

## Studying the Effect of Chemical Solutions on Bending Behavior of Epoxy Reinforced With CDs Waste

Nervana A. Abd Alameer \*

Received on: 20/2/2011

Accepted on: 21/7/2011

### Abstract

The aim of this study is the effect of salt, acid and base solutions on bending behavior of CDs reinforced epoxy. Epoxy resin matrix is reinforced with weight fraction 15, 30&45 % chopped chips CDs waste. The experimental results indicate that the composites materials have higher flexural stiffness than the matrix material where the young modulus of epoxy is improved from 2.6GPa for matrix to 3.936 GPa reinforced with 45% CDs that is 60% increasing, due to CDs were more contact which have high flexural stiffness. The test solutions chosen were 10 % NaCl, NaOH & H<sub>2</sub>SO<sub>4</sub>. The results indicate that the 45% CDs reinforced epoxy chosen is good chemical resistant to NaCl and NaOH whereas flexural stiffness changes are relatively for each examination time, while the maximum flexural stiffness occurred in H<sub>2</sub>SO<sub>4</sub> solution was approximately -10% for 8 week due to epoxy is less resistant to sulfuric acid.

**Keywords:** flexural stiffness, epoxy, CDs waste, NaCl, H<sub>2</sub>SO<sub>4</sub> &NaOH

### دراسة تأثير محاليل كيميائية على سلوك الانحناء لمادة متراكبة من الايبوكسي المدعم باقراص مدمجة تالفة

#### الخلاصة

يهدف البحث دراسة تأثير المحاليل الملحية والقاعدية والحامضية على سلوك الانحناء لراتنج الايبوكسي المدعم باقراص مدمجة تالفة. الايبوكسي مدعم بكسور وزنية (15,30,45) من رقائق الاقراص المقطعة. اشارت نتائج التجارب العملية ان معامل يونك للمادة المتراكبة اعلى من المادة الاساس بنسبة (60%) عند التدعيم بنسبة (45%) من الاقراص المقطعة. المحاليل المختارة كانت كلوريد الصوديوم وهيدروكسيد الصوديوم وحمض الكبريتيك وبتركيز (10%). النتائج اظهرت ان الايبوكسي المدعم ب(45%) من الاقراص المدمجة له مقاومة كيميائية جيدة لكل من كلوريد الصوديوم وهيدروكسيد الصوديوم، في حين جساءة الانحناء اظهرت تغير نسبي عند محلول حمض الكبريتيك وكان تقريبا (-10%) خلال (8) اسابيع وذلك بسبب مقاومة الضعيفة لحمض الكبريتيك.

### Introduction

The first of all some important remarks are needed regarding the component materials and structure of the CDs. From manufacturing of view, it may be noted that repetitive manufacturing of CDs is made by injection of the polycarbonate in mould. An Aluminium layer having the thickness of 50 nm is set over the

Surface. Polycarbonate is a type of thermoplastic resin. Polycarbonates are generally stable under the action of water, organic acids and minerals. It is known that the tensile strength and elasticity modulus decrease when the temperature increases. Polycarbonates are widely used as a raw materials automobile industry, electric equipment industry and building materials [1]. Epoxy is a type of thermosetting resin. Epoxy resins are a group of cross-

linking polymers and are sometimes known as the oxidant group which is reactive toward a broad range curing agents. The most widely used matrices for advanced composites are the epoxy resins even though they are more costly and do not have the high temperature capability of the polyamide. The advantages are listed, solvent and chemical resistance, high or low strength and flexibility, resistance to creep and fatigue and good electrical properties [2]. A composite is a multiphase material that is artificially made, as opposed to one that occurs or forms naturally. In addition, the constituent phases must be chemically dissimilar and separated by a distinct interface. Thus, most metallic alloys and many ceramics do not fit this definition because their multiphases are formed as a consequence of natural phenomena. In designing composite material, scientists and engineer have ingeniously combined various metals, ceramics and polymers to produce a new generation of extraordinary materials. Most composites have been created to improve combination of mechanical characteristics such as stiffness, toughness, and ambient and high-temperature strength. Many composite materials are composed of just two phases, one is termed matrix, which is continuous, and surround the other phases, which are called the dispersed phases. The properties of composite are a function of the properties of the constituent phases... "Dispersed phase geometry" means the shape of the particles and the particle size, distinction, and orientation [3]. Flexural properties such as flexural strength and modulus, a composite beam specimen of rectangular cross section is loaded in either a three point

