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Fabrication and Testing of Physical Behavior of Coconut Shell Micro Particulate and Walnut Shell Micro Particulate Reinforced Epoxy Composites

Kalpana Sharma[1,*], Bhavana Mathur[2], Ratnesh Kumar Sharma[3]

Abstract

Enhancing the physical characteristics of high-performance materials is largely dependent on the reinforcement of polymers by microparticles. The physical behavior of polyester composites containing coconut and walnut shell microparticles was thus investigated in order to create an engineering material for industrial use. Most researchers investigated the flammability test of fiber bio-composites only. There is a possibility that two particular polymers embedded in a thermoset polymer matrix could provide the lowest burning rate in length per unit min. Microparticles from walnut and coconut shells were mixed completely with polyester resin in separate batches. In this study, a new set of polymer composites with varying weight percentages of CSμP/WSμP (1:1) (2.5, 5.0, 7.5, 10.0, 12.5, and 15.0 wt%) and epoxy resin (LY 556) as a PMC material are used. At room temperature, epoxy resin (LY 556) and hardener (HY951) are mixed 10:1. Physical attributes including dimensional stability, density, and moisture content are examined. The enhanced binding between the epoxy resin and the CSμP/WSμP, as well as the decreased void formation, are responsible for the maximum density of 15.450 g/cm³ that the CSμP/WSμP (1:1) particulate-reinforced epoxy composites display. According to the results, these composites' dimensional stability is at its best when the particle level is 2.5 weight percent. It is used in the door frames, windows and partitions of the kitchen and bathroom areas.

Keywords: Epoxy-based composite, physical characteristics, dimension stability, coconut and walnut shell micro particulate.

INTRODUCTION

Polymer composites are used in many different fields these days. What sets them unique from other metals are their characteristics. A polymer composite is a blend of polymers with either organic or inorganic additives that have certain geometries (fibres, flakes, spheres, or particles) and combine important characteristics of each separate material, such as density, water absorption, dimensional stability, and better mechanical qualities [1–7].

As epoxy resins are a good solvent they are widely used in industrial applications because of their high mechani-cal and adhesion characteristics and chemical resistance together with their curability in a wide range of tempera-tures without the emission of any volatile byproducts. The properties of epoxy-based organic/inorganic filled composites can be finely tuned by an appropriate choice of the structures of epoxy pre-polymer and hardener, type and amount of inorganic filler. The composites have many advantages over traditional silica powder or inorganic mineral filled materials, including lower cost, lighter weight, environmental friendliness and recyclability. As epoxy resins are a good solvent they are widely used in

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industrial applications because of their high mechanical and adhesion characteristics and chemical resistance together with their curability in a wide range of temperatures without the emission of any volatile byproducts. The properties of epoxy-based organic/inorganic filled composites can be finely tuned by an appropriate choice of the structures of epoxy pre-polymer and hardener, type and amount of inorganic filler. The composites have many advantages over traditional silica powder or inorganic mineral filled materials, including lower cost, lighter weight, environmental friendliness and recyclability. As epoxy resins are a good solvent they are widely used in industrial applications because of their high mechanical and adhesion characteristics and chemical resistance together with their curability in a wide range of temperatures without the emission of any volatile by products. The properties of epoxy-based organic/inorganic filled composites can be finely tuned by an appropriate choice of the structures of epoxy pre-polymer and hardener, type and amount of inorganic filler. The composites have many advantages over traditional silica powder or inorganic mineral filled materials, including lower cost, lighter weight, environmental friendliness and recyclability.

The polymer matrix that is most frequently used in the creation of composites is epoxy resin. Because of their physical, chemical, and mechanical qualities, epoxy resins are excellent solvents and frequently employed in industrial applications. With growing environmental awareness, Researchers are focusing on developing new classes of natural fibre-reinforced polymer (NFRP) composites, driven by increasing environmental awareness and the economic benefits associated with different types of polymer composites. NFRP composites have emerged as a promising area of research due to their numerous advantages over synthetic fibre-reinforced composites. These benefits include lower cost, reduced density, local availability, ease of manufacturing, non-toxicity, good mechanical properties, excellent insulation capabilities, and their renewability and biodegradability. Furthermore, NFRP composites are partially or fully recyclable, making them a more environmentally friendly alternative. Non-abrasive, renewable, and biodegradable are the qualities of natural fibres. These have good mechanical qualities, a good calorific value, and are reasonably priced [7–15].

