Effect of chopped cane sugar fibers on some Mechanical Properties of Phenol-Formaldehyde and Urea-Formaldehyde Composites

تأثيرألياف قصب السكر المقطعة على بعض الخصائص الميكانيكية لمتراكبات الفينول- فورمالديهايد و اليوريا- فورمالديهايد

Mohammad Nadhum B. AL-Baiati
Department of Chemistry /College of Education for pure sciences/University of Karbala

Keyword : Composite Materials ; Mechanical Properties ; Phenol-Formaldehyde Resin ; Urea-Formaldehyde Resin ; Fibers ; Matrix ; Cane Sugar fiber .

Abstract

This research was carried out by reinforcing the matrix (phenol-formaldehyde and urea-formaldehyde) resins respectively, with natural material (cane sugar fibers) . Each specimen was reinforced with different weight percentage, (5% , 10% , 15% , 20% and 25 %) of chopped cane sugar fiber . After preparation of composite material, some of the mechanical properties, flexural, tensile and impact tests were studied of prepared specimen.

The results obtained from these tests indicated that, 25% from chopped Cane sugar reinforcing with urea-formaldehyde composite has the higher values of mechanical properties, compared with 5% from same composite, and 25% from chopped Cane sugar reinforcing with phenol-formaldehyde composite has the higher values of mechanical properties, compared with 5% from same composite.

الخلاصة :

في هذا البحث تم تدعيم المادة الاساس (الفينول- فورمالديهايد و اليوريا - فورمالديهايد) بمواد طبيعية (ألياف قصب السكر المقطعة) .

جميع النماذج دعمت بنسب وزنية مختلفة (5% , 10% , 15% ، 20% و 25%) من ألياف قصب السكر المقطعة . بعد تحضير المتراكبات, تم دراسة بعض الخصائص الميكانيكية للنماذج المحضرة وهي أختبار قوة الأنحناء ، أختبار قوة الشد وأختبارمقاومة الصدمة .

أن النتائج التي تم الحصول عليها هده الأختبارات تشير الى أن متراكب اليوريا- فورمالديهايد مع نسبة وزنية 25 % من ألياف قصب السكر المقطعة يمتلك قيم أعلى للخواص الميكانيكية ، مقارنة مع نفس المتراكب الحاوي على نسبة وزنية 5% من الألياف . كذلك أظهرت النتائج أن متراكب الفينول- فورمالديهايد مع 25% من الألياف ، يمتلك قيم أعلى للخواص الميكانيكية ، مقارنة مع نفس المتراكب الحاوي على نسبة وزنية 5% من الألياف .

Introduction

The use of natural fibers in organic matrix is highly beneficial because the strength and toughness of the resulting composites are greater than those of the unreinforced materials. Moreover, lignocelluloses natural fibers are usually strong, light in weight, cheap, abundant and renewable. Over the past decade, natural fibers have found use as a potential resource for making low-cost composite materials. One difficulty that has prevented the use of natural fibers is the lack of good adhesion to polymeric matrix. In particular, the high moisture sorption capacity of natural fibers adversely affects adhesion with a hydrophobic matrix and, as result, it may caused material degradation and loss of strength [1] .

Natural fibers are considered as strong candidates to replace the conventional glass and carbon fibers. The chemical, mechanical, and physical properties of natural fibers have distinct properties;

depending upon the cellulosic content of the fibers which varies from fiber to fiber [2] . The properties of the fiber–matrix interface are of great importance for the macroscopic mechanical properties. Physical and chemical treatments can be used to optimize this interface, bearing in mind that the efficiency of fibers varies with the materials and the methods used [3] . The physical properties of natural fibers are mainly determined by their chemical and physical composition, such as structure of fibers, cellulose content, angle of fibrils, and cross section, and by the degree of polymerization [4] . The combination of a plastic matrix and reinforcing fibers gives rise to composites having the best properties of each component. The most commonly used are thermoset polymers such as polyester, epoxies and phenols [5] . The fracture energies for natural fiber–polyester composites (fiber content of approximately 50%) in the impact-test, he found out that, except the natural fiber–polyester composites, an increase in fracture energy was accompanied by an increasing fiber toughness . Natural fiber reinforced plastics with fibers which show a high spiral angle of the fibrils, indicated a higher composite-fracture-toughness than those with small spiral angles [6] .

