# Experimental Investigation of Hygrothermal Aging on Mechanical Properties of Hybrid Fiber Reinforced Polymer Composites

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**Abstract -** *The natural fibers are hydrophilic in nature and environmental degradation of their composites takes place during the service. In the present study the effect of the hygrothermal aging on tensile and flexural properties of hemp and sisal /epoxy Hybrid fiber reinforced polymer composites are investigated. The composites are fabricated by hand layup with weight percentages of 0, 15, 30, and 45%. After hygrothermal aging an attempt has been made to study the variations in tensile properties, flexural properties of the prepared composites. The percentage of moisture uptake increased as the weight percentage of fibre is increased due to the high cellulose content. The present studies showed that exposure to the hygrothermal environment like saline water leads to increase in the maximum tensile and flexural strength.*

*Key Words:* **hybrid composites, natural fibers, hygrothermal aging, water absorption, mechanical properties.**

## 1. INTRODUCTION

Composite materials are often presented as materials of the future. They provide various mechanical functions that can be grouped according to their life, safety and ease in design. Due to increased environmental awareness, demand for green products and to stop the effect of global warming there is the need to replace the synthetic material with the natural material. However, the use of these materials in composites requires the knowledge of their mechanical behaviour, under both static and dynamic conditions. In the majority of cases, the industrial demand is limited to knowledge of the behaviour of a structure under a spectrum of stress and environment, which represents the best conditions in service. Natural fibers have the advantages of low density, low cost and biodegradability. However, the main disadvantage of natural fibers is the relative high moisture absorption.

As natural fibers are easily available, remarkably cheap, eco-friendly, renewable, it is a desired option for the replacement of Synthetic fibers [1]. In order to utilize the natural fibers there is a need to investigate their properties . The effect of fiber length and weight percentage of banana and sisal fiber composites on mechanical properties are used to determine the optimum fiber length and wt. percentage [2]. In the report [3] the mechanical properties, on water absorption of Kenaf/Kevlar hybrid composites at different volume fractions before and after water aging were studied. In the earlier literature on natural fibers, noted that dry sisal/phenolic composites had more the tensile strength than the humid sisal/ polyurethane [4]. It was also observed that the effect of the addition of sisal fiber to banana fiber composites results in the improved mechanical and moisture absorption property [5]. The mechanical properties of E-glass-polyester matrix composites upon immersion in water and lubricated oil were reduced [6]. The effect of fiber orientation of E-glass/epoxy and carbon/epoxy composites, on the phenomenon of humidity diffusion was evaluated in the study [7]. The effect of void contents on long term hygrothermal behaviors of glass/epoxy laminates for different autoclave pressures was determined [8]. The effect of hygrothermal aging on flexural properties of glass/epoxy, glass linseed oil and castor oil was studied.[9]. In the report [10] mechanical behavior of mixed short fiber/woven composite laminates upon hygrothermal aging in different media, different durations and different temperatures was investigated. The tensile properties of banana fiber epoxy composites was investigated under hygrothermal conditions [11]. The hybrid composite sisal/hemp reinforced with epoxy matrix has been developed by compression moulding technique. Morphological examinations to analyze the interfacial characteristics, internal structure and fractured surfaces by using scanning electron microscope [12]. The diffusion coefficient of water absorption and maximum moisture content were calculated for Kenaf/Kevlar and jute Kevlar laminates with epoxy resin [13].

In the present study the effect of aging in saline water on mechanical properties of sisal/hemp hybrid fiber reinforced polymer composites were determined.

## 2. MATERIAL AND METHODS

### 2.1 Materials:

Sisal and Hemp fibers were used as reinforcement materials, (see in fig.1, 2) were procured from SL Groups, Vijayawada. The low temperature Epoxy resin (MY740) and corresponding hardener-Amine based (HY 941) (see fig.3) were used to fabricate hybrid composite. The matrix material was prepared epoxy and hardener at a ratio of 10:1.