bending mode or four point bending mode. In either mode, a large span-thickness (L/h) ratio is recommended. Three-point flexural tests have received wide acceptance in the composite material industry because the specimen preparation and fixtures are very simple [4]. In general, plastics, as compared with metals and alloys, are much weaker, softer, and more resistant to chloride ions and hydrochloric acid, less resistant to concentrated sulphuric acid and oxidizing acids such as nitric, less resistant to solvents. Plastic do not generally dissolve like metals. They are degraded or corroded because of swelling, loss in mechanical properties [5]. Ohama studied the resistance of polyester in hot water for 1 year before being tested in tension. It was concluded that erosion depth in polyester increased with immersion time and tensile decreased with no appearance or weight change [6]. Yamamoto immersed polyester resin in 10% hydrochloric acid and 10% sulphuric acid for 28 days. No loss in weight was observed [7].

#### **Experimental work**

The materials studied were epoxy as a matrix (250 gm) reinforced with (15, 30 & 45%) of CDs chopped chips as shown in table 1. CDs were cutting at approximate dimensions of 1x1 mm. Epoxy resin and its hardener were added and mixed to ensure complete melting at approximate 3:1, then Chopped chips of CDs were added for different weight fractions. The mixture was introduced in a mould which has (20x20x0.35 cm) to obtain a plate made of the new composite materials. The dimensions of the specimen for flexural test (three point method) (Instron universal testing

machine) are shown in figure 2, according to ASTM (D790 ). Young modulus is measuring by the following relationship [8]:

$$E = \frac{\text{mass} \cdot g \cdot L^3}{\text{deflection} \cdot 48 I} \quad \dots\dots (1)$$

Where:

(Mass/ deflection) is representing the slope which is calculated from mass/ deflection curve.

g : acceleration of gravity ,9.81 m.sec<sup>2</sup>

L: length of the specimen, 100 mm

I: momentum of the bending [8]

$$I = \frac{bd^3}{12} \quad \dots\dots (2)$$

b: width of the specimen, mm

d: thickness of the specimen, mm

The specimen chosen in immersion tests was epoxy reinforced with 45 % chopped chips CDs because it has higher young modulus as shows in table 4(from the experimental work). The specimen subjects to 10% (NaCl, H<sub>2</sub>SO<sub>4</sub>& NaOH) solutions for 8 week.

**Results and Discussion**

The consideration in the selection of a matrix is its basic mechanical properties. For high performance composites, the most desirable mechanical properties of a matrix are:

1. High tensile modulus, which influences the compressive strength of the composite.
2. High tensile strength, which controls the interplay cracking in a composite laminate.

For a polymer matrix composite, there may be other consideration, such as good dimensional stability at elevated temperatures and resistance to moisture or solvents. Resistance to moistures and solvents means that polymer should not dissolve, swell, crack, or otherwise degrade in hot wet

environments or when exposed to solvents [8].

Table 2 indicates all experimental results for bending tests of matrix and matrix reinforced different weight fractions of 15, 30& 45 CDs.

It can be observed that the deflection is proportional to its applied load. The ratio of mass to the deflection is represented the slope which is calculated from mass-deflection curve and followed young modulus was calculated by eq.1&2, also the figures 3, 4&5 show the forces-deflection for all specimens reinforced with 15, 30 &45% CDs.

The results also indicate that young modulus of the epoxy (matrix) is 2.46 GPa. This value increases to 3.936 GPa for matrix (epoxy) reinforced by 45% chopped chips CDs waste. The young modulus improvement is about 60% as shown in figure 6. While the other composites of 15 and 30 % chopped chips is slightly improved.

This improvement in flexural stiffness for the composite materials produced with different weight fractions of 15, 30& 45 % chopped chips CDs is due to the presence of aluminium as coating material on polypropylene during the CDs manufacturing which has young modulus about 20GPa [ 9].

**After immersion**

The flexural stiffness results for composites materials of 45 % chopped chips CDs after immersed in 10% NaCl, NaOH and H<sub>2</sub>SO<sub>4</sub> solutions for a period up to 8 weeks are shown in table 3 and figure 7 respectively.

When the matrix exposed to solutions environments, many polymer matrix composites absorb moisture by instantaneous surface absorption followed by diffusion through the matrix. Analyses of moisture

absorption data for epoxy matrix composites show that the moisture concentration increases initially with time and approaches an equilibrium (saturation) level after several days of exposure to these environments.