Various application areas of the NFRP composites are in automotive industry: Interior panels, seat cushions, door trims, headliners, and aesthetic appeal, Construction and building materials: Door frames, window frames, wall panels, floorboards, ceiling tiles, and insulation materials, Furniture manufacturing: Chairs, tables, cabinets, and other furniture components, especially where a natural look is desired, Sporting goods: Tennis racquets, golf clubs, cricket bats, and other sports equipment where a good balance of strength and flexibility is needed, Marine applications: Boat hulls, interior components, and non-structural parts due to their corrosion resistance, Packaging industry: Eco-friendly packaging materials like boxes and trays.

We employed a composite material mixture consisting of microparticles from walnut and coconut shells for our investigation [15–22].

India, Brazil, Sri Lanka, the Philippines, and Indonesia are the top five coconut-producing nations. Gujarat, Maharashtra, and Assam are among the Indian states. Typically, the coconut's centre and water are eaten, while the remaining shell is discarded. Natural fibres and composites found in these shells are inexpensive, renewable, and environmentally beneficial. Elevated Density Low density polyethylene was the only kind of polyethylene created, and it functions similarly to a hardener. Singh et al. examined the mechanical behaviour in coconut shell particles (600–212 μm), as well as its density and water absorption behaviour. Using an open mould casting technique, the researchers created three specimens with varying weight percentages of CSP (20, 30, and 40 weight percent), and the remaining material was calculated using a 5:4 mixture at room temperature. It was found that as the amount of coconut (up to 40 weight percent) in composites grew, so did the density value and the percentage of water absorbed[5]. Bhaskar and V.K. Singh investigated the modulus of elasticity, and percentage of elongation, and the physical properties, such as density, of an epoxy-based composite reinforced with coconut shell microparticles (size ranging from 200 to 800 μm). The researchers were fabricated four specimens by open mould casting technique with different weight percentage of Coconut shell (20, 25, 30 and 35 wt%) and remaining according to calculation epoxy resin SY-12(319) and hardener SY-31(B) mixed in 10:1 at room temperature. It was observed by author that the value of density is decreased with increment of coconut (maximum at 20 wt %) content in composite. Similarly it was also observed by author that the value of ultimate strength, modulus of elasticity and percentage of elongation are decreased with increment of coconut (maximum at 20 wt %) content in composite. The composite has maximum value of density (1.288 gm/cm^3), ultimate strength (30.60 N/mm^2), modulus of elasticity (856.00 N/mm^2) and percentage of elongation (25.44) at 20 wt% of coconut shell[22]. M. G. L. Ramirez et al. investigated physical properties like dimensional stability and moisture absorption of coconut fiber. The researchers were fabricated seven samples by thermal molding technique with different weight percentage of CCF (0, 5, 10, 15, 20, 25 and 30 wt %) and remaining according to calculation cassava starch and glyceraol mixed in ratio of 70:30. It was observed by author by experiments that the value of dimensional stability and moisture absorption are decreased with increment of amount of coconut fiber amount in composite. It was examined by researcher that higher CCF content got better mechanical properties (maximum at CCF 30 wt %) of composite [23–28].

The second natural fiber in our fabrication is walnut shell micro particulate. India's four main walnut-growing states are Himachal Pradesh, Arunachal Pradesh, Uttarakhand, and Jammu and Kashmir. Jammu & Kashmir is India's largest region in terms of both area (85,620 ha) and output (2,75,450 MT). The shell of walnuts makes up more than 50% of the plant and can be utilised to make natural fibre reinforced polymer composites. Physical properties, including dimension stability, of WSF/TPS with and without nanoclay composites were studied by A. Sarsari et al. The researchers were fabricated thirteen samples in the variation of nanoclay content 0, 3 and 5 by percentage of weight with increment of WSF from 0 wt% to 50 wt% in each step. It was observed by author that the maximum amount of weight loss after soil burial degradation occurred in 100 wt% of TPS composites[23]. N. Ayrilmis et al. examined WSF reinforced polypropylene composites, including their density, water absorption, tensile strength, dimensional stability. Using the injection-molded process, the researchers created seven specimens with varying weight percentages of WSF (0, 40, 50, and 60 wt%), 3 weight percent MAPP, and the remaining amount of polypropylene resin added based on calculations. Additionally, it was noted that composites with 3 weight percent MAPP had lower tensile strength and water absorption than other composites. It was studied from experiment that density of composites is increased with increment of WSF wt% in composite [25].

