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Fabrication and Investigation of Bending Test on Hybrid (Sisal and Banana) Fiber Reinforced Polyester Composite Material

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***Abstract*— This paper constitutes the study of Mechanical Properties like Bending Strength of 10%, 20%, 30% and 40% HFRPC material used as Bio-material. An attempt is made to develop 10%, 20% 30% and 40% HFRPC material with low density, economical for bone implant with respect to biocompatibility and the mechanical behavior of human bone, such as cortical, according to the ASTM D-790-02 for Bending test using the polyester resin as the matrix material with the HFRPC 10%, 20% 30% and 40% of the material with fiber weight fraction, random continuous long fiber orientation, by using the Hand Layup fabrication technique the specimens are prepared. The bending tests are conducted by preparing varying percentage of standard specimen. It is found that there is appreciable improvement in bending Properties of 10%, 20%, 30% and 40% HFRPC material. This Study suggests 30% and 40% of HFRPC material may be suitable for the different application in the replacement of human bone. From the Experimental results it is found that by increasing the weight fraction of the fiber or percentage of fiber which will increase the bending strength and also increases the density and mass of composite specimen.**

This study suggests that the HFRPC material is less cost, low density and high strength biocompatible material and may be suggested for implant, especially for cortical bone. From the Experimental results the strengths of HFRPC materials may be suitable the cortical Strength. Finally 30% and 40% HFRPC material can be suggested for cortical. Further it can be tested for remaining mechanical cortical properties.

***Keywords*— Hybrid (sisal and banana) Fibre Reinforced Polyester Composite Materials (HFRPC), cortical, bending test and Hand lay-up Technique. UTM.**

I. Introduction

Natural fibers are a major renewable resource material throughout the world specifically in the tropics. According to the food and agricultural organization survey, natural fibers like jute, sisal, coir, banana, etc. are abundantly available in developing countries.

Natural fibers are an attractive research area because they are eco-friendly, inexpensive, Abundant and renewable, lightweight, low density, high toughness, high specific properties, biodegradability and non-abrasive to processing characteristics, Therefore, natural fibers can serve as reinforcements by improving the strength and stiffness and also by reducing the weight of the resulting biocomposite materials although the properties of natural fibers vary with their source and treatments.

A Bio-material is defined as any systemically, pharmacologically inert substance or combination of substances utilized for implantation within or incorporation with a living system to supplement or replace functions of living tissues or organs. Biomaterial devices used in orthopedics are commonly called *implants*; these are manufactured for a great number of orthopedic applications [5]

Beghezan [1] defines as “The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings”, in order to obtain improved materials.

The biomechanical performance of long bones is dictated by four key factors: element size, element shape, loading conditions, and material properties.[12]

“A Biomaterial is a non-viable material used in medical device, so it’s intended to interact with biological systems”[5].Requirements of Biomaterials are It must be inert or specifically interactive. It must be Biocompatible. Mechanically and chemically stable. Biodegradable. Process able (manufacturability): It must be machinable, and moldable. Sterilizable. Non-carcinogenic, non-pyrogenic, non-toxic, non-allergenic, blood compatible, non-inflammatory. Physical Characteristics Requirements: Strength, Toughness, Elasticity, Corrosion-resistance, Wear resistance, Long term stability [3].

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Natural fibers represent an environmentally friendly alternative by virtue of several attractive attributes that include lower density, lower cost, non-toxicity, ease of processing, renewability and recyclability [6].

Bone Structure: Bones are highly calcified structures which provide a support and protective function for the rest of the body. In addition to the structural framework and protective functions of bone, it also serves as a mineral reservoir for the rest of the body. Long bones make up the majority of bones and primarily consist of two different types; cortical and trabecular. These types of bone have differing structures which affect associated mechanical properties [9].

Cortical Bone: Cortical bone facilitates bone's main functions: to support the whole body, protect organs, provide levers for movement, and store and release chemical elements, mainly calcium. As its name implies, cortical bone forms the cortex, or outer shell, of most bones. Cortical bone contributes about 80% of the weight of a human skeleton. The primary anatomical and functional unit of cortical bone is the osteon.[9]

Cortical bone, also referred to as compact bone, is dense bone found in the shafts or diaphyses of long bone. This bone is characterized by low, 5-10%, porosity and is often tested to determine the mechanical properties of bone. Cortical bone is primarily made up of primary or secondary bone. The ratio of primary to secondary bone greatly affects the properties of the bone. The main structural component of this type of bone is the osteon which gives bone the ability to withstand torsion and bending stresses [2]. The remodeling of compact bone, or replacement of bone reduces its flexural fatigue strength and resistance to Tension, compression, shear, and bending [4].

