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Physico-Mechanical Behavior of *Euphorbia abyssinica* and Wood–Chips Composites

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Abstract

In this study, we prepared composite test specimens from Eucalyptus chip particles of sizes 0.5 mm, 1 mm, and 2 mm combined with Euphorbia abyssinica fluid at an 80:20 mass ratio. We produced the particleboard under a compression load of 150 KN and kept it in the compression machine for thirty minutes inside the mold. After removing it from the machine, we secured it with C-clamps for twenty-four hours. We covered the inner side of the mold's base and cover plates with a thin plastic layer to make it easier to remove the composite after compression. After a safe removal, we marked the specimen's dimensions according to ASTM standards with a permanent marker. Finally, we cut the mat along the marked dimensions using a cutter machine and dried it at room temperature for three weeks. Test results showed that the bending strength, or modulus of rupture, was 37, 35, and 35 MPa with deflections of 18, 11, and 10 mm, respectively, for Eucalyptus chip particles of 2, 1, and 0.5 mm. The maximum compression strength in the tests were 23, 40, and 67 MPa, respectively. The water resistance results indicated that thickness swelling percentages were 22%, 13%, and 12% in mm, while the water absorptivity was 138%, 124%, and 108% in grams, respectively.

Keywords: Adhesives, *Euphorbia abyssinica*, particleboard, modulus of truss swelling, modulus of rupture

INTRODUCTION

The mechanical and physical traits of *Euphorbia abyssinica*, like those of other plants, can vary based on factors – such as its environment, age, and specific parts – that are being examined. The plant's mechanical properties are essential for its survival in nature. The plant's important features are its tensile strength, due to the fibrous nature of its branches and stems. The tensile strength helps the plant bear elongating forces, make it more stable although during windy conditions or when it bears snow and rain [1, 2]. Another important property is the flexural strength of its stems, which permits them to bend without cracking or breaking. These properties are important for the plant's survival, making them it to handle environmental pressures, like stout winds, that could impairment more rigid plants [3–7]. Moreover, the hardness of *Euphorbia abyssinica*'s stems and branches growths its robustness, making it less susceptible to damage from harsh weather. The plant's fibrous structure might also offer some impact resistance, helping it absorbs shocks from falling objects [8–9].

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The thermal properties of *Euphorbia abyssinica* disturb its response to temperature changes in its situation. For illustration, a plant with lower thermal conductivity can sustain heat better, which is helpful in serene areas [10, 11]. *Euphorbia abyssinica* is known for its several advantages and uses. The anti-malarial action is possible due to various bioactive amalgams found in the plant, with alkaloids, tannins, and glycosides, which are known for their medicinal potentials [12–16]. *Euphorbia abyssinica* illustrates great promise as an anti-malarial representative, the need for more detailed studies on its chemical composition, safety, and pharmacological effects. As a moist, *Euphorbia abyssinica* has thick, heavy stems that store water, vital for living in dry zones. This ability is vigorous for its progress in the montane forests and scrub grasslands of Eastern Africa, everywhere water is limited [17, 18]. The plant is covered in spines that protect it from being eaten [19]. Moreover, *Euphorbia abyssinica* produces a poisonous milky fluid that can annoy the skin and have further harmful effects. This fluid offers a chemical barrier against animals and helps seal sores to prevent water loss. *Euphorbia abyssinica* can flourish at altitudes between 1400 and 2400 meters [20]. Its physical properties help it endure the mechanical force from wind and altering weather conditions.

Euphorbia abyssinica's success in stony areas shows that it has a robust root system [21–24]. A robust root system is vital to clasp the plant, contributing significantly to its mechanical strength [25, 26]. This adaptation makes the tree withstand evacuating during strong winds or heavyweight rain [27]. Euphorbia species are known for their strong and fibrous wood. This strength makes the tree useful for various purposes, such as construction and live fencing, particularly in zones where it is abundant [28–30]. Wood chips have different mechanical properties that limit their applications in various conditions. The strength of wood chips, both in compression and tension, differs based on the wood kind and processing methods [31]. Moreover, the density of wood chips influences their usefulness in construction and energy probably. These chips are used in several applications, for example lightweight fillers in composite materials. They also serve as a biomass fuel source, with energy production influenced by moisture levels and the specific wood species [32, 33].

Composites are made through pre-treated wood chips demonstrate better flexural strength than those made from untreated chips. While using without dried wood chips increases flexural strength, it also decreases the modulus of elasticity, signifying a balance between flexibility and stiffness. The composite utilizing pre-treated undried wood chips (PU-PP) attained the maximum overall mechanical performance, with a flexural strength of 57.7 MPa [34]. In terms of moisture content, the amount of moisture in wood chips knowingly affects composite properties. mainly, a higher moisture content of 33 wt.% in undried wood chips enhanced flexural strength but reduced the modulus. This research highlights the importance of managing moisture content to improve the mechanical properties of wood–plastic composites (WPCs) [35]. Twelve concrete mixes were formed with different volumes of wood, aiming for a density under 2125 kg/m^3 and a compressive strength of 25 MPa. These mixes combined various proportions of wood chips and sawdust, with some attaining compressive strengths over 30 MPa. But, as the wood content increased, compressive strength decreased, showing a 33.35% drop for the mix with 25% wood chips equated to the control mix. Flexural strength also reduced, mostly in the mix that both types of wood [36, 37].