MATERIALS AND METHODOLOGY

Material Selection

To create various kinds of composites, coconut shell micro specific, and walnut shell micro particular were utilised. Epoxy resin has a density of 1026 gm/cm3 at 250 °C and cures at low/room temperature.

Fabrication of Composite

The process for creating the composite materials is called the hand layout technique. The simplest processing approach with the best specifications is this one. The hand lay-up technique consists of the following phases (as indicated in Figure 1 and Table 1).

TEST AND RESULTS

Density Measurement Test

The 40 x 20 mm specimens used for the density test were cut from the composite product. The density vs weight percentage of CSμP/WSμP (1:1) composites is displayed in Figure 2, Figure 3 and Figure 4. The improved bonding between the epoxy resin and the decreased void formation were responsible for the 2.5 weight percent CSμP/WSμP (1:1) particulate-reinforced epoxy composite's density of 6.325 g/cm^3 [4–8]. Vapour generated during the mixing of the epoxy, hardener, and leftover solvents, as well as air bubbles trapped within the PMC (polymer matrix composite), are some of the common causes of void creation in composites. Additionally, voids can form due to the difficulty of the resin in fully wetting the CSμP/WSμP (1:1) particles after mixing, which can prevent proper consolidation of the composite material [8–12].

Density can be calculated by this formula [26]:
Density = $W_a \times \sigma_w / (W_a - W_w)$

The mass of the specimen weighed in distilled water is represented by Ww.

Wa is the specimen's mass measured in air.

