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Performance Evaluation of Epoxy Resin/Modified Bentonite Composite

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Abstract

Performance evaluation of the prepared composite such as tensile strength, flexural strength, impact strength, hardness strength, and abrasion/wear resistance were carried out. The results obtained as: tensile (the epoxy is 6.25 MPa while, for the 5% bentonite reinforced composite is 6.79 MPa), flexural (the epoxy is 8.42 MPa while, for the 5% bentonite reinforced composite is 14.64 MPa), impact (the epoxy is 40.82 J/m^2 while, for the 5% bentonite reinforced composite is 60.78 J/m^2), hardness (the epoxy is 48.32 MPa while, for the 5% bentonite reinforced composite is 62.82 MPa), abrasion/wear resistance (the epoxy is 0.24×10^{-3}mm^3/Nm while, for the 5% bentonite reinforced composite is 0.14×10^{-3}mm^3/Nm), the results of performance evaluation shows that the epoxy resin/modified bentonite composite have potential application in surface coating, packaging, and tiles.

Introduction

Epoxy resins, also known as poly epoxides, are a class of reactive pre-polymers and polymers which contain epoxide groups. The epoxy resin is made of bisphenol (and there is more than one type) and epichlorohydrin. The most common type of bisphenol is a combination of acetone and phenol known as bisphenol A [1]. Most of the commercially

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used epoxy monomers are produced by the reaction of acidic hydroxyl groups and epichlorohydrin [2]. Uncured epoxy resins have a poor mechanical, chemical, and heat resistance properties. However, good properties are obtained by reacting the linear epoxy resin with suitable curatives to form a three dimensional cross-linked thermoset structures. This process is commonly referred to as curing or gelation [3].

Bentonite was named after Fort Benton, montana in the mid-19th Century by the U.S Geological Survey. Bentonite is an absorbent aluminum phyllosilicate clay consisting mostly of montmorillonite that is usually formed from weathering of volcanic ash, most often in the presence of water. The greatest use of bentonite in industry results from its swelling action in water. Combinations of water and bentonite can perform a multitude of jobs in industry because physical properties of the mixtures change as the water-to-clay ratio changes. The swelling capacity of the clay is of prime importance: this property is controlled in large part by the types of associated exchange ions. [4] prepared polymer composites using clay as filler material and epoxy as matrix materials with different concentrations of clay particles (2.5-10 wt%) by shear mixing followed by ultra-sonication process. The mechanical properties such as compressive strength properties and tensile strength properties were characterized using ASTM standards. It was found that the addition of clay particles improved both compressive strength and tensile strength of pure epoxy significantly. As the clay content increased in epoxy matrix the moduli values found to increase and were further analyzed using micromechanical models. XRD pattern revealed the interaction between clay nanoparticles and epoxy matrix. The thermal decomposition behavior revealed that there is an enhancement of onset of decomposition temperature by 31^{o}C for 10wt% clay filled epoxy than that of pure epoxy for 5% weight loss. Falalu et al. [2] synthesized and characterized epoxyresin bentonite composite using tetra phenyl phosphonium bromide (TPPB) which exhibit better dispersion than the raw bentonite.

Materials

In this study, we utilized a modified epoxy resin as per reference [2]. Additionally, we employed diglycidyl ether and triethylene tetramine (TETA), both obtained from Sigma-Aldrich. All other chemicals used in this study were of the highest standard analytical grade and were utilized without the need for additional purification.

Method

Water absorption property test

The pre-weighed dry composites were immersed in water bath at 25°C for 7 days. The thickness of the samples as well as their weights were determined before and after immersion. They were then removed and dried by pressing their both sides with filter paper at 25°C. The samples were then weighed, and the loss/gain was determined using equation (i).

$$\text{water absorption } (\%) = \frac{W_i - W_o}{W_o} \times 100 \tag{i}$$

where, W_i is the weight of composites samples after immersion and W_o is the weight of composites samples before immersion [5].