The durability of select mixes was assessed through artificial aging tests, which involved wet–dry cycles, and thermal shock. Together evaluated mixes, WC25 and WC20SD5, sustained compressive strengths above 30 MPa after these tests. Moreover, hydrothermal tests yielded satisfactory results, with little water absorption of around 1% and a substantial deterioration in thermal conductivity, up to 54% lesser than the reference concrete [38]. The mechanical properties of concrete made with untreated wood chips showed a notable decline in compressive strength over time, while concrete with treated wood chips demonstrated a stronger bond with the cement matrix [39]. Density decreased as the amount of wood chips increased, with untreated wood chips resulting in lower density compared to treated ones. Regarding thermal conductivity, concrete containing untreated wood chips offered better insulation than that with treated wood chips, suggesting these materials could be a suitable option for eco-friendly construction [40, 41]. This paper examines the physico-mechanical behavior of *Euphorbia abyssinica* (kulkual) and wood–chips composites.

MATERIALS AND METHODS

Material Preparation

The materials needed to prepare the sample specimens were *Euphorbia abyssinica* (kulkual) fluid and chip particles from local Eucalyptus. Figure 1 represents the *Euphorbia abyssinica* (kulkual) Fluids. For collecting the fluid, it has hammered the stem until a white fluid called "kulkual" started to bleed out. Then gathered this fluid in plastic bottles. For two molds, fluids have collected one-fourth of a liter in about 20 to 30 minutes.

Figure 1. Collecting *Euphorbia abyssinica* (kulkual) fluids in plastic bottles.

Eucalyptus Chip Particles

This study focuses on eucalyptus particles that crush eucalyptus logs into various particle sizes.

Separation Process of Particle Sizes

The eucalyptus chip particles were separated into different desired sizes in the laboratory using sieve sizes of 0.5 mm, 1 mm, and 2 mm (Figure 2). Sifting began with the largest particle size.

Figure 2. Sieves are used for separation and sample eucalyptus chip particles of sizes 0.5, 1, and 2 mm.

The process started with the largest sieve size, allowing all chip particles of 2 mm and smaller to pass through the 2 mm sieve. Chip particles larger than 2 mm remained on top of the sieve and were rejected first.

Mold Preparation

Figure 3 represents the CAD assembly drawing and actual picture of the mold after production.

