Investigation the compression strength and thermal Properties of Composites Using Natural Additives with Epoxy

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Abstract. The main objective of this work was to investigate the effect of natural additives with an animal and vegetable source in the form of (short fibers and particle) on the mechanical and thermal properties for epoxy. (wood dust, date palm fiber, cow bones and sheep wool) were selected as natural additives with different weight ratios such as (%5,%15,%25) reinforcements for the epoxy matrix based composites, which were produced by the hand lay-up technique. mechanical test such compression strength and thermal properties such thermal conductivity were carried out according to ASTM standards to characterized these composites. It was found that the mechanical and thermal properties can be increased or decreased depending on the type of material additives, its origin, as well as the weight percentage used.

Keywords: Epoxy, Natural Composites, Compression strength, Thermal conductivity, Wood Dust, Date Palm Fiber, Cow Bones, Sheep Wool.

1. Introduction

The natural composite materials may be a combination of either synthetic resin/natural fibers or bio-resin/natural fibers. The synthetic as well as the bio-resin may either be in a form of thermoplastic or thermoset resin type. The benefit of the natural fibers compared to the synthetic ones keeps continuously increasing, due to its less weight, low cost, abundance, low manufacturing cost, renewable resources, rather sufficient mechanical and physical characteristics, like the bending strength, tensile modulus, tensile strength, and biodegradable and environmentally friendly characteristics. Mohd Zuhri et al. [1] have researched the mechanical characteristics of short random oil palm empty fruit bunch (OPEFB) fiber reinforced epoxy composites. Results revealed that the mechanical properties decreased with an increase in the fiber percentage in the composites. Maleque and Sapuan [2] studied The pseudo stem banana fiber reinforced composite of epoxy. The comparison was done with epoxy and banana reinforced epoxy composite It revealed that all the mechanical properties showed tremendous rise in banana reinforced composites compared to only epoxy resin without fiber. Subramanian Raman, et al. [3] have researched the fabrication and assessment of Jute-Epoxy braided in addition to the short fiber reinforced composites, which are environment friendly, inexpensive, renewable, have high specific strength, low density, no health hazards, and decreased energy requirements for the processing. Biswas et al. [4] have conducted a research about the importance of the length of the fiber on coir/epoxy composite’s mechanical character. It was discovered that composite hardness is decreased with increasing the fiber length up to 20mm and then it is increased. Romli et al. [5] have researched the coir reinforced epoxy composite’s tensile strength. In this work, curing duration, compression load and volume fractions
throughout the composites’ solidification have been considered as the parameters. According to results, they have reached a conclusion that the volume fraction affects the composites’ tensile strength. Low et al. [6] have specified the impact of fiber loading on the cellulose fiber/epoxy composites’ mechanical behaviors. The researchers have noticed that an increase of cellulose fiber content in the matrix of the polymer results in the enhancement of the mechanical characteristics. Benjamin et al. [7] have observed the impact of the lignin on hemp/epoxy composites’ mechanical characteristics. They have noticed that the composite has shown 145% rate of enhancements in impact strength on adding 5% w/w of the lignin. Nasscimento et al. [8] have researched the impact of fiber content upon mechanical features of composites of the piassava fibers/epoxy. They have found that with increasing fiber load in epoxy resin, there was 30% enhancements in flexural characteristics and 41% enhancement in the tensile of the composites. Alamri et al. [9] researched the impact of the concentration of the clay on the recycled cellulose fiber/epoxy composite’s mechanical behaviors. They have discovered that mechanical strength (fracture impact as well as the fracture toughness) of composite 30-40% ameliorates on adding clay to about 1wt% in the matrix of the cellulose fiber/epoxy. Low & Alamri [10] investigated the effects of the fiber loading upon the recycled cellulose fibers/epoxy composites’ mechanical properties. They have stated that the composite had shown improved impact strength, fracture toughness and flexural strength when adding the fiber. Mahjob et al. [11] have investigated the effects of fiber loading upon mechanical behavior of kenaf fibers/epoxy composites. They discovered that the mix analytical model’s Rule has validated tensile characteristic data of respective composites that have been attained from experimental results. A composite that includes 40% of the fiber content exhibited more sufficient flexural, tensile and impact strengths. Nirmal et al. [12] have studied the impact of the orientation of the fiber on bamboo fiber/epoxy composites’ fractional and wear characteristics. They have stated in their study that the antiparallel bamboo fiber composites’ orientation has a sufficient adhesive wear efficiency (which has been enhanced by approximately 60%) compared to any other orientations. Srivastava & Gupta [13] have performed an analysis of tensile and flexural behaviors of the unidirectional and mat form sial fiber/epoxy composites. The researchers have noticed that 30wt% unidirectional sial fiber composites showed quite high flexural and tensile characteristics. Scida et al. [14] have observed the effects of the hydrothermal aging upon mechanical and damage behaviors of the flax-fibers/epoxy composites. They have noticed that the hygrothermal aging, which results from the re-orientation of the respective fibers’ micro-fibrils, has fundamentally influenced the properties of a composite’s tensile strength. Romil et al. [15] performed an analysis of the fiber content effect, the period of the curing and compression load upon coir/epoxy composites’ tensile behaviors. They have stated that composite tensile characteristics are mostly influenced by the curing time and fiber content whereas a compression load does not have any negative effect on it. Coroler et al. [16] studied fiber content impact upon tensile characteristics of flax fiber reinforced epoxy composite. From the morphology of the SEM, it was discovered that the composite that was developed has a suitable fiber dispersion and fewer fiber bundles. Anshuman et al. [17] indicated that better compressive and tensile strengths are shown via jute epoxy composites. The increase of the amount of fibers in the bundle result in a reduction in the fibers’ bundle strength. There will be also a tensile strength increase with the Jute fiber reinforcement. There is an increase of bending strength when the Jute fiber’s percentage is increased, while there is an increase of the compressive strength when Jute fiber’s percentage is increased. Mishra et al. [18] who studied the mechanical characteristics that are related to the jute composed with the Epoxy. Yet, the study reported 55.8 Mpa and 110MPa of flexural and tensile strength in which results were high compared to the ones reported via Singh with regard to hemp fibers, although Mishra didn’t conduct any process of mercerization to his fibers. Kumar et al. [19]. Indicated the fiber loading’s impact on the mechanical properties related to wood dust reinforced epoxy composites. This work has specified that fiber loading composites of 10% showed excellent mechanical characteristics (for instance, improvement of 200% in flexural strength and improvement of 161% in tensile). Suleiman et al. [20] have researched thermal conductivity of the short fiber of wood in the longitudinal as well as the transverse directions in a range of temperature between 20oC-100oC. The results of this study have shown that the thermal conductivity has been approximately 1.5 times higher in longitudinal orientation compared to it in transverse direction as a result of the wood’s non homogenous nature. Chandana and Hussain [21] have determined thermal conductivity of the bamboo fibers that have been reinforced in the
composites of the epoxy resin. They have prepared test sample according to the standards of the ASTM with the use of the simple hand lay-up approach at a variety of the fractions of the fiber weight (10, 20, 30, 40, 50, and 60)%. The composite materials’ thermal conductivity, K, has been experimentally specified and confirmed by results that have been obtained by mixture rule. Mangal et al. [22] have researched the effects of pineapple leaves’ fiber volume fraction on thermal characteristics of a composite utilizing the transient plane source approach. The increase of fiber content in a matrix results in the decrease of thermal diffusivity and thermal conductivity of the pineapple leaves’ fiber reinforced composites, meaning the fact that it couldn’t ensure conductive path to heat energy in composite materials.