Reduction in modulus is due to volumetric expansion (swelling) resulted from moisture absorption, and scission or alteration polymer molecules by chemical attack as shown in figure [2].

The results exhibited that the flexural stiffness of 45% CDs reinforced epoxy of all samples decreased after immersion in chemical solutions as shown in figure 7.

The change in composite properties is resulted from polymer degradation, this change is usually undesirable.

Polymer can be degraded by solvolysis and hydrolysis to give lower molecular weight molecules. The hydrolysis takes place in the presence of water containing an acid, base and salt. Hydrolysis of polymer was a reverse reaction of the synthesis of the polymer.

Chemical solutions have different effects on polymer composite behaviour; while the sulphuric acid has maximum effect in reducing flexural stiffness. In the other side, the (Cl) ions have minimum penetration to the polymer matrix (minimum absorption) [8].

Diffusion of small molecules in a polymeric matrix is a function of the structure of both the polymer matrix and the penetrant, When a small molecule diffuses through a polymer matrix, it finds its way past the polymer segment. While the bending values in NaOH solution located between them.

## Conclusions

Young modulus of composite materials increases 60% with reinforced 45% CDs chopped chips.

1. The specimens of epoxy reinforced with 45% CDs chopped chips which are immered in different solutions exhibit poor resistance to sulphuric acid
2. Salt solution is slightly effected epoxy matrix reinforced with 45% CDs chopped chips.

## References

- Camellia, "bending behaviour of the composite materials made by recycling of the CDs and DVDs", proceeding of the world congress on engineering, London, 2009.
- [1]R. E. Wright, "polymer and plastic handbook", Mc Graw- Hill, New York, 1994.
- [2]D. Hull, "*An Introduction to Composite Materials*", 1<sup>st</sup>ed., Cambridge University Press, U.K., (1981).
- [3]P. K. Mallick, "fibre reinforced composites" p. 25, ch.4, 3<sup>th</sup> ed. New York, 2007
- [4]G.Fontana, 'corrosion engineering', 3<sup>th</sup> ed, p263, New York, 2006.
- [5]Y. Ohama, "hot water resistance of polyester resin concrete", proceeding of 20<sup>th</sup> Japan congress on materials resistance, Tokyo, Japan, 1977.
- [6]T. Yamamoto, "the production performance and potential of polymers in in concrete", proceedings of 5<sup>th</sup> international congress on polymer in concrete, Japan, 1986
- [7]Phillip A., "corrosion of polymers and elastomers", corrosion engineering handbook, 2<sup>nd</sup> addition, New York, 2006.
- [8]Krishan K. Chawla, "composite materials"2<sup>nd</sup> ed. India.2006

**Table 1: Weight fractions of each epoxy and CDs**

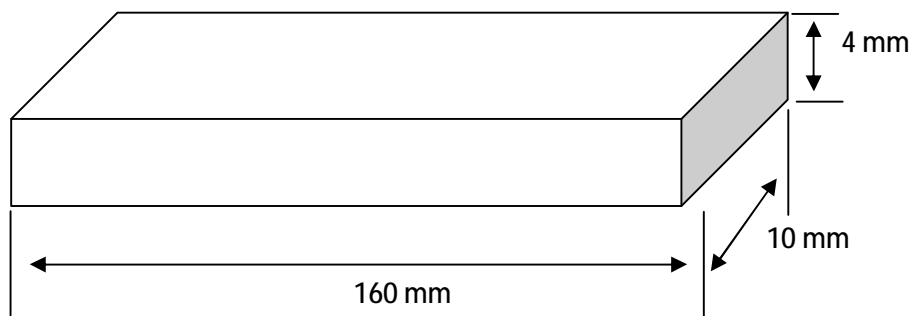
|             |     |       |     |       |
|-------------|-----|-------|-----|-------|
| Samples     | 0   | 15%   | 30% | 45%   |
| Epoxy(gm)   | 250 | 212.5 | 175 | 137.5 |
| CDs (gm)    | 0   | 37.5  | 75  | 112.5 |
| Totals (gm) | 250 | 250   | 250 | 250   |