At NTP, σw is the density of distilled water = 0.998 gm/cm^3

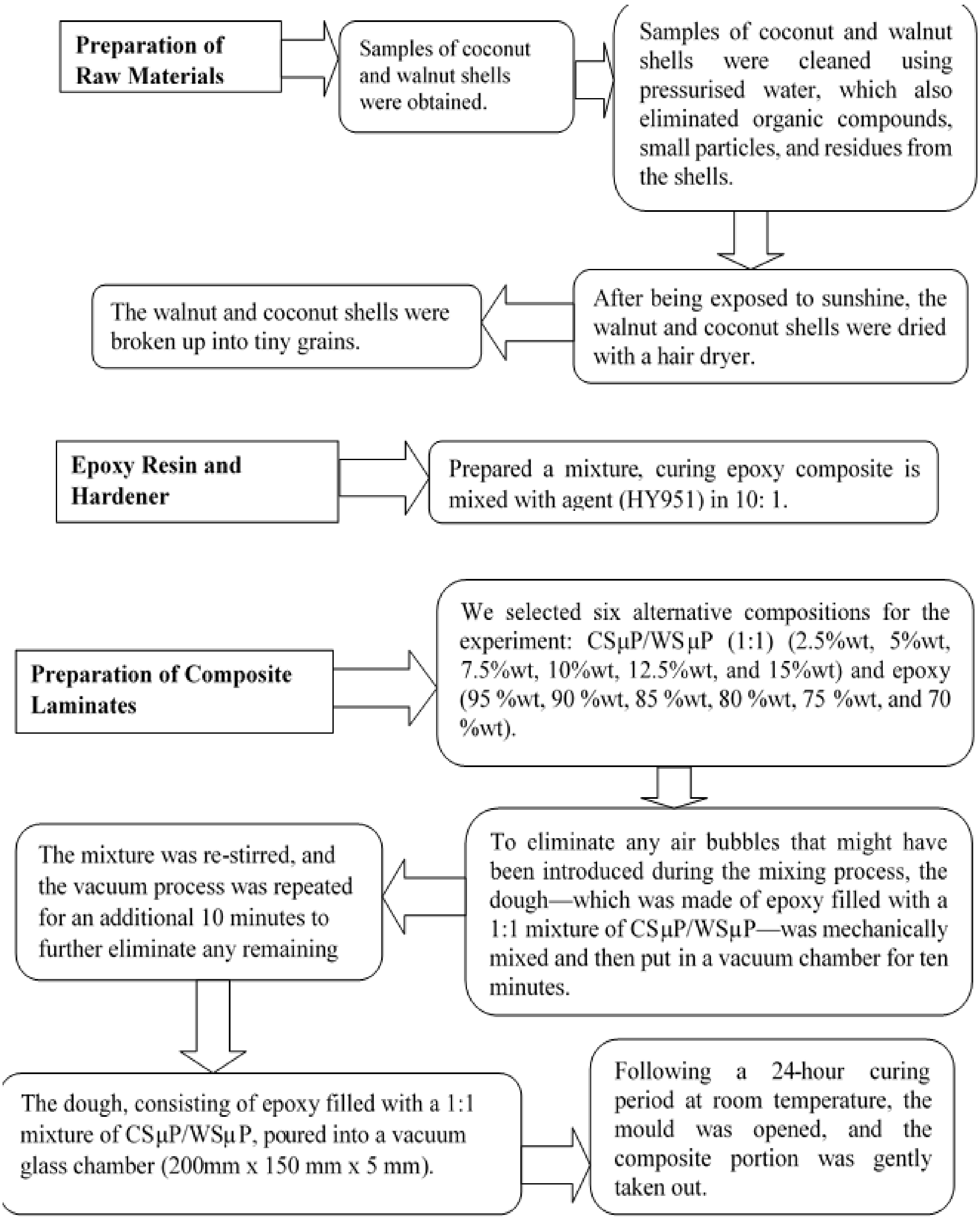
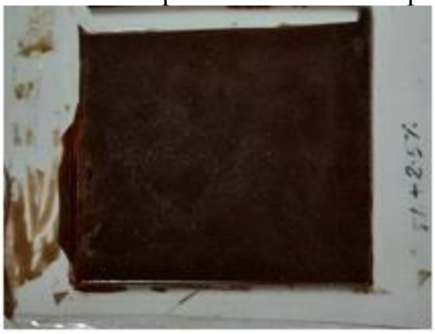


Figure1. Process Flow Diagram of Specimen Using Hand Lay-Up Technique.

Table 1. Designation and Compositions of the Composites.

Specimen		
Compositions	**A** - Epoxy (95wt%) + 2.5 wt% CSμP + 2.5 wt% WSμP	**B** - Epoxy (90 wt%) + 5 wt% CSμP + 5 wt% WSμP
Specimen		
Compositions	**C** - Epoxy (85wt%) + 7.5% wt CSμP + 7.5 wt% WSμP	**D** - Epoxy (80 wt%) + 10 wt% CSμP + 1 wt% WSμP
Specimen		
Compositions	**E** - Epoxy (75 wt%) + 12.5 wt% CSμP + 12.5 wt% WSμP	**F** - Epoxy (70 wt%) + 15 wt% CSμP + 1 wt% WSμP

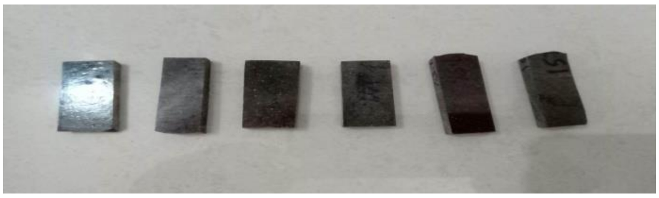
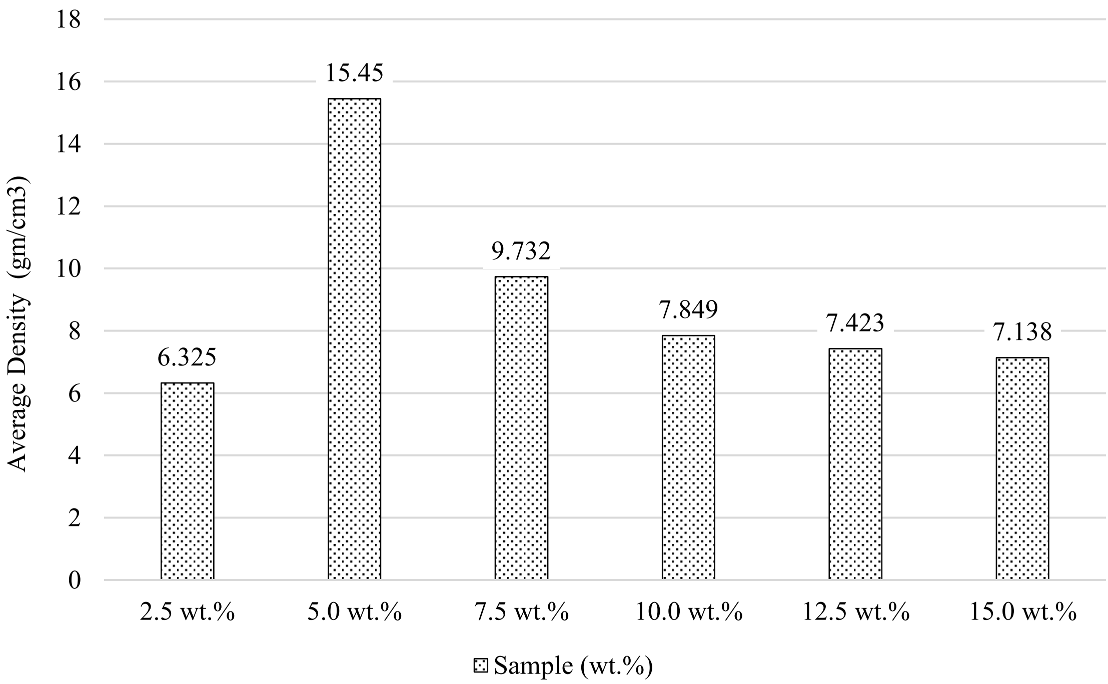


Figure 2. Specimens for Density Test

Figure 3. Weighing of Specimen



Figurer 4. Comparison of Density of Different Percentages of Weight.

Water Absorption Test

The weight % approach was used to calculate water absorption. Cutting the specimens to 20 mm in length and 20 mm in width, with an average thickness of 5 mm, was done for the moisture content test and specimen shown in Figure 5 and Figure 6. To eliminate any moisture, each specimen was kept in an electric oven set to 80°C for the whole day. The initial dry weight was calculated by recording each specimen's weight after drying. After soaking them in water for 72 hours, remove them and weigh them once again[13–15].

The water absorption can be calculated by using following equation [26]:

Water absorption = $[(W_{t1} - W_{t0}) / W_{t0}] \times 100$

Figure 5. Specimens for Water Absorption Test.

Figure 6. Soaking up of Specimen in Tap Water for Water Take up Test.