The present work thus aims to develop this new class of natural fiber based polymer composites with fiber lengths and to analyze their mechanical behavior by experimentation and compare strength with cortical bone.

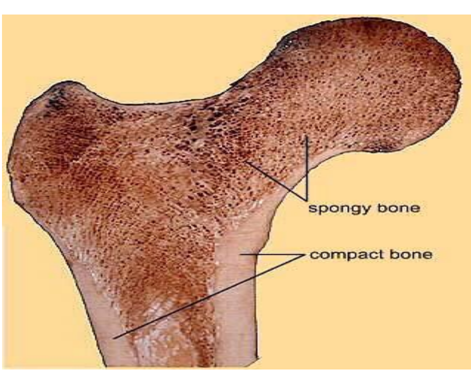

Fig – 1.1 cortical bone in human body

Table 1.1:
cortical properties

TYPE	CORTICAL BONE
Bending strength	103-238 Mpa

II. Objectives

- Fabrication of HYBRID (SISAL AND BANANA) based composites.
- To prepare the specimens as per ASTM standards.
- To Study the mechanical behavior of hybrid fiber reinforced polyester based composites
- Evaluation of mechanical properties of the composites such as bending strength.
- Compare the results with cortical properties.

Besides all these the main objective is to develop a low cost, low weight, low density & high bending strength natural fiber based composite that can be used for orthopedic implant applications (cortical bone).

III. Methodology

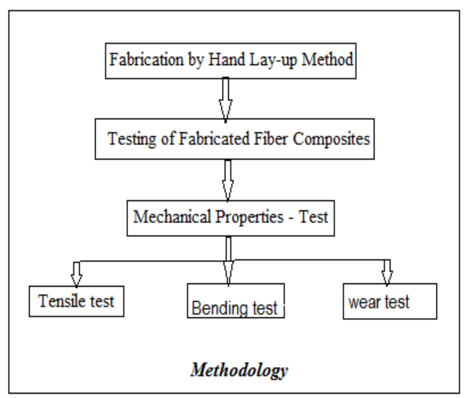

Fig 3.1- methodology

i) Fiber Extraction : Hybrid (sisal & banana) fibers are collected and extracting from plant using manual or mechanical extraction procedure.

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Fig – 3.2 Hybrid (sisal+ banana) fiber extraction

ii) Hybrid fiber preparation : Here continuous fibers are used to fabricate the natural fiber composites. First clean the natural fibers in distilled water. After cleaned natural fibers are dried in the sun light. The dried natural fibers are again cleaned by chemical cleaning process. In chemical cleaning process the 80% sodium hydroxide is mixed with 20% distilled water. The dried natural fibers dipped in the diluted sodium hydroxide solution. It's again dried in sun light .The dried natural fibers are cut to the length of 300 mm by manually. The cut natural fibers are used to fabricate the natural fiber composites.

iii) Materials and pattern used for fabrication: The pattern is designed as per ASTM standard. The pattern is made up of mild steel. The pattern Size is 300 x 300 x 3 mm the pattern consist of three parts Base plate, frame and weight. The main purpose of the weights applied is for even distribution of load on mixture which is filled in the pattern.

Fig – 3.3 Pattern

Materials used for fabrication work are polyester resin, Hardener, fiber, Sodium Hydroxide (NaOH), Weighing Machine, Roller, Bowl, Stirrer.

iv) Mould preparation for bending test

In mould preparation the resin is mixed with hardener in the ratio of 4:1. The mixer is strewed with stirrer for 15 minutes continuously.

