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Manufacturing of Structural Sections Made of Papyrus Cane With Unsaturated Polyester Adhesives for Building Eco-Friendly Houses

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Abstract. Papyrus cane was used in different applications since ancient times, and it can be employed to build modern houses as well. To do so structural sections of papyrus cane were formed together using polymeric adhesive from unsaturated polyester resin (UP). The study consisted of manufacturing samples of different size ratios of the bulk reed material and also studying the effect of adding reeds with polymeric plasters, as the study included some mechanical and physical properties. The manual molding method was used in this project to prepare the structural section with weight rations of (10%, 20%, 30%, 40%) W_t. A group of practical tests were done to ensure the effectiveness of these sections including hardness test, Impact resistance, and thermal conductivity test. The results obtained from the test (Hardness, Impact) showed that there is a significant increase and improvement in the properties when reinforcing the highest weight fraction of the cane slices, which is at (40%) W_t, where the highest values were obtained at this percentage, were as follows: (85.15 N/mm2) for the hardness test and (21.31 KJ/m2) for the impact test. As for the thermal conductivity test, the results showed that the thermal conductivity decreases with the increase in the weight fraction, where the lowest value of the thermal conductivity was at the weight fraction of (40%), which is a value of (0.245 W /mC).

Keywords: Papyrus Cane,Eco-Friendly Houses,Unsaturated Polyester, Structural Sections, Physical and Mechanical Properties.

INTRODUCTION

Cane is one of the biological annual plants that is found almost all over the world. The reed is one of the indigenous plants in Iraq and is abundant in the marshes and the humid areas [1]. This plant has high physical and mechanical properties and characteristics that have made it the focus of the attention of researchers and the world in the past and the present. Due to its free availability, we decided to adopt a project in our research to build environment-friendly houses using structural sections made from reeds supported by unsaturated polyesters with specific size ratios with the studying and measurement of the physical and mechanical properties of samples prepared in the laboratory according to ASTM global standards.

Natural and biological building materials represent a promising solution to improve the environmental sustainability of buildings and it is also a major economic factor. Therefore, reed is a wealth if employed in the right way. It is one of the annual plants widely spread all over the world except for the North and South poles, it is found in humid areas and on riversides. It is a natural product that could be used as a building product with great human satisfaction in terms of thermal, electrical and sound insulation, energy-saving, and in terms of positive impact on the environment and other physical and mechanical properties [2]. Therefore, this study aims to show how we can use this reed as a support material with unsaturated polyester resin to protect it from environmental conditions in the manufacturing of structural sections for building houses and house decorations that are environment-friendly. Europe has developed a path towards a more sustainable society based on vital elements since the beginning of the century, the increase in the use of sustainable building materials is a major area for the growth of the construction sector. Buildings represent about 40% of the total final energy consumption in Europe [3,4] and about 41% of primary energy consumption in the United States [5]. In particular, the amount of energy consumption in residential compounds for air conditioning is about 68% in Europe and about 53% in the United States of America [3]. This confirms the need for a significant reduction in energy consumption by maintaining indoor air quality, comfort conditions, and high thermal insulation. This same warning has been confirmed by the European research (Horizon 2020), which aims by the year of 2020 to reduce greenhouse gas emissions to about (80-95%) in 35 years [6].

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The high cost of traditional reinforcing and building materials such as synthetic fibers is one of the most important factors that impede the work of researchers, and due to the increase in economic and environmental requirements, the need to find alternative natural materials such as hemp, papyrus, bamboo, coconut, pineapple, flax, and others have emerged to be used in strengthening Polymeric materials and other materials, therefore efforts have been directed towards the use of the waste of these materials, such as the use of their fibers or their outer shells, which are considered among the environmental wastes, by using them to reinforce polymeric materials, building materials, and others. With that we are doing two important roles: first is getting rid of the wastes and the second is using them as eco-friendly materials, so the issue of recycling and reusing materials has become one of the most important pillars of today's industrial world [7].

MATERIALS AND METHODS

Testing of Composite

1) **HardnessTest:** Use the (Elcoeterl 120 Shore D) device was used by the English Elcometer to perform a hardness test of the prepared composite material samples and , as this device consists of a needle-shaped stitching tool that penetrates the sample surface and then the amount of hardness is read through the existing indicator Directly into the device.