The mechanical performance of short randomly oriented natural fiber reinforced polyester composites with reference to the relative volume fraction of the two kinds of fibers at a constant total fiber loading of 0.40 volume fraction, he found a positive effect was observed in the flexural strength and flexural modulus of the composites [4] . The effect of natural fibers on thermal and mechanical properties. Composites of polypropylene and various natural fibers including kenaf fibers, wood flour, rice hulls and newsprint fibers were prepared at 25% and 50% (by weight) fiber content level, and studied dynamic mechanical properties and compared with the pure plastic. They found that natural fibers filled polypropylenes behave more elastically than their pure counterpart [7] .

The main aim of this work, is to use the natural fiber like cane sugar that comes from nature without any kind of synthetic preparation; moreover to develop new composites using fibers and resins from renewable resources and studying some of the mechanical properties of this composites .

Experimental Methods

1. Materials

Phenol-formaldehyde resin, type resole; Urea-formaldehyde resin; imported from Fluka Co. . Cane sugar fibers, in chopped form, imported from Harrer Co. (Egypt) ; The density of cane sugar fibers is (0.87 gm/cm^3); and Hexamethylenetetramine , as a hardener for both resins , imported from BDH .

2. Fibers treatment:

Chemical treatment was used to improve the compatibility bonding between fiber and matrix . Cane Sugar fibers was cut into 10 mm length and 2 mm width . Before any composite production, natural fibers experienced chemical treatment . Firstly fibers are immersed in water contain 4 % NaOH solution for about 10 hours. Then the fibers are dried in oven at 40C° for 8 hours . The fibers were left for 72 hours to dry at room temperature before being used [1] .

3. Preparation of composites:

Composites were made by using a glass mould having dimensions (200 x 200 x 10) mm respectively. The composites were prepared by varying the relative volume fraction of fibers, and then mixed the solution very well before poured it to obtain homogeneity. The chopped cane sugar fibers were put in mould and the resin poured onto fibers. The mould left for 72 hours to get solid samples (post curing).

4. Measurements

In this work, Flexural (three bending point) test was used. The test was carried out in accordance with ASTM D-790 [8] . The flexural modulus was calculated from this test. The flexural strength was calculated from the following relationships:

$$\textbf{Flexural Strength (MPa)} = 3PS / 2bt^2$$

Where: P : applied force till the failure of specimen occurs ; S : Span ; b : width of specimen and t : thickness of specimen .

Tensile properties may provide useful data for plastics engineering design purposes. However, because of the high degree of sensitivity exhibited by many plastics to rate of straining and environmental conditions, data obtained by this test method cannot be considered valid for applications involving load – time scales or environments widely different from those of this test method. The obtained results then used to evaluate the tensile strength, from the following equations. The test was carried out in accordance with ASTM:D-638 [9] .

Tensile Strength (MPa) = Stress / Strain

where : Stress = dP / A and Strain = dl / l , dP = Chang in applied load (N) , dl = Change in length of specimen (mm), l = Length of specimen (mm) , and A = Original area of specimen (mm2) .

Impact strength test was used to measure the impact strength, which may be defined as toughness or ability of material to absorb energy during plastic deformation. Toughness takes into account both the strength and ductility of the material . Hammers of (45 Joul) was used in this test with specimens of impact . The test was carried out in accordance with ISO-179 [10] .

The impact strength value was calculated by dividing the energy in KJ recorded on tester by cross sectional area of specimen, as shown in the following equation :

$$\textbf{Impact Strength (Kg / m}^2\textbf{)} = F.E / C.S.A$$

Where:

F.E = Fracture energy, and C.S.A = Cross sectional area for the specimen .

Results and discussion

The mechanical properties of natural fibers vary considerably depending on the chemical and structural composition, fiber type and growth conditions. The mechanical properties of composites are influenced mainly by the adhesion between the matrix and fibers [11] .

The results obtained from these tests indicated that, the values of a composites reinforced with phenol-formaldehyde resin are smaller compared with the values of composites reinforced with urea-formaldehyde resin and the specimen which contain on 25% of weight percentage of chopped cane sugar fibers have higher results compared with that contain on 5% of same composite, as shown in Tables 1& 2 .

The values of mechanical properties will be increasing with increased the weight percentage of fibers, that means an increase in fracture energy was accompanied by increasing fiber toughness. Moreover, this is because the compatibility between cane sugar fibers and matrix is strong enough to support this stress, therefore increases the interfacial resistance between these materials , and the presence of the compatibility between cane sugar fibers and matrix had a very significant effect on increasing the composites, this was attributed to the improvement of the interface between the two phases due to the better compatibility of the phases , as illustrated in Figures 1 & 2 and Figures 3 & 4 .

The results of impact strength for a specimen of the composites reinforced with phenol-formaldehyde resin are smaller than the results of composite reinforced with urea-formaldehyde resin, as shown in Tables 1&2, because of the brittle characteristics of the reinforced fibers, show low impact energy absorption. This can be explained due to the presence of chemical treatment and modification which provided a stronger adhesion between fibers and matrix. So that, the shorter pull-out is observed in composites which indicated stronger adhesion between natural fibers and matrix resulted higher impact strength, and a little fiber pull out which indicate to good bond and interfacial adhesion between the matrix and fiber so higher interfacial stress can develop, reducing the work of fracture and causing the fracture to be more brittle, as shown in Figure 5 & 6 .

Conclusions

The mechanical properties of composites are influenced mainly by the adhesion between matrix and fibers. The chemical treatments of the fibers improve the mechanical properties of fibers. The composites between urea-formaldehyde resin and chopped cane sugar fiber showed higher values of mechanical properties compared with the values of composites between phenol-formaldehyde resin and chopped cane sugar fiber and the values of mechanical properties were increased with increasing of weight percentage of chopped cane sugar fiber in both composites.

Chemical modification of fiber surface is needed to increase attractive interactions at the fiber - resin interface; this shows that the combination of fibers capable to overcome the weakness of individual chopped fibers where there is lack of interfacial bonding between chopped fibers and polymeric matrix.

References

1 - M. Behzad, M. Tajvidi & R. H. Falk ; 2004 **;** Dynamic Mechanical Analysis of Compatibles Effect on The Mechanical Properties of Wood Flour - High-Density Polyethylene Composite ; J. of Transactions and Applications ; Vol. 17 ; No.1 ; P. 95 .

2 - R. Malkapuram, V. Kumar, & Y. S. Negi ; 2009 ; Recent Development in Natural Fiber Reinforced polypropylene Composites ; Journal of Reinforced Plastics and Composites ; Vol.28 ; No.10 ; P.1169 .

3 - S. Marais & F. Gouanve ; 2005 ; effect of cold plasma and autoclave treatments on mechanical and permeation properties Composites ; Vol. 36 ; P. 975 .

4 - M. Idicula & N.R. Neelakantan ; 2005 ; A study of the Mechanical Properties of Randomly Oriented Short Banana and Sisal Hybrid Fiber Composites ; J. of Applied Polymer Science ; Vol. 96 ; No. 5 ; P.1700 .

5 - J. Geore , M. *S.* Sreekala & S. Thomas ; 2001 ; A Review on Interface Modification and Characterization of Natural Fiber Reinforced Plastic Composites ; J. Polymer Engineering and Science ; Vol. 41 ; No. 9 ; P. 1471 .

6 - C. Pavthran , P. Mukherjee & M. Brahmakumar ; 1991 ; Coir-Glass Intermingled fiber Hybrid Composites ; J. of Reinforced Plastic and Composites ; Vol. 10 ; No.1 ; P.91 .

7 - M. Tajvidi , R. Falk & J.C. Hermanson ; 2006 ; Effect of Natural Fibers on Thermal and Mechanical Properties of Natural Fiber Polypropylene Composites ; J. of Applied Science ; Vol. 101 ; PP. 4341 .

8 - R. Rajput ; 2004 ; a Text book of Material Science ; 6^{th} edition ; kararia & Sons Co. ; Delhi; P.274 .

9- A. H. Sharifah , A. P. Martin , C. J. Simon & P. R. Simon ; 2005 ; Modified Polyester Resins for natural fiber composites ; J. of Composite Science and Technology ; Vol. 65 ; P. 525 .

10 - T. Kang & C. Kim ; 2000 ; Impact energy absorption mechanism of largely deformable composites with different reinforcing structures ; J. Fiber and Polymers ; Vol. 1 ; No. 1 ; PP. 45 .