The aim of this study is to improve the compressive strength and increase the epoxy heat resistance by adding natural materials of animal and vegetable sources. Natural materials were used as granules such as wood dust, cow bones and other materials such as short fibers such as palm fibers and sheep wool.

2. Materials and Method

2.1 preparation of specimens

Epoxy type (Quick mast 105) (Base and Hardener) was selected first as show in figure (1). They provided from (DCP) company and mixing in room temperature.

![Figure (1): Epoxy Quick Mast 105.](image)

The natural vegetable and then animal particle and short fiber material was prepared. The added natural materials were washed with distilled water to remove the impurities on the surface. As for the cow bones, it was boiled in distilled water to remove the stuck pieces of meat and fats. Then the materials were dried in an oven at a temperature of 60 C for two hours and then dried for 24 hours at room temperature. After that, the bones were crushed by Hammer into small pieces and then grind the cow bones and sawdust with a grinder and mixed with epoxy by method (hand lay-up) as it is the simplest and oldest method used at room temperature. start preparing the epoxy with a mixture base and hardener by mixing (2:1) Weight in grams at room temperature where this epoxy without additives will be compared with epoxy by adding natural materials in terms of thermal and mechanical properties. start by preparing the natural compound material using wood dust and cow bones particle with diameter (600 µm) and date palm, sheep wool with average length (5-10 mm) by mixing (2:1) Weight in grams at room temperature. have to prepare molds of size (28 x 22 x 1.5 cm) silicon rubber with density (15 g/cm3) for the preparation of required composite as shown in figure (2). A clean smoothed surfaced. Then the wax is applied on it due to easy removal of the specimen of composites material. According to the ASTM Standards, the various Samples conducted as shown in figure (3). The preparation shall be in multiple weight ratios as shown in table (1, 2) and figure (4-7) shown. The natural vegetable and animal particle and short fiber, and Samples remain in the mold for a period of time (72) hours.
Figure (2): Mold Preparing.

Figure (3): Silicon Rubber Molds.

Table 1: Mixing Weight Ratios of Particles with Epoxy.

| Wood dust | Cow bones |
|-----------|-----------|
| %5        | 5%        |
| 15%       | %15       |
| %25       | 25%       |

Figure (4): Wood Dust Particle.

Figure (5): Cow Bones Particle.
Table 2: Mixing Weight Ratios of Short Fiber with Epoxy

| Sheep wool | Data palm |
|------------|-----------|
| %5         | %5        |
| %15        | %15       |
| %25        | %25       |

3. Mechanical and thermal Test

3.1 Compression Strength

Manual hydraulic press the maximum capacity of the compression test is (7.5 KN) as shown in figure (8) compression test type at the Technological University / Department of applied sciences. The specimens are manufactured according to (ASTM -D 695). Where the examination was carried out on two samples and the average of the results was taken. The dimensions of compression specimen is (14x7x7) mm as shown in figure (9 and 10).
3.2 Thermal conductivity

Thermal conductivity test is carried out by (Lee dick) at the Technological University / Department of applied sciences. The specimens are manufactured according to specification instrument. The dimensions of Thermal conductivity specimen is (40mm) diameter and (5mm) thickness according to ASTM C518 – 04, as shown in figure (11) The device consists of a chamber and a reader. The chamber has an electric heater, and there is a group of discs where the specimen should be placed between the hot and cold discs. The chamber has sufficient thermal insulation. The electric circuit was switched on until the equilibrium condition is reached. The reader recorded the temperatures across the specimen using sensors connected to a thermometer, as shown in figure (12)
4. Results and Discussions

4.1 Compression strength

Compression strength Natural Composites in the different percentage shown in table (3)

| Sample                      | Compression strength (Mpa) | Strain |
|-----------------------------|---------------------------|--------|
| Epoxy without addition     | 41.060                    | 0.169  |
| Epoxy +5% wood dust         | 45.514                    | 0.184  |
| Epoxy +15% wood dust        | 43.269                    | 0.141  |
| Epoxy +25% wood dust        | 48.986                    | 0.290  |
| Epoxy +5% cow bones         | 40.649                    | 0.152  |
| Epoxy +15% cow bones        | 38.350                    | 0.184  |
| Epoxy +25% cow bones        | 40.769                    | 0.213  |
| Epoxy +5% date palm fiber   | 46.879                    | 0.267  |
| Epoxy +15% date palm fiber  | 41.834                    | 0.261  |
| Epoxy +25% date palm fiber  | 36.624                    | 0.463  |
| Epoxy +5% sheep wool        | 38.632                    | 0.118  |
| Epoxy +15% sheep wool       | 43.516                    | 0.175  |
| Epoxy +25% sheep wool       | 37.734                    | 0.205  |

In the case of adding wood dust to the epoxy, all the percentage that increases the compression strength, because the percentage of wood dust leads to an increase in the adhesion and homogeneity of the epoxy with these granules, and the best ratio of adding wood dust to epoxy is (25%) as shown in figure (13).

Figure (12): (Lee dick) test machine

Figure (13): Variation of compression test with wood dust content -Epoxy
In the case of adding cow bone granules to the epoxy, all the percentage that decreases the compression strength, because the percentage of cow bone granules leads to a decrease in the adhesion and homogeneity of the epoxy with these granules as shown in figure (14).

![Figure (14): Variation of compression test with cow bones content-Epoxy](image)

In the case of adding date palm short fiber to the epoxy, the percentage that increases the compression strength is (5%, 15%). As for the ratio (25%), they lead to a decrease in the compression strength of the epoxy, because increase date palm short fiber leads to a decrease in the adhesion and homogeneity of the epoxy with this date palm short fiber In addition to the high absorbency of this fiber and increasing the voids reduced the compressive strength at this ratio as shown in figure (15).

