# EVALUATION OF MECHANICAL PROPERTIES OF CALOTROPIS GIGANTEASTEM FIBER-REINFORCEDCOMPOSITE MATERIAL

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**Abstract**- The awareness in natural fiber reinforced composite materials is rapidly growing both in terms of industrial applications and fundamental research. Natural fibers have recently become attractive to researchers, engineers and scientists as an alternative reinforcement for fiber reinforced polymer (FRP) composites. Owing to their availability, low cost, good mechanical properties, high specific strength, non-abrasive, eco-friendly and bio-degradability characteristics, they are exploited as a replacement for the conventional fiber, such as aramid and carbon. Several chemical modifications are employed to improve the interfacial matrix-fiber bonding resulting in the enhancement of mechanical properties of the composites.Calotropisgigenteais a species of calotropis, native to Cambodia, Indonesia, Malaysia, Philippines, Thailand, Sri Lanka, India, China, Pakistan, Nepal, and tropical Africa. Itsfiber was extracted manually from the plant's stem and treated chemically.The samples have been prepared by varying the fiber percentages and epoxy resin. Hybrid Composites are fabricated using raw calotropisgigenteastem fiber/glass with varying fiber weight percent5:0 to 5:3 weight by using hand layup method. The fabricated specimens were cut as rectangular pieces according to the ASTM standards for conducting all tests. The purpose of this paper is to assess the tensile strength, impact strength, density and hardness of hybrid calotropisgigantea stem fiber reinforced composites. Results illustrates that the use of less than 12 gm glass fiber in this composite increases tensile strength, impact, density and hardness.

**Keywords**- Calotropisgigentea, Stem fiber, Composites, Mechanical properties, Epoxy resin.

## I. INTRODUCTION

Sustainable development is progressively becoming a priority of governments and business sectors which is driven by growing environmental attentiveness. Much academic research explores new ways to create greener and environmentally friendlier materials for variety of applications ranging from aeronautic, automotive and construction industry. Natural fibers are renewable resources in many developing countries of the world. The interest in natural fiber-reinforced composite materials is rapidly growing their industrial applications and fundamental research [1, 2].

Calotropisgigenteais drought resistant, salt tolerant to a relatively high degree, grows wild up to 900 metersthroughout the country [3] and prefers disturbedsandy soils with mean annual rainfall: 300-400 mm.Through its wind and animal dispersed seeds, it quicklybecomes established as a weed along degradedroadsides, lagoon edges and in overgrazed nativepastures. It has a preference for and is often dominant in areas of abandoned cultivation. It is assumed to be anindicator of over cultivation [4].It is one of the few plants not consumed bygrazing animals [5].The bark is thick, rough and corky and ayellow-brown colour; twigs are green andfleshy and may have a covering of tomentum(white fur like hairs).The stem of calotropisgigentea is a source of natural cellulosic bastfibres wherein the commercially valuable properties like cellulose content, fiber strength and fiber elongation are found to be intermediate between that of cotton and linen. Other than high tensile and abrasive strength, fibers from calotropisgigenteapossess more weight per square meter than the cotton fibers. Since calotropis is a wildly growing shrub in major parts of India, its use as a source of excellent cellulose fibers might have enormous economicalimplications. This fiber has enough potential for replacing or supplementing other fibrous raw materials as reinforcing agent.Calotropis yields a durable fiber (commercially known as Bowstring of India) useful for ropes, carpets, fishing nets, and sewing thread.

The mechanical behaviour of a fiber-reinforced compositebasically depends on the fiber strength and modulus, matrixstrength, the chemical stability and the interface bondingbetween the fiber/matrix to enable stress transfer [6].Polyester matrix based composites have been widely usedin marine applications, in marine field the water absorptionwas an important parameter in degradation of polymercomposites. The different mechanisms used to identify thedegradation of material such as initiation, propagation,branching and termination [7].

Calotropisbast fiber is one of these types that have been extracted manually up to now. Some research article investigates the effect of new decorticator machine on properties of extracted fiber and compared with separated fibers manually. The mentioned decorticator machine was able to extract bast fiber without shattering stems and flowing latex. Some studied properties were morphological characterization, tensile properties (tensile strength, Young's modulus and strain) and density of fiber. The results indicated that machinery extraction method had no significant effect on the fiber morphology[8].

Calotropis stem has valuable fibers with various applications in the industry. Since extraction found to be more complex, extraction machine with the capacity of 2 kg/h based on dried mass of barks and fibers was developed [9]. Calotropisgigentea fruit fiber reinforced composites was prepared and mechanically tested. The tensile strength increased with increase in fiber content. Further, the wear behavior of the calotropis gigentea fruit fiber composite were studied with increase in fiber content [10].

Several chemical modifications are employed to improve the interfacial matrix-fiber bonding resulting in the enhancement of mechanical properties of the composites. They determined the mechanical and machining characteristics of the calotropis gigentea fruit fiber composites which are found good [11].Study on the mechanical properties of calotropisgigantean compositesrevealed very less than the flax fiber composites. The suitable coupling agent and itsconcentration can be used out to improve its mechanical properties [12]. The feasibility of applying two kinds of mudar (Calotropis gigantea) fibers, namely bark fibers and seed fibers, as an alternative raw material for fiber-reinforced composite (FRC) was investigated. The mechanical properties of the mudar bark fibers are: tensile strength 381 MPa, strain at break 2.1% and Young's modulus 9.7 GPa. In general, both types of fibers have enough potential for replacing other fibrous raw materials as reinforcing agent [13].

