Tikrit Journal of Eng. Sciences/Vol.16/No.3/September 2009, (30-37)

Use of Lignin Fibers to Improve Mechanical Properties of Coated Wood

Dr. Falak O. Abass*, Raghad O. Abass, Mukheled A. Hussien***
***Environmental Research Center/University of Technology**
**** Material Engineering Department/ University of Technology**

Abstract

In this research, a new method for the production of the blend consists of polyester resin as a matrix-binder at fixed weigh and different weighs of epoxy resin that can be used to coat wood is developed. Several experiments are performed under different conditions to identify the most favorable operating conditions for the preparation of blend (polyester/epoxy) resins. Optimum conditions, namely, mixing speed, mixing time, heating temperature and heating time are investigated and found experimentally as 500rpm, 5min, 75^0C and 6hr respectively. In addition, solid palms wastes (lignin) as reinforcement fibers is employed in order to improve the mechanical properties: impact strength, bending deflection and bending distortion of coated wood. The optimum ratio of prepared blend is characterized by the mechanical (impact and bending) tests of the untreated samples occurred at a ratio of polyester/epoxy resins of 0.91w/w. It showed the best bonding force and physical interaction between two resins. The impact strength of the treated samples with one and two layers of prepared lignin fibers are higher than that of the untreated sample, while the bending distortion and bending deflection of treated samples are lower than that of the untreated sample. Experimental results showed that the treated sample with biofibers (lignin) led to enhancement in the mechanical properties of coated wood.

Keywords: polyester, epoxy, lignin fibers and mechanical properties.

استخدام اللكنين لتحسين الخواص الميكانيكية للخشب

الخلاصة

تم في هذا البحث تطوير طريقة جديدة لإنتاج مزيج يستخدم لتدعيم الخشب يتكون من وزن ثابت من لاصق البولي استر (كرابط) مع أوزان مختلفة من لاصق الايبوكسي. أنجزت مجموعة من التجارب تحت ظروف مختلفة لكشف عوامل التشغيل المثلى لتحضير ذلك المزيج المكون من (بولي استر/ايبوكسي). وقد وجدت عمليا كالأتي: سرعة الخلط (500rpm) وزمن الخلط (5min) ودرجة التسخين (75^oC) وزمن التسخين (6hr). ومن ثم استخدام مخلفات النخيل الصلبة (اللكنين) كالياف تقوية لتحسين الخواص الميكانيكية (قوة الصدمة وانحراف الانحناء وتشويه الانحناء) للخشب المدعم بمزيج اللواصق. وقد حددت افضل نسبة وزنية للمزيج المحضر عن طريق الاختبارات الميكانيكية للنماذج غير المعاملة عند 0.91 w/w والتي أظهرت أفضل قوى ترابط وتجاذب فيزيائي بين اللواصق. إذ ظهرت قيم قوة الصدمة للنماذج المعاملة بطبقة واحدة او طبقتين من الياف اللكنين أعلى مقارنة مع قيم النماذج غير المعاملة، بينما قيم تشويه الانحناء وانحراف الانحناء للنماذج المعاملة كانت اقل مقارنة مع النماذج غير المعاملة. أظهرت التجارب العملية ان النماذج المعاملة بالياف اللكنين ادت إلى تعزيز الخواص الميكانيكية للخشب المدعم.

Introduction

Wood adhesives are polymeric materials that are capable of interacting physically or chemically, or both, with the

surface of wood in such a manner that stresses are transferred between bonded members, hopefully without rupture of the adhesive or detachment of the adhesive from the wood. Adhesives and the physicochemical phenomenon of adhesion play an important role in more than 70% of all wood-based materials in use today [1]

Biocomposites are the combination of natural fibers (biofibers) such as wood fibers (hardwood and softwood) or nonwood fibers (e.g., wheat, bamboo, kenaf, hemp, jute, sisal, and flax) with polymer matrices from both of the renewable and nonrenewable resources [2].

The use of natural fibers such as different plant fibers and wood fibers as reinforcement in thermoplastic, thermosets and elastomers has increased dramatically during the last years. With regard to the environmental aspects, it would be very interesting if natural fibers could be used instead of inorganic fillers. Natural fibers have many advantages compared to those ones made by men, for example low density, low cost, non-abrasive, availability from renewable natural resources. They are renewable raw materials and have relatively high strength and stiffness. These types of natural fibers are able to satisfy both economical and ecological interests [3-7].

