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Experimental investigation on natural fibre biocomposites by using destructive testing

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Abstract: The primary objective of the paper deals with the process of making the natural fiber biocomposites which are derived from the coconut powder and walnut powder which are derived from the extraction process. It is also investigates the determination of tensile strength, impact strength and hardness of the bio composite materials made with coconut fiber powder and walnut fiber powder under loading with different mechanical or destructive tests have been carried out. The behaviour of the same is determined in terms of ultimate tesnsile stress and ultimate yield stress which can be compared with steel specimen as reference. Uniform distriution of fiber particles are observed during Metallography test.

Keywords: Composite materials, Fiber-reinforced Plastic, Destructive Testing, Resin matrix material, Tensile Strength,

1. Introduction:

The composite materials industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. [3]Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibers of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance Fibre-Reinforced Plastic (FRP) can now be found in such diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc. Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures. Composites are now extensively being used for rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity. Unlike conventional materials (e.g., steel), the properties of the biocomposite material can be designed considering the structural aspects.

2. Why use composites?

[6][7]Modern aviation, both military and civil, is a prime example. It would be much less efficient without composites. In fact, the demands made by that industry for materials that are both light and strong has been the main force driving the development of composites. It is common now to find wing and tail sections, propellers and rotor blades made from advanced composites, along with much of the internal structure and fittings. The airframes of some smaller aircraft are made entirely from composites, as are the wing, tail and body panels of large commercial aircraft.

In aircraft planes, it is worth remembering that composites are less likely than metals (such as aluminium) to break up completely under stress. A small crack in a piece of metal can spread very rapidly with very serious consequences (especially in the case of aircraft). The fibers in a composites act to block the widening of any small crack and to share the stress around. The right composites also stand up well to heat and corrosion. This makes them ideal for use in products that are exposed to extreme environments such as boats, chemical-handling equipment and spacecraft. In general, composite materials are very durable.

3. Classification of natural fibre

[3][4] A Natural fiber made from plant, animal or mineral sources, and is classified according to the origin. Plants that produce natural fibers are categorized into primary and secondary depending on the utilization. Primary plants are grown for their fibers (examples, Jute, hemp, kenaf, and sisal) while secondary plants are plants where the fibers are extracted from the waste product (examples, Pineapple, Bagasse, oil palm and coir). There are six major types of fibers namely; bast fibers (jute, flax, hemp, ramie, baggase, linen, bamboo, and kenaf), leaves fibers (abaca, banana, sisal and pineapple), leaflets (palm, coconut, etc.) seed fibers (coir, cotton and kapok), grass and reed fibers (wheat, corn and rice) and all other types (wood and roots). A large variation is found in the mechanical and physical properties of natural fibers. Those properties are affected by many factors of natural fibers. The experimental conditions are different such as type of fibers, moisture content and form of fibers (yarn, woven, twine, chopped, felt, etc.). Moreover, the properties are also affected by the place where the fibers are grown, cultivation condition. The part of the plant they are harvested from growing period and retting or extracting process.

4. Work Flow for Bio composite Processing

[3]The uncrushