EFFECTS OF GLYCEROL IMPREGNATION ON COMPRESSIVE STRENGTH PARALLEL TO GRAIN OF ACACIA AURICULIFORMIS UPON DRYING

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ABSTRACT. *This study deals with the chemical treatment of the Acacia Auriculiformis species with a 99.5% glycerol solution with the aim of demonstrating the possibility of producing better ultimate compressive strength parallel to the grain upon drying. The vacuum pressure method was used to impregnate the glycerol solution into the cell wall of the wood. The results indicate a significant improvement (about 30% higher) of the properties investigated; specifically the compressive strength of wood perpendicular to the grain, however, the non-impregnated sample still has superiority when it comes to toughness.*

KEYWORDS: AcaciaAuriculiformis, compression test, drying defect, glycerol

INTRODUCTION

Tropical acacias were first introduced to Sabah, Malaysia from Queensland, Australia over 40 years ago (Mead & Miller, 1991). Their ability to grow well even in poor soil and its adaptability to humid climates with an annual rainfall up to 1800mm makes them important as a plantation species (Semsuntud&Nitiwattanachai, 1991; Yamamoto et al., 2003).At present there are three Acacia species planted in many areas of tropical Asia; namely the Acacia Mangium, *Acacia Auriculiformis* and hybrid Acacia (Mead & Miller, 1991; Yamamoto *et al*., 2003).

One of the most essential characteristic of wood is the moisture content (MC). Water is an important component in wood, which accounts for about 50% to 200% of the fresh weight (Yamamoto et al., 2003; Remond et al., 2007). Depending on the application and the environment of the location, mostly the amount of MC required removed is to achieve a value of approximately 8% to 15%of the fresh weight (Remond*et al*., 2007).The removal of moisture from wood is a difficult process in which several drying defects such as cell wall damage, stresses, cracks, collapse, and discoloration may occur (Yamamoto *et al*., 2003; Remond*et al*., 2007; Thuvander*et al*., 2001).

In a related study byThuvander*et al*. (2001), cell wall damage due to drying was analyzed. Green sapwood of Swedish pine was impregnated using two sets of treatment; 1) soaking in a solution of water and glycerol and 2) soaking specimens in just water. The specimens were then subjected to tensile tests. It was found that the tensile strength parallel to the grain for wood impregnated in the green (fresh) state showed significantly higher strength. It was suggested that this was due to

the damage of the wood's cell walls of the non-treated specimen which was caused by the drying stress (Thuvander*et al*., 2001).
In another study done by Stolf& Lahr (2004), where physical and mechanical properties of Pine and Eucalyptus species impregnated with Styrene and Methyl Methacrylate were examined, the test result indicated an improvement in dimension stability and hardness parallel and perpendicular to the grain of the impregnated specimens (Stolf& Lahr, 2004).

Also it has been shown that impregnation of wood with some organotin polymers, show an improvement of ultimate flexural strength, flexural modulus of elasticity and impact strength value in the direction parallel to the grain (Subramanian*et al.*, 1981; Subramanian*et al.*, 1981). The interaction between wood,Pinussylvestris with glycerol has been studied by Wallström*et al.* (1995), and it was found that the dimensional and mechanical stabilization effect of glycerol impregnated wood was very good (Wallström*et al.*, 1995).

In short, drying influences the mechanical properties of wood in three ways; 1) direct effect of moisture loss, 2) internal drying process and 3) strains (Bachrich, 1980). Therefore by controlling these factors, the mechanical properties of wood can be improved (Bekhta *et al.*, 2006). There have been many studies done on wood modification treatment to reduce the effect of these drying defects but these studies are insufficient especially for tropical acacias species. This paper deals with the chemical treatment of *Acacia Auriculiformis* species with a99.5% glycerol solution with the aimof demonstrating the possibility of producing better ultimate compressive strength parallel to the grain upon drying.

MATERIALS AND METHODS

Wood

AcaciaAuriculiformis species used for this study was cut down from KampungBundusan, Indah Permai, Kota Kinabalu. The age of this tree was about 15 years old and was sawn into three logs.