Theobjective of this work is to examine the fiber extraction from calotropisgigenteastem by retting method and the use of these fibers as reinforcement in polymer matrix. Calotropisgigenteastem fiber reinforced composites at various percentage volume of fiber are fabricated, tested and characterized to evaluate their mechanical properties.

## II. EXPERIMENTAL DETAILS

### 2.1. Materials and Procedures

Calotropis plant is generally known as “Milkweed”, which has lots of medical applications. Calotropisbastfiber was extracted manually from the plant’s stem by retting process to reinforce in the polymeric matrix, calotropis plant, andcalotropisbastfibersare shown in **Fig.1, 2**.The extraction of fibers involves retting process followed by decorticating. The stems of calotropiswere cut at their base and immersed in water for one day. Later, they are removed; the fibers were stripped from the stalks byhand, washed and dried in the sun. After drying, any unnecessary matter that may still be adhering to them was removed manually. The extracted fibers are treated with5% aqueous NaoH solution and used for composite making after drying.Alkaline treatment or mercerization is one of the most used chemical treatments of natural fibers when used to reinforce thermoplastics and thermosets. The important modification done by alkaline treatment is the disruption of hydrogen bonding in the network structure, thereby increasing surface roughness. This treatment removes a certain amount of lignin, wax and oils covering the external surface of the fiber cell wall, depolymerises cellulose and exposes the short length crystallites.

**Fig.1.Calotropis gigentea Plant**

**Fig.2.Calotropis gigentea fiber after mercerization**

Addition of aqueous sodium hydroxide (NaoH) to natural fiber promotes the ionization of the hydroxyl group to the alkoxide. In alkaline treatment fibers are immersed in NaoH solution for the given period of time. Normality of NaoH solution is 0.5N.

Polymers generally act as a good binder for fibers as observed from the literature review. Availability has provoked Epoxy as the matrix material for this investigation. Epoxy resins are the most commonly used thermoset plastic in polymer matrix composites. Epoxy resins are a family of thermoset plastic materials which do not give off reaction products when they cure and so have low cure shrinkage. They also have good adhesion to other materials, good chemical and environmental resistance, good chemical properties and good insulating properties. The epoxy resins are generally manufactured by reacting epichlorohydrin with bisphenol.

#### 2.1.1. HAND LAY-UP TECHNIQUE

The process is studied with a standard Response surface methodology design called a Central Composite Design (CCD) with three variables; eight cube points, four central points, six axial points and two center points in axial, in total 20 runs. Total numbers of experiments conducted with the combination of parameters are presented in Table 1. The CCD is used since it gives a comparatively accurate prediction of all responsevariable averages related to quantities measured during experimentation [14]. The response variables investigated are the Tensile strength, Impact strength, Hardness and density.The compositions of samples are given in **Table 1.**

**Table 1:Central composite experimental design**

| Sample | Calotropis Fiber, gm | Epoxy resin gm | Glass Fiber gm |
|---|---|---|---|
| 1 | 30 | 165.5 | 0 |
| 2 | 30 | 165.5 | 4.5 |
| 3 | 13.18 | 165.5 | 4.5 |
| 4 | 20 | 171 | 0 |
| 5 | 20 | 160 | 9 |
| 6 | 40 | 171 | 0 |
| 7 | 30 | 174.75 | 4.5 |
| 8 | 40 | 160 | 0 |
| 9 | 30 | 165.5 | 4.5 |
| 10 | 40 | 171 | 9 |
| 11 | 30 | 165.5 | 4.5 |
| 12 | 30 | 165.5 | 12.06 |
| 13 | 20 | 160 | 0 |
| 14 | 30 | 165.5 | 4.5 |
| 15 | 20 | 171 | 9 |
| 16 | 30 | 165.5 | 4.5 |
| 17 | 30 | 156.25 | 4.5 |
| 18 | 40 | 160 | 9 |
| 19 | 46.81 | 165.5 | 4.5 |
| 20 | 30 | 165.5 | 4.5 |

Hand lay-up is the simplest and oldest open molding method of the composite fabrication processes. It is a low volume, labor intensive method suited especially for large components, such as boat hulls. Glass or other reinforcing mat or woven fabric or roving is positioned manually in the open mold, and resin is poured, brushed, or sprayed over and into the glass plies. Entrapped air is removed manually with squeegees or rollers to complete the laminates structure. Room temperature curing epoxies and polyester are the most commonly used matrix resins. Curing is initiated by a catalyst in the resin system, which hardens the Fiber reinforced resin composite without external heat. For a high quality part surface, a pigmented gel coat is first applied to the mold surface.

20 composite sampleswere prepared with the dimension of 120 mm x 30 mm x 3 mm usingthe molding pattern prepared in mild steel. Wax is applied on all surfaces of the mould, which helps to remove the pattern, and to takeout the fabricated composite material easily.