**Table 2: experimental results from bending test**

|                | Width B (mm) | Thick D (mm) | Length L (mm) | Max. Force (N) | Max. Stress (GPa) | Max. deflection (mm) | Young Modulus (E) (GPa) |
|----------------|--------------|--------------|---------------|----------------|-------------------|----------------------|-------------------------|
| Epoxy          | 10           | 3.51         | 100           | 14.715         | 0.0179            | 2.14                 | 2.46                    |
| Epoxy +15% CDs | 10           | 3.53         | 100           | 24.52          | 0.0295            | 3.9                  | 2.642                   |
| Epoxy +30% CDs | 10           | 3.53         | 100           | 24.52          | 0.0293            | 5.2                  | 2.811                   |
| Epoxy +45% CDs | 10           | 3.5          | 100           | 24.52          | 0.03              | 5.24                 | 3.936                   |

**Table3: flexural – stiffness change E(GPa) of45% CDs reinforced epoxy**

| 10% solution                   | E, GPa |        |        |        |        |        |        |        |        |
|--------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                                | 0 week | 1 week | 2 week | 3 week | 4 week | 5 week | 6 week | 7 week | 8 week |
| NaCl                           | 3.936  | 4.132  | 4.329  | 3.739  | 3.739  | 3.89   | 3.88   | 3.89   | 3.88   |
| NaOH                           | 3.936  | 3.876  | 3.837  | 3.836  | 3.781  | 3.662  | 3.661  | 3.658  | 3.656  |
| H <sub>2</sub> SO <sub>4</sub> | 3.936  | 3.837  | 3.836  | 3.837  | 3.739  | 3.542  | 3.541  | 3.541  | 3.542  |



**Figure (1) Standard Specimen Dimensions**

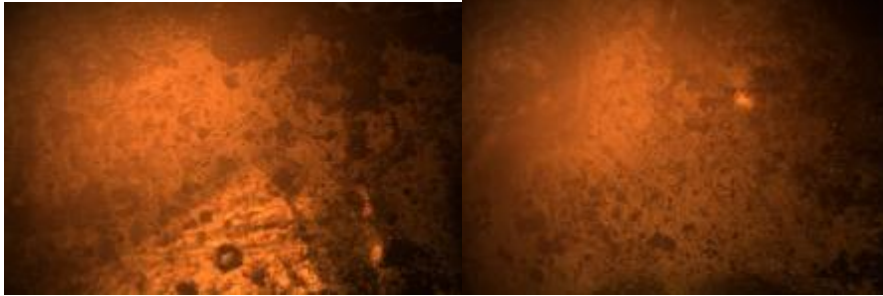


Figure 2: microstructure of specimen before and after fracture

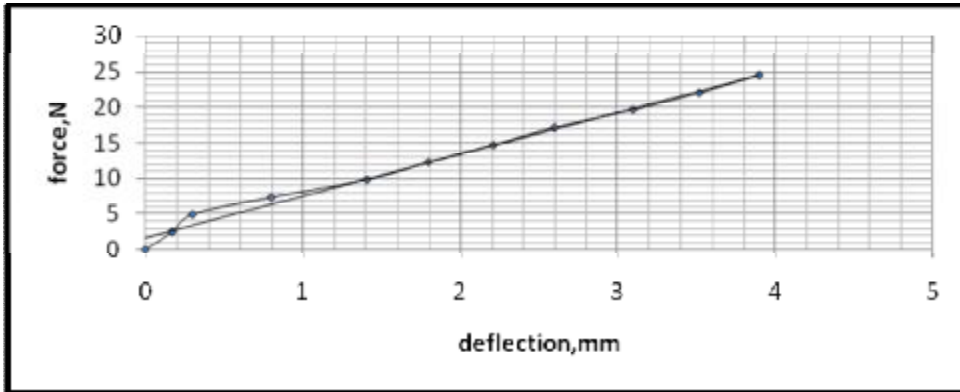


Figure 3: forces – displacement at 15% CDs (bending).

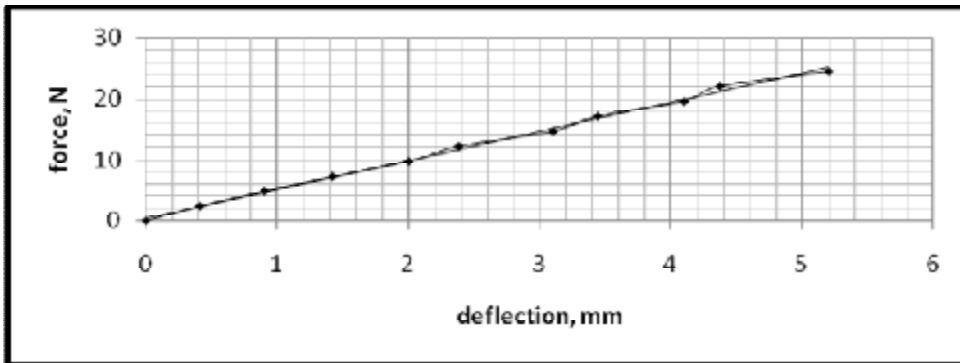


Figure 4: force-displacement at 30% CDs (bending).