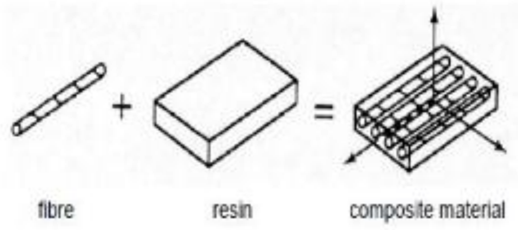

Fig -3.4 Mould Preparation

Take the Top mould or Die and bottam mould which is made up of Cast Iron of size 360mm* 300mm* 20mm in rectangular shape and place these moulds one above the other and tight these plates by using of 2” Clamps. Surrounding Die very thick rubber sheet is used to prevent the material and to avoid air or blow holes on the specimens and this rubber sheet is withstand up to temperature of 100^0c The working surface was cleaned with thinner to remove dirt and a thin coat of wax is applied on the surface to get smooth finish. Then a thin coat of polyvinyl alcohol (PVA) is applied for easy removal of mould.

v) Fabrication Process

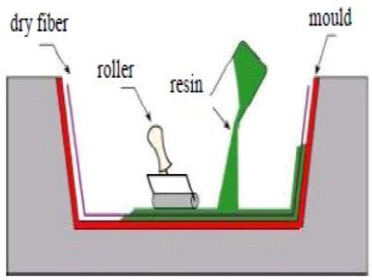

Fig -3.5 Hand lay up method

Fig -3.6 Fiber arrangement

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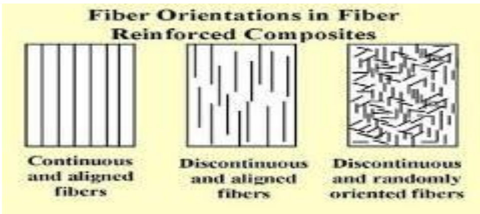

Fig -3.7 Fiber orientation

Here Hand Laminating Molding is used for fabricate the natural FIBER composites. The base plate is fixed inside the frame for fabricate the natural fiber composites 70% of rein hardener mixture and remaining natural fibers are used. The mixed resin and hardener is filled in the pattern. The prepared natural fibers are randomly poured in the resin hardener mixture without any gap. The roller is rolled in the mould. Again the mould is filled in pattern by next layer and fibers poured randomly .This process is simultaneously done till the height of the mould .The weights is fixed on the top of the frame for distribute the load evenly on the mould. The setup is kept in the dry place for 24 hours. After 24hours the mould is take away

From the pattern, finally the natural fiber composite is fabricated.

Fig -3.8 Natural Fiber composite fabricated

The mould is prepared and loose the clamps and remove the fabricated material and for this go for annealing process for dry the material by maintaining the temperature of 82˚ c for an 15 minutes and take out the material Mould Preparation. Cutt the fibers required dimensions for test All test specimens were molded and prepared according to ASTM standards to avoid edge and cutting effect, thereby minimizing stress concentration effect. Fabrication steps showed in the figures.

Fig 3.9 Furnace for annealing

Vi) Fabricated Composites

Polymer hybrid matrix composites, The compositions of polymer composites with long fiber are given in the following table.

Table 3.1
Composites of fiber reinforced polymer

Composites	Orientation	Composition	
		Resin In Wt %	Fibers In Wt %
H1	Long fiber	90	10
H2	Long fiber	80	20
H3	Long fiber	70	30
H4	Long fiber	60	40

Fig 3.10 Specimens after fabrication before testing

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IV) Experimental Testing

Fig 4.1: Electronic Universal Testing Machine interfaced with computer

Universal testing machine specification

Capacity:	40ton
Motor:	2.3hp
Voltage:	400 to440 volts
Dimension:	L*W*H (2060 x 750 x 2180)

The main objective is to determine the mechanical properties of hybrid fiber reinforced polyester composite material by conducting bending Test .

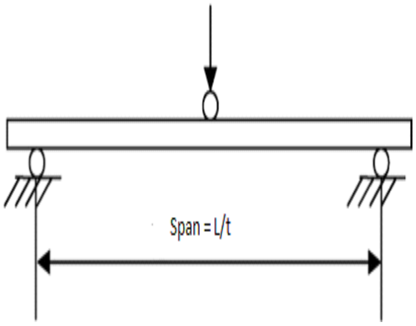

Fig: 4.2 Bending Test/Flexural strength test:

Bending tests were conducted using universal testing machine Flexural analysis was carried out at room temperature through three-point bend testing as specified in ASTM D790-02 , using universal testing machine. The speed of the crosshead was 5 mm/min. Three composites specimens were tested for each sample and each test was performed until failure occurred. Flexural strength was calculated from the Equation.

