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# EFFECTS OF FIBRE SURFACE TREATMENT ON THE MECHANICAL PROPERTIES OF UKAM FIBRE REINFORCED POLYESTER COMPOSITES

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## ABSTRACT

This study arises on the opportunities of using ukam fibre as reinforcement for polyester matrix composites. Cellulose fibres are generally incompatible with polymers due to their hydrophilic nature. It has been suggested that the compatibility of hydrophobic thermoplastic and hydrophilic cellulose fibres can be enhanced by the modification of polymeric matrix of the fibre surface. Silane, alkaline and acidic treatments were used to perform the surface modification on the ukam fibre. The results revealed that an improvement in the fibre adhesion characteristics of the ukam fibers increased its tensile modulus by 12%, 68% and 79% after acidic, silane and alkaline treatment respectively. The tensile strength of the fibre composites improved by 46% after silane and alkaline treatment and the 32% water absorption rate reduced by 23% after alkaline treatment for the composites with treated fibers, the bending strength improved from 199.1 Mpa to 238.9Mpa by 20%, modulus improved from 11.89Gpa to 14.69Gpa by 23% and compressive strength increased from 0.238Mpa to 0.2834Mpa. Based on the results obtained in this work it can be concluded that fibre surface treatment have significant impact on the mechanical properties of natural fibres.

Keywords: Ukam fibre, polyester, compression, tensile, bending and composites.

## INTRODUCTION

In recent years, thermoplastic materials are being increasingly used for various applications. Compounding thermoplastic polymers with natural fibres is already a well-established approach to obtain special composites with useful properties; fully biodegradable composites are a particular class of materials obtained by the combination of a biodegradable polymer matrix with natural fibres. Although these materials can offer very desirable properties, only a few studies concerning their characterization have been reported. One disadvantage of biodegradable polymers lies in their high cost; the use of low cost fillers results in an important reduction in the overall end product cost. On the other hand, the use of natural fibres in thermoplastic composites provides a further benefit because the strength and toughness of the plastic is markedly improved. Cellulose – based natural fibers are relatively of higher strength, lower density, cheaper, more abundant and renewable. Among cellular-based fibers, Ukam fibers are attractive due to their high strength and modulus. In addition, these fibers offer an excellent opportunity to utilize an abundant source of such materials available from nature.

Cellulose fibers are generally incompatible with polymers due to their hydrophilic nature. Therefore, several treatments to improve the fibre-matrix interfacial bonding have been proposed by previous workers. It has been suggested that the compatibility of hydrophobic thermoplastic and hydrophilic cellulose fibers can be enhanced by the modification of polymeric matrix of the fibre surface.

A more recent paper Singh, B.et al [1]* on the alkali treatment of cellulosic fibers reports the partial removal of lignin and hemicellulose that affect the tensile characteristics of the fibers. When the hemicellulose is removed, the interfibrillar region is likely to be less dense and less rigid.

Interface plays an important role in the physical and mechanical properties of composites. Joseph et al [2] reported the effect of various chemical treatments such as sodium hydroxide, Tetraoxosulphate (IV) acid and permanganate on the tensile properties of sisal fibre-low density polystyrene (LDPE) composites. Martin et al. [3] incorporated treated and non-treated sisal fibre and tire rubber and studied the mechanical and morphological behavior of the composites. In both works, it was found an improvement on the mechanical behavior of the composite, which was attributed to the chemical treatments performed on the fibers. These results encouraged a similar research on composites materials based on Ukam Fibre Reinforced polyester.

The aim of the present work is to assess the influence of chemical treatments carried out on Ukam fibre-reinforced polyester composites.

## MATERIALS AND METHOD

### Experimental Methods

### Materials

Twelve laminate specimens A, B, C, and D having untreated and treated with different surface treatment produced in hand lay-up under similar conditions. The length, width and thickness of each specimen being made to conform to same size for all test samples. The tests are carried out under three subheadings: Tensile, compression and Bending test conditions also are two: first, tests on the untreated specimen for each subheading for each specimen sample: tests on the various treated laminates.

Hounsfield (Monsanto) tensometer (Universal Testing Machine) (model No. S/N 8889) was used in the mechanical properties testing. The machine is more of a universal tester i.e. it has various interchangeable attachments for performing different tests. Such tests include tensile, bending, compression, etc. with the appropriate attachment for each test in place; force is applied manually by turning the fine loading arm at the right end of the machine clock-wise. This causes the operating screw to move rightwards, thus giving pushing or pulling effect, depending on the type of test performed. At the end of the machine is a precisely ground spring beam supported on rollers. The force is transmitted through a simple lever system to a mercury piston which displaces mercury into a uniform plain glass tube thus magnifying the beam deflection by approximately 160 and providing easy readable marks. The reading is indicated by sliding the cursor with the mercury convex head.