**Fig.1** Hemp fibers

**Fig.2** Sisal fibers


**Fig.3** Matrix

### 2.2 Fiber Surface Treatment:

Washed and dried sisal, hemp fibers were taken in separate trays, to these trays 10% NaOH solution was added, and the fibers were soaked in the solution for 10 hours. The fibers were then washed thoroughly with water to remove the excess of NaOH sticking to the fibers. Treated sisal and hemp fibers were dried in sun light for two days before using as reinforcement in the synthesis of composite. This treatment was used to remove the bacteria in fibers.

### 2.3 Preparation of Hybrid Composites:

A simple compression moulding method was used to prepare the hybrid composites (sisal and hemp fibers). Hydraulic pressing machine was used to fabricate the hybrid composite specimens. The mould was prepared according to the ASTM standard; the dimension of the mould is 250 x 250 x 6 mm. Sisal and hemp fibers were mixed and added in to matrix the weight percentages of fibers (0%, 15%, 30%, 45%). A well-mixed mixture of matrix and fibers was poured into the female die cavity. The male die was placed on the female die and pressurized to 410.4 kg/cm$^2$ from hydraulic pressing machine for 3 hours. After that specimens were sized according to the ASTM standard for evaluating the mechanical properties such as tensile and flexural test.

### 2.4 Conditioning of the Samples:

#### 2.4.1 Specimens under Normal Weather Condition:

The normal weather conditions in India were temperature 28°C and relative humidity 65%. In order to maintain these constant conditions a hygrothermal chamber was used. Once chamber attained the required conditions the test specimens placed in the chamber. The specimens were exposed to the conditioning for 48hrs as shown in fig.4. After removing the specimens from chamber each specimen was weighed by an electronic balance (corrected up to 2 decimal places).

**Fig.4** Specimens under normal weather condition

#### 2.4.2 Aging in Saline Water:

Aging tests were conducted on the materials to evaluate their behaviour under marine environment saline water (seawater).The specimens were immersed in saline water for 48hrs at room temperature (see fig.5). The moisture was absorbed during aging and therefore the weight was measured using mass balance. Water uptake was measured as a weight percentage (%) increase over a period of time. To measure the weight gain ratio, samples were removed from the water, wrapped with filter paper and then weighed, weights were measured using an electronic balance with o.1 mg accuracy. The weight absorption (uptake at time t,$w_e$) of the sample is evaluated as below;

$$we(t) = 100 \times \frac{Wt - Wo}{Wo}$$

Where Wo is the initial weight of dry specimen, and $W_t$ is the weight of the specimens at immersion time t. The absorption weight W(%) of the water in the state of saturation, which represents the solubility of the solvent in the material or the absorption weight content.

**Fig 5**. Aging specimens in saline water

### 2.5 Testing of Mechanical Properties:

The tensile test & Flexural test were carried out on the specimens under normal weather conditions and after aging in saline water. The tests were carried on specimens as per ASTM D638M& ASTM D79M standard using computerized UTM .The testing speed was 1mm/min. For tensile test the specimen is held in the upper and bottom jaw of machine and the uni-axial load is applied through the ends. For flexural test the specimen is held in the upper and bottom jaw of machine and the bending load is applied at the middle of the sample. The load is applied until the breaking of the specimen as shown in fig.6. The tensile stress and strain are recorded and graphs are generated. For each test two specimens were tested and average values are noted.

The specimen was placed in fixed grip and the movable grip is manually moved. The specimen must be fixed without slackness. Power is supplied to measure the load and extension of the specimen. Extensometer was adjusted to zero, when the load on the specimen was zero. Cross head speed of 0.2 mm/min was applied on movable grip. Electronic motor was fitted to the UTM was started. At every 0.5 mm extension the load indicator shows the applied load values and these are noted until the specimen breaks. Now final load and elongation values were recorded at the end of the test. Then the stress, strain and young's modulus are calculated from that data.