11 - M. Philip & B. Bolton ; 2002 ; Technology of Engineering Materials ; Oxford ; P.148 .

Table – 1 : The mechanical tests of phenol-formaldehyde composites with different weight percentage of cane sugar fibers .

Weight percentage of Cane Sugar fiber	Flexural Strength (MPa)	Tensile Strength (MPa)	Impact Strength (kJ / m^2)
5%	98.37	217.40	60.31
10%	136.04	395.07	84.76
15%	511.68	720.62	104.18
20%	898.53	1118.91	131.01
25%	1206.07	1426.03	159.42

Table – 2 : The mechanical tests of urea-formaldehyde composites with different weight percentage of cane sugar fibers .

Weight percentage of Cane Sugar fiber	Flexural Strength (MPa)	Tensile Strength (MPa)	Impact Strength (kJ / m^2)
5%	152.14	324.52	120.70
10%	210.75	506.18	145.03
15%	772.31	847.93	162.41
20%	924.06	1231.41	187.62
25%	1283.20	1512.65	205.07

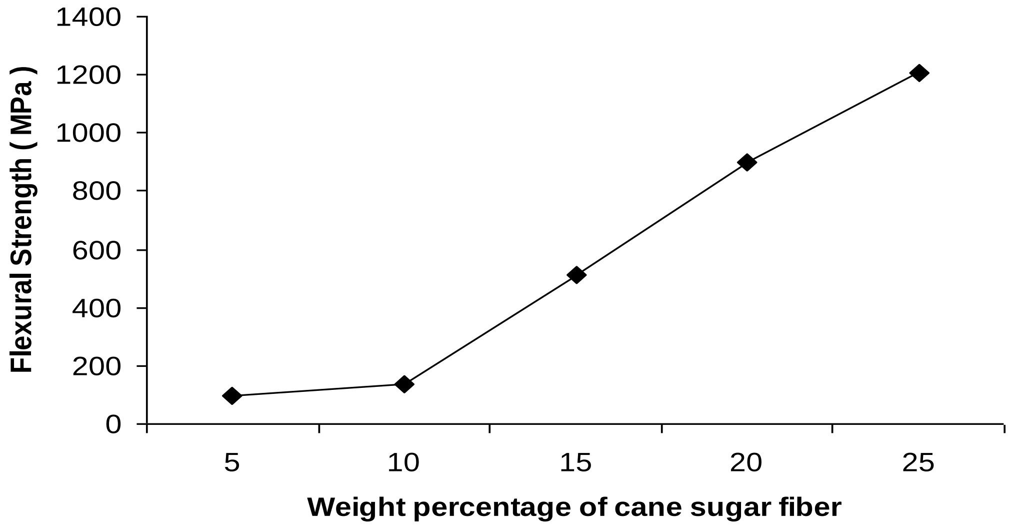

Figure – 1 : Effect of flexural strength on varying the relative weight percentage of cane sugar fiber composites with phenol-formaldehyde .