Composite materials consist of two or more constitutes with physically separable phases. In polymer composites, the binder aterial is a polymer. The binder, or matrix, surrounds the reinforcing elements may be plates, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material [8-9].

Polymer matrices for high performance composites are often thermosets. Common thermosetting resins are vinyl ester, unsaturated polyester, epoxy and phenolic [10].

Rajulu et al. [11] investigated the effect of untreated and treated bamboo fibers coating with epoxy, unsaturated polyester and their blends on the mechanical property (tensile strength). They found that the blend coated fibers had higher tensile strength. This was attributed to the hydrogen bonding between the unsaturated polyester and epoxy groups. Another study carried out by Rajulu et al. [12] who studied the chemical resistance and tensile strength of epoxy/ polycarbonate blend coated bamboo fibers and suggested that these are favorable materials for making the composites.

Park et al.[13] observed an increase in the physical properties when 5% by weight of unsaturated polyester is used in the epoxy and unsaturated polyester blend. Similarly Harani et al.[14] have used unsaturated polyester for toughening the epoxy resin.

Falak et al.[15] used solid waste (lignin) as reinforcement fiber for the urea-formaldehyde/resorcinol system and found that the mechanical properties are significantly increased with increasing the percentage of bonding material (resorcinol) adhesive at different arrangement of lignin fibers.

The aim of the Present Work

The first aim of this work is to investigate the optimum operating conditions, such as, mixing speed, mixing time, heating temperature and heating time on the mechanical characteristics of coated wood to achieve an optimum performance. The second aim is to find the optimum ratio of prepared blend (polyester/epoxy) resins so as to give high efficiency of the mechanical properties. The third aim is to ascertain whether blend lignin system can

be effectively employed for making the composites.

Experimental Work

Materials

1. Two different types of chemical adhesives, polyester with commercially specifications and epoxy that is obtained from *Gulf International Chemical SAOG (Tuf cote NT)* are used in this work.

2. Solid wastes-lignin fibers are collected from the local palms.

Procedure

1. All of the attached dirt materials are removed and cleaned from lignin fibers by washing for several times with tap water. After that, the lignin fibers are left in an open air for several days until dryness. The dry lignin fibers of treated sample for one layer are cut into the rectangular cross-section of 10*mm* width, 0.1*mm* thickness without using any cutting machine, and length for the bending and impact tests are 135 and 55*mm* respectively. Later, lignin samples used as reinforcement fibers in the experiments are designated as prepared lignin in this work.

2. Different weighs of epoxy with its required quantities of hardener are varied from 14.5 to 56*mg* and added to a fixed weigh (25.5*mg*) of matrix-base (polyester with its fixed quantity of hardener). Different weight ratios of blend 1.77, 1.20, 0.91, 0.53 and 0.46 w/w are prepared.

Each prepared blend ratio is agitated thoroughly at constant mixing speed of 500rpm using a (Labinco BV, model L-81, Netherland) stirrer, for a fixed period of mixing time (5 minutes) under room temperature of 25^{o}C.

Each prepared blend is divided into three portions. The first portion, the two internal surfaces of wood moulds is coated directly. The second and third portions are coated and saturated the prepared lignin fibers that are put after coating them between the two moulds of wood. Afterwards, each prepared sample of wood moulds is tied extremely using woolen wire. Note that first, second, and third prepared samples are designated as untreated sample-without lignin fibers (W.L), treated sample with one layer of prepared lignin fibers (O.L) and treated sample with two layers of prepared lignin fibers (T.L) respectively.

All prepared samples (untreated and treated) are placed in an oven under 75^{0}C for 6hours. Then the samples are allowed to cool under room temperature before conduction the laboratory tests.

Methodology

Experiments are performed to characterize the mechanical properties of coated wood by different weighed ratios of prepared blend (polyester/epoxy) resins using prepared lignin fibers. The untreated (W.L) and treated (O.L, T.L) samples of coated wood are loaded into the instruments so as to investigate the mechanical (impact and bending) tests. The impact strength is determined using charpy impact instrument (time testing machine, xju-22, pendulum, time group, 2007, Inc., usa). While the bending distortion and bending deflection are determined using PHYWE instrument (three point bending tester according to ASTM D790).

