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Evaluation of Physical and Mechanical Properties of Paulownia Wood Core and Fiberglass Surfaces Sandwich Panel

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Abstract. The purpose of this study was to determine some physical and mechanical properties of sandwich panels manufactured from the core of Paulownia wood and surfaces of multilayer of fiberglass and resins. Paulownia was selected among Hardwoods because of its s low density (0.26 g/cm3) and high strength/weight ratio. Eight treatments were used for experiments: Two kinds of fiberglass (needle and combination of the needle and curtain type), two various resins (polyester and epoxy) and two core thicknesses (9mm and 19mm). Physical properties including density, resistance to water absorption, Dimensional stability, and Mechanical Properties such as internal bonding, compressive and bending strength of panels were measured following ASTM Standard. The results indicated that panels with 19 mm thick core had lower density (0.5g/ cm3) compared to the 9mm thick panels (0.7g/cm3). Bigger volume of wood in the core of panels with higher thickness was the main reason of this result. The experimental results showed that thickness of wood was effective on the modulus of rupture, modulus of elasticity, and compressive strength, significantly. Epoxy resin presented higher internal bond compared to the polyester resin. The two kind of fiberglass (needle one and the combination of needle and curtain type) didn't have noticeable differences on mechanical properties. It also was found that Paulownia is a promising species for manufacturing sandwich panel.

Introduction

Sandwich panels offer great potential for the development of optimized structures with high stiffness and strength-to-weight ratio [1]. These panels are a combination of outer skins bonded with structural adhesives to a solid core, a foam core, or honeycomb core material.

This structure is a combination of thin, high strength facing on each side of a much thicker, light weight core material. Sandwich technology is gradually making the advantages of composites available for an ever wider range of applications [2].The performance characteristics of composite panels are greatly superior to those made from traditional materials, such as plywood or metal.

Composite sandwich panels are widely used in various industries, because they exhibit extremely high stiffness-to-mass ratios. The primary advantages of composite panels compared to conventional materials. Those are significantly lighter panels, vastly stronger panels, and fatter panels when manufactured and when in use, economically superior, capacity for medium to very large volume production runs [3]. Sandwich constructions has broad applications in diverse industries where lightweight, stiff panel construction is required, from boat hulls to aircraft structures, from truck sidewalls to building panels, from space platforms to bridge decks [4].

On the other hand the high specific strength and stiffness of reinforced polymer-matrix composite materials have made them attractive for use in sandwich constructions [5] and their environmental durability and corrosion resistance offer superior serviceability in many applications compared to traditional materials [6]. This product is fiberglass-reinforced Polymer facings laminated onto a Paulownia wood core. End-grain Paulownia core blocks is sandwiched between and adhered to facing skins.

There was some reason for selecting Paulownia wood in core. Paulownia low density (0.26g/cm3) was of main factors that we decided to use it. Physical and mechanical properties of Paulownia wood estimated before selection for using in sandwich panel core. End grain Paulownia is an ultra-light wood product with one of the highest strength to weight ratios for a core material [7].

It was supported that the vibration properties of this wood satisfy the necessary conditions (low loss tangent and high acoustic converting efficiency).This wood is a good thermal insulator and it has excellent heat/cool insulation properties [8]. In addition to these properties, Paulownia wood is suitable for weight critical applications. End grain Paulownia configuration has the ability to handle dynamic loads with high resistance to fatigue. However all of these properties make it suitable for aircraft, ship and building structures.

Material and Fabricating Method

Eight sandwich configurations are fabricated in Gorgan University of agricultural sciences and natural sources. The sandwich panels were manufactured using hand lay up method producing fiberglass laminate and resin transfer process was by hairbrush [9]. Fiberglass with epoxy/polyester resins used as face sheets over a Paulownia blocks core. Paulownia blocks used in the core had a cross section of 25*50 mm2 and 9 and 19 mm thicknesses .Wood blocks were conditioned at 23˚c and 50% relative humidity for a few days. Five layers of fiberglass with resin for covered every surface and the two kind of fiberglass (needle one and the combination of needle and curtain type) were used. Catalysts were added to resins. After preparing of resins, they applied to fiberglass layers by hairbrush. The glued layers were placed on core layer one by one. A small roller was used for flattening and removing of extra resins and air from fiberglass multilayer. When sandwich was assembled a weight block placed over that and left for one day. During this epoxy or polyester binder was cured and sandwich panels was produced.