As an initial step, catalyzed resin applied on the inner edges of the molding pattern, this step helps the pattern would be fixed. The measured fiber is spreaded on the moulding box. Then epoxy resin is poured on the fiber and it is dipped within the fiber inside the moulding box. Thus 20samples are prepared through hand lay-up method, the mixture should be spread over all area of the pattern evenly and before pouring the mixture into the mold pattern, the overhead projector (OHP) sheet and wax is used to prevent the sticking of polymers and to get good surface finish. For this hand lay-up method 5 kN load is applied in compression moulding machine and the whole set up was let it as for 24 hours. The obtained composite plate is shown in **Fig.3.**

**Fig.3. Calotropisgigentea stem fiber reinforced compositeplate**

A 3 mm thick plate was made from the epoxy and hardener taken in the ratio of 100 and 10 parts by weight respectively. Then the moulding box was loaded with the matrix mixture of calotropis and glass fibre with varying percentage for respective samples. After curing, the plate was removed from the moulding box with simple tapering and it was cut into samples. A Hacksaw blade was used to cut each material into smaller pieces, for various experiments. Composite specimen for tensile test is shown in **Fig.4.**

**Fig.4. Composite specimen for tensile test**

## III. RESULTS AND DISCUSSION

### 3.1.Tensile Test

The tensile test was performed on all the samples as per ASTM D3039-76 teststandards. The tension test is generally performed on flat specimens. A uni-axial load is applied through the ends. The

ASTM standard test recommends that the specimens with fibers parallel to the loading direction should be 11.5 mm wide.

Length of the test section should be 120 mm. The test-piece used is having dimensions according to the standards.Among these composites there is a considerable increase of tensile strength peak load 276.49kg/cm²for the hybrid sample-12as the percentage of glass fibre increases to 12 gm. The experiment was conducted on both samples of calotropis /glass combinations.Three number of specimens were tested for each combination and the average was considered for analysis.5 sample test resultsare given in **Table 2.**

**Table 2: Test results**

| Sample | Tensile strength kg/cm² | Impact strength Joules | Hardness HV | Density g/cc |
|---|---|---|---|---|
| 4 | 260.78 | 3.321 | 87.2 | 1.005 |
| 12 | 276.49 | 6.559 | 95.5 | 1.012 |
| 6 | 272.55 | 4.563 | 92.3 | 1.013 |
| 11 | 275 | 6 | 94.9 | 1.00 |
| 10 | 272.12 | 4.67 | 93.1 | 1.01 |

Tensile tested specimensare given in **Fig. 5, 6.**

**Fig.5. Tensile tested composite sample–12**

**Fig.6. Tensile tested composite sample - 10**

### 3.2. Impact test

Analog Izod/charpyimpacttester is used fortestingtheimpactproperties ofcalotropis fiberreinforced composite specimen.Theequipmentwithaminimum resolutiononeachscaleof0.02J,0.05J, 0.1Jand0.2Jrespectively.Fourscalesandcorresponding hammers (R1,R2,R3,R4) areprovidedforalltheaboveworking ranges.

TheImpactenergy of 20gmweight percentage of calotropisgigentea stemfiber reinforcedcomposites (Sample 12)is6.559 J which is greater thanother samples due to increase in glass fiber content.**Fig.7** shows thetestedimpact strength sample-6.

**Fig.7. Impact tested composite sample - 6**

### 3.3. Hardness test

Hardness is defined as the ability of a material to resist plastic deformation.The test samples with dimensions of 20mm x 20 mm x 3 mm are used for the hardness test conducted on vicker'shardness testing machine.The proposed composite provides high hardness as 95.5 HV for sample 12(increasing the composition of fiber from 20 gm to 30 gm and glass fiber to 12 gm).

### 3.4. Density test

The density of a substance is the relationship between the mass of the substance and how much space it takes up. The test samples with dimensions of 20 mm x 20 mm x 3 mm was used and the density test was conducted on density tester equipment.**Fig.8** shows the density test samples.

**Fig.8. Density tested specimens**

## CONCLUSIONS

To explore new natural materials with high efficiency results in continuous invention.The increase in fiber content gradually increases tensile strength,impact strength and hardness.The highest value of tensile strength forcomposites containing 30gmcalotropis gigantea stem fiber was obtained with addition of 12 gmglass fiber. The above comparison clearly shows the usage of less than 12 gm glass fiber which in turn increases tensile strength, impact, density and hardness. The Izod impact strength significantly decreased to 3.321 J (sample 4) when the glass fiber content is decreased. The resulting properties reveal that composites with goodstrength could be successfully developed using calotropis gigantea stem fiber.

It is observed from the figure that the surface looks smooth and lesser void content as shown on the upper surface of the composite sample. This lesser void is actually caused by an excess of resin squeezed during solidification, which causes shortage of resins between two adjacent fibers. Despite the fact this study produce a new natural fiber into the research but has some limitations, this study considered the weight proportion ratio of fiber to composite by 50% each, hence in future this can be extended with various composition using glass fibers.

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