![Figure (15): Variation of compression test with date palm content- Epoxy](image)

In the case of adding sheep wool short fiber to the epoxy, the percentage that increases the compression strength is 15%. As for the other ratios, they lead to a decrease in the compression strength of the epoxy, because the percentage of sheep wool short fiber leads to a decrease in the adhesion and homogeneity of the epoxy with these sheep wool short fiber In addition to the high absorbency of this fiber as shown in figure (16).
4.2 Thermal Conductivity

Table (4) Shows the Thermal Conductivity of Composites with Particulate Filler.

| Sample (particulate 600 µm) | K = watt/m.k |
|-----------------------------|--------------|
| Epoxy without addition      | 0.484583     |
| Epoxy +5% cow bones         | 0.448912     |
| Epoxy +15% cow bones        | 0.449689     |
| Epoxy +25% cow bones        | 0.53821      |
| Epoxy +5% wood dust         | 0.4782       |
| Epoxy +15% wood dust        | 0.497284     |
| Epoxy +25% wood dust        | 0.575572     |

For Epoxy + 5% cow bones and Epoxy +15% cow bones, the thermal conductivity of the composites will decrease but when adding (cow bones) in the rate of (25%) to Epoxy the thermal conductivity of the composites will increase, because (cow bones) particle has good thermal insulation ability at the above-mentioned ratios as a result of presence of air voids, which reduces the thermal conductivity of composites, but when the percentage is increased to 25%, the homogeneity is increase and the air voids will be reduced which will lead to an increase in the amount of heat passing through the composites as shown in figure (17).

Figure (16): Variation of compression test with sheep wool content - Epoxy

Figure (17): Variation of thermal conductivity with (% cow bones – Epoxy content)

For Epoxy + 5% wood dust and Epoxy +15% wood dust, there is a very small increase in the thermal conductivity of the composites but when adding (wood dust) to the Epoxy ratio (25%) the
thermal conductivity of the composites was a significant increase because the (wood dust) that was used from soft wood that has little heat resistance, and therefore when the weight ratio increases with the composites, the amount of heat passing increases as shown in figure (18).

![Figure (18): Variation of thermal conductivity with (% wood dust – Epoxy content)](image1)

| Table (5) Thermal conductivity of (Composites with short fiber filler) |
|---------------------------------------------------------------|
| Sample (short fiber 5-10 mm)                                   | $K$ = watt/m.k |
| Epoxy +5% sheep wool                                           | 0.484754      |
| Epoxy +15% sheep wool                                          | 0.420697      |
| Epoxy +25% sheep wool                                          | 0.490578      |
| Epoxy +5% date palm                                            | 0.499147      |
| Epoxy +15% date palm                                           | 0.426499      |
| Epoxy +25% date palm                                           | 0.47614       |

For Epoxy + 5% sheep wool and Epoxy +25% sheep wool, There is a very small increase in the thermal conductivity of the composites but at the ratio (15%) there is decrease in the thermal conductivity of the composites because (sheep wool) has good thermal insulation ability at the (15%) ratios as a result of good homogeneity, but when the percentage is (5%, 25%) the homogeneity is decrease and thus the amount of heat passing increases as shown in figure (19).

![Figure (19): Variation of thermal conductivity with (% sheep wool - Epoxy content)](image2)
For Epoxy +5% date palm a significant increase in the thermal conductivity of the composites but when adding (date palm) to Epoxy ratio (%15 and %25) There is decrease in the thermal conductivity of the composites due to date palm has good thermal insulation ability as a result of good homogeneity between fiber and Epoxy , as well as the presence of voids at these ratios lead to a decrease in the thermal conductivity in composites, as shown in figure (20).

![Figure (20): Variation of thermal conductivity with (%date palm - Epoxy content)](image)

5. Conclusion

Compression Strength:- added weight percentage wood dust to epoxy is (%25). All ratio of cow bones when added to epoxy decrease compression strength. added weight percentage date palm to epoxy is (5%). added weight percentage sheep wool to epoxy is (15%). In addition, the addition of a weight of natural materials to the epoxy when performing the Compression Strength tests mentioned above (25% date palm).

Thermal conductivity natural composites:- added weight percentage wood dust to epoxy is (5%). added weight percentage cow bones to epoxy is (5%), added weight percentage date palm to epoxy is (15%), added weight percentage sheep wool to epoxy is (15%). In addition, the addition of a weight of natural materials to the epoxy when performing the Thermal conductivity tests mentioned above is (15% sheep wool).

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