The specimens were tested with UTM Flexural testing machine. The tests were conducted at a load speed of 51mm/min following ASTM –D79M standards. The tested data was set to be three in order to be as accurate as possible by obtaining an average value and test specimen dimension are 100 x 20 x 3 mm.

**Fig.6** Tested specimens for Tensile and Flexural

## 3. RESULTS AND DISCUSSION

### 3.1 Absorption Weight:

The composites with different weight percentages of the sisal/hemp hybrid fiber and their percentage of weight absorption after aging in saline is shown in table.1. With increase in the weight percentage of fibre the water absorption was also increased due to increase in the cellulose content of natural fibres.

Table.1 Absorption weights for Aging specimens

| Samples weight % | Absorption Weight % |
|---|---|
| 0 | 0 |
| 15 | 16.86 |
| 30 | 52.90 |
| 45 | 232.6 |

### 3.2 Tensile Properties:

The test specimen as per ASTM D638M standards, the dimensions are 160 x 20 x 3mm. The stress and strain produced on the composite at the different weight percentages of Hemp & Sisal fiber were calculated.

Ultimate Tensile strength: It is the ratio of ultimate load at failure to the cross sectional area of the specimen.

Area of the Specimen = Width x Depth ($mm^2$)

Stress = Load/ Area ($N/mm^2$)

Young's Modulus (E) = Stress / Strain ($N/mm^2$)

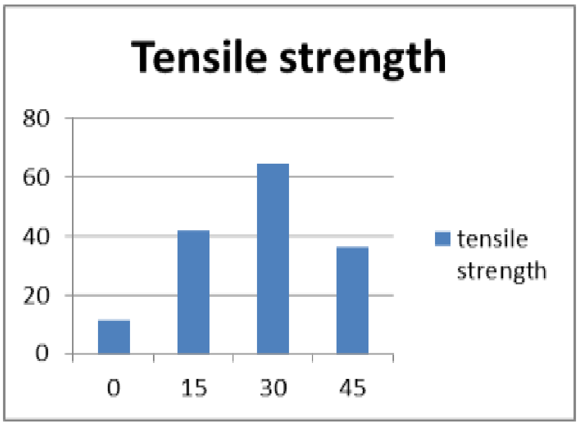


**Fig.7** Tensile strength for normal conditions

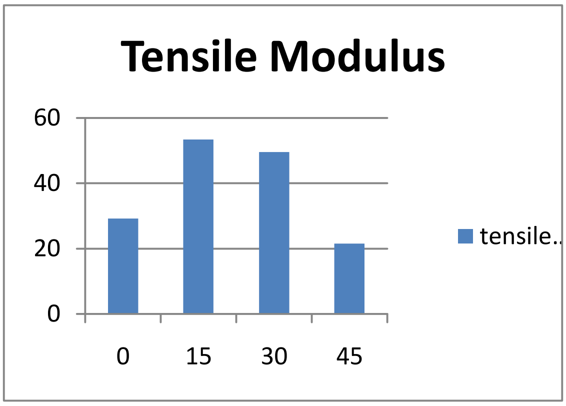


**Fig.8** Tensile modulus for normal conditions

Figure.7 shows the tensile strength of hemp& sisal at various weights percentages. The tensile strength of the composite is increased by increasing the hemp& sisal weight percentage up to 30% and decreased for 45%. The higher mean tensile strength value of 64.72 N/mm$^2$ is noticed at 30% hemp& sisal weight. From the results of tensile modulus (fig.8)higher value is observed for 15% hemp & sisal weight. That is 53.445N/mm$^2$.