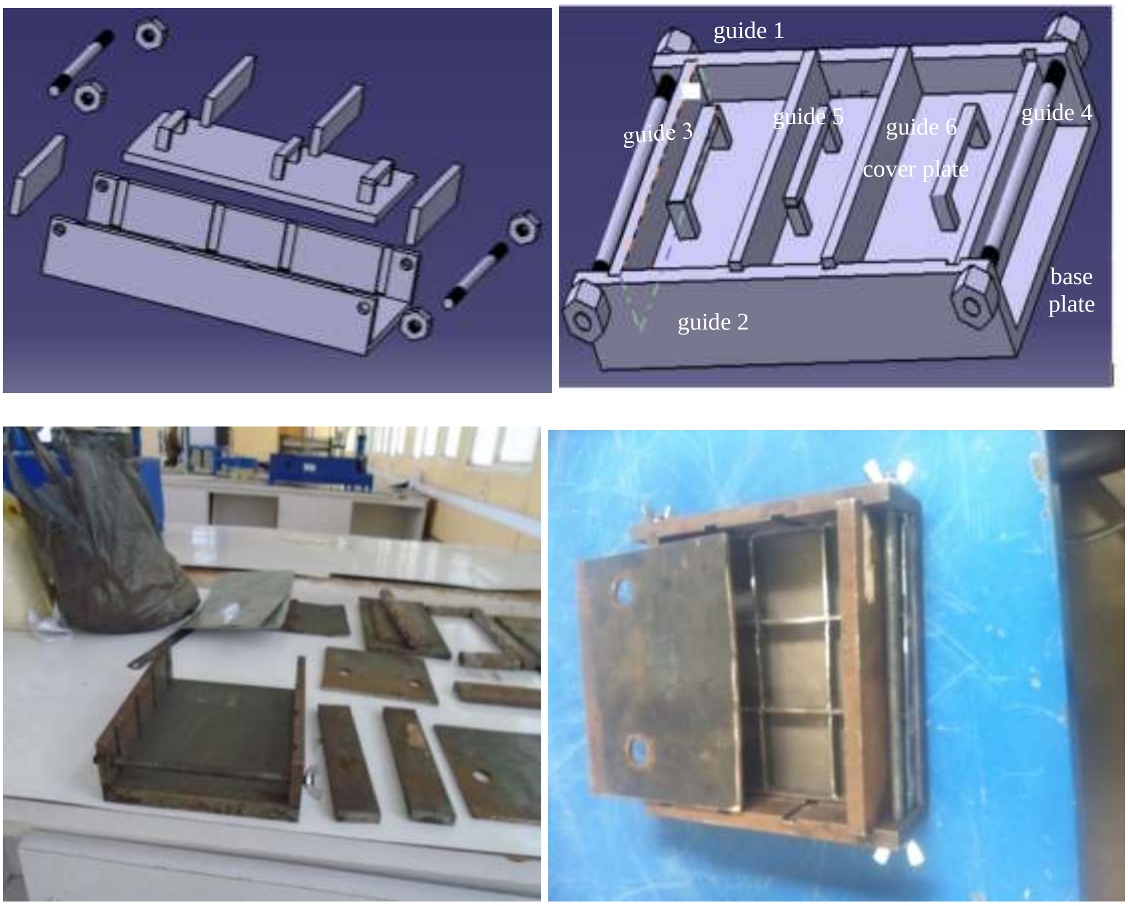

Figure 3. CAD assembly drawing and picture of the mold after production.

Milled steel plates with thickness of 10 and 15 mm were cut in to desired dimensions for all test types according to ASTM standards.

Specimen Preparation

Figure 4 shows the details of compression bending and water absorption specimens.

(a) (b)

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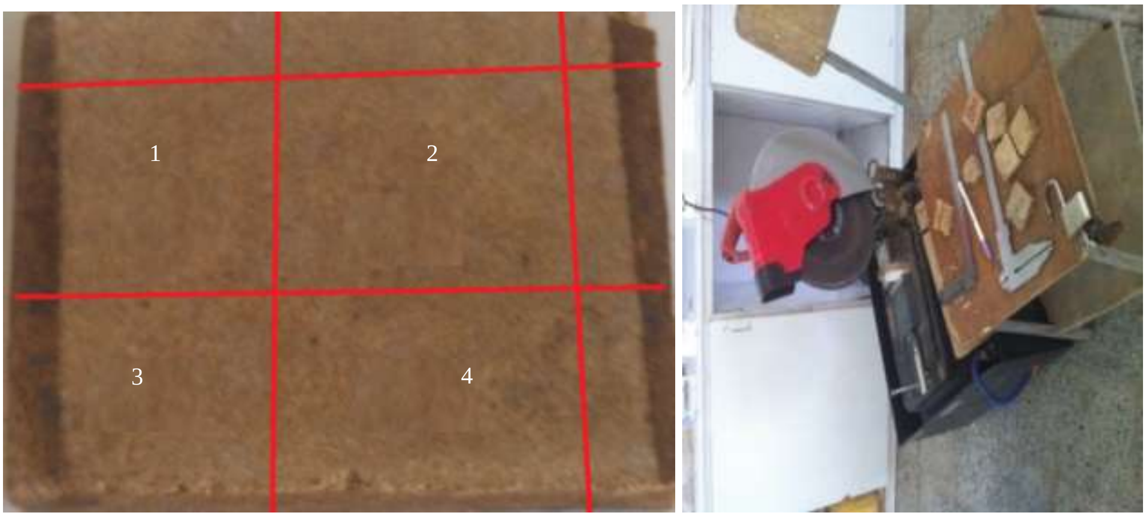

(c)
Figure 4. A, B, and C show compression bending and water absorption specimens.

Blending and Compressing Mold

Figure 5 shows the details of blending and compression mold. The samples were prepared manually by mixing *Euphorbia abyssinica* (kulkual) fluid with Eucalyptus chip particles based on a mass ratio of 80 to 20. It measures the mass of the fluid/adhesive and the chip particles using an electronic beam balance. A load of 150 KN was applied to the steel mold cavity under laboratory conditions to achieve the desired specimen size. The load was controlled until the cover plate reached the mark on the side guide plate. The mold remained in the compression machine for 30 minutes and was then repressed using a C-clamp for 24 hours to ensure the specimen attained the desired thickness.

Figure 5. Blending and compression mold.

Testing of Specimens

Figure 6 represents the details of specimens (a, b, c and d) under the testing machine for compression bending and water absorption test.

- According to the specifications of ASTM, D-1037 the sample will cast into cubical sizes of 25 x 25 x 25. Therefore, a mold having a cavity 25 x 25 x 25 was constructed using mild steel plates.
- As per ASTM D-790, the specimen produced for flexural testing will be on a mold cavity of 150 x 50 x 25 mm in like others the mold cavity constructed.

