# Experimental Testing of Composite Panels Reinforced with Cotton Fibers

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*Abstract*— A research project to develop composite panels reinforced with cotton fibers. The primary aim of the project is to examine the mechanical properties of such panels for use in secondary structural members such as wall or door systems. The use of natural fibers such as cotton, flax or sisal fibers has the primary advantage of being eco-friendly, low cost and low weight compared to glass fibers on the expense of lower structural properties. This project presents results from experimental work on composite plates made from polyester resin reinforced with cotton fibers, with special attention given to the effect of the fiber type on the structural properties of the plates. The results from this study showed that the structural performance of cotton fiber composites is satisfactory for structural parts with low requirements, such as wall panels or doors.

***Keywords:*** Biodegradable Composites, Cotton Fibers, Eco-Friendly Materials

## I. Introduction

This research study revealed two major findings associated with the fabrication and the performance of composite plates reinforced with cotton fibers. It showed that specimens with treated or untreated cotton fibers (woven) have similar property values with specimens reinforced with cotton textile (oriented fibers). It also showed that if moisture is absorbed, the material strength is significantly reduced for woven fiber coupons, while for cotton textile the strength is similar or even higher than dry coupons strength.

## II. Methodology

### A. *Methodology of the Project Work*

- Fabrication of cotton composites
- Evaluation of cotton form composites
- Comparison of Experimental result.

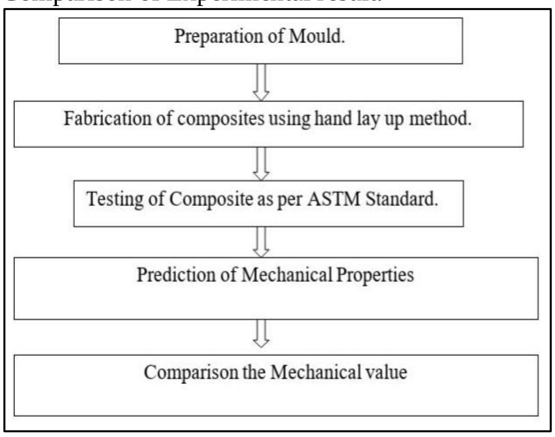


Fig. 1: Flow chart of project work

## III. Experimental Procedure

### A. *Material Selection*

1) Cotton fiber

Cotton fibers of various types have been considered. More specifically, three categories of cotton fibers have been examined, namely,

- Untreated fibers,
- Treated fiber
- Cotton textile (Figures 1-3)

2) Polyester resin
3) Accelerator

### B. *Material preparation*

| Materials | Plate -1 | Plate-2 | Plate-3 |
|---|---|---|---|
| 1) Cotton – untreated fibers, (level, 1) – treated fibers (level, 2) – cotton textile (level, 3) | 30g | 102g | 184g |
| 2) Polyester resin | 929 g | 2250g | 1619g |
| 3) Accelerator | 0.29 g (0.03% of the resin). | 0.68 g (0.03% of the resin) | 0.49 g (0.03% of the resin) |
| 4) Catalyst | 7 g | 20.25 g | 14.57 g |

Table 1: Levels of Produced for Cotton foam composites

### C. *The GROSS Dimensions of the Coupons pre – Paredes for Tensile Testing*

- 250 × 25 × 5 mm for untreated cotton fibers;
- 250 × 25 × 10 mm for treated cotton fibers; and
- 250 × 25 × 6 mm for cotton textile, while the dimensions of the coupons prepared for three point bending were:
- 100 × 25 × 10 mm for treated cotton fibers; and
- 100 × 25 × 6 mm for cotton textile. No bending tests have been conducted for untreated cot- ton fiber composites.

Fig. 2: Plate specimen preparation.

 

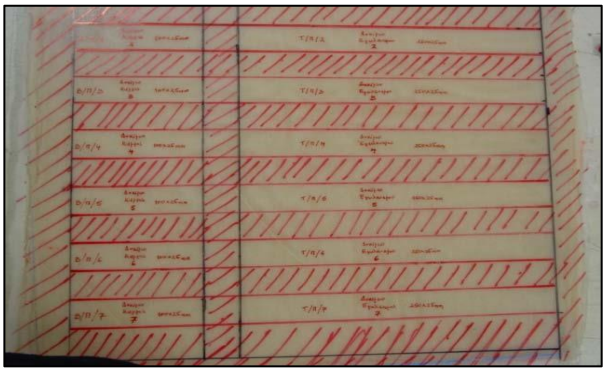

Fig. 3: Coupon marking.

