requirement of tensile strength value ($\geq$ 10 N/mm^2). Failure modes of treated and untreated finger-jointed Pine specimens also described. Thus, it can be recommended that Boron treated finger-jointed Pine timber planks with 19 mm long fingers can be effectively used in industrial applications with enhancing the durability of Pine wood timber planks.

Introduction

Wood is considered to be one of the most important renewable natural resources available to man. The strength properties of solid wood and the natural durability of certain species of timber offer a material which could be used in a wide range of applications such as a building material, tools and utensils, furniture, as well as providing a source of extractive for industrials, domestics and pharmaceutical purposes. In addition wood is the basic raw material in the paper making and textile industry and is also used in the manufacture of wood composites and panel products (Youngs, 1989). In fact timber is considered to be the man's first structural material and today timber is used for a greater number of products than any other material (Brazier, 1987).

Human induced climate change is one of the most pressing and complex issues facing society in the 21st century. Increased use of forests and wood products, while not replacing the need to reduce greenhouse gas emissions at source, does make an important contribution towards tackling the problem of climate change (Hannah et al, 2004). Trees sequester carbon during their life, pulling carbon dioxide (CO_2) from the atmosphere and storing it in their mass. For every kilogram of wood grown, 1.5 kg of CO_2 is removed from the atmosphere (ASCE, 2010). Storing CO_2 in wood could therefore be considered as an effective means of mitigating climate change, though wood also releases CO_2 when they used as fuels (Philippe, 2013). Wood processing operations generate enormous amount of wood residues and effective use of them for alternative uses is therefore have a significant impact on lessening the effect of climate change (Bernad, 2014).

Wood residues like saw dust, trimmings and edgings are typically viewed as a burdensome disposal problem (FAO, 1990). However the material has a potential to become a usable resource (Bernad, 2014). Wood particles such as saw dust, timber off-cuts, wooden crates, wooden packaging, wooden pallets, wood shavings and similar materials are considered as wastes (NSWEPA, 1997). The New South Wales Department of Environment and Climate Change defined wood wastes as waste referring to the end-of-life products, failed products, off-cuts, shavings and sawdust from all timber products (NSWWB, 2000). Four types of wood wastes are usually generated within the furniture manufacturing companies as the result of the technological process: solid wood offcuts, engineered wood offcuts, sawdust and shavings (Daian & Ozasrka, 2009).

Off-cut wood is currently one of the wastes dumped by sawmills and as they failed to fully utilize the wood supply. Waste sawn timber material of furniture factory and short length of sawn timber are considered to be a key issue in timber industry, though a few of them is already being used in fuel kiln dried boiler. Another means of utilization of the wastes is applying a jointing system through the finger joint technique. This technology ensures maximum utilization of the timber wastes minimizing the pressure on forest resources (Muthumala et al, 2019). Finger joints are explained as interlocking end joint formed by machining a number of similar tapered symmetrical fingers in the ends of timber members using finger joint cutters and then connected together by bonding material (BS EN, 15497). Finger joint is a sustainable, eco-friendly and economically valuable concept for furniture industry. It ensures the sustainable utilization of small wood cut pieces which removed as waste (Sandika, 2017).

Wood in suitable environmental conditions can be attacked by bacteria, fungi, algae, insects, marine borers and some other biological pests. The presence of wood-damaging agents has to be limited by using suitable techniques in order to minimize the contact of wood with rain and other sources of water, which could enhance the creation of water condensate. Chemical protection of wood is performed with preservatives, such as fungicides, insecticides, fire retardants and UV protective finishes that are applied on the wood's surface. The chemical protection of wood is performed with chemical protective agents called “wood preservatives”. Fungicides which used for wood protection are classified into two groups as organic and inorganic, according to their chemical structure (Reinprecht, 2016).

Some treatment processes like drying, impregnation and surface treatments are applied to enhance the durability of wooden materials and the most commonly applied protection method for wooden materials is to treat them with an appropriate chemicals (Şen and Hafızoğlu, 2001). Boron compounds are the impregnation material that effectively against both insecticide and fungicide properties against insects and fungi destroying wooden materials. Boron compounds can be used for controlling wood attacks encountered due to termites and insects. Boron compounds are responsible for lower levels of environmental damage and no more toxic than common salt to humans. Boron compounds are accepted as one of the safest chemicals utilized as a preservative impregnation substance without heavy metals. (Lloyd, 1998; Kartal and Green, 2002; Yaşar and Atar, 2017, Muhammed and Hakan, 2019).