Flexural strength test

The cured neat epoxy resin and the composite samples were tested using Shimadzu Universal material testing machine (MODEL AG-1) at Mechanical Engineering Department Bayero University Kano Nigeria, with 100kN of capacity at strain rate of $1.6\times10^{-2}s^{-1}$ and span-to-depth ratio of 9, according to the ASTM D790-03 a standard procedure at a cross head speed of 20mm/min and a support of 51mm, the samples were cut into rectangular specimens with 125×25 mm sized dimension and thickness of 6.4mm, which determines their bending properties. The flexural rapture strength was calculated using equation (ii).

$$\delta_f = \frac{FL}{2bd^2} \tag{ii}$$

where F is the maximum applied load until rapture, L is the distance between support, b and d are the width and thickness of the specimen respectively [6].

Impact strength test

The impact tests of the cured neat epoxy resin and the prepared composite samples were carried out at CHELTECH Basawa Zaria, using a Resil impactor (CEAST) 6957 impact tester at 25°C in accordance with the British standard BSEN 6603-2. The samples were cut into rectangular shape of 21mm×8mm sized dimension. This method involves measuring impact behavior of plastic sheets or moldings under the impact of a striker applied at right angles to the plane of the sheet [6].

Hardness strength test

Hardness of cured composite as well as that of the neat epoxy samples were measured at CHELTECH Basawa Zaria, using Durometer instrument; model 5019. The measurement was in accordance with ASTM-D2240. The samples were cut into rectangular shape of 21mm×8mm sized dimension. This test method is based on the penetration of specific type indenter when forced to the material under specific conditions. The geometry of indenter and applied force influence the measurement such that no simple relationship exists between the measurements obtained with one kind of Durometer and those obtained with another type of Durometer or other instrument used for measuring Hardness [7].

Abrasion/wear rate property test

Abrasion/wear rate test of the cured composite as well as that of the cured neat epoxy resin samples were carried out at CHELTECH Basawa Zaria, using HEICO Revolving disk model with 12 rpm and uniform load of 22N/disk in accordance with ASTM D4060-01. The samples were cut into cyclic shape of 21mm with 6.1mm thickness sized dimension. This method involves measuring the resistance of the prepared composite material and the cured neat epoxy resin samples to scuffing, scratching, wearing down, marring or rubbing away. The total time of test was 1 hour and 5 min [6].

Flammability property test

Flammability test of the prepared composite was conducted in order to measure the ability of the composite to extinguish the flame after ignition and its dripping behaviour in response to a small open flame or radiant heat source under controlled laboratory conditions so that the material will become suitable for a particular application such as in electronic devices and appliances parts. The samples were cut into a rectangular specimen (125mm×25mm) and placed over a Bunsen burner horizontally (horizontal burning usually abbreviated as HB). The flammability of the sample was evaluated using the time it takes to catch with fire, the time it takes the flame to travel along the test specimen and the maximum length burnt on the specimen [8].

Results

Tensile strength test

The results of the tensile strength tests conducted on the composite samples as well as the cured neat epoxy resin samples are presented in the chart shown in Figure 1.

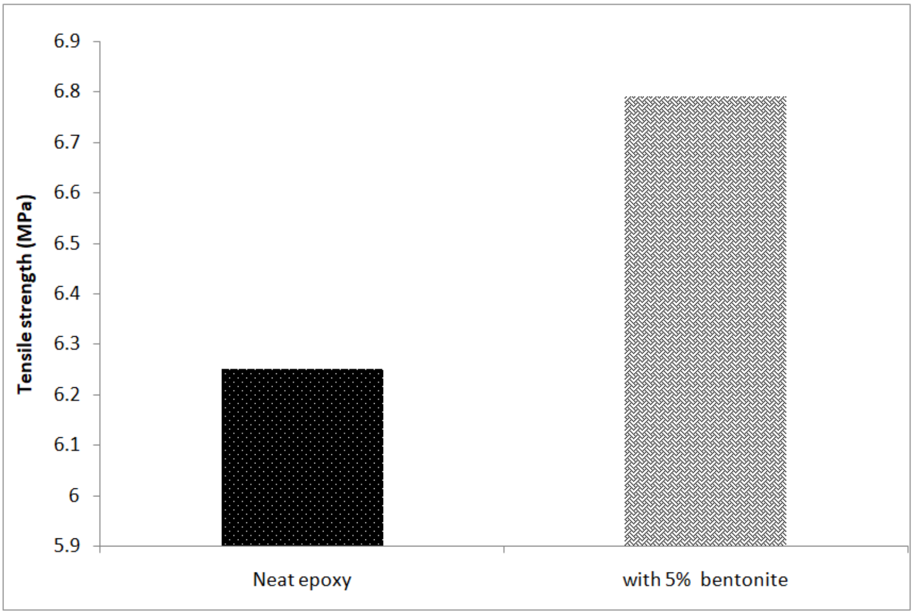

Figure 1. Tensile strength of neat epoxy and epoxy/bentonite composites (MPa).