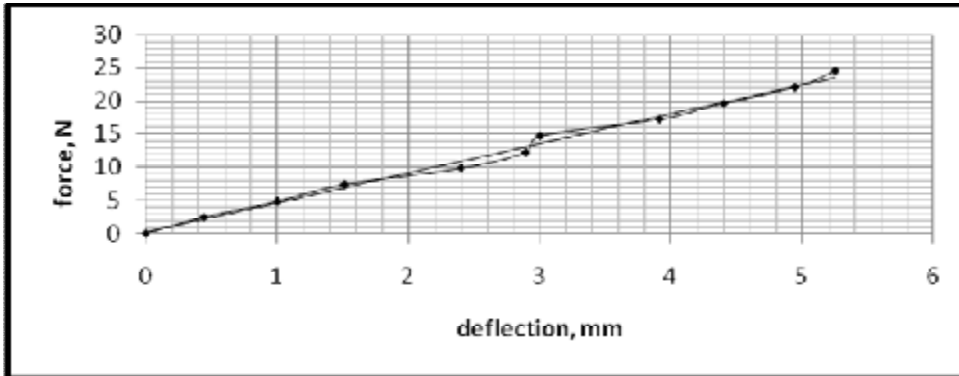


Figure5: force-displacement at 45% CDs (bending).

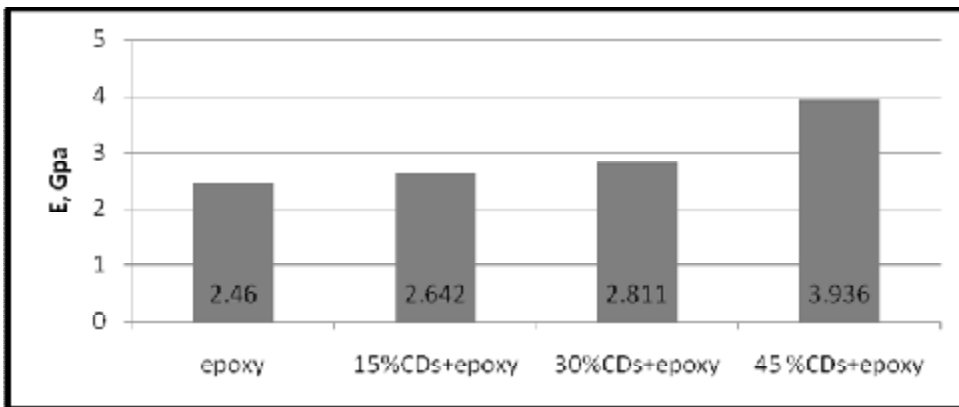


Figure 6: flexural stiffness for all specimens before immersion

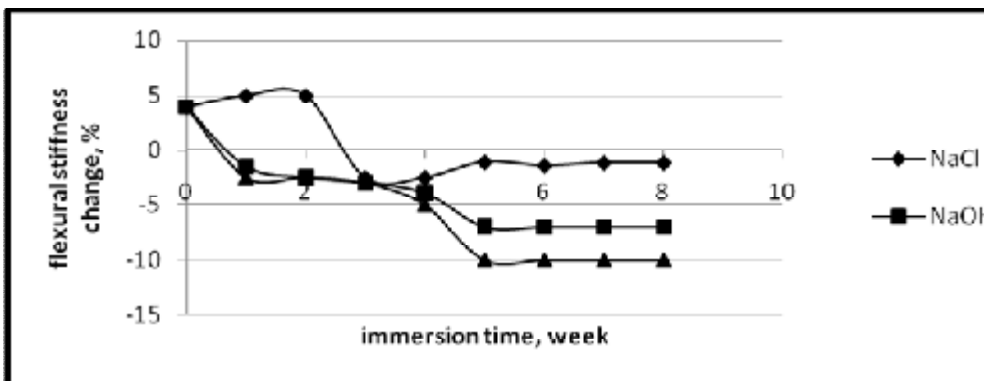


Figure 7: flexural – stiffness change % of 45% CDs reinforced epoxy