Results and Discussion

First Test

The effect of different weight ratios of prepared blend in terms of bending distortion in *mm* versus load in *grams* is shown in Figure 1. It seems that the ratio of prepared blend at 0.91w/w showed better resistance and lower bending

Tikrit Journal of Eng. Sciences/Vol.16/No.3/September 2009, (30-37)

distortion values. The results provided evidence that the blend at the ratio of 0.91w/w reached to the strong chemical interaction and maximum bonding forces between the two concentrations of polyester and epoxy resins because it gave the minimum bending distortion at this ratio when compared with the other ratios of prepared blend. On the other hand, this can be attributed to the hydrogen bonding between polyester and epoxy resins which promote close packing at molecular level as suggested by Varada Ragulu et al. (2001).

As shown in Figure (1), at any fixed weight ratios of the prepared blend, for example, 0.91w/w, see Figure 1, as the load values increased from 0 to 250 gram, less resistance arises and higher bending distortion is noticed. This trend is expected due to the change of the resistance of prepared blend against the load values. Similar trends are obtained for the other ratios of prepared blend.

Second Test

Figure (2) shows the effect of untreated (W.L) sample on the impact strength in J/cm^2 under different weight ratios of prepared blend. It is seen from Figure 2 that the impact strength of untreated (W.L) sample increased from 3.2 to 3.6 J/cm^2 with increasing the ratios of prepared blend from 0.46 to 0.91w/w. This trend is due to the increase of the epoxy concentration more than that of the polyester concentration, i.e. the concentration of epoxy resin at these ratios of prepared blend is predominant. While it decreased to 2.7 J/cm^2 with increasing the ratios of prepared blend from 1.2 to 1.77w/w. This trend is due to the increase of the polyester concentration more than that of the epoxy concentration, i.e. the concentration of polyester resin at these ratios of prepared blend is predominant. It is clear from Figure (2) that the maximum value of impact strength for untreated (W.L) samples occurred at the ratio of prepared blend of 0.91w/w.

The effect of untreated (W.L) sample on the bending deflection at different weight ratios of prepared blend is shown on Figure (2). It seems clearly that the bending deflection of untreated (W.L) sample decreased from 5.1 to 4.4 and increased to 6 mm with increasing the ratios of blend from 0.46 to 1.77w/w. This behavior is due to the increase in the ratios of prepared blend from 0.46 to 0.91w/w is associated with a decrease in the concentration of the epoxy resin until an optimum concentration at the ratio of 0.91w/w. After that the concentration of the polyester resin become greater than that of the epoxy resin.

On the other hand, it can be clearly seen from Figure (2) that the minimum bending deflection of untreated (W.L) samples occurred at the ratio of prepared blend of 0.91w/w.

The results of these two mechanical tests gave an evidence that the blend of the ratio of 0.91w/w exhibited the best mechanical resistance of coated wood against the mechanical properties of impact strength and bending deflection due to their strong chemical interaction and bonding forces between polyester and epoxy resins. This can be attributed to the hydrogen bonding between the hydroxyl end group of the polyester and the epoxide group of the epoxy [12].

The ratio of prepared blend at 0.91w/w is designated as the optimum ratio of prepared blend.

Investigation of Lignin Fibers Effect on Mechanical Properties of Coated Wood

(A) Impact Test

Figure 3 shows the effect of untreated (W.L) and treated (O.L, T.L) samples of prepared lignin fibers on the impact strength under different weight ratios of prepared blend. It is clear that maximum impact strength for both untreated and treated samples occurred at the optimum ratio of prepared blend. Also, it clearly obvious that the impact strength of the treated (O.L, T.L) samples have higher values when compared to that of untreated (W.L) sample.

Percent increase of impact strength for treated (O.L, T.L) samples of different weight ratios of prepared blend are presented in Table (1). It seems that, at fixed ratio of prepared blend, for example, at the optimum ratio, the impact strength for the treated O.L and T.L samples increased by 17.9 and 34% respectively compared to that of the untreated (W.L) sample. This higher increase in the impact strength of treated samples can be attributed to the hydrogen bonding between the hydroxyl end group of the polyester and the epoxide group of the epoxy Varada Ragulu et al.(200001). On the other hand, it is observed that the treated samples with one and two layers of lignin fibers showed better mechanical resistance and better physical interaction with prepared blend of polyester/epoxy resins.