Flexural strength test

The results of the flexural strength tests conducted on the composite samples as well as the cured neat epoxy resin samples are presented in the chart shown in Figure 2.

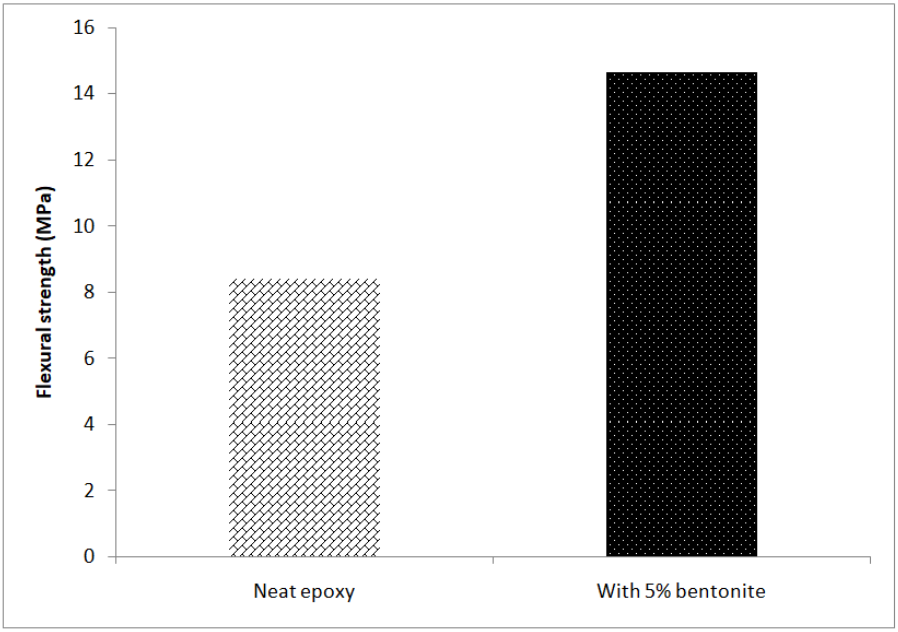

Figure 2. Flexural strength of neat epoxy and epoxy/bentonite composites (MPa).

Hardness strength test

The results of the hardness strength tests conducted on the composite samples as well as the cured neat epoxy resin samples are presented in the chart shown in Figure 3.