Glycerol

Glycerol is used due to its special characteristic of non-toxicity, hygroscopic and humectant action on woods. Glycerol/Glycerin 99.5%, Qrec supplied by Eastern Laboratory Supplies SDN. BHD. is used in this study.Bulking agents such as Glycerol can be used in order to replace the moisture content in the cell wall to limit dimensional changes in wood (Stamm, 1977).

Sampling Process

Acacia dries slowly and has the tendency to distort; it is therefore recommended that an air drying (under shed) period of about 3 weeks should be undertaken before the actual oven drying(Lim *et al.*, 2003).The log was conditioned (air dried) under shed for about a month before it is sawn into 2 (radial direction) × 2 (tangential direction) × 5 cm (longitudinal direction) in dimension, figure 1(a) shows the specimens after they have been cut and (b) shows thedirection schematically.These specimens were grouped into two sets, 10 specimens to be impregnated with glycerol and another 10 for control testing.

Each test specimen was identified with a number 1i to 10i for the impregnated specimens and 1c to 10c for the control specimens. The machines used to cut these specimens into mentioned

dimensions are the bend saw and sander, which both are located at the School of International Tropical Forestry (SITF), University Malaysia Sabah (UMS). The initial weight of the wood is measured before oven drying.

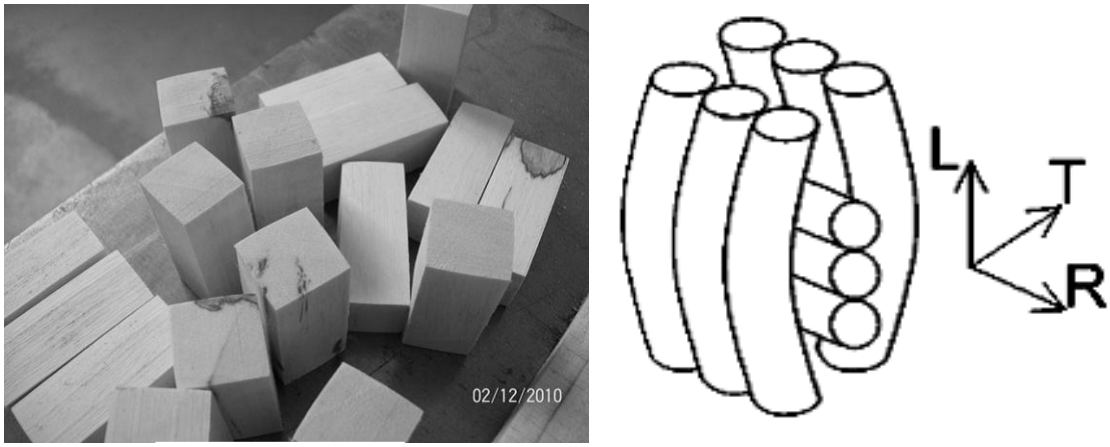

Figure 1: (a) Samples for compression test and (b) Three principle axes of wood growth

With the intention of reducing the moisture content, these specimens were then dried to achieve 12% moisture content. Due to the presence of moisture in the wood pores, the impregnation process and consequently, the test results would be affected. To prevent this, the specimens were dried at a starting temperature of 40˚C,which was then gradually raised to 104˚C,thus also preventing cracking and warping. Specimens were wrapped in aluminum foil before being placed in the oven.The vacuum oven dryer is located at the Concrete Lab, School of Engineering and Information Technology (SEIT), University Malaysia Sabah (UMS). The moisture content (MC) of the samples of *Acacia Auriculiformis* species that had undergone drying wereobtained by using the Eq. (1):

$$\text{MC} = \frac{w_i - w_o}{w_o} \times 100\% \quad (1)$$

Where,w_i and w_o are oven dried weight and initial weight of wood specimen respectively.

Oven dried density for each sample was then determined by using water immersion method (Bowyer et al., 2003). The calculation is done using Eq. (2):

Density = mass of wood/volume of wood (2)

Impregnation Process

Impregnation process was done by adapting the methods done by Thuvander*et al.*, (2001). All specimens with the same dimension were soaked in a glycerol solution in a high pressure chamber. The pressure chamber was then closed and vacuumed for 30 minutes. This was done to remove all the air from inside the specimens. A pressure of 0.5 MPa was then applied to the pressure chamber for 12 hours. The specimens were then taken out and air dried to get rid of the excess glycerol on its surface. The weight of the specimens was measured once again after the

impregnation process. The impregnated specimens were then oven dried once again at 104˚C using a vacuum oven dryeruntil no weight difference was detected between these specimens and the control specimens. Finally the specimens were removed from the vacuum oven, weighed, and their dimensions measured, in preparation for thecompression test.