- Water absorption (WA) and thickness swelling (TS) tests were performed according to ASTM D-1037. Specimen was prepared with a dimension of 50 mm x 50 mm x 10 mm.


(a)


(b)

(c)


(d)

Figure 6. A, B, C, and D are specimens under testing machine for compression bending and water absorption test.

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RESULTS AND DISCUSSION

Bending Test Results

Figure 7 shows the bending specimens' details, before and after bending test performed.

Before bending test

After bending test

Figure 7. Bending specimens before and after bending test.

Figure 8 shows the specimen with a large chip particle size has better values of modulus of rapture and deflection or in other words modulus of rupture and deflection increases with chip particle size.

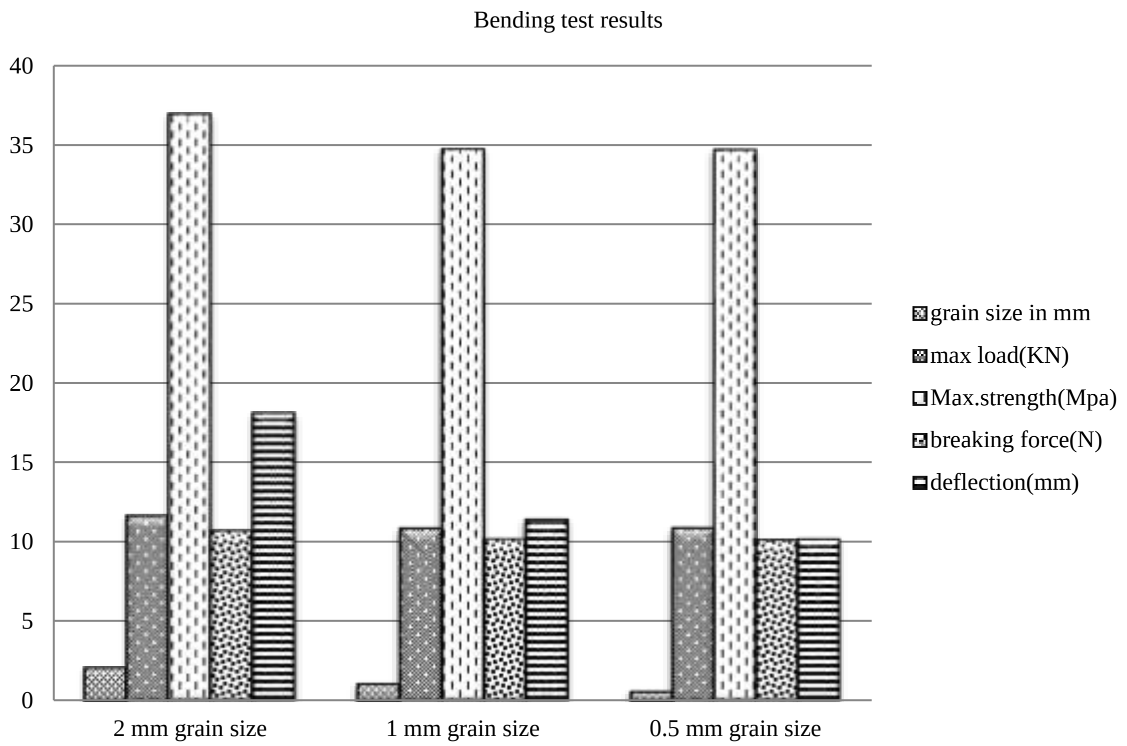

Figure 8. Graph showing bending test results.

This result shows that the ratio of the fluid to particle is better for large sizes of particles due to the reason that the surface areas are decreased in large particles. Furthermore, Figure 9 shows the Modulus of Rapture (MOR) of particleboard (PB) made from different adhesives Plyometric Methylene Di-Isocyanine (PMDI), Urea formaldehyde (UF), Polymeric urea formaldehyde (PUF) and *Euphorbia abyssinica* (EA).