(B) Bending Test

Bending Deflection

The effect of untreated (W.L) and treated (O.L, T.L) samples of prepared lignin fibers on the bending deflection of different weight ratios of prepared blend is shown on Figure 4. It is seen from this figure that the minimum bending deflection of untreated (W.L) sample corresponded to the optimum ratio of prepared blend. Similar observations are found for the other treated (O.L, T.L) samples.

Table (2) shows the increase in the bending deflection for treated (O.L, T.L) samples at different weight ratios of prepared blend. At fixed ratio of prepared blend, for example, at the optimum ratio, the bending deflection for the treated O.L and T.L samples increased by 30.3 and 56.3% respectively more than that of the untreated (W.L) sample. This increase in the bending deflection of treated samples with one and two layers of prepared lignin fibers can be attributed to the bonding forces between the polyester and epoxy resins as well as to the physical interaction between the lignin fibers and the prepared blend. This behavior leads to show better mechanical resistance of coated wood against bending deflection. It is generally observed that the effect of treated sample with two layers of lignin fibers is predominant due to the best the mechanical resistance of lignin fibers.

Bending Distortion

Figure 5 shows the effect of untreated (W.L) and treated (O.L, T.L) samples of prepared lignin fibers at the optimum ratio of prepared blend in terms of bending distortion versus load. The bending distortion of untreated (W.L) samples has higher values when compared with that of treated (O.L, T.L) samples. For example, at fixed value of load 250*gm*, the bending distortion decreased by 28% for treated (O.L) compared to that of untreated sample, while for treated (T.L) sample it decreased by 69%. This trend is expected because the treated (O.L, T.L) samples showed better resistance to the mechanical properties and bending distortion. It is clear that mechanical properties and bending distortion is improved for the treated samples with one and two layers of

lignin fibers. Similar observations are found for the other ratios of prepared blend.

Conclusions

1. The optimum operating conditions namely: mixing speed, mixing time, heating temperature and heating time are 500rpm, 5min, 75^0C and 6hours respectively.

2. The optimum ratio of prepared blend that gives best mechanical properties, impact strength, bending deflection and bending distortion of the untreated samples is 0.91w/w polyester/epoxy resins.

3. The maximum impact strength and the minimum bending deflection of untreated (W.L) sample occurred at the optimum ratio of prepared blend and it is found equal to 3.6 J/cm^2 and 4.39mm, respectively.

4. The bending distortion of untreated (W.L) samples are higher than that of the treated (O.L, T.L) samples. The best results obtained at the optimum ratio of prepared blend.

5. Experimental results showed that treated samples with biofibers (lignin) led to enhancement in the studied mechanical properties of coated wood compared to that of untreated sample.

6. The improvement of treated samples with two layers of lignin fibers for impact and bending tests is predominant.

7. The prepared blend of polyester and epoxy resins and biofibers (lignin) is recommended as favorable materials for making composites-blend lignin system

References

1- Marra G G , The role of adhesion and adhesives in the wood industry. In: Gillespie RH (ed). Adhesives for wood. Noyes, Park Ridge, NJ, pp.2-9 , 1984.

2- Roger M. Rowell, A New Generation of Composite Materials from Agro-based Fiber, Polymers and other advanced materials: emerging technologies and business opportunities. Proceedings of the 3d international conference on frontiers of polymers and advanced materials;; Kuata Lumpur, Malaysia. New York, NY: Plenum Press: 659-665, January 16-20,1995.

3- Bledzki, A.K.; Gassan, J. Composites reinforced with cellulose based fibres. Progress in Polymer Science, v. 24, p. 221-274, 1999.

4- Bledzki, A.K.; Reihmane, S. ; Gassan, J. Thermoplastics Reinforced with Wood Fillers: A Literature Review. Polymer- Plastic Technology Eng., v. 37, n. 4, p. 451 - 468, 1998.