The hardness test enables us to know the cohesion of the mass of the material and its durability. Therefore, this test was conducted to measure the surface hardness of samples prepared from the composite materials and for various support ratios. six readings were taken for each sample, then the average of these readings was taken to find out the hardness value, and the test was conducted at a Laboratory temperature of (37 $^{\circ}$C),

2) **Impact Resistance Test:**Use the (Izod Charpy Tension Impact Test Instrument) device manufactured by (Testing Machines , Inc , Amityville New York).To conduct a impact strength test for prepared composite material sample, where the IZOD method was used, in which the test sample is taken and placed in the place designated for it, then the pendulum is raised to the top and installed on the upper part of the device, then the device makes a hissing, and when the pendulum is released, it he collides with the sample and breaks it in motion, oscillation is where the energy is converted, and the potential pendulum turns into kinetic energy, where a part of this energy is lost when the sample is broken, then a reading of the fracture energy is taken, noting that the hammer used in this test has an energy (5.5J).

The purpose of the impact resistance test is to measure the energy absorbed upon breaking for the samples prepared from the composite materials and for the various reinforcement ratios to determine the extent of their resistance to the external impact stresses affecting them. The basis for this test is that potential energy (Impact energy) is absorbed by the sample before the fracture occurs, and the following relationship was used to find the impact strength [8].

$$\mathbf{I.S} = \frac{\boldsymbol{U_c}}{\mathbf{A}} \qquad (1)$$

Where: I.S is the impact strength and measurement unit (J/m^2), U_c is the fracture energy and measurement unit (J), A is the area of the cross section.

3) **Thermal conductivity test:**Use the (Lee's disk) device manufactured by (Griffen & George).To conduct a thermal conductivity test for prepared composite material sample, Heat is transferred from the heater to the next disk until it reaches the last disk. The temperature of the three tablets (TA, TB, TC) can be read (° C) using thermometers placed inside them respectively.

Where a Lee 's method was used to find thermal conductivity which the calculated by the following relationship [9].

$$K\left(\frac{T_{B-}}{\quad}\right) \quad \left[T \quad -\left(d \quad - \quad\right)T \quad — \quad\right] \qquad (2)$$

Where: (K) is the thermal conductivity, ($T_{A,B,S}$) is the disk temperature, ($d_{A,B,S}$) is the disk thickness,(r) is the disk radius, (e) is the thermal energy which passes through a unit area per unit time, and calculated from the following relationship [10].

$$e(T \quad) \quad \left[d \quad -(T \quad) \quad \right] \tag{3}$$

Where: H is the time rate of the energy applied to the file, the amount of current (I) involved (0.25A) and the potential difference (V) involved (6V) the thermal connections

The aim of conducting this test is to study the thermal conductivity of samples prepared from composite materials and for the various support ratios, as the thermal conductivity is one of the basic physical phenomena through which it is possible to study and interpret how the material is affected by heat, it occurs when there is a difference in temperature that leads to the generation of Thermal flux and continues until the gradient of temperature becomes equal to zero due to the transfer of energy from the higher temperature side to the lower side.

Samples were prepared in the laboratory using two materials to form a composite material consisting of the base material (Unsaturated polyester) and papyrus cane us a reinforcement material:

A) Base material: In this research, the unsaturated polyester resin was used for the preparation of the composite material, it is pinkish-transparent, viscous material at room temperature, it is one of the thermally hardened polymers with a density of (1.19 g / cm3) that turns into a solid-state after adding the hardener to it, which is also a transparent liquid that is added to unsaturated polyester with a ratio of (2 g) per (100 g) of resin, according to the instructions of the producing company.

B) Reinforced materials: papyrus cane was used us a reinforcement material , which is one of the biological annual plants found in all parts of the world, especially in Iraq. Papyrus cane is one of the green renewable materials and is ideal for sustainable construction. Reeds were used for their permanent availability in nature and their lightweight and free abundance.

As for the method of work, the manual molding method was used in preparing the samples, which can be summarized in several steps:

1- Papyrus cane: The cleaning process is carried out and the cane is cut into slices commensurate with the size of the mold according to the required measurements, after weighing the required amount according to the support ratios proposed for the project, the reeds are arranged inside the mold in a regular horizontal manner.

2- A quantity of unsaturated polyester resin was mixed with hardener at a weight ratio of (2g) to (100g).

3- Instade of mix the mixture well inside a plastic container until the hardener is spread within the unsaturated polyester resin completely, and to prevent bubbles or clumping during the mixing process inside the substance, mixing must be slow, so that the mixture has good homogeneity and sufficient viscosity.

4- The liquid mixture is poured into the mold regularly and slowly until the mold is full and according to the required level.

5- We knock lightly on the end of the mold so that the bubbles disappear, if any, and also so that the mold is filled correctly.

6- Samples are left for (1) hour in the mold to solidify at room temperature.