In addition, two specimens with dimensions 250 × 25 × 10 mm with treated cotton fibers and two specimens with dimensions 250 × 25 × 6 mm with cotton textile were tested in tension after remaining 21 days in pure water at 23˚C.

## IV. RESULTS AND DISCUSSION

1) Nineteen plate specimens were tested under tensile load, where three different types of cotton fibers have been considered, i.e. untreated cotton, treated cotton, and cot- ton textile.
2) These correspond to five specimens with code T/U (tension/untreated), seven specimens with code T/T (tension/treated), and seven specimens with code T/C (tension/cotton-textile), respectively.
3) In one T/U specimen, premature failure was observed in the grip area, thus this specimen has been excluded and the results dis-regarded.
4) The remaining four T/U specimens were successfully tested in tension up to failure. The exact dimensions of the specimens are listed in Table 3.
5) The observed mode of failure was fracture as shown in Figure 4.
6) The stress-strain curves for the four T/U specimens shown in Figure 5 were used to obtain the modulus of elasticity $E_s$ in tension.
7) A summary of the test results is given in Table 1 according to ISO 527-1: 1993 [15] and to ISO 527-4: 1997 [16].
8) The same procedure has been followed for the seven T/T and T/C specimens and corresponding results were obtained as shown in Figures 6 and 7.In both test groups, specimens T/T 1 through 5 were tested in dry

| Specimen | $E_{ini}$ [MPa] | $E_{tan}$ [MPa] | $E_{sec}$ [MPa] | dimensions |
|---|---|---|---|---|
| T/U 2 | 784.12 | 808.38 | 713.96 | 24.98 × 5.18 |
| T/U 3 | 1323.03 | 812.18 | 750.02 | 25.58 × 5.89 |
| T/U 4 | 1508.71 | 847.13 | 855.55 | 25.29 × 5.86 |
| T/U 5 | 1344.44 | 825.85 | 771.65 | 25.30 × 5.88 |

Table 3: Tensile properties of untreated cotton coupons.

Fig. 4: Failure mode of plate coupons in tension.

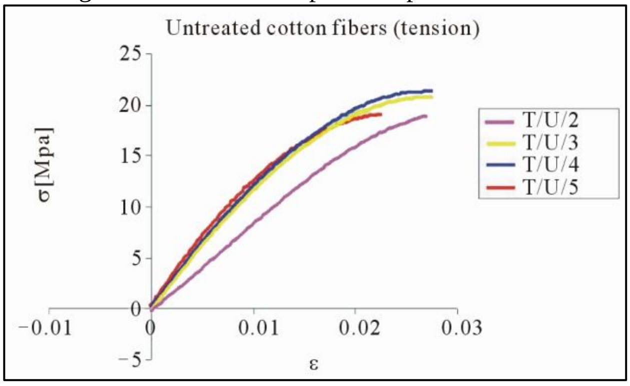


Fig. 5: Stress-strain curves for untreated cotton fiber specimens in tension.

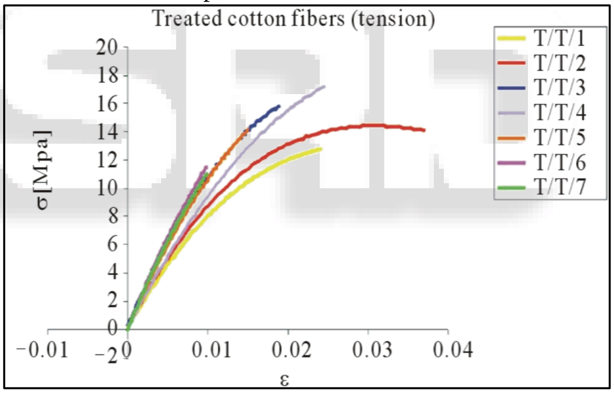


Fig. 6: Stress-strain curves for treated cotton fiber specimens in tension.

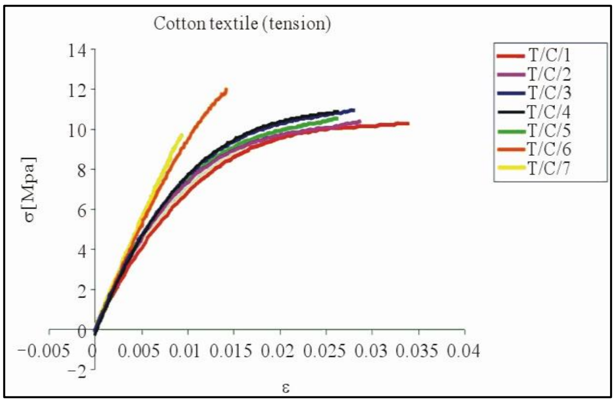


Fig. 7: Stress-strain curves for cotton textile specimens in tension.

State, while specimens T/T 6 and T/T 7 were tested after remaining in pure water for 21 days in pure water at 23˚C. The same holds for cotton textile specimens T/C 1 through 5 (dry) as well as for specimens T/C 6 and T/C 7 (with moisture absorption). A summary of the T/T and T/C test results is also given in Tables 4 and 5 respectively. From the tensile experimental results, we can extract the following mean values according to ISO 527-1: $E_t$ = 1240.07 MPa for untreated cotton fiber specimens, $E_t$ = 1160.50 MPa for treated cotton fiber specimens and $E_t$ = 1101.58 MPa for cotton textile specimens. Also, after 21 days in pure water it was found $E_t$ = 1476.91 MPa for treated cotton fiber specimens and $E_t$ = 1093.82 MPa for cotton textile specimens

In a second stage, ten plate specimens were tested in 3-point bending, where two different types of cotton fibers have been considered, i.e. treated cotton, and cotton textile. These correspond to five specimens with code B/T (bending/treated) and five specimens with code B/C (bending/cotton-textile), respectively. All B/T and B/C specimens were successfully tested in 3-point bending up to failure. The observed mode of failure was fracture as shown in Figure 8 a slippage within acceptable limits was observed for the B/T/2 specimen, see Figure 9. The exact dimensions of the specimens are listed in Tables 6 and 7 respectively.

| Specimen | $E_{ini}$ [MPa] | $E_{tan}$ [MPa] | $E_{sec}$ [MPa] | dimensions |
|---|---|---|---|---|
| T/T 1 | 1022.12 | 504.52 | 527.24 | 25.60 × 10.15 |
| T/T 2 | 1112.21 | 310.03 | 386.13 | 25.39 × 10.67 |
| T/T 3 | 1298.63 | 930.15 | 940.12 | 25.57 × 10.84 |
| T/T 4 | 1283.58 | 823.23 | 815.15 | 26.64 × 10.17 |
| T/T 5 | 1086.11 | 696.63 | 696.15 | 26.64 × 10.17 |
| T/T 6 | 1508.24 | 1075.82 | 1162.35 | 23.84 × 9.96 |
| T/T 7 | 1445.82 | 1031.46 | 1113.22 | 25.02 × 9.91 |

Table 4: Tensile properties of treated cotton coupons.

| Specimen | $E_{ini}$ [MPa] | $E_{tan}$ [MPa] | $E_{sec}$ [MPa] | dimensions |
|---|---|---|---|---|
| T/C 1 | 962.29 | 204.57 | 302.10 | 25.21 × 6.48 |
| T/C 2 | 1116.82 | 242.83 | 362.90 | 54.98 × 6.51 |
| T/C 3 | 1133.23 | 285.30 | 393.31 | 24.97 × 6.42 |
| T/C 4 | 1169.21 | 325.87 | 413.25 | 24.76 × 7.04 |
| T/C 5 | 1126.33 | 298.63 | 404.12 | 24.20 × 7.09 |
| T/C 6 | 1108.83 | 979.63 | 843.57 | 24.84 × 6.90 |
| T/C 7 | 1078.84 | 1129.88 | 1043.26 | 25.58 × 6.61 |

Table 5: Tensile properties of cotton textile coupons.

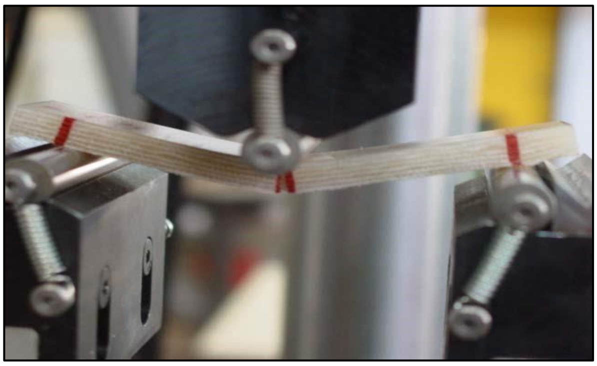

Fig. 8: Failure of coupons in 3-point bending.

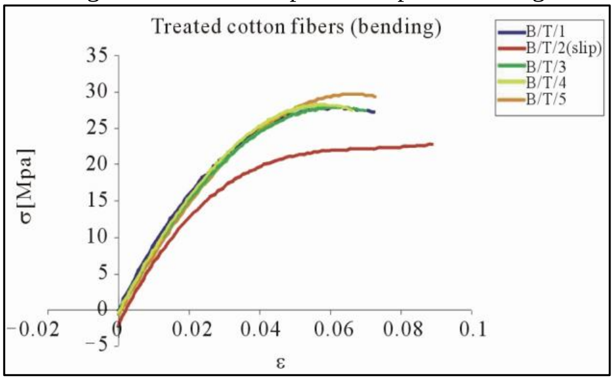


Fig. 9: Stress-strain curves for treated cotton fiber specimens in 3-point bending.

The stress-strain curves for the five B/T and the five B/C specimens shown in Figures 10 and 11 were used to obtain the modulus of elasticity $E_b$ in bending. A summary of the test results is given in Tables 6 and. 7 respectively, with corresponding mean values $E_b$ = 877.05 MPa and $E_b$ = 1001.38 MPa.

In Table 8 one can see the properties of natural and manmade fibers and typical resins.

| Specimen | $E_b$ [MPa] | □$_{max}$ [mm] | dimensions |
|---|---|---|---|
| B/T 1 | 894.49 | 7.85 | 26.28 × 9.71 |
| B/T 2 | 772.50 | 8.41 | 25.56 × 11.00 |
| B/T 3 | 890.13 | 7.12 | 25.96 × 10.45 |
| B/T 4 | 947.69 | 6.95 | 26.47 × 10.02 |
| B/T 5 | 880.42 | 7.28 | 25.34 × 10.48 |

Table 6: Bending properties of treated cotton coupons.

| Specimen | $E_b$ [MPa] | □$_{max}$ [mm] | dimensions |
|---|---|---|---|
| B/C 1 | 876.74 | 8.01 | 26.11 × 6.32 |
| B/C 2 | 1021.63 | 6.27 | 25.37 × 6.30 |
| B/C 3 | 1059.73 | 5.99 | 25.69 × 6.62 |
| B/C 4 | 1077.11 | 6.02 | 26.81 × 6.85 |
| B/C 5 | 971.67 | 4.83 | 26.10 × 7.06 |

Table 7: Bending properties of textile cotton coupons.

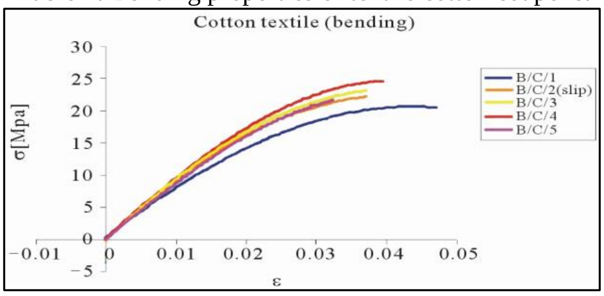


Fig. 10: Stress-strain curves for textile cotton specimens in 3-point bending.

## V. CONCLUSIONS

The scientific world is facing a serious problem of developing new and advanced technologies and methods to treat solid wastes, particularly non-naturally-reversible polymers.

The processes to decompose those wastes are actually not cost-effective and will subsequently produce harmful chemicals. Owing to the above ground, rein- forcing polymers with natural fibers is the way to go.

In this paper, most of the natural fibers mentioned were plant-based but it should be noted that animal fibers like cocoon and can be used to replace the conventional fibers such as glass, carbon in reinforcing plastic materials. A major drawback of using natural fibers as reinforcement in plastics is the incompatibility, resulting in poor adhesion between natural firs and matrix resins, subsequently lead to low tensile properties.

In order to improve fiber-matrix interfacial bonding and enhance tensile properties of the composites, novel processing techniques, chemical and physical modification methods are developed. Also, it is obviously clear that the strength and stiffness of the natural fiber polymer composites is strongly dependent on fiber loading. The tensile strength and modulus increase with increasing fiber weight ratio up to a certain amount. If the fiber weight ratio increases below optimum value, load is distributed to more fibers, which are well bonded with resin matrix resulting in better tensile properties. Further increment in fiber weight ratio has resulted in decreased tensile strength as de- scribed in the main text. Mathematical models were also found to be an effective tool to predict the tensile proper- ties of natural fiber reinforced composites.

## REFERENCES

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