## Surface Treatment

The Extracted ukam stem fibers were treated with different chemicals to investigate the variation in the properties after treatment. These are:

- Treatment with a Silane solution.
- Treatment with sodium hydroxide (NaoH)
- Treatment with a dilute tetraoxosulphate (IV) acid.

## Silane Treatment

Extracted ukam stem fibers were allowed to react with silane by immersing in silane dissolved in a water-ethanol mixture for 3 h. This contains 60% ethanol and 40% water mixed well and allowed to stand for an hour. Ph of the solution was carefully controlled to bring about complete hydrolysis. The pH of the solution was 9.0. After that the solution is decanted and the fibre is dried. The Silane solution helps to dissolve out some impurities detracting to the resin. These impurities prevent good adhesion of the resin to the fibers.

## Alkali Treatment (NaOH)

For alkaline treatment, NaOH concentration of 5% was used as it has been reported improve the tensile strength and the flexural strength of the fibers [4]. The ukam fibers were soaked in 5% of NaOH for 24 hours at room temperature. After that, the coir fibers were rinsed and dried under the sun that the fibers were straight with no slacking, thus preventing intersection of fibers within the matrix. This helps to dissolve out the lignin on the fibre. The lignin has a way of interacting with the resin in such a way as to cause de-lamination in the molded work.

## Acid Treatment ($H_2S0_4$)

After the treatment with sodium hydroxide, the entire fibers were alkaline in nature and so a dilute acid was applied for the neutralization. The fibers were washed finally with water containing a few drops of $H_2S0_4$ to remove the final traces of alkali. Then the fibers were dried in an oven.

## DISCUSSION

The effect of different treatment methods on tensile properties of composites is described in Table 5-8. Silane solution treated and alkali treated ukam/polyester composites exhibit marginally better tensile strength than the untreated ukam/polyester composites. The alkali on fabrics may be expected to be less effective due to poor exposure of individual fibers to the alkaline solution. However, as is shown by tensile properties {1, 5, 6, 7, 8} that the tensile strength of jute composite (30% fiber content) to be 75% to 400% larger than the resin. Additionally, tensile properties of composites with alkali treated fibers have been shown to be comparable or up to 60% larger than the untreated jute composites.

When these results are compared with the data obtained in the case of jute composite, it can be concluded that there is a reasonable agreement in the qualitative variation of tensile properties of ukam/polyester composites. Alkali treatment improves the fiber surface adhesive characteristics by removing natural and artificial impurities and thereby producing a rough topography. In comparison with untreated fibers a rougher surface morphology was typical for the treated fibers because of the removal of lignin and hemi cellulose {1}. Silane treatment improves the fiber/ matrix interface by reducing the moisture content of the fibers. Bending properties of composite specimens and polyester are shown in Table 9-13.The polyester resin itself has high bending strength. The change in bending strength as well as bending modulus, due to reinforcement, is much smaller when compared to the change observed with tensile properties. Similar to the tensile properties, silane treatment of ukam fibers leads to superior bending properties when compared to untreated and alkali treated jute fabrics. The improved bending strength of silane treated fibers results from a change in the surface nature of the fibre by formation of a chemical bond between the substrate fibre and the modifier. Siloxane bond formation occurs between fibers and silane by dehydration condensation during the drying process. Silane forms a thick interphase which consists of chemically bonded silane and a physically adsorbed layer. The interfacial strength between the fibre and the matrix is increased when the chemically bonded silane reacts with the thermoplastic molecules [9].

Tables' 1-4 shows the effects of fabric treatment on inter laminar compressive strength and modulus of ukam/polyester composites. Unlike tensile and bending properties, alkali treatment of ukam fabrics leads to better inter laminar compressive strength than silane treatment or no treatment. Similarly, reinforcement with alkali treated fabrics leads to significant increase in the compressive modulus. The compressive modulus of other composite specimen is same or marginally higher than that of polyester. In summary, alkali treated jute fabric composites shows superior compressive strength and modulus.
Silane treated ukam fabric composites show superior tensile and bending properties. It should be noted that the mechanical properties of alkali treated jute fabric composites and silane treated ukam composites are not considerably different than each other.