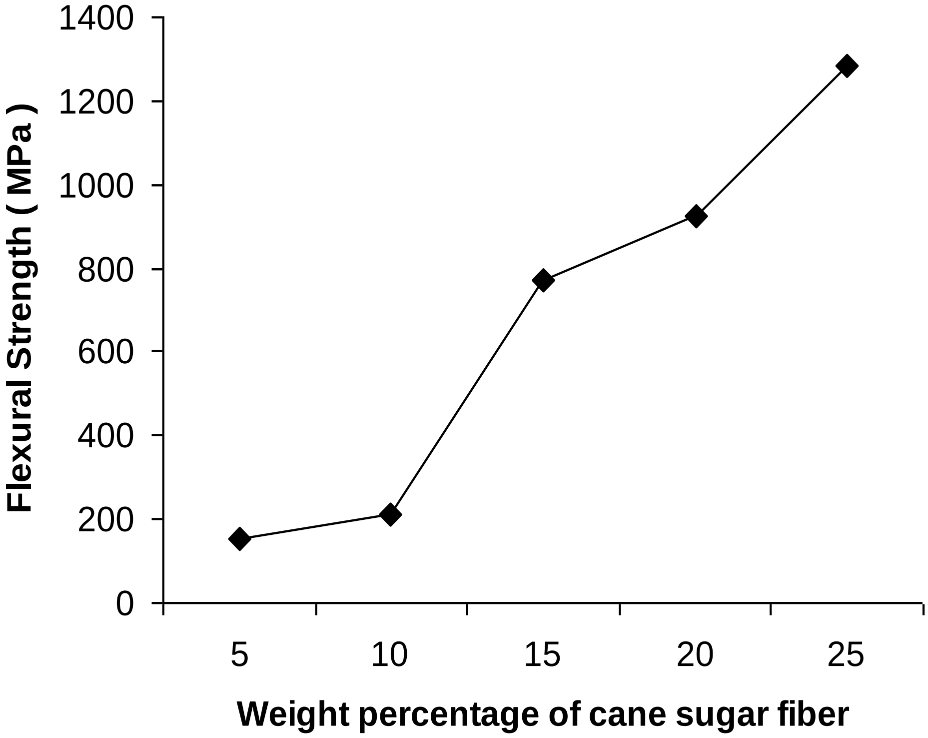

Figure – 2 : Effect of flexural strength on varying the relative weight percentage of cane sugar fiber composites with urea-formaldehyde .

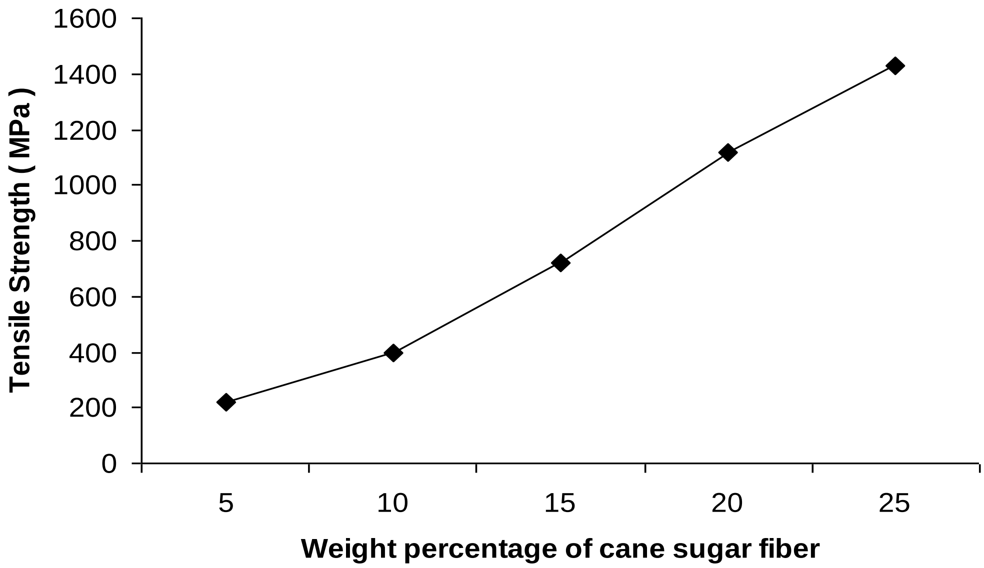

Figure – 3 : Effect of tensile strength on varying the relative weight percentage of cane sugar fiber composites with phenol-formaldehyde.