Fig. 1. some stages of sandwich panel production (right to left)

Three variables were used for manufacturing sandwich panels: Two kinds of resins (epoxy and polyester), two kinds of fiberglass (needle one and the combination of needle and curtain type) and two core thickness (9mm and 19 mm). The experimental of design is shown in table 1.

Tests were determined using 5 specimens from each panel. Data for each test were statistically analyzed. Analyze of variance (ANOVA) was used to test for significant difference between factors and levels. When the ANOVA indicated a significant difference among factors and levels, a multiple comparison of the means was done employing tukey test to identify which groups were significantly different from other group. All data of measuring mechanical properties are presented in table 2.

Table 1. The experimental design

Panel type	resin	fiberglass	thickness
A	epoxy	curtain and needle	19(mm)
B	epoxy	needle	19(mm)
C	polyester	curtain and needle	19(mm)
D	polyester	needle	19(mm)
E	epoxy	curtain and needle	9(mm)
F	epoxy	needle	9(mm)
G	polyester	curtain and needle	9(mm)
H	polyester	needle	9(mm)

Evaluating Sandwich Panel Properties

Water Absorption. The present study evaluated the effect of water immersion on Paulownia wood as core material and fabricated panels. Those were subjected to water immersion to determine the relative resistance to property change. Samples were studied for dimensional change, weight gain after immersion .The results of immersed specimens were compared with dry specimens to determine the effect of immersion. Samples dimensions were 25*50 mm^2 for 19 and 9 mm thicknesses. Dimensional stability following water absorption test investigated. The water absorption performed according to ASTM 272_01.

Edgewise Compression Test. This test method covers the determination of flat structural sandwich construction compressive properties in a direction parallel to sandwich facing plane. The edgewise compressive strength of sandwich construction specimens provides a basis for judging the load carrying capacity of the construction in terms of developed facing stresses as compared to the facing yield stress [10]. The shorter edges of the specimens are sanded to ensure uniform load transfer and to avoid local yielding of the faces .Tests results are shown in table2. Samples dimensions were 19* 50*100 mm^3 or 9*50* 60 $mm^{3.}$ The edgewise compression is performed according to ASTM C364–99.

Single-point-load Bending Test. Flexure tests on produced sandwich panels conducted to determine the sandwich modulus of rupture (MOR) and modulus of elasticity (MOE). Bending strength was determined in accordance with ASTM C393_00, as shown in fig. 2 and 3. Samples dimensions were 19*60*290 mm^3 and 9*30*170 mm^3 .The results summarized in table2.

Flatwise Tensile Test. This test method covers the determination of the flatwise tension strength between core and facings of an assembled sandwich panel. Samples dimensions were 25*25 mm^2 for19 and 9 mm thicknesses. Table 2 summarized the core/face bonding strength test properties. Tensile strength was determined in accordance with test method C297_ 94.

Results and Discussion

Bending Test. The experimental results showed that the thickness parameter was effective on the MOR, MOE, significantly.

Amount of shear in panels containing thicker wood blocks in the core was higher. This may be related to higher shear that occurs in solid wood part of panel in higher thickness. In accordance with this reason that thinner panels (9mm thick) presented higher MOR and MOE compared to thicker panels (19mm thick). Interaction effect resin and thickness also was found in MOE that is shown in fig.6. (1: polyester and
2: epoxy)

Although higher thicknesses (19mm) had negative influence on MOR and MOE ،this influence on panels that were produced with polyester resin was further .This may be due to higher brittle property in polyester resin that indicated increasing MOE and MOR further. Analyzed results are shown in fig. 2 and 3.