σf = (3PL) / (2bd2),

Where, P = Load at a given point on the load deflection curve in Newton (Peak load)

L = support span in mm

b =width of the samples in mm d = thickness of the samples in mm, bending testing

IV. CALCULATION

General Procedure of Calculation

For to Find the Mass of the Fiber for bending Specimen

POLYSTER: 90% AND HYBRID 10 %(SISAL 5%+ BANANA5%)

Volume of die: 300x300x3=270000mm^3

Density of sisal =1.33g/cm3

Density of banana=1.48g/cm3

Density of polyester= 1.37 g/cm3

Mass of fiber= density X volume

$V_C = V_{polyester} + V_{sisal} + V_{banana}$

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$mc/\rho c = m_{polyester}/\rho_{polyester} + m_{sisal}/\rho_{sisal} + m_{banana}/\rho_{banana}$

$1/\rho c = 0.9/1.33 + 0.05/1.33 + 0.05/1.48 = 0.748$ Cm3/g

$\rho c = 1.33 g/cm^3$

$mc = \rho c \times Vc$

mc = 1.33x270=359gms

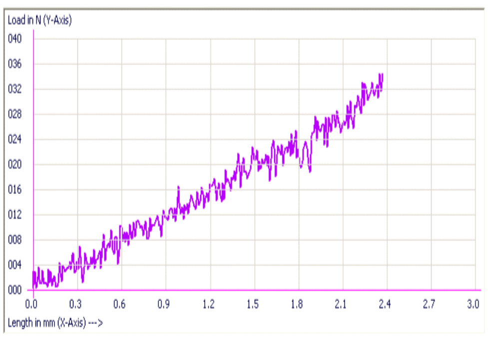
For 90% polyester=323 gms

For 5% sisal= 17.95gms

For 5% banana=17.95 gms

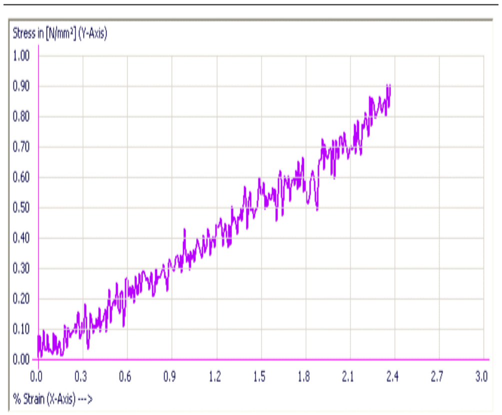
Similarly the calculation is done for 20%,30%,40% of HYBRID natural composites.