7- The samples are then placed in the electric oven for (1) hour and at a temperature of (55c) for heat treatment.

8- Then the oven is turned off and the samples are left inside for (2) hours until the hardening process is done gradually. This process is necessary to obtain the best possible cross linking, and also to reduce the stresses generated during the hardening process.

9- Samples were prepared with specific proportions (10%, 20%, 30%, 40%) W_t.

RESULTS AND DISCUSSIONS

1) **Hardness test:** This test is one of the easy tests because it does not require complicated and expensive devices, and the samples are not subject to damage as they do not break when performing the test and are not significantly deformed. The (Shore - D) method involves measuring the resistance of hardened polymeric materials to penetration caused by a special needle that causes indentations within the surface of this material [11].

The results obtained as shown in Fig.1 regarding the hardness values of the prepared samples showing that there is a significant improvement in the hardness of all samples when supported with slices of papyrus cane.

The reason of this is due to the presence of those supporting layers that are characterized by their high hardness, as the external stresses are transmitted from the base material to the reinforced strips across the interface, so these slides impede the movement of the polymeric chains, which leads to improvement in mechanical properties, including the property of hardness, and thus leads to an increase in the resistance of the materials supported by these strips to scratch and penetration, as well as the reinforcing strips make the polymeric material stiffer and thus raise the hardness values of the prepared composite material, as well as these strips will create a large bonding force between it and the resin through a narrow and strong area called the interface which increases the durability of the prepared samples. Moreover, these slices will work to distribute the applied load, which reduces the penetration rate of the surface of the overlaying material and raises its hardness values. Furthermore, the more the number of slices added to the polymeric substrate the more the hardness values of the prepared material, that is because, the chips occupy the largest possible space within the resin, allowing for a better distribution of the applied load, this agrees with what the researcher came up with S. S.Al-Zubaidi [12]. Besides, the presence of a high percentage of lignin in the composition of the supporting strips used enhances the hardness of these slices and thus increases their resistance to external stresses, and increases the hardness of the prepared compound materials too, this all agrees with the researcher results [13].

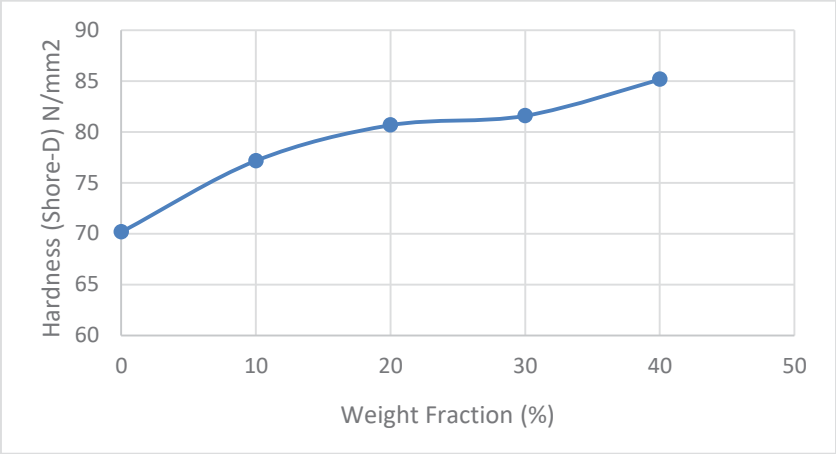

FIGURE 1. the relationship between hardness and weight fraction values

2) **Impact resistance test:**The Impact test was calculated for all prepared samples and for various reinforcement ratios through the impact tester directly depending on the energy required for the occurrence of the fracture, divided by the cross-sectional area of the sample, the test was performed at the laboratory temperature. The results are shown in Fig. (2), the impact resistance values of the prepared samples showed that there is a significant improvement in the impact resistance of all samples when supported with Papyrus (cane) slices. The reason for this is due to the presence of those supporting slices that bear the bulk of the impact stress imposed on the material and transmitted from the base material to those slices across the interface, as these slices distribute the external kinetic stress imposed on a larger volume of the sample and reduce the possibility of stress concentration at its central region so that the slices will stunt the occurrence of the fracture, this agrees with the researcher [14]. Also, the laminates reduce the main defects in the molding of thermosetting polymers (shrinkage during casting, fragility, and surface cracks) and thus improve their mechanical properties, including the impact absorption, it has also been noted that the number of slices leads to reinforcement of bonds at high loads which in turn will increase resistance to impact. This agrees with the researcher [15].