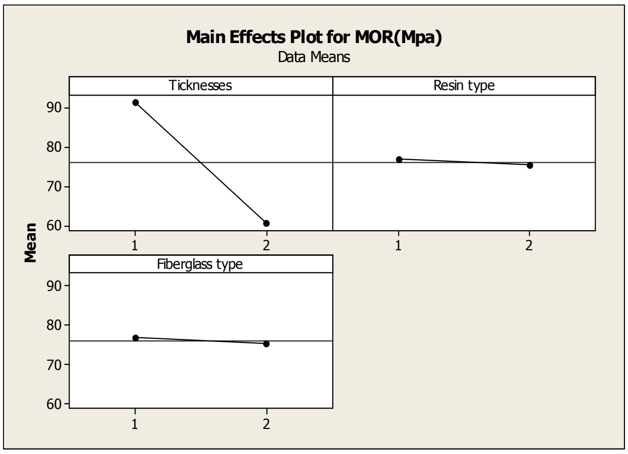

Fig. 2. Effect of different treatments On bending strength

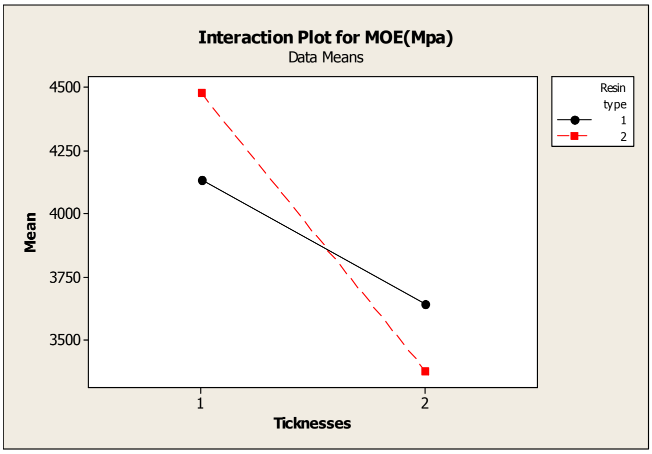

Fig. 3. Interaction effect between the resin and thickness on bending strength

Compressive Test. Positive influence of the core wood lower thickness on compression test´s samples is shown in fig..5 (1: 9mm thickness and 2: 19 mm thickness). It indicates that 9 mm thicknesses samples had higher compressive strength compared to 19mm thicknesses samples. Using of epoxy resin also showed higher compressive strengths in comparison to polyester resin. . This can be due to higher strength of epoxy resin after solidification in comparison to polyester resin .There wasn't significant influence between panels with facings produced with two type fiberglass (needle one and the combination of needle and curtain type). Effect of different treatments on compressive strength is shown in fig. 4.

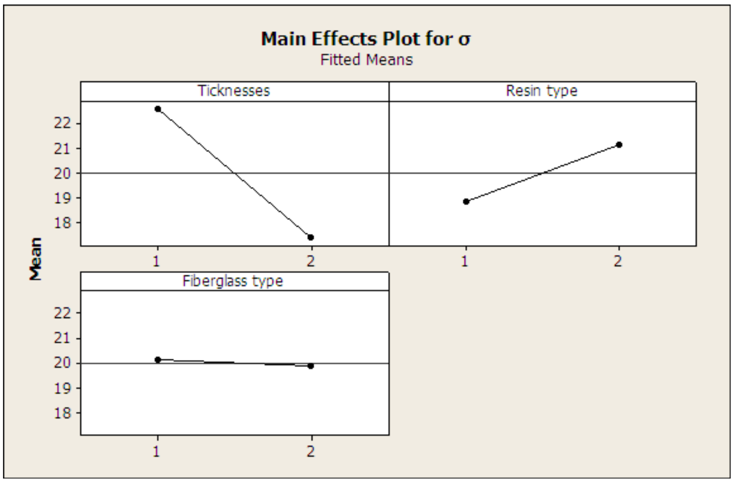

Fig. 4. Effect of experimental factors on sandwich panel, compressive strength

Bonding Test. Using of epoxy resin instead of polyester resin improved the tensile strength, significantly. Investigation of deboned propagation in composite sandwich panels with epoxy resin containing lower face/core delamination at the panel has been conducted. This can be due to higher adhesion property of epoxy resin in comparison with polyester resin. Thicknesses and fiberglass type influents on bonding strengths there weren’t significantly. Effect of different treatments on bonding strength is shown in fig. 5.