Compression Test Parallel to the Grain

This test was performed on the impregnated and control specimens using the INSTRON 8801 Universal Testing Machine located in SEIT, UMS. The compression test was carried out for all specimens to get their ultimate compressive strength.Figure 2(a) shows the setup for this test.Load was applied in axial compression parallel to the fiber as indicated in figure 2(b), with the rate of loading of 2mm/min.

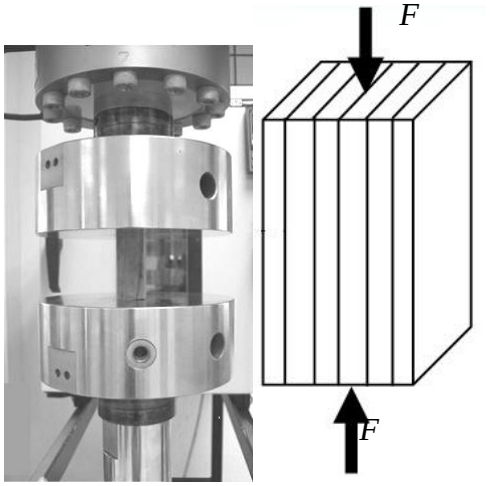

Figure 2: (a) Setup for compression test with specimen grain parallel to the applied load (b) schematic diagram of axial compression parallel to the grain

Microstructure Observation

Fractured surfaces of the specimens from both the impregnated set and control set that had undergonethe compression test were sawn into segments of 5 mm × 5 mm × 5 mm. Microstructure observation was done using the Scanning Electron Microscope (SEM) model ZEISS EVO MA 10 located in SITF, UMS. These specimens were coated in advance with gold in a dried state.

RESULT AND DISCUSSION

The volumetric shrinkage for most samples is about 7.5%. The average weight gained after the impregnation process is about 3-4 grams, which is about 11% - 14% of the oven dried weight. Based on our observation there were no signs of warping and cracking of the samples after the impregnated specimens were oven dried once.Table 1 and Table 2 show the value of maximum compressive strength and compressive strain percentage parallel to the grain for all specimens for both control and impregnated sets. Both density and specific gravity of all specimens were also shown in these tables.

Table 1: Maximum compressive strength (MPa) and compressive strain percentage (%) parallel to the grain for control specimens.

Control Sample				
Specimen	Density (g/cm^3)	Specific Gravity	Ultimate Compressive Strength (MPa)	Compressive Strain (%)
1c	1.21	1.21	47.51	2.99
2c	1.25	1.25	44.44	3.99
3c	1.30	1.30	41.07	2.97
4c	1.21	1.21	44.64	3.72
5c	1.32	1.32	49.86	2.19
6c	1.23	1.23	45.29	2.39
7c	1.22	1.22	51.69	2.66
8c	1.26	1.26	47.02	2.20
9c	1.23	1.23	47.31	3.44
10c	1.19	1.19	43.65	3.98

Table 2: Maximum compressive strength (MPa) and compressive strain percentage (%) parallel to the grain for impregnated specimens.

Impregnated Specimen				
Specimen	Density (g/cm^3)	Specific Gravity	Ultimate Compressive Strength (MPa)	Compressive Strain (%)
1i	1.39	1.39	47.51	2.99
2i	1.41	1.41	44.44	3.99
3i	1.44	1.44	41.07	2.97
4i	1.37	1.37	44.64	3.72
5i	1.45	1.45	49.86	2.19
6i	1.39	1.39	45.29	2.39
7i	1.43	1.43	51.69	2.66
8i	1.40	1.40	47.02	2.20
9i	1.45	1.45	47.31	3.44
10i	1.39	1.39	43.65	3.98

The average compressive strength of the control specimens is 46.25MPa whereas the average compressive strength of those impregnated specimens is 61.15MPa. The results indicated a slight improvement (33%) in compressive strength parallel to the grain of *Acacia Auriculiformis* after the glycerol impregnation process. Studied on the effect of crosslinker on mechanical properties of tropical wood material composite done by Islam et al. (2011), strongly support that by impregnating a crosslinker agent in wood, there was a significant increase (67-78%) in compressive strength for all 4 types of woods (Pulai, Batai, Terbulan and Rubber) used in their

study. Untreated wood species fail in compression caused by relatively thin cell walls, hence unstable. (Islam et al, 2011).