5- Rowell, R.M.; Sanadi, A.R.; Caulfield, D.F.; Jacobson, E. Utilization of Natural Fibers in Plastic Composites: Problems and Opportunities. In: Leão, A.L.; Carvalho, F.X. & Frollini, E. eds. Lignocellulosic-Plastic Composites, São Paulo, USP & UNESP, p. 23-51, 1997.

6- Joseph, K.; Mattoso, L.H.C.; Toledo, R.D.; Thomas, S. Carvalho, L.H.; Pothen, L.; Kala, S.; James, B. Natural Fibers Reinforced Thermoplastic Composites. In: Frollini, E.; Leão, A.L.; Mattoso, L.H.C. eds. Natural Polymers and Agrobibers Based Composites. Embrapa Instrumentação Agropecuária Ed., São Carlos, SP.Section II – Agrofibers Composites, p.159-201, 2000.

7- Leão, A.L.; Caraschi, J.C.; Tan, I.H.: Curaua Fiber - ATropical Natural

Fibers From Amazons Potential andApplications in Composites. In: Frollini, E.; Leão, A.L.; Mattoso, L.H.C. eds. Natural Polymers and Agrobibers Based Composites. Embrapa Instrumentação Agropecuária Ed , São Carlos, SP. Section II – Agrofibers Composites, p. 257-272 , 2000.

8- D.H. Mueller, A. Krobjilowski, "New Discovery in the Properties of Composites Reinforced with Natural Fibers", Journal of Industrial Textiles, 33(2), 111-129 , (2003).

9- H.Lilholt, J. M. Lawther, "Comprehensive Composite Materials", chapter 1.10, Elsevier Ltd. (2000).

10- A.K. Bledzki, O. Faruk, "Wood Fibre Reinforced Polypropylene Composites: Effect of Fibre Geometry and Ccoupling Agent on Physico-Mechanical Properties", Applied Composite Materials, 10(6), 365-379, (2003).

11- A. Varada Ragulu, L. Ganga Devi, G. Babu Rao And Lakshminaryana Reddy. J. Journal of Reinforced Plastics And Composites, Vol. 22, No. 11, 2003.

12- Varada Ragulu, A., Babu Rao, G., Lakshminaryana Reddy. R. and Sanjeevi J. Journal of Reinforced Plastics and Composites, 20: 335, (2001).

13- Park**,** S.J., W.B. and Lee, J.R. Polymer J., 31: 28 , (1999).

14- Harani, H., Fellahi, S. and Barkar**,** M. , J.Appl.Polym. Sci., 71: 29, (1999).

15- Falak O. Abas, Raghad, U. Abass, Tarek H.M, National Journal of chemistry, volume 23, 327-334, (2006).

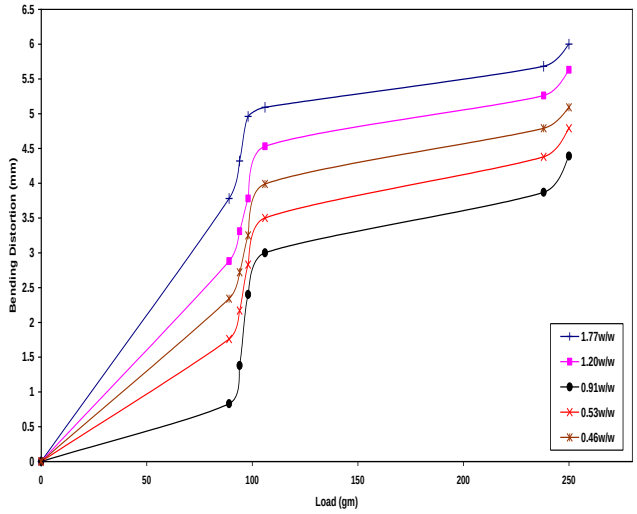

Figure (1) Effect of different weight ratios of prepared blend on bending distortion

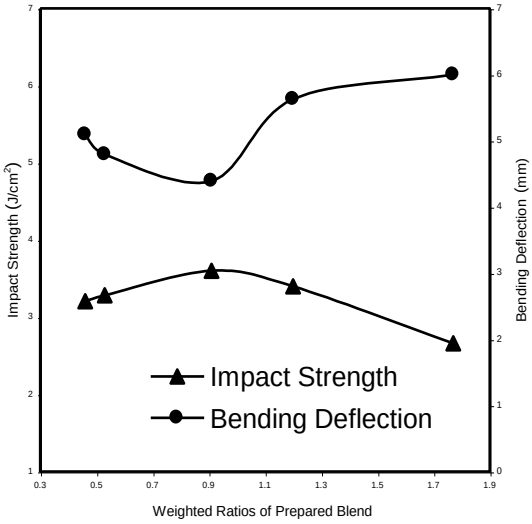

Figure (2): Effect of untreated samples on impact strength and bending deflection at different weight ratios of prepared blend