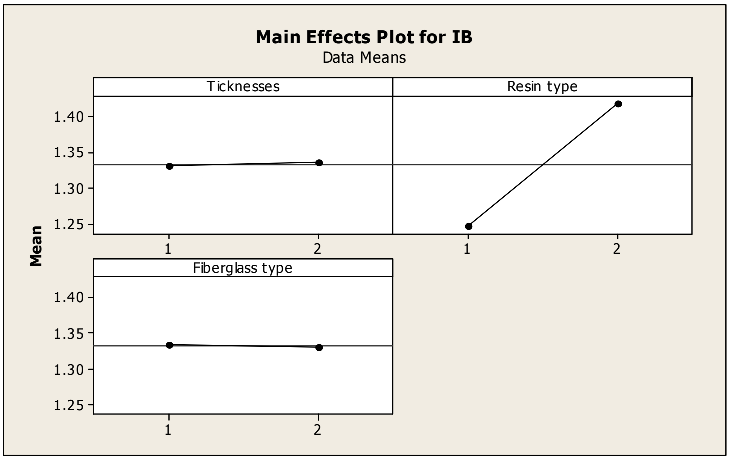

Fig. 5. Effect of different treatments on Sandwich panel, flatwise tensile strength

Water Absorption. The Paulownia wood samples showed average density value 0.26 g/cm^3. The Paulownia wood in water gained increase in density (around 20 %). This wood showed high percentage of weight gain (around41%). Reason for the water absorption of Paulownia wood is the more hydrophilic nature of its constitudes (such as cellulose fibers and hemi cellulose).This constituents attract more and more water which significantly weakness the interface between the constituents thereby reducing the durability. But results in panels indicated there is a few effect of water immersion on density. (around 6.9%). This property should be due to closing of wood vessels by facings that reduces influence of the water absorption.

Volume Stability. The effect of water immersion swelling characteristics (volume change) in Paulownia wood is high. The Paulownia wood expanded to about 22 % during the test time (24 hours). But a little volume change in sandwich panel's samples observed during 24 hours immersion time (4%).That's reason is referred to prevision section.

Table 2. Test mechanical results

Panel type	MOR[MPa]	MOE[MPa]	δ [MPa]	Bonding Strength [MPa]	Density [g/cm^3]
A	61.44	3399.93	18.99	13.91	0.5
B	57.32	3353.81	18.21	13.72	0.5
C	61.78	3542.48	16.20	11.95	0.5
D	62.1	3737.57	15.92	12	0.5
E	93.04	4637.77	22.66	15	0.7
F	91.04	4312.56	24.41	13.62	0.7
G	86.39	4065.46	21.65	12.34	0.7
H	96.86	4196.73	21.17	11.95	0.7
I	41.1	390.41	21.9	---	0.26
J	23	3200	15.5	---	0.15

I: Paulownia wood[11]
J:balsa wood [11]

Summary

1. Panel core thickness negatively effected the mechanical properties of panels. In addition to higher mechanical properties, smaller wood material is used which is economic.
2. Based on the initial findings of this study, it can be stated that Paulownia wood as and light and stiff raw material has various advantages for sandwich manufacturing.
3. The results of this study showed that Paulownia wood blocks used as core in manufacturing sandwich panels improved properties of the product. Therefore it has potential as a raw material for using in sandwich panel core and it was possible to produce valuable, strong sandwich panels.
4. In this study paulownia wood was used instead of balsa wood that is employed widespread all over the word that the results were satisfactory and it was revealed that function of paulownia wood is better than balsa one.
5. The increase in wood material consumption due to the increasing world population requires optimum utilization of the natural recourses. Paulownia wood in addition to good strength properties (table2) [11] is a fast-growing tree (5-6 years old) .It can be suggested for using in sandwich panel industries. On the other hand it has cost-reducing advantage.

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