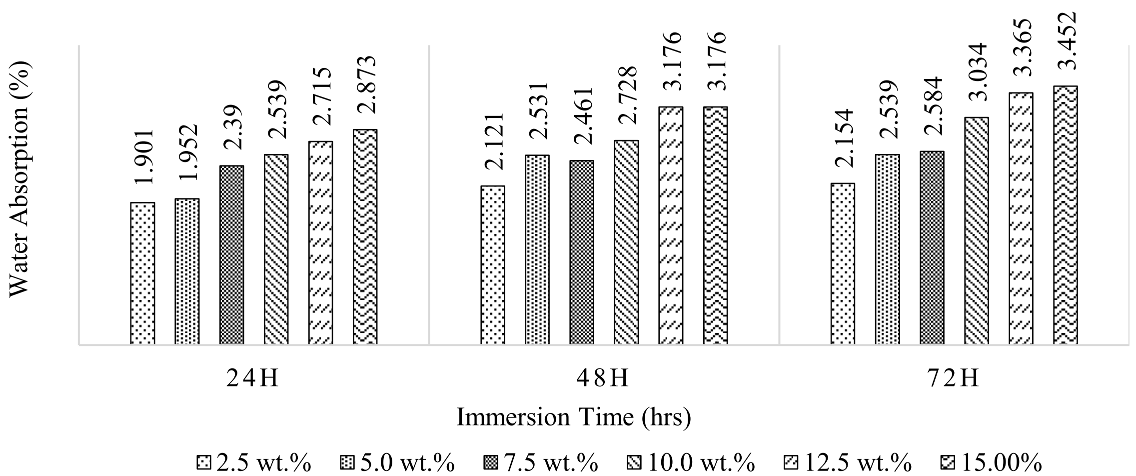


Figure 7. Represents Water Absorption Curve.

The water absorption (WA) of CSµP/WSµP (1:1) reinforced epoxy composites was measured over an immersion period. The maximum water absorption percentage for the 15 wt% CSµP/WSµP (1:1) reinforced epoxy composite was found to be 3.452%. This value is attributed to the presence of free hydroxyl groups within both the resin matrix and the CSµP/WSµP particles, which can attract and retain moisture [16–18].

As shown in Figure 7, the percentage of water absorption (WA) increased from 2.154% to 3.452% as the CSµP/WSµP (1:1) content in the epoxy-based composites was raised from 2.5 wt% to 15 wt%. This increase in WA is attributed to the higher content of cellulose and hemicelluloses—hygroscopic materials—within the composites, which absorb more moisture as the weight percentage of CSµP/WSµP (1:1) particulate increases.

Linear Swelling Test

Linear swelling provides insight into the changes in thickness, width, or length of a composite material when exposed to moisture. The linear swelling was determined using the thickness/width/length percent method. The linear swelling test specimens were cut to 20 mm in length and 20 mm in width, with an average thickness of 5 mm, in compliance with ASTM D570. To eliminate any moisture prior to testing, all specimens were placed in an electric oven set to 80°C for a whole day.

The linear swelling can be calculated by using following equation [26]:
Linear Swelling = $[(L_1 – L_0) / L_0] \times 100$

Figure 8 and 9 illustrates Specimens for linear Swelling Test. The maximum thickness swelling value, 16.197%, was observed for the 15 wt% CSµP/WSµP (1:1) particulate-reinforced epoxy composite. This high swelling is attributed to the poor compatibility between the epoxy resin and the CSµP/WSµP particles, which results in increased WA (water absorption) and consequently higher thickness swelling.

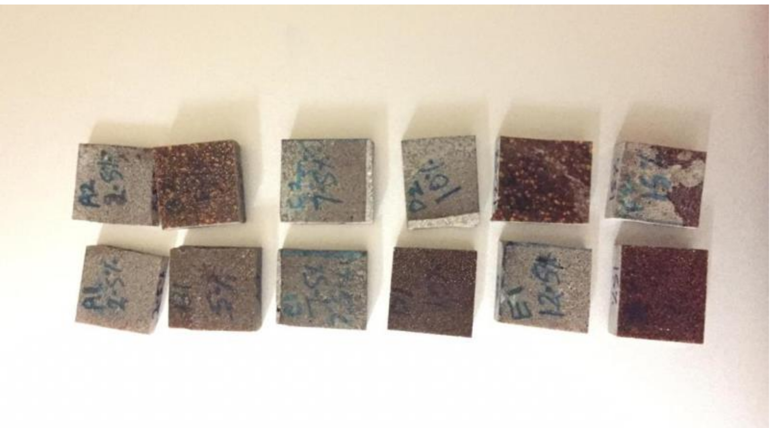


Figure 8. Specimens for linear Swelling Test.