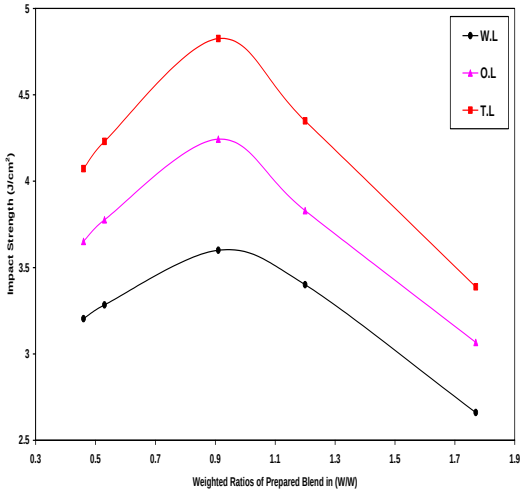

Figure (3): Effect of untreated and treated samples on impact strength at different weight ratios of prepared blend

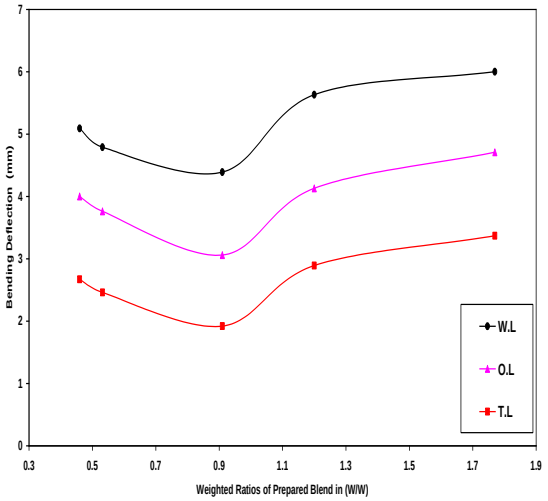

Figure (4): Effect of untreated and treated samples on bending deflection at different weight ratios of prepared blend

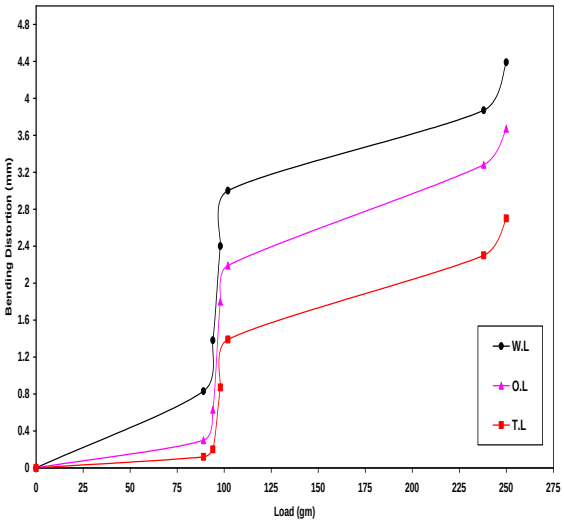

Figure (5): Effect of untreated sample on bending distortion at the optimum ratio of prepared blend

Table 1 Percentage increase of impact strength for treated samples under different weight ratios of prepared blend

Weighted ratios of prepared blend	Percentage increase of impact strength in (J/cm^2) for treated samples	
	O.L%	T.L%
1.77	15.3	27.4
1.20	12.6	27.9
0.91	17.9	34.0
0.53	15.0	28.9
0.46	14.0	27.1

Table (2) Percentage increase of bending deflection for treated samples at different weight ratios of prepared blend

Weight ratios of prepared blend	Percent increase of bending deflection for treated samples	
	O.L%	T.L%
1.77	21.5	43.8
1.20	26.6	48.7
0.91	30.3	56.3
0.53	21.5	48.6
0.46	21.4	47.5