Boron (B^{3+}) in the form of boric acid (H_3BO_3), sodium tetraborate (borax, $Na_2B_4O_7.10H_2O$) and sodium octaborate is normally used in aqueous solutions (Lin & Furuno, 2001). Borax and boric acid mixture is mixed with water for preserving the softwood as an indoor preservatives. Pine (*Pinus caribaea*), a major softwood species grown in Sri Lanka is used in furniture and other light construction works. Pine is an important source of raw material for sawmills, veneer plants, and paper mills (Gomes et al, 2004). Softwood timber species are subjected to easily deteriorate easily by the actions of wood destroying agents. Thus preservation is needed to enhance the durability of such wood. Main objective of this paper is to discuss the assessment of the impact on Borax-boric acid treatment for treated and untreated finger-jointed Pine wood under impregnation method.

Materials and methods

Materials

Pine wood samples were taken from the breast height of the first logs available of the State Timber Corporation, Galle, Sri Lanka. All the samples were made after the preservation and seasoning processes (moisture content 12%-14%). Borax and boric acid mixture was mixed with water (23 kg of borax and 15 kg of boric acid mixed in 1000 l of water) and used for the solution strength of 8% for the treatment. First, impregnation process was started with initial vacuum, 635 mmHg for 30 minutes and then impregnation treatment was done by borax-boric acid mixture with the maintaining the temperature of 60 ^{0}C and pressure of 200–210 psi for 45 minutes. After the ffinal vacuum was done with 635 mmHg for 45 minutes.

Manufacture

All the samples were made accordance with the finger geometry shown in Fig. 2 and samples were prepared in finger joint factory in the State Timber Corporation, Galle, Sri Lanka. Horizontally oriented finger jointed timber planks with 19 mm long fingers be used in industrial applications and that timber made from soft wood species like Pine (Muthumala et al 2021).

Assembling pressure of 6 MPa was used in this study. Polyvinyl acetate (PVA, P-SWR) D3 adhesive was used for making finger joint samples (Muthumala, 2018). Sawn timber planks which were placed under normal room temperature for seven days showed good structural performance compared to those placed under hot and wet conditions (Vivek et al, 2016).

Tensile testing

Testing of the finger-jointed samples was conducted in accordance with BS 373:1957 (BSI, 1999). Dimensions of the sample and experimental setup are shown in Fig. 3. Ten finger-jointed wood samples without Boron treatment and boron treated ten samples of the Pine wood were used as the controls.

Tensile strength was calculated using the Eq. 01.

$$\text{Tensile Strength} = \frac{\text{Maximum load (N)}}{\text{Area of cross-section of test length (mm}^2\text{)}} \qquad \text{Eq. (1)}$$

Failure modes were also identified both treated and untreated specimens under tension test.

Calculation of the wood density

The density values were calculated using Eq. 2. Dry weight of the timber samples were taken after placing the samples in an oven at 105^0C for 48 hours (BSI, 1999).

$$\text{Density} = \frac{\text{Weight of oven dried wood (kg)}}{\text{Volume of wood (m}^3\text{)}} \qquad \text{(Eq – 02)}$$

Results and discussion

Impact on Borax-boric acid treatment for finger-jointed specimens was investigated using untreated finger-jointed Pine specimens and treated finger-jointed Pine specimens. Average density value of pine specimens varies between 645–650 kgm^{-3}.

In all cases, failure of the finger -jointed samples occurred by after the tension test shown in Fig. 4. T- test results and failure modes of the tested samples were shown in Table 1.