## CONCLUSION

1. Based on the investigations made in this study, the following conclusions are drawn:
Successful fabrication of ukam plant fibre reinforced polyester composites is possible by simple hand-lay-up techniques. Such composites have adequate potential for applications when properly treated. Although they exhibit poor tensile and compressive strength their compressive strength performance shows significant improvement with the reinforcement of treated fibers.
2. The mechanical properties of the NaOH treated fiber composites showed the best performance in tensile strength test, while the silane solution treated composites gave the best result in compression strength test.
3. This study leaves wide scope for future investigations. It can be extended to newer composites using other reinforcing phases and the resulting experimental findings can be similarly analyzed.

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**APPENDIX:**
**RESULTS**
**Compressive Test**
**Specimen 1**

Material: Ukam plant fibre- reinforced polyester composites (Control sample)
Test piece: 20 by 20 by 20 mm
Area: $400mm^2$
Length: 20mm

**Table 1: Compressive Stresses and Strain of Ukam Plant Fibre Reinforced Polyester Resin Composites (Control Sample).**

| Load (N) | Deformation (mm) | Compressive stress (MPa) | Compressive strain x $10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 1000.00 | 0.50 | 2.50 | 25.00 |
| 2000.00 | 1.00 | 5.00 | 50.00 |
| 3000.00 | 1.25 | 7.50 | 62.50 |
| 4000.00 | 1.50 | 10.00 | 75.00 |
| 5000.00 | 1.75 | 12.50 | 87.50 |
| 5900.00 | 2.00 | 14.75 | 100.00 |
| 6900.00 | 2.25 | 17.25 | 112.50 |
| 7900.00 | 2.50 | 19.75 | 125.00 |
| 8900.00 | 2.75 | 22.25 | 137.00 |

**COMPRESSIVE STRESS**
**Specimen 2**

Material: Ukam plant fibre- reinforced polyester composites (NaOH)
Test piece: 20 by 20 by 20 mm
Area: $400mm^2$
Length: 20mm

**Table 2: Compressive Stresses and Strain of Sodium Hydroxide (NaOH) Treated Ukam Plant Fibre Reinforced Polyester Resin Composites**

| Load (N) | Deformation (mm) | Compressive stress (MPa) | Compressive strain x $10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 1100.00 | 0.63 | 2.75 | 31.25 |
| 2000.00 | 1.10 | 5.00 | 55.00 |
| 3000.00 | 1.25 | 7.50 | 62.50 |
| 4000.00 | 1.50 | 10.00 | 75.00 |
| 5000.00 | 1.88 | 12.50 | 94.00 |
| 6000.00 | 2.20 | 15.00 | 110.00 |
| 7000.00 | 2.50 | 17.50 | 125.00 |
| 8000.00 | 2.75 | 20.00 | 137.50 |
| 9000.00 | 3.00 | 22.50 | 150.00 |

## COMPRESSIVE TEST

### Specimen 3

Material: Ukam plant fibre- reinforced polyester composites (Silane Treatment)
Test piece: 20 by 20 by 20 mm
Area: 400mm$^2$
Length: 20mm

**Table 3: Compressive Stresses and Strain of Silane Solution Treated Ukam Plant Fibre Reinforced Polyester Resin Composites**

| Load (N) | Deformation (mm) | Compressive stress (MPa) | Compressive strain x $10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 1000 | 0.625 | 2.50 | 31.25 |
| 2200 | 1.25 | 5.00 | 55.00 |
| 3100 | 1.00 | 7.75 | 62.50 |
| 4100 | 1.25 | 10.25 | 75.00 |
| 5100 | 1.50 | 12.75 | 87.50 |
| 6100 | 1.75 | 15.25 | 100.00 |
| 7100 | 2.00 | 17.75 | 112.50 |
| 8000 | 2.25 | 20.00 | 118.75 |
| 9000 | 2.38 | 22.50 | 131.25 |

## COMPRESSIVE TEST
## Specimen 4

Material: Ukam plant fibre- reinforced polyester composites ($H_2$ $SO_4$ Sample)
Test piece: 20 by 20 by 20 mm
Area: 400mm$^2$
Length: 20mm