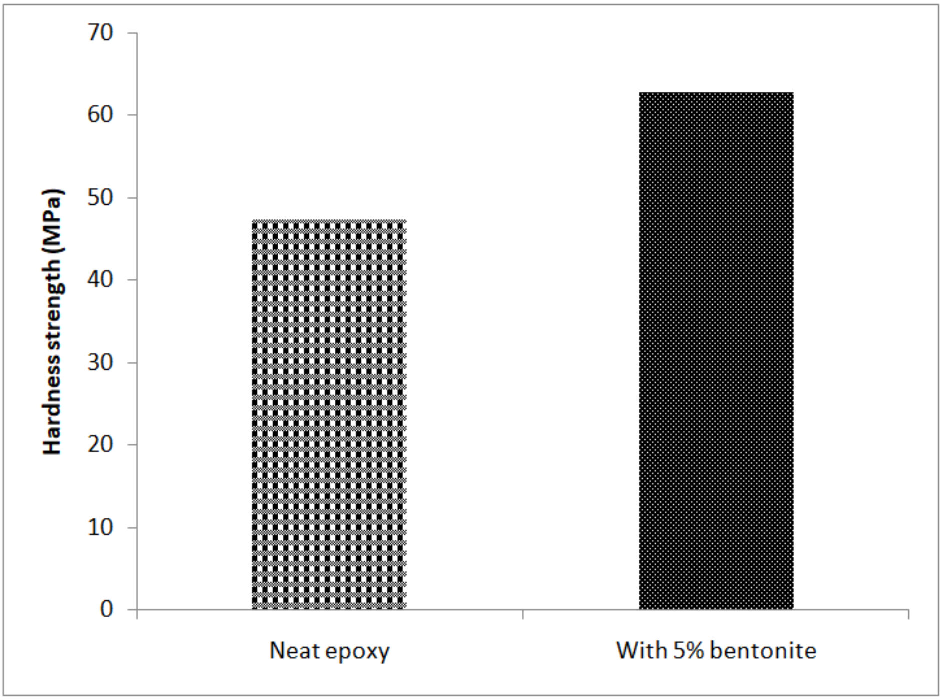

Figure 3. Hardness strength of neat epoxy and epoxy/bentonite composites (MPa).

Impact strength test

The results of the impact strength tests conducted on the composite samples as well as the cured neat epoxy resin samples are presented in the chart shown in Figure 4.

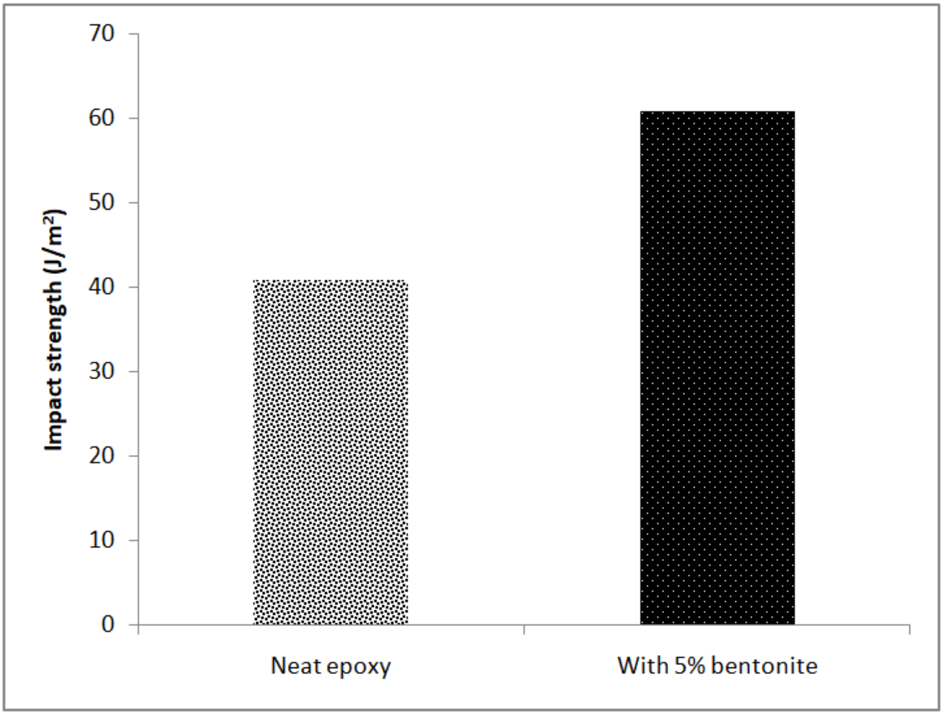

Figure 4. Impact strength of neat epoxy and epoxy/bentonite composites (J/m^2).

Abrasion/wear rate test

The results of abrasion/wear rate tests conducted on the composite samples as well as the cured neat epoxy resin samples are presented in the chart shown in Figure 5.