Table 1
T-test results and failure modes of Boron treated specimens and untreated specimens

Untreated/Treated timber sample	**Glue failure %**	**Wood grain failure %**	**Finger broken failure %**	**Average tensile strength (N/mm^2)**	**Standard deviation**	**Standard mean**
Untreated	-	20	80	35.46	9.23	3.1
Treated	70	-	30	12.96	4.72	1.6
T-Value = 6.51 P-Value = 0.000 DF = 11						

Average tensile strength values of boron untreated Pine was 35.46 (N/mm^2) and treated Pine was 12.96 (N/mm^2). According to two sample T-test results, T value is 6.51 and P value is 0.000. Hence, strength value of boron treated finger-jointed specimens was lower than untreated finger-jointed specimens. It is reviled that boron preservative was negatively affected for bonding of the finger-jointed specimens.

Tensile Failure modes were identified as wood grain failure, finger broken failure and glue line failures (Table 2). With regards to treated samples, failures were observed on the finger-jointed connecting points. Majority of the failure mode of treated samples were glue line failures (70%) and therefore it is emphasized that boron preservative was negatively affected for bonding of the finger-jointed timber. Finger broken failures were observed in the samples around 30%, and Glue line failures were clearly observed to the naked eye. Majority of the failure mode of untreated samples were finger broken failures and that was around 80%, of tested samples.

All the finger-jointed specimens showed higher strength values than DIN/EN 204-D3 test. With regard to DIN/EN 204-D3 test, Rosenheim (2006) revealed that the minimum requirement of tensile strength value should be ≥ 10 N/mm^2 after keeping them under dry conditions for seven days (EN 204, 2001). This study revealed that, all the tensile strength values of finger-jointed specimens bonded with SWR-D3 glue comply this value as all the tensile strength values are higher than ≥10 N/mm^2. Mean Carbon stock (t/ha) of Pine monoculture forest plantations of Sri Lanka is 130.19 t/ha which is significantly higher than that of the Teak monoculture forest plantations 42.7 t/ha (De Costa et al, 2012). Therefore use of Pine for commercial replanting programme and utilization of Pine wood for finger-jointed wood production could be regarded as an environmentally sound sustainable solution.

Conclusion

With regard to impact of borax-boric acid wood preservatives, the results confirmed that the average strength value of boron treated finger-jointed specimens was lower than untreated finger-jointed specimens. But average tensile strength values of treated finger-jointed Pine specimens are higher than the recommended minimum requirement of tensile strength value (≥ 10 N/mm^2) after seven days. Thus, it can be recommended that Boron treated finger-jointed Pine wood timber planks with 19 mm long fingers can be effectively used in industrial applications with enhanced the durability. Less durability of untreated pinewood is a major disadvantage for their maximum utilization. Therefore, preservation of pinewood is vital and the boron treatment is an effective method to increase the durability of Pine wood, which is a mixture of Boric acid and Borax.

Declarations

Author Contribution

C.K.Muthumala - Main researcher and research writerSudhira de Silva - Technical AssistanceK.K.I.U.Arunakumara - Wrote the discussion partP.L.A.G.Alwis -Main Supervisor and to Assist Technicial Support