From Fig. 2 it appears that when the support is increased by the weight fraction of the cane segments, the value of impact resistance will increase, as the highest value obtained for impact resistance is at the weight fraction of (40%) with a value of (21.31 KJ/m^2). Where the impact resistance of the composite material of cane and polyester is 22 times higher than that of

pure polyester, and the stiffness is more than 75% higher than the durability of softwood, this all accordingly with the results of the researcher, the impact load was also observed when reinforcing with slats. The cane was found to be able to stop the progression of the crack from the edge of the crack and thus the composite material of the papyrus can be placed with the important engineering materials [16].

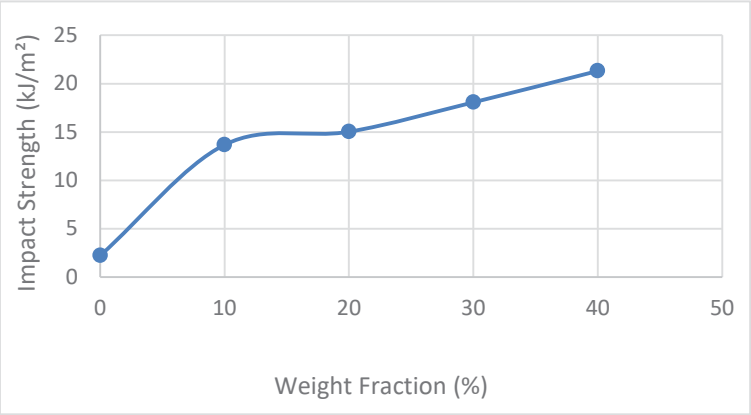

FIGURE 2. The relationship between the values of impact resistance and weight fraction.

3)The results are shown in Fig. (3), the thermal conductivity values showed that the thermal conductivity decreases for all samples when supported with papyrus cane slices.

The reason for this is due to the presence of these interlocking and random support slices, regularity in the superposition structure, which hinders the flow of heat in one direction and its transfer to the other side, but rather it is distributed in different directions and is dispersed within the body of the model [17]. Worth mentioning, that the ability of insulation here depends on the ability of the micro-fibrous filaments of the strips to transmit thermal energy, as the elastic waves (phonons) are transmitted through the base material and the solid part of the support strips by the vibrational movement of the atoms, and when the phonons reach the capillary part of the support strips, they are obstructed in their movement. This is due to the difference in the structural formation of this medium because it has atoms and bonds that differ from the previous medium, which leads to lower thermal conductivity values and thus lower thermal conductivity [18. We notice through Fig. 3 that the thermal conductivity of the weight fraction (40%) has achieved the lowest values compared to the prepared ratios, the reason for this is due to the nature of the polymeric chain of unsaturated polyester, which is greatly restricted, and thus the ability of the sample to conduct a vibrational movement is less, hence, it is known that the thermal conductivity of the prepared samples depends on the amplitude of the vibration of the particles, thus we will obtain higher thermal insulation.

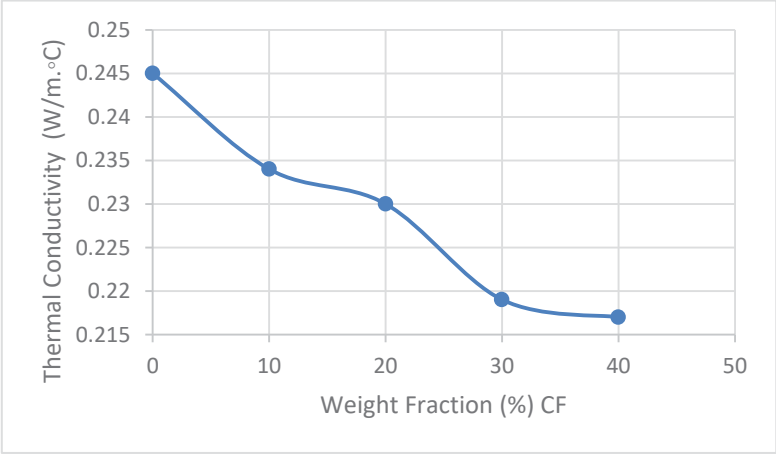

FIGURE 3. The relationship between the values of thermal conductivity and weight fraction.

CONCLUSIONS

Papyrus cane is a naturally abundant material, it has been proven that reed is revitalizing and a material that can be relied upon also. Ancestors have used it in different life applications. We tried here in this work to prove some of the properties scientifically. We came up with the following conclusions in this study:The mechanical properties (Hardness,Impact) of the prepared composites are improved as a result of adding reinforced papyrus cane slices, the thermal isolation of the prepared compositions increasing as a result of the addition of slices of papyrus cane, papyrus cane can be used in some structural applications that require good mechanical and thermal insulation properties.

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