**Table 4: Compressive Stresses and Strain of Dilute Tetra Oxosulphate IV ($H_2SO_4$) acid Treated Ukam Plant Fibre Reinforced Polyester Resin Composites**

| Load (N) | Deformation (mm) | Compressive stress (MPa) | Compressive strain x $10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 1100.00 | 0.38 | 2.75 | 18.75 |
| 2000.00 | 0.75 | 5.00 | 37.50 |
| 3000.00 | 1.13 | 7.50 | 56.25 |
| 4000.00 | 1.63 | 10.00 | 81.25 |
| 5000.00 | 1.75 | 12.50 | 87.50 |
| 6000.00 | 2.00 | 15.00 | 100.00 |
| 7000.00 | 2.25 | 17.50 | 112.50 |
| 7900.00 | 2.50 | 19.75 | 125.00 |
| 8800.00 | 2.70 | 22.00 | 135.00 |

## TENSILE TEST
## Specimen 5

Material: Ukam plant fibre- reinforced polyester composite (Control sample)
Test piece: 20 by 5 by 300 mm
Area: 100mm$^2$
Length: 300mm

**Table 5: Tensile stresses and strain of the Ukam fibre Reinforced Polyester Resin Composites (control sample).**

| Load (N) | Extension (mm) | Tensile stress (MPa) | Tensile strain $x\ 10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 300.00 | 0.75 | 3.00 | 2.50 |
| 500.00 | 1.75 | 5.00 | 5.83 |
| 700.00 | 2.75 | 7.00 | 9.17 |
| 900.00 | 3.75 | 9.00 | 12.50 |
| 1100.00 | 4.75 | 11.00 | 15.83 |
| 1300.00 | 5.75 | 13.00 | 19.17 |

**TENSILE TEST**
**Specimen 6**

Material: Ukam plant fibre-reinforced polyester composites (NaOH Treatment)
Test piece: 20 by 5 by 300 mm
Area: $100mm^2$
Length: 300mm

**Table 6: Tensile stresses and strain of the Sodium Hydroxide (NaOH) Treated Ukam fibre Reinforced Polyester Resin Composites**

| Load (N) | Extension (mm) | Tensile stress (MPa) | Tensile strain $x\ 10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 400 | 1.00 | 4.00 | 3.30 |
| 800 | 3.00 | 8.00 | 10.00 |
| 1200 | 5.00 | 12.00 | 16.70 |
| 1600 | 6.50 | 16.00 | 21.7 |
| 2000 | 7.50 | 20.00 | 25.00 |
| 2400 | 8.75 | 24.00 | 29.20 |
| 2800 | 10.00 | 28.00 | 33.30 |
| 3200 | 11.00 | 32.00 | 36.70 |
| 3600 | 11.50 | 36.00 | 38.30 |

**TENSILE TEST**
**Specimen 7**

Material: Ukam plant fibre- reinforced polyester composites (Silane Treatment)
Test piece: 20 by 5 by 300 mm
Area: $100mm^2$
Length: 300mm

**Table 7: Tensile stresses and strain of the Silane Solution Treated Ukam fibre Reinforced Polyester Resin Composites**

| Load (N) | Extension (mm) | Tensile stress (MPa) | Tensile strain x $10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 100.00 | 1.25 | 1.00 | 4.17 |
| 300.00 | 2.75 | 3.00 | 9.17 |
| 500.00 | 4.00 | 5.00 | 13.33 |
| 800.00 | 6.00 | 8.00 | 20.00 |
| 1000.00 | 7.20 | 10.00 | 24.00 |
| 1400.00 | 8.75 | 14.00 | 29.17 |
| 1800.00 | 10.50 | 18.00 | 35.00 |
| 2100.00 | 11.25 | 21.00 | 37.50 |

**TENSILE TEST**
**Specimen 8**

Material: Ukam plant fibre- reinforced polyester composites ($H_2SO_4$ Treatment)
Test piece: 20 by 5 by 300 mm
Area: 100mm$^2$
Length: 300mm

**Table 8: Tensile stresses and strain of the Dilute Tetra Oxosulphate IV ($H_2SO_4$) acid Treated Ukam fibre Reinforced Polyester Resin Composites**

| Load (N) | Extension (mm) | Bending stress MPa | Tensile strain x $10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 600.00 | 2.00 | 6.00 | 6.67 |
| 700.00 | 2.31 | 7.00 | 7.70 |
| 800.00 | 2.63 | 8.00 | 8.77 |
| 900.00 | 2.94 | 9.00 | 9.80 |
| 1000.00 | 2.94 | 10.00 | 10.83 |