Figure 3 and 4 show the stress vs. strain curve obtained from the compression tests. Observed from these figures, the stress versus strain behavior of both control and impregnated samples are quite similar. The curves are initially linear and elastic. With the generation of cracks the behavior of the curves become nonlinear this indicates that the wood fibers start to buckle. For all samples, the moment peak stress was reached, the resisting stress decreased with increase in strain.

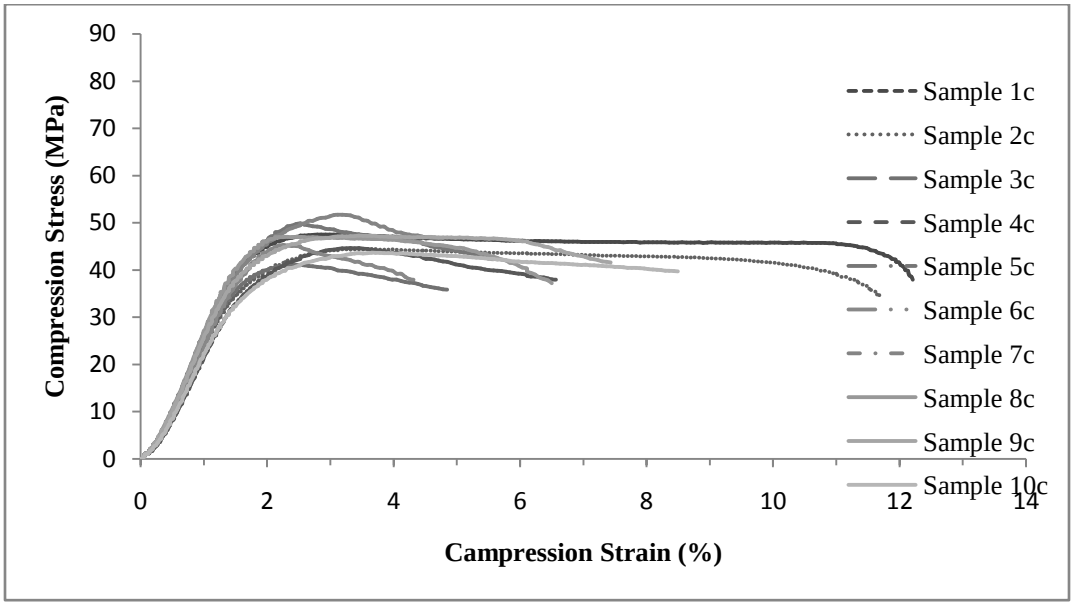

Figure 3: Stress vs. strain result for the control specimens

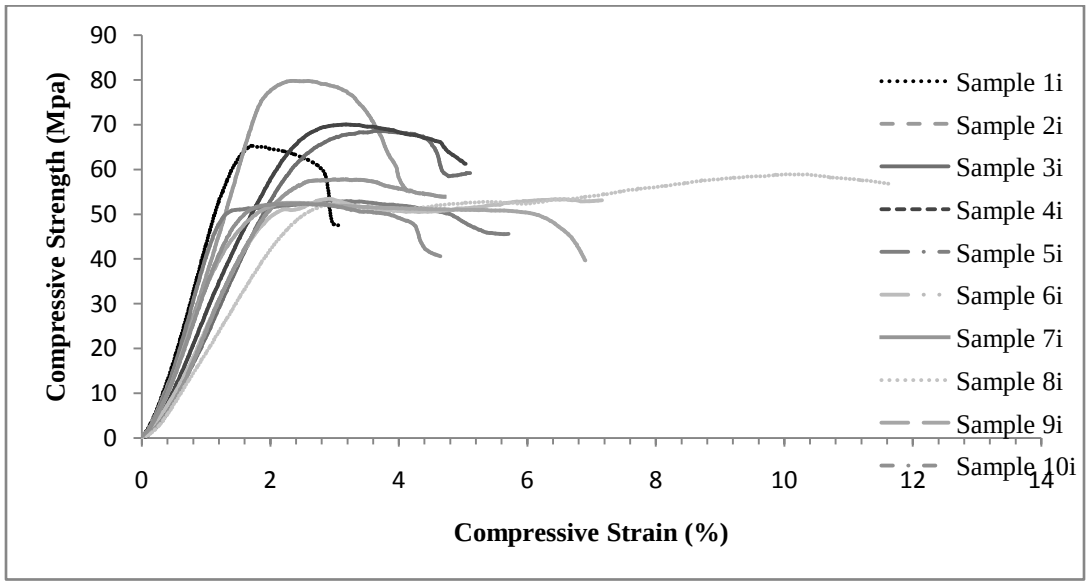

Figure 4: Strain vs. strain result for the impregnated specimens

Although the higher strength shown by those impregnated specimens proved their superiority, some insight on the failure mechanism was needed.

The analysis of the microscopic structure of the control specimens of *Acacia Auriculiformis* compared with the glycerol impregnated specimens shown in Figure 5 revealed that the cell wall damage shows a rough appearance after the compression test was done to the control specimen (see Fig. 5(a)), we postulated this fractograph as having a sign of ductile cell wall damage with the impression of better toughness. As for the impregnated sample (see Fig. 5 (b)) at the scale of cell wall, the sign of brittle fracture was obvious as the surface appears flat.