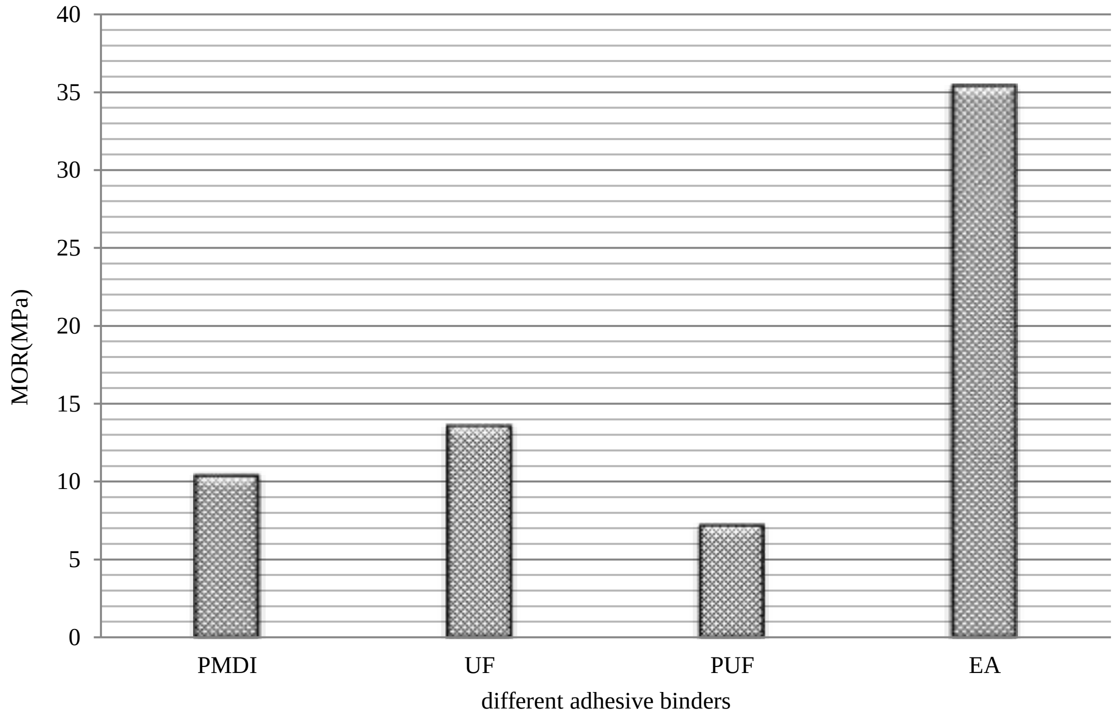

Figure 9. Comparison of MOR of different resins.

As the graph clearly shows the specimen made from EA is having large MOR Compared to the particleboard made from other three adhesives. So, in comparison to other adhesives EA is good resistance for flexural applications.

Compression Test Results

Figure 10 shows the compression test specimen after and before test. The load versus stress and deflection relations for the compression test was also shown in Figure 11. The load versus stress relation graph shows there is a linear relationship between the two parameters, but somewhat parabolic with deflection.

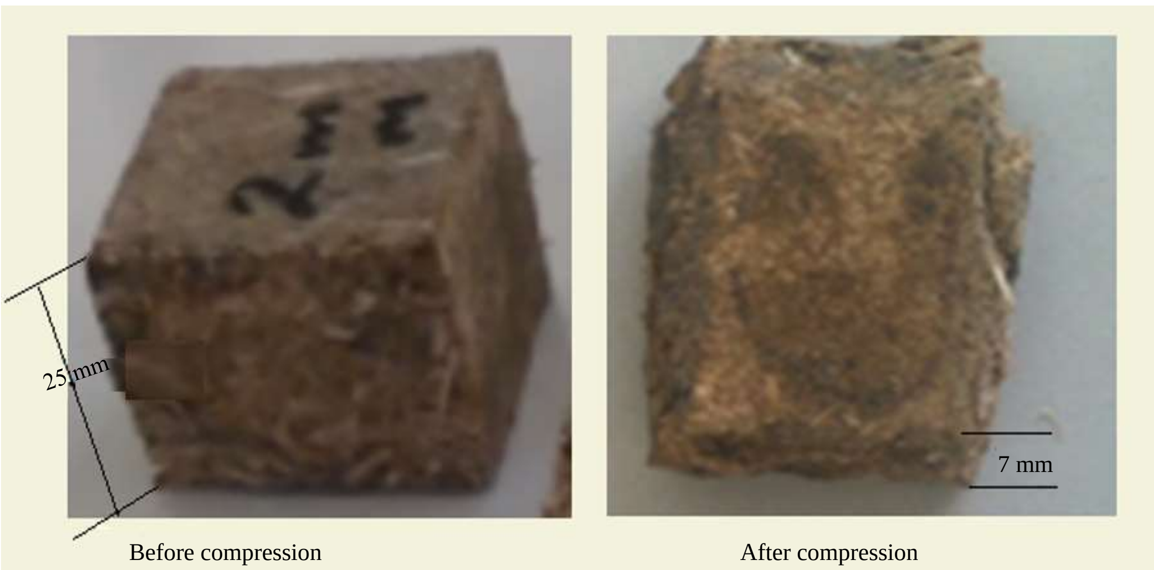

Figure 10. Compression test specimen after and before test.

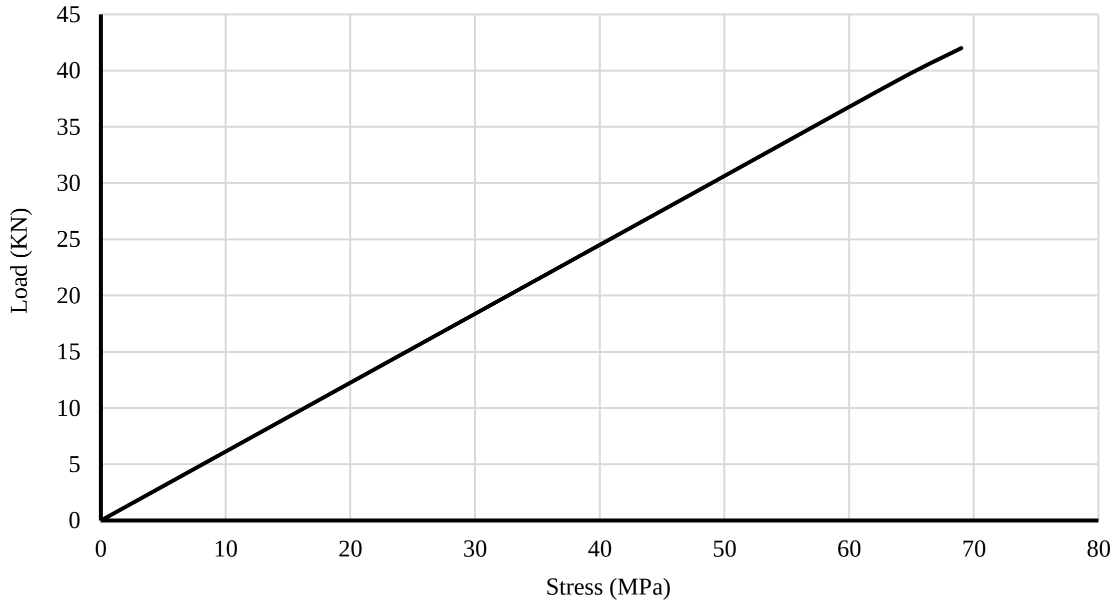

Figure 11. Loads versus stress.

From Figure 12, for each of the chip particle sizes the first column represents the chip size, second column shows the maximum load, third column highlights the maximum strength (modulus of rupture) and the fourth column shows the load of total compression.

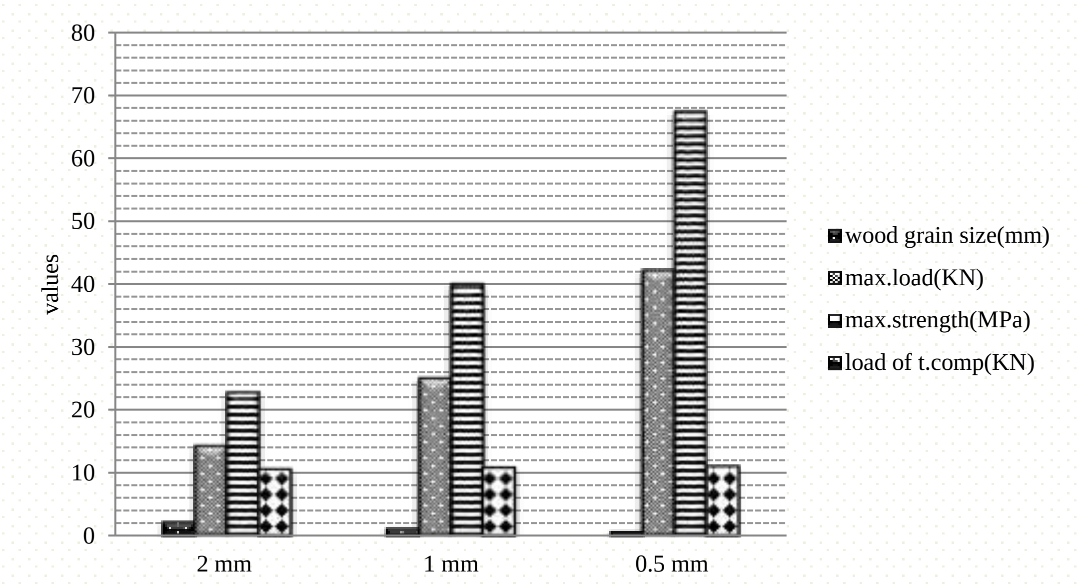

Figure 12. Compression test results.

As the load versus displacement graph shows, the displacement of the specimen (compression displacement) reaches up to 18 mm without any failure. The result shows that from a thickness of 25 mm cubic specimen dimension; it means that the specimen can be compressed without failure up to 7 mm thickness by forming a new particle board having good densities. So, this result shows that a further pressing load is required to produce more compressive resistance particleboard as well as densities. The MOR is observed that increasing with decreasing in chip particle size. The larger in grain size the lower in MOR. This shows that the pressing load is sufficient to press the smaller chip particle size. Increasing grain size requires more mold pressing load.

Thickness Swelling and Water Absorptivity Test Results

The test results of environmental (physical) properties of particle board made EA adhesive binder is compared with particle boards made from other adhesive binder are compared graphically as shown in Figure 13(A–B) below.