V. Results And Discussion



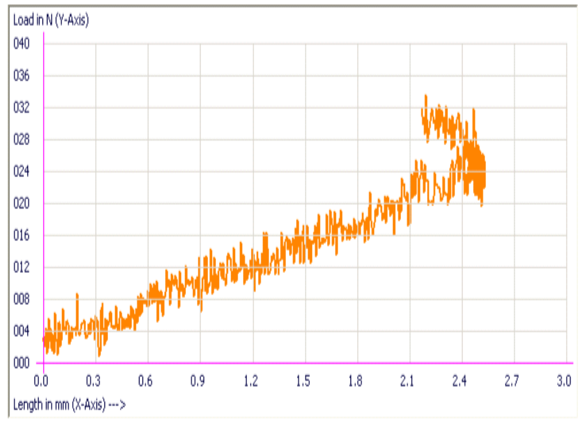
Load v/s length

Graph6.1: 10% HFRPC for bending test

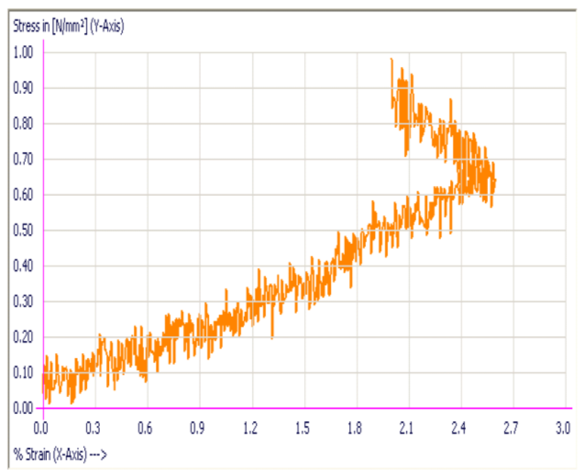


Stress V/s strain

Graphs 6.1 : 10% HFRPC for Bending test

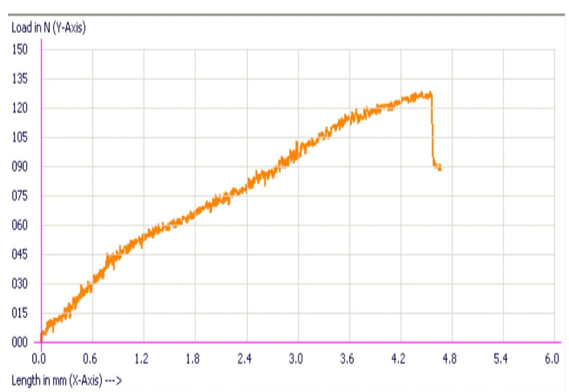


a) Load V/s length



Stress V/s strain

Graphs 6.2: 20% HFRPC for bending test



Load verses length

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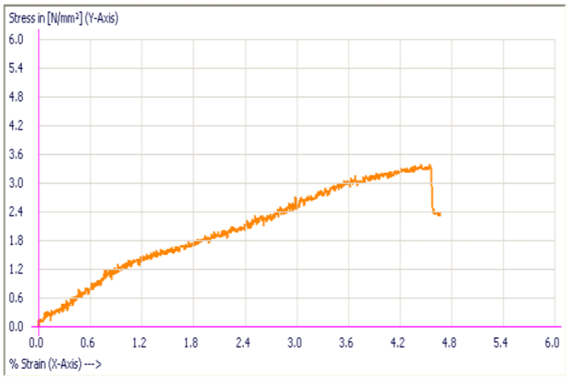
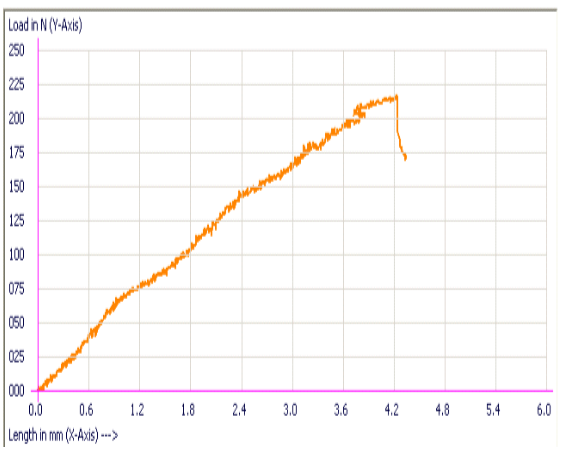
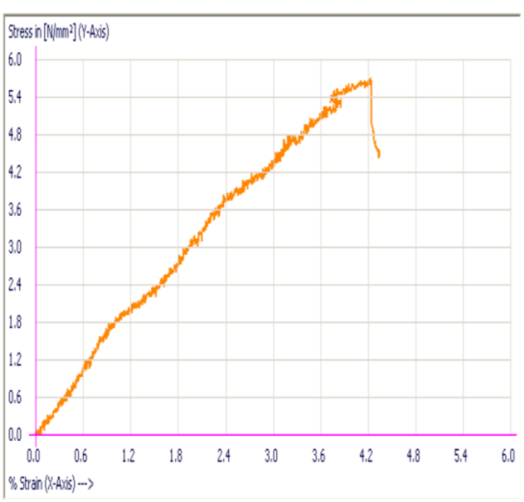


a) Stress V/s strain

Graphs 6.3: 30% HFRPC for bending test



a) Load verses length



b) Stress verses strain

Fig6.4: 40% HFRPC for bending test

Table 6.1:
Tabular column shows graphs of bending test of 10% HFRPC

Sl No	Peak Load(N)	C/A area mm^2	3Pt bend flexural strength Mpa	3Pt bend flexural moduli Gpa
1	52	38.10	68.37	73315.84
2	48	38.10	62.99	12160.98
3	34	38.10	45.21	7.29