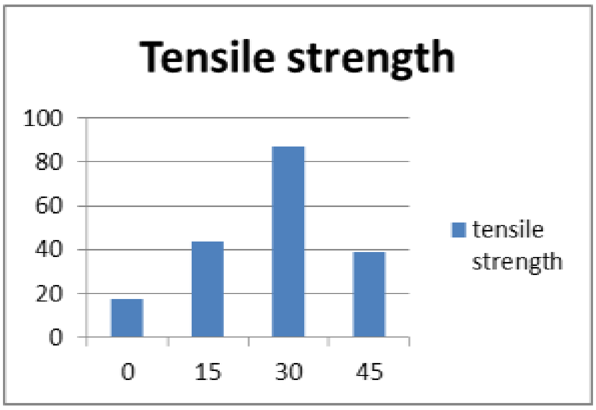


**Fig.9** Tensile strength for aging in saline water

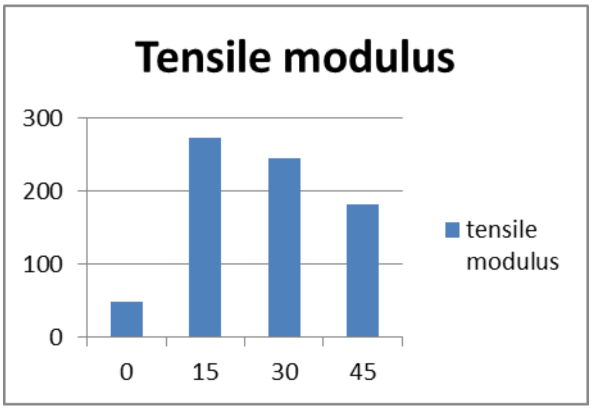


**Fig.10** Tensile modulus for aging in saline water

Figure.9 shows the tensile strength of composites after aging. The tensile strength of the composite is increased by increasing the hemp& sisal weight percentage. The higher mean tensile strength value of 87.06N/mm$^2$ is noticed at 30% hemp& sisal weight. The variation tensile properties is similar to the variation of sample under normal weather conditions. From the results highest tensile modulus (fig.10) value of hemp& sisal fiber composites is observed at 15% hemp & sisal weight. That is 273.51N/mm$^2$.

### 3.3 Flexural Properties:

The test specimen as per ASTM D79M Standards the dimensions are 100 x 20 x 3mm. The flexural strength and flexural modulus of the specimens were determined: Flexural strength is the ratio of Maximum Bending Moment to the section modulus of the specimen

Maximum bending strength $S = 3pL/2bt^2$

Therefore,

$E_f$ =Flexural modulus = $mL^3/4bt^3$

Where, P = maximum applied load (N)

m = slope of load deflection curve (N/mm)

b = width of specimen (mm)

L = span length of specimen (mm)

t = thickness of specimen (mm)