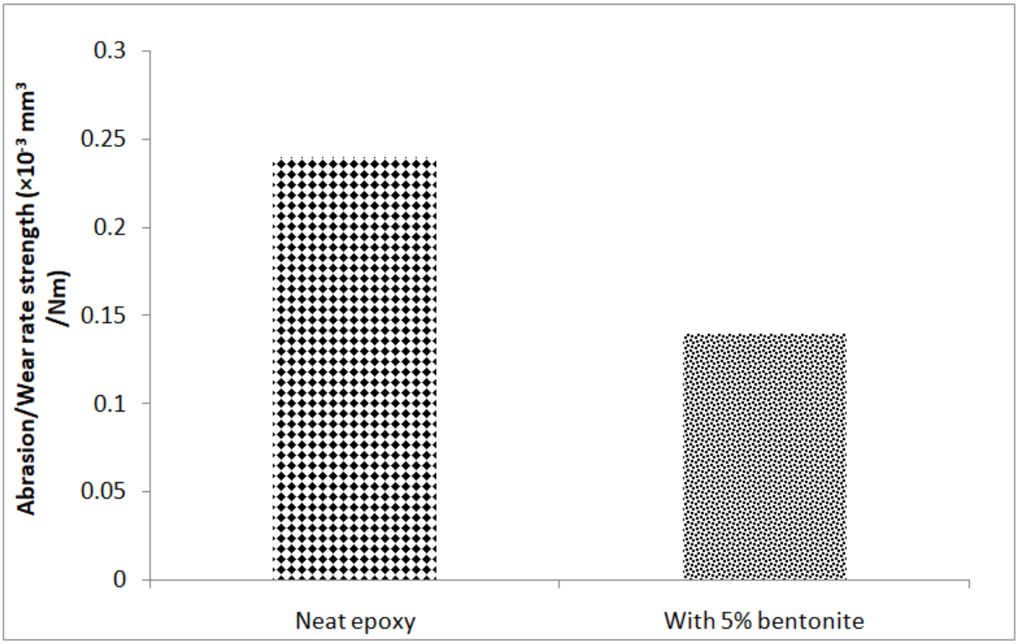

Figure 5. Abrasion/Wear rate of neat epoxy and epoxy/bentonite composites ($\times 10^{-3}$ mm^3 /Nm).

Discussion

The results of the tensile strength tests conducted on the composite samples as well as the cured neat epoxy resin samples showed that the tensile strength of the neat epoxy resin samples have the average value of 6.25 MPa while, the samples with 5% bentonite reinforced filler showed the average tensile strength of 6.79 MPa. However, it can be noticed that reinforcement of modified bentonite with the epoxy resin matrix have improved the tensile strength of the neat polymer by 8.64%. The effects of filler content on the performance of epoxy/potassium titanate whisker where they found that, increasing the percentage of filler content increased the Tensile strength of the composite by 33.45%. The results of the flexural strength tests conducted on the composite as well as the cured neat epoxy resin samples. The result showed the average bending strength value of 8.42 MPa while, the samples with 5% bentonite reinforced filler showed the average bending strength value of 14.64 MPa. However, it can be noticed that reinforcement of modified bentonite with the epoxy resin matrix have improved the flexural strength of the neat polymer by 73.87% as a results of a better intercalation of the modified bentonite clay into the epoxy matrix. The results of the hardness strength tests carried out on six samples of the composites as well as the cured neat epoxy Three neat epoxy samples, three epoxy resin reinforced with 5% modified bentonite composite samples were tested for hardness, The results showed that, cured neat epoxy resin have the hardness strength value of 48.32 MPa while, that of epoxy resin reinforced with 5% of the modified bentonite composite have the highest hardness strength value of 62.82 MPa. This implies that, reinforcement with the modified bentonite have increased the mechanical properties of the neat epoxy polymer matrix and as such increased the hardness strength of the composite by 30.01%. Hence, the addition of small quantity of clay into epoxy act as mechanical interlocking between epoxy polymer chains which increased its hardness with 38.40% compared with pure epoxy specimen. The results of the impact strength tests showed that composite reinforced with 5% modified bentonite have a better impact strength of 60.78 J/m^2 than the neat epoxy polymer having 40.82 J/m^2 as such increased the impact strength of the composite by 48.89%. The specific wear/abrasion results of the cured neat epoxy resin polymer were observed to be 0.24×10^{-3} mm^3/Nm, and that of epoxy resin reinforced with 5% modified bentonite showed a significant decrease to 0.14×10^{-3} mm^3 /Nm as such decreased the abrasion/wear rate of the composite by 41.67%. This implies that, with time the 5% modified bentonite filled epoxy resin composite becomes more difficult to abrade out compared to the neat epoxy resin. The enhancement in the abrasion resistance property of epoxy resin is attributed to the increased in the molecular interaction and compactness due to the organo-bentonite filled inside the matrix and higher rigidity there by making it tougher for abrasion.

Conclusion

Mechanical properties tests conducted on the composite in comparison with the cured neat epoxy revealed that the tensile, flexural, hardness and impact strength values of the composite increased whereas the abrasion/ wear rate decreased.

Recommendation

The purified and modified bentonite can be used as reinforcement with other synthetic polymer matrix and evaluate their mechanical properties.

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