Table 6.2:
Tabular column shows graphs of bending test of 20% HFRPC

Sl No	Peak Load(N)	C/A area mm^2	3Pt bend flexural strength Mpa	3Pt bend flexural moduli Gpa
1	34	38.10	44.53	8092.74
2	37	38.10	48.96	2690
3	58	38.10	79.25	8202

Table 6.3:
Tabular column shows graphs of bending test of 30% HFRPC

Sl No	Peak Load(N)	C/A area mm^2	3Pt bend flexural strength Mpa	3Pt bend flexural moduli Gpa
1	129	38.10	168.7	1210.2
2	116	38.10	152.7	10236.2
3	88	38.10	114	5161.8

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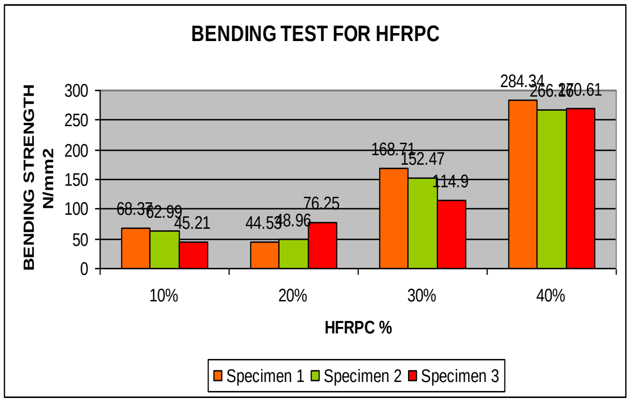
Table 6.4:
Tabular column shows graphs bending test of 40% HFRPC

Sl No	Peak Load(N)	C/A area mm^2	3Pt bend flexural strength Mpa	3Pt bend flexural moduli Gpa
1	217	38.10	284	2114
2	203	38.10	266	1137
3	206	38.10	270	5504.52

Comparison of bending strength of HFRPC for bending test



Bending Test/Flexural Strength Test:

From experimental results for 10% HFRPC peak load=52 N, Flexural strength =68.7Mpa, similarly for 20% HFRPC peak load=58N, Flexural strength =76.25 Mpa, similarly for 30% HFRPC peak load=129N, Flexural strength =168.2Mpa , similarly for 40% HFREC peak load=217N, Flexural strength =284Mpa , from this conclude that by increasing the weight fraction of HYBRID fiber it increases the strength of the specimen and from this experimental results the bending strength of specimen composition 30% and 40% may be suitable for cortical bone bending strength.

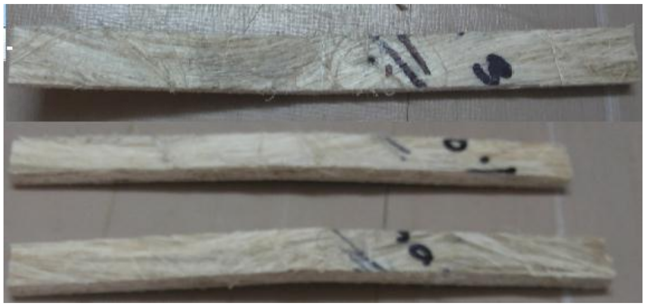


Fig6.1: Bending test specimen after testing

VI. CONCLUSION

1. From experimental results it is found that HYBRIB fiber will have good bending strength
2. From experimental results it is found 10%, 20%, 30% and 40% HFRPC, that out of 30% and 40% HFRPC is having good bending strength and it may be suitable for cortical bone Properties.
3. From the above experimental results it indicates that the hybrid fiber reinforced polyester composites will have better mechanical properties like bending properties by increasing the percentage of hybrid fiber.

VII. FUTURE SCOPE OF WORK

1. This work is carried out for bending strength and tests can be carried out for other properties like Compression, tensile, impact, shear, and vibration tests.
2. FEM analysis can be carried out and can be compared with experimental results.
3. Water absorption test can be conducted and reliable fiber composites are selected based on the results.
4. Wear test can be done under different operating conditions like varying time, track radius & speed.
5. Corrosion test can be conduct.
6. SEM analysis can be conduct.

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