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Figures

Figure 1

Vacuum pressure impregnation plant

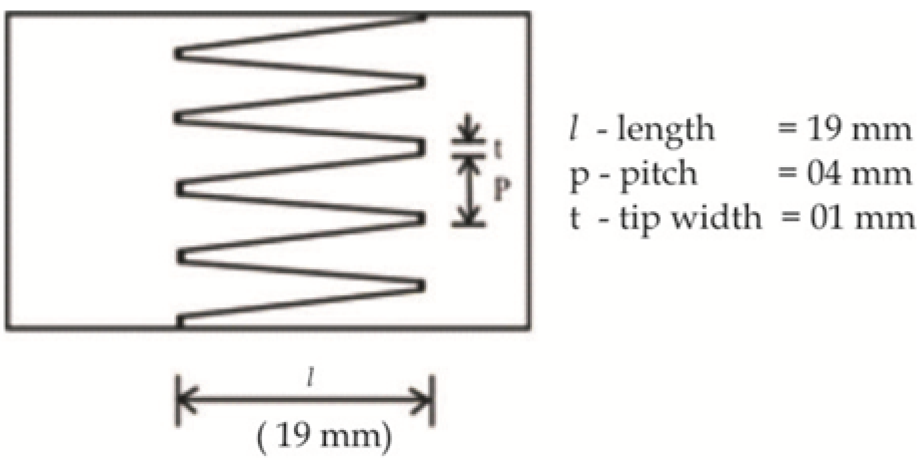

Figure 2

Geometric parameters of Finger joint

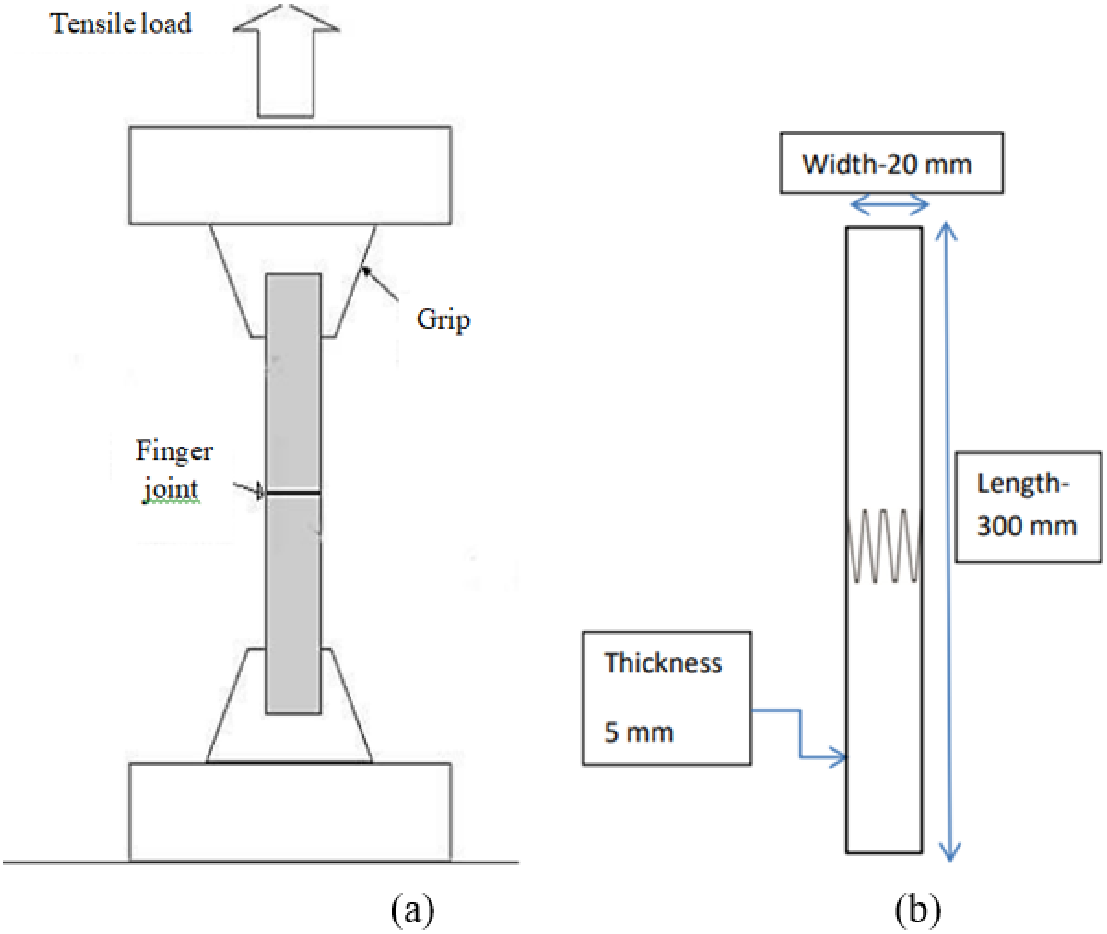

Figure 3

The Experimental set-up (a) Dimensions of the sample (b) preparation for tension test.