From the compression test results and microscopic analysis that has been done, it can be seen that there is a correlation between the observed fractograph and the stress vs. strain diagram presented. The tougher appearance of the fracture surface of the control specimen is parallel with the larger area under the stress-strain curve shown in Figure 3, meanwhile the impregnated sample shows a higher strength with little strain at higher stress compared to aforementioned control specimens.

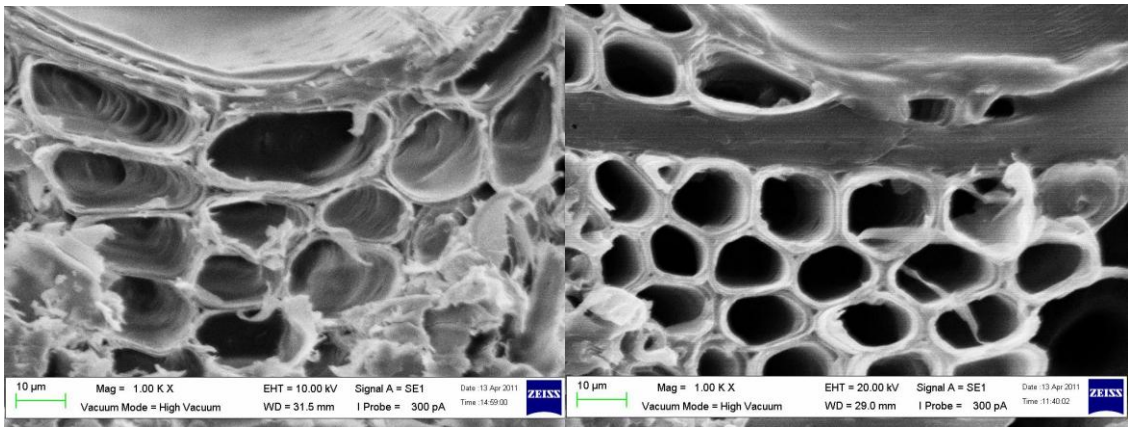

Figure 5: a) SEM micrograph of a compression test fracture surface of an Acacia Auriculiformis sample without glycerol impregnation b) SEM micrograph of a compression test fracture surface of an Acacia Auriculiformissample with glycerol impregnation

CONCLUSION

This study provides clear benefits of using glycerol as a treatment for *Acacia Auriculiformis* to improve its properties from drying defects. The results obtained from the glycerol impregnation of *Acacia Auriculiformis* showed a significant improvement in compressive strength parallel to the grain compared to the non-impregnated specimens upon drying. The results from this study denotes that future investigation on the other mechanical properties such as strength in tension, shear strength, toughness and impact bending need to be carried out in order to get a better understanding on the effect of this glycerol treatment on *Acacia Auriculiformis*.

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