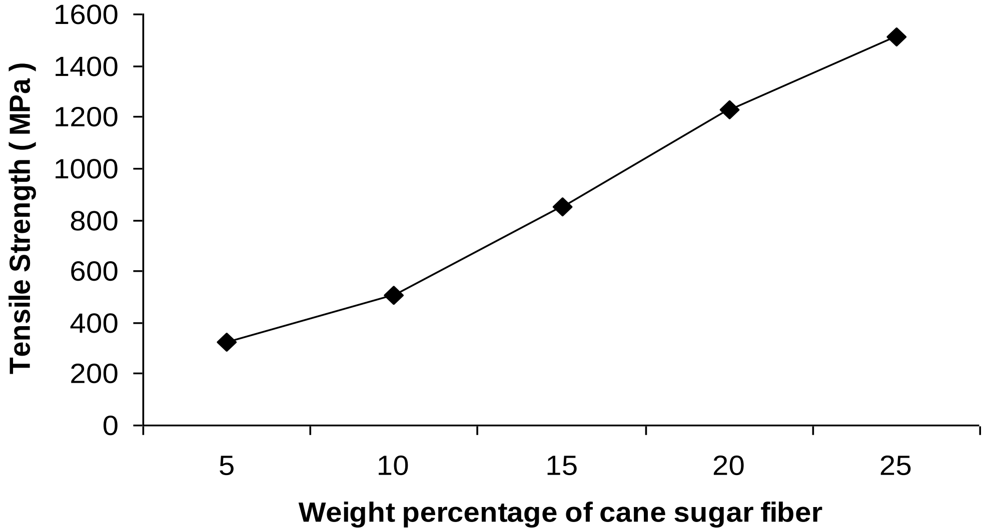

Figure – 4 : Effect of tensile strength on varying the relative weight percentage of cane sugar fiber composites with urea-formaldehyde.

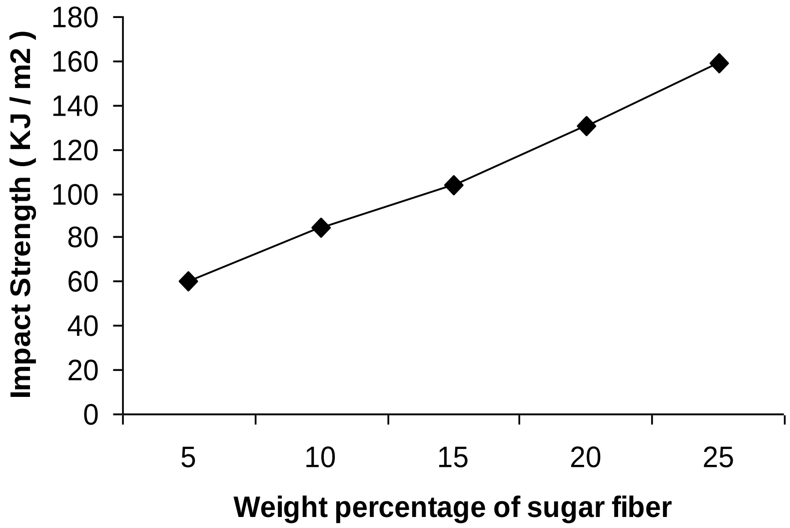

Figure – 5 : Effect of impact strength on varying the relative weight percentage of cane sugar fiber composites with phenol-formaldehyde.

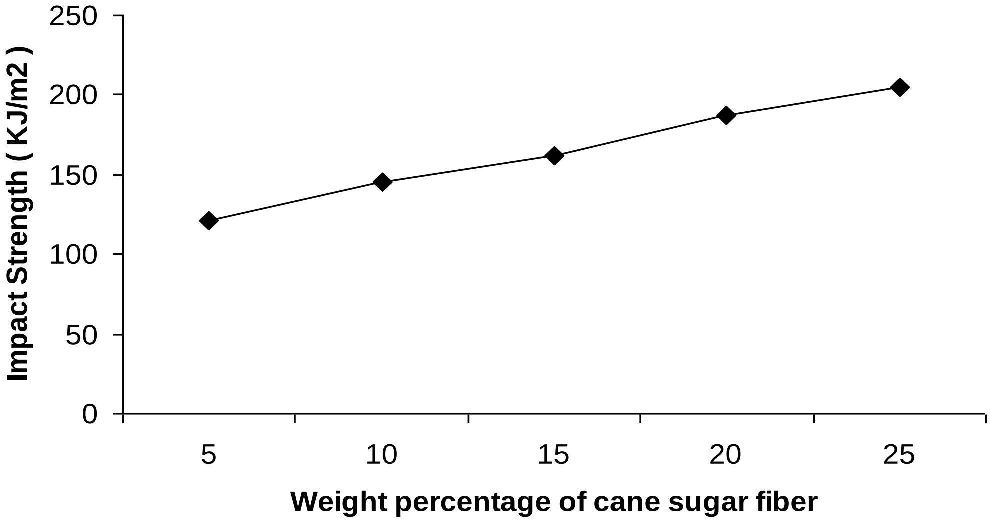

Figure – 6 : Effect of impact strength on varying the relative weight percentage of cane sugar fiber composites with urea-formaldehyde .