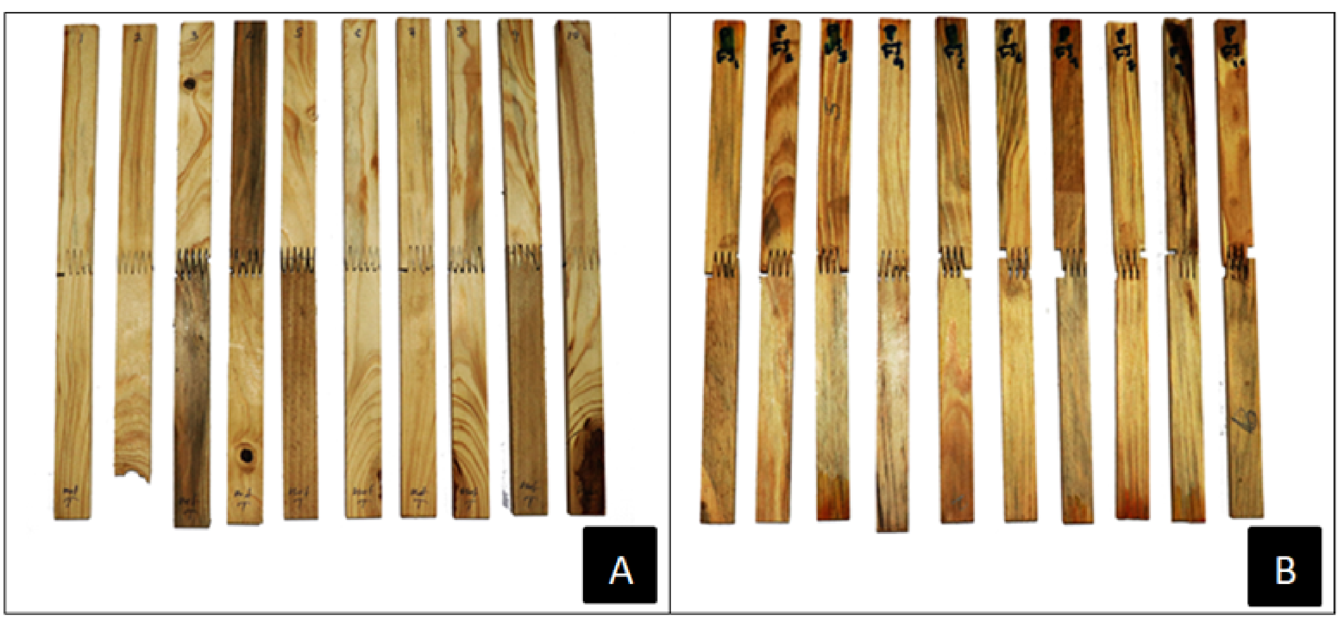

Figure 4

(A) Untreated failure specimens (B) Treated failure specimens

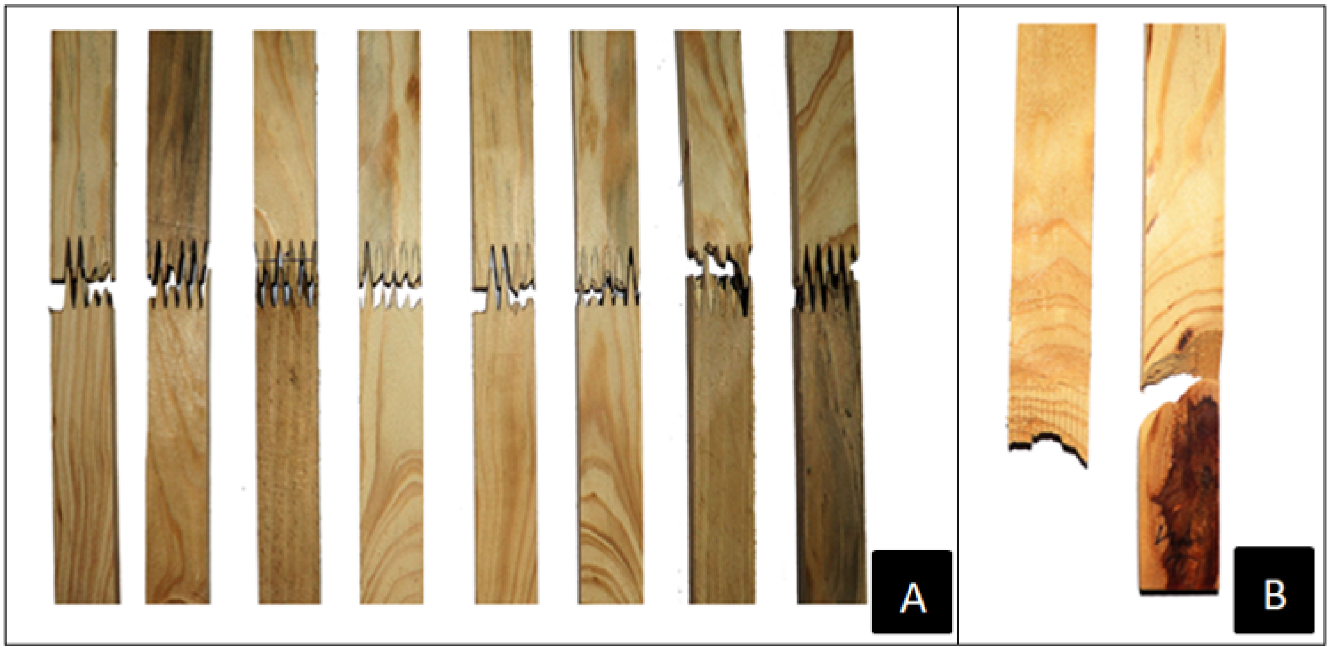

Figure 5