**BENDING TEST**
**Specimen 9**

Material: Ukam plant fibre- reinforced polyester composites (Control Specimen)
Test piece: 20 by 20 by 300 mm
Area: 400mm$^2$
Length: 300mm

**Table 9: Bending stresses and strain of Ukam fibre Reinforced Polyester Resin Composites (Control sample)**

| Load (N) | Deflection (mm) | Bending stress (MPa) | Bending strain x $10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 1000 | 0.75 | 2.50 | 37.50 |
| 2000 | 1.13 | 5.50 | 56.50 |
| 2900 | 1.50 | 7.25 | 75.00 |
| 3900 | 2.00 | 9.75 | 100.00 |
| 4800 | 2.38 | 12.00 | 118.75 |
| 5800 | 2.63 | 14.50 | 131.25 |
| 6100 | 2.70 | 15.25 | 135.00 |
| 6200 | 2.88 | 15.50 | 143.75 |

**BENDING TEST**
**Specimen 10**

Material: Ukam plant fibre- reinforced polyester composites (Silane Treatment)
Test piece: 20 by 20 by 300 mm
Area: 400mm$^2$
Length: 300mm

**Table 10: Bending stresses and strain of the Silane Solution Treated Ukam fibre Reinforced Polyester Resin Composites**

| Load (N) | Deflection (mm) | Bending stress (MPa) | Bending strain x $10^{-3}$ |
|---|---|---|---|
| 0.000 | 0.000 | 0.00 | 0.000 |
| 1000 | 0.750 | 2.50 | 37.50 |
| 2000 | 1.000 | 5.00 | 75.00 |
| 3000 | 1.875 | 7.50 | 93.75 |
| 4000 | 2.000 | 10.00 | 100.00 |
| 5000 | 2.4375 | 12.50 | 121.87 |
| 6000 | 2.875 | 15.00 | 143.75 |
| 7000 | 3.125 | 17.50 | 156.25 |
| 8000 | 3.625 | 20.00 | 181.25 |
| 8400 | 3.750 | 21.00 | 187.25 |

**BENDING TEST**
**Specimen 11**

Material: Ukam plant fibre- reinforced polyester composites (NaOH Treatment)
Test piece: 20 by 20 by 300 mm
Area: 400mm$^2$

Length: 300m

**Table 11: Bending stresses and strain of the Sodium Hydroxide (NaOH) Treated Ukam fibre Reinforced Polyester Resin Composites**

| Load (N) | Deflection (mm) | Bending stress (MPa) | Bending strain x $10^{-3}$ |
|---|---|---|---|
| 0.000 | 0.00 | 0.000 | 0.00 |
| 900 | 1.00 | 2.250 | 50.00 |
| 1900 | 1.50 | 4.750 | 75.00 |
| 2800 | 1.75 | 7.000 | 87.00 |
| 3800 | 2.12 | 9.500 | 106.25 |
| 4800 | 2.50 | 12.00 | 125.00 |
| 5800 | 2.80 | 14.50 | 140.00 |
| 6800 | 3.13 | 17.00 | 156.25 |
| 7800 | 3.50 | 19.50 | 175.00 |
| 8700 | 3.75 | 21.75 | 187.50 |

## BENDING TEST

## Specimen 12

Material: Ukam plant fibre- reinforced polyester composites ($H_2 SO_4$ Treatment)

Test piece: 20 by 20 by 300 mm

Area: 400mm$^2$

Length: 300mm

**Table 12: Bending stresses and strain of the Dilute Tetra Oxosulphate IV ($H_2SO_4$) acid Treated Ukam fibre Reinforced Polyester Resin Composites**

| Load | Deflection (mm) | Bending stress MPa | Bending strain x $10^{-3}$ |
|---|---|---|---|
| 0.00 | 0.00 | 0.00 | 0.00 |
| 1000 | 1.00 | 2.50 | 50.00 |
| 2000 | 1.50 | 5.00 | 75.00 |
| 3000 | 2.00 | 7.50 | 100.00 |
| 4000 | 2.32 | 10.00 | 116.00 |
| 5000 | 2.64 | 12.50 | 132.00 |
| 5900 | 2.88 | 14.75 | 144.00 |
| 6900 | 3.25 | 17.25 | 12.50 |
| 7900 | 3.50 | 19.75 | 175.00 |
| 8900 | 4.00 | 22.75 | 200.00 |
| 9100 | 4.375 | 22.75 | 218.75 |