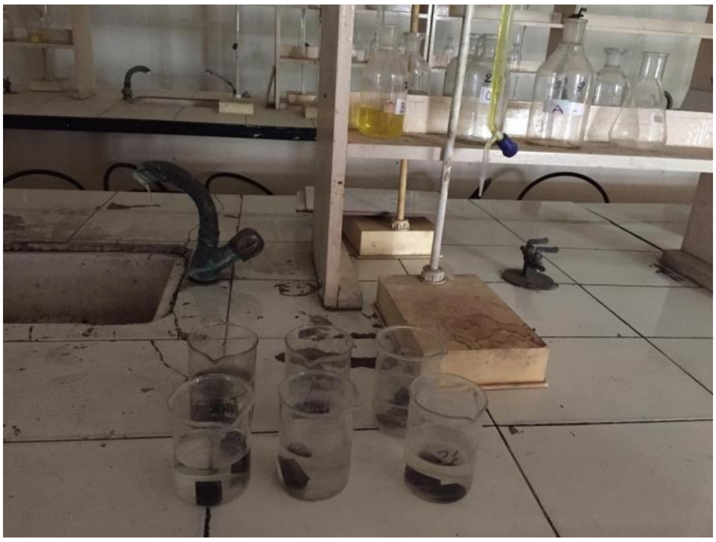


Figure 9. Soaking up of Specimen in Tap Water for Linear Swelling Test [RCERT, Jaipur].

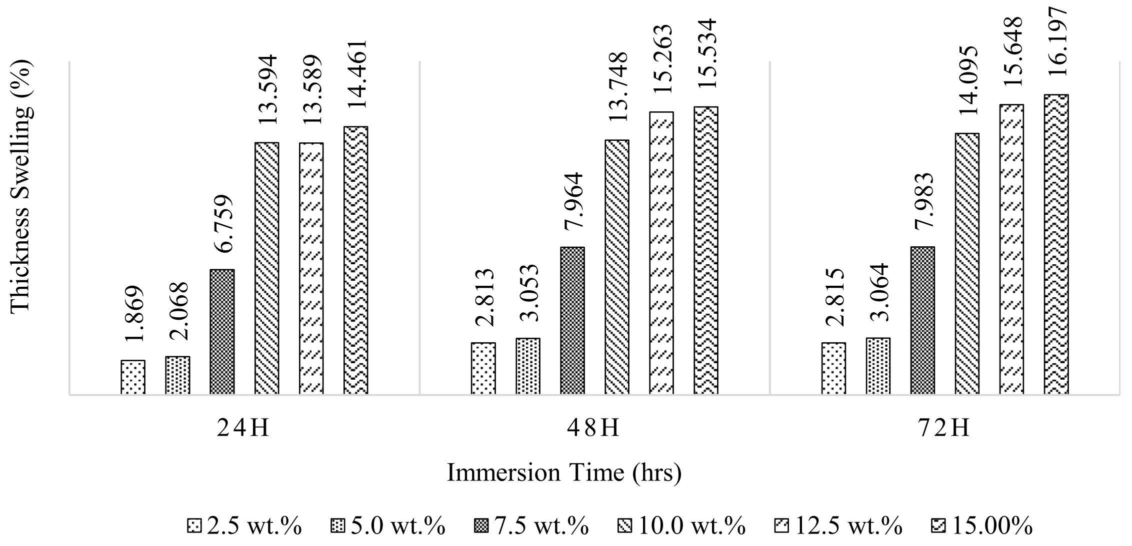


Figure 10. Thickness Swelling.

As observed from Figure 10, the percentage of thickness swelling (TS) increased from 2.815% to 16.197% as the CSμP/WSμP (1:1) content in the epoxy composites was raised from 2.5 wt% to 15 wt%. This increase in TS is attributed to the higher content of cellulose and hemicelluloses—hygroscopic materials—within the composites. As the weight % of CSμP/WSμP (1:1) particulate increases, these materials absorb more moisture, leading to greater swelling of the composite [20].