Failure modes of untreated specimens (A) finger broken failure (B) Wood grain failure

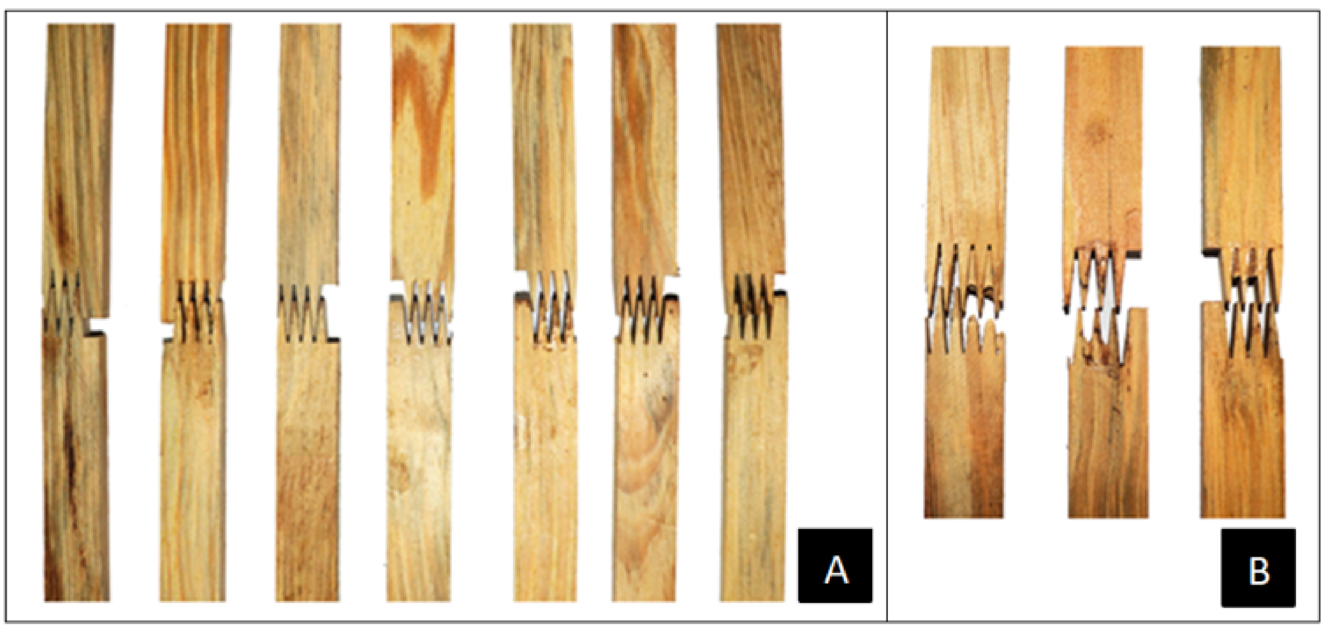

Figure 6

Failure modes of treated specimens (A) glue failure (B) finger broken failure