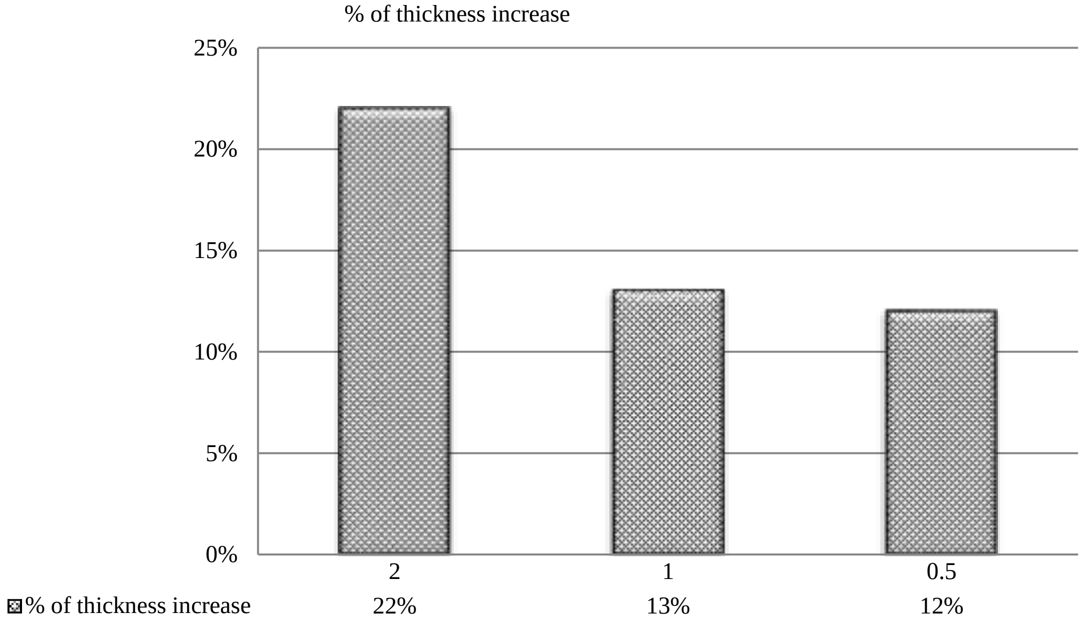

Figure 13. (a) Thickness swelling of eucalyptus chip particles.

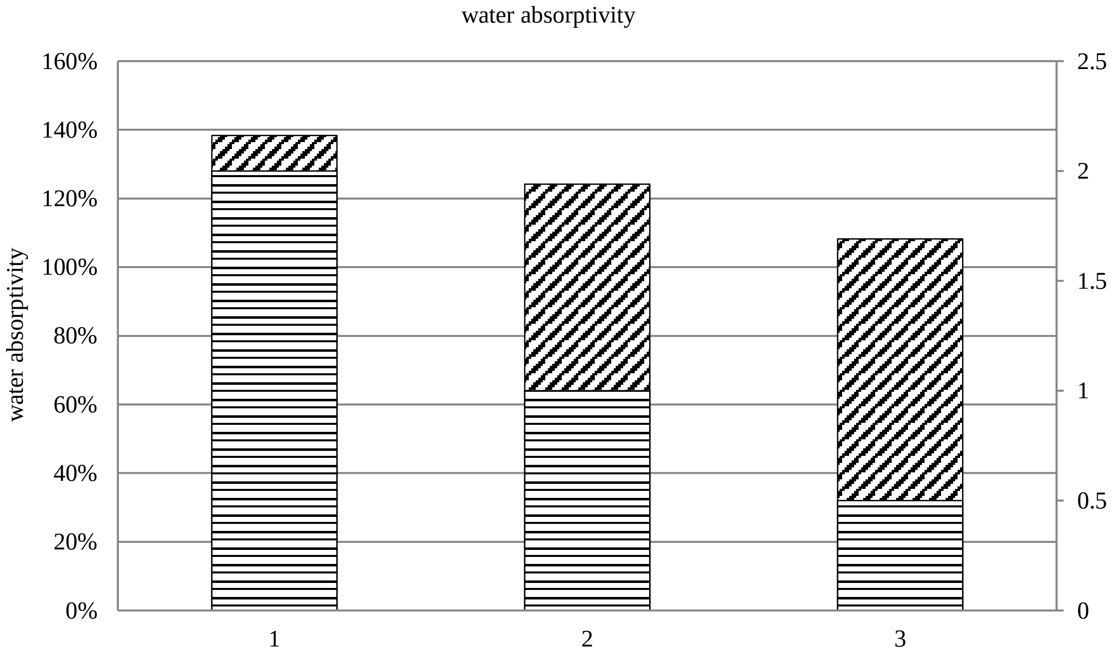

Figure 13. (b) Water absorptivity test results.