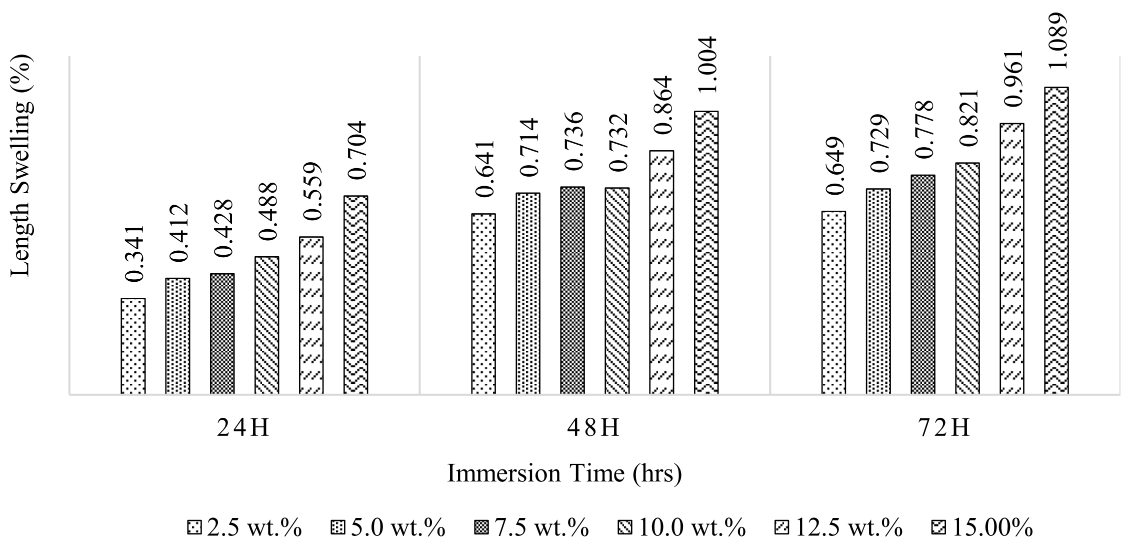


Figure 11. Length Swelling.

Similarly, as shown in Figures 11 and 12, the percentage of length swelling increased from 0.649% to 1.089%, and the % of width swelling increased from 0.728% to 1.041% as the CSμP/WSμP (1:1) content in the epoxy composites was raised from 2.5 wt% to 15wt%. These increases in length and width swelling are attributed to the higher content of cellulose and hygroscopic materials (hemicelluloses) within the composites. As the weight percentage of CSμP/WSμP (1:1) increases, the composite absorbs more moisture, leading to greater swelling in both length and width.

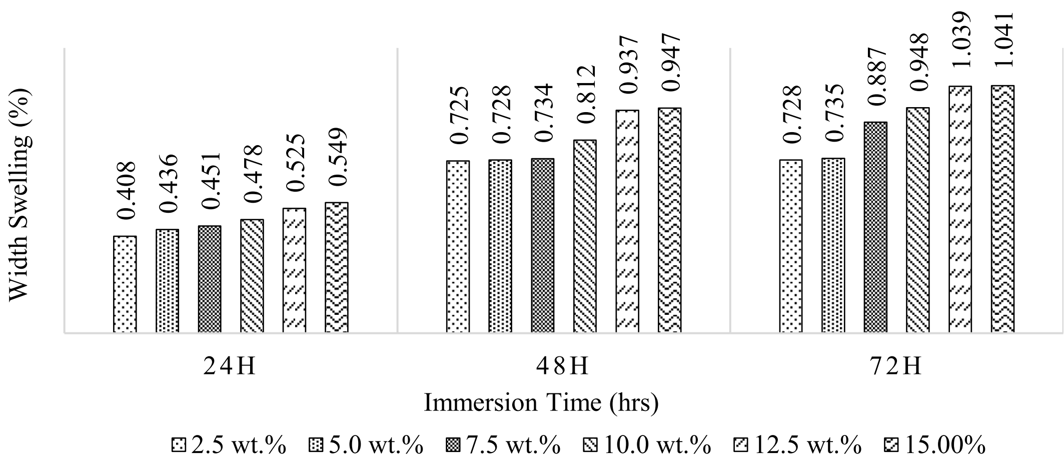


Figure 12. Width Swelling.

CONCLUSION

The determination of physical properties on CSµP/WSµP (1:1) reinforced epoxy composites by experimental as well as analytical techniques showed that.

- The high density value of 15.450 gm/cm³ obtained for the composite was due to the good bonding of epoxy resin with CSµP/WSµP and the least void formation.
- The 15 weight percent CSµP/WSµP suggesting that this specimen is more vulnerable to moisture-related variables than the others. These higher values suggest that the increased content of hygroscopic materials, such as cellulose and hemicelluloses, in the composite leads to greater moisture uptake and subsequent swelling.

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