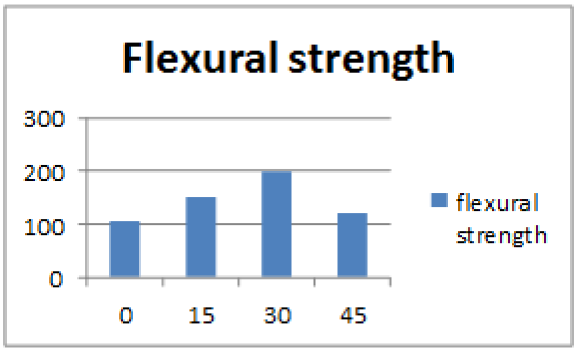


**Fig.11** Flexural strength for normal conditions

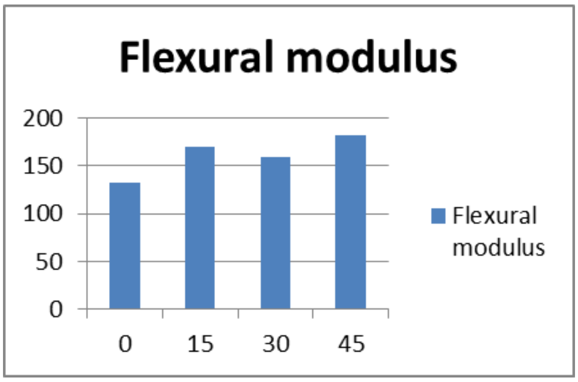


**Fig.12** Flexural modulus for normal conditions

Figure.11 shows the graph between flexural strength of the composite at different hemp& sisal weight percentages under normal conditions. The flexural strength of the composite increased with increased hemp& sisal weight percentage. The higher flexural strength is observed at the 30% of hemp& sisal weight percentage. That is 200.28 N/mm². The highest value of flexural modules (fig.12) value 182.52(KN/mm2) occur at 45% of hemp& sisal weight percentage.

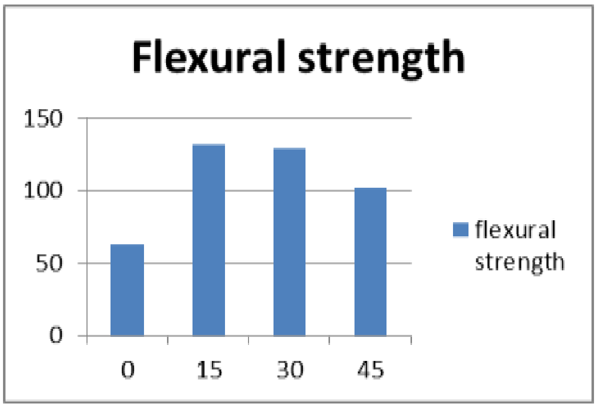


**Fig.13** Flexural strength for aging in Saline water

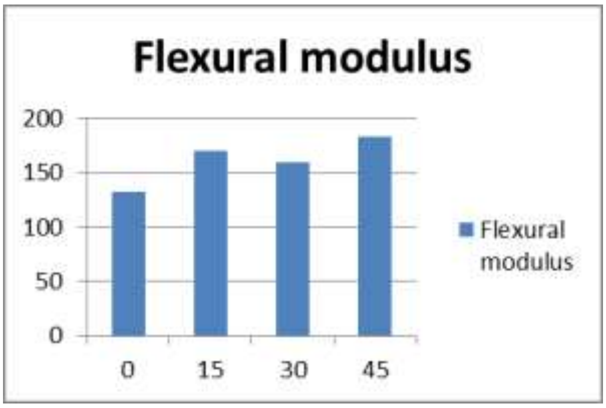


**Fig.14** Flexural modulus for aging in Saline water

Figure.13 shows the graph between flexural strength of the after aging in saline water composite. The flexural strength of the composite increased with increased hemp& sisal weight percentage. The higher flexural strength is observed at the 15% of hemp& sisal weight percentage. That is 131.92 N/mm². The highest value of flexural modules (fig.14) value 198.3(KN/mm2) occur at 45% of hemp& sisal weight percentage.

The reasons for decrease in properties with increase in fibre content of the samples under both conditions may be a result of lower interaction between matrix and fibre, void, and poor dispersion of the fiber in the matrix.