During the two-hour water absorption test, EA has the lowest value of percentage increase in mass as compared to PUF, PMDI and UF, but this situation was changed for the 24-hour test. EA rapidly increases its absorption percent and becomes the highest of percent of absorption than the rest adhesives. Considering the graph of percent of thickness swelling for the four types of adhesives during the 2 hour and 24-hour tests, the percent of thickness swelling for particleboard made from EA, PUF and PMDI have almost similar swelling percent that have better resistance to swelling compared to the particle board made from UF. Figure 14 clearly indicates the percent of thickness swelling increases with soaking hours for particleboards made from *Euphorbia abyssinica* and Eucalyptus chip particles. But in case of sago chip particle percent of thickness swelling increases with decreasing chip particle size.

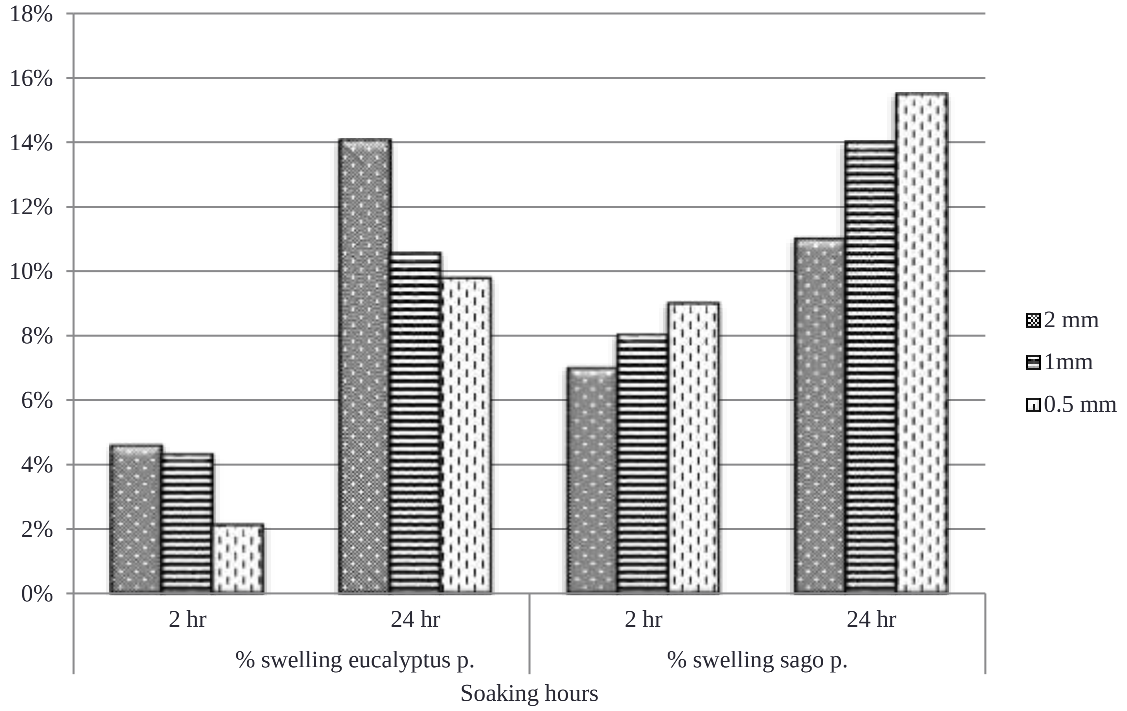

Figure 14. Comparison of thickness swelling eucalyptus chip particles and sago particles for chip sizes 2, 1, and 0.5 mm.

CONCLUSION

Flexural tests, compression tests, thickness swelling, and water absorptivity tests were conducted in this study. The test results show that the average bending strength or modulus of raptures (MOR) is 37, 35, and 35 MPa with a deflection of 18, 11, and 10 mm, respectively, for the grain size 2, 1, and 0.5 mm and the average maximum compression strengths are 23, 40, and 67 MPa, respectively. The water resistance properties or results of thickness swelling 22%, 13%, and 12% in mm, and the water absorptivity 138%, 124%, and 108%, in grams, respectively. The densities of the particleboard produced also lie between 615 to 629 kg/m^3.

The mechanical and physical properties results show that modulus of rupture (MOR) and deflection increases with particle size in case of the reason for this phenomenon is as chip particle size increases the surface area of the chip particles decrease so the given ratio of the fluid becomes sufficient to impregnate all surfaces of the chip particle. As it is observed from compression tests more compressive load is required in composite press to achieve better physical and chemical properties. Water absorptivity and thickness swelling increases with chip particle size increase, the compression test result show that there is a high deformation with the increase of particle size and compression strength increases with decrease in particle size. In a conclusion, *Euphorbia abyssinica* (kulkual) can be utilized adhesive in interior application boards. as the physical – properties test shows high value of percent of mass and thickness swelling is not recommended for external applications. The fluid can also be utilized in particleboard industry to serve as an adhesive agent.

Declaration of Interest

There is no conflict of interest regarding the publication of this manuscript.

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