### 3.4 Comparision:

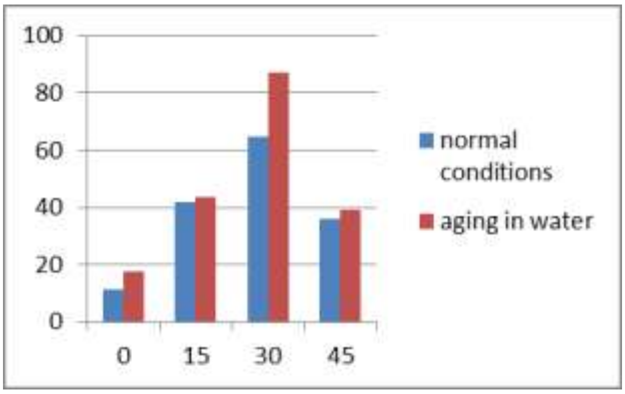


**Fig.15** Comparison between the tensile strength

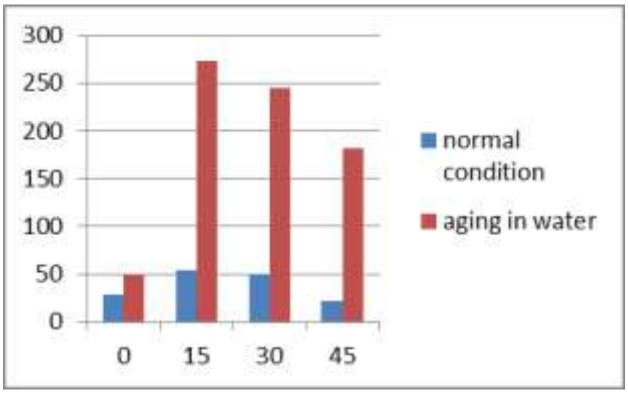


**Fig.16** Comparison between the tensile modulus

Figure.15 and 16 shows the graph of comparison of tensile properties between the aging specimens in saline water and specimens under normal conditions. For all the samples aging in saline water increased the tensile strength and especially the increase in tensile modulus is remarkable and the highest value is obtained for 15% of the sample.

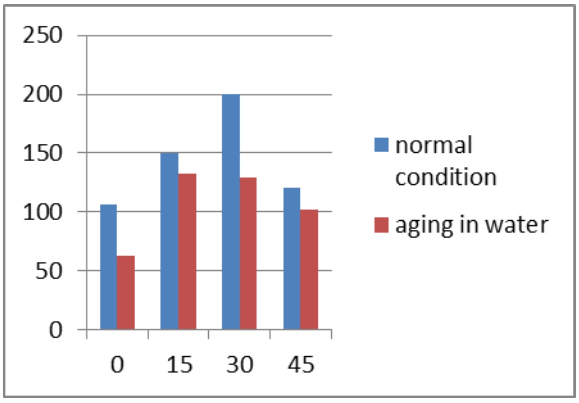


**Fig.17** Comparison between the flexural strength

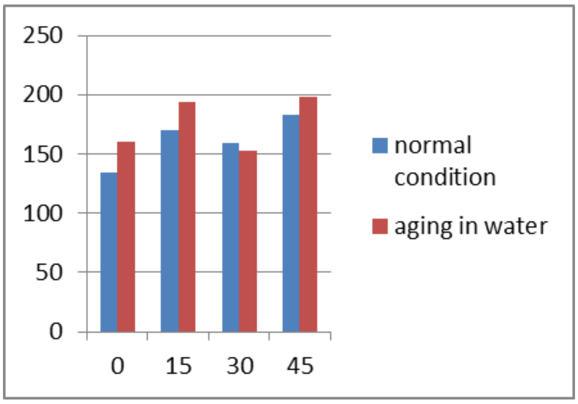


**Fig.18** Comparison between the flexural modulus

Figure.17 and 18 shows the graph of Comparison of flexural properties the aging specimens in water and specimens under normal conditions. In contrast to tensile properties flexural strength decreased upon aging in saline water. The highest value is obtained for 30% composites .The flexural modulus is increasing for 0, 15, and 45%. The highest flexural modulus was obtained for 45% of the sisal and hemp hybrid composites after aging in saline water.

**CONCLUSIONS**

The present work experimentally investigated the variations of mechanical properties of hemp and sisal/ epoxy hybrid fiber composites up on aging in saline water .from the above study the following conclusions can be drawn :

- The composite with 30% hemp & sisal have shown the better tensile strength for aging in saline water.
- The 15% hemp and sisal exhibited better tensile modulus to both aging in saline water and normal conditions.
- The 45% hemp and sisal exhibited better flexural modulus in aging in saline water compared to normal condition.
- These natural fibre hybrid composites with better tensile and flexural properties can be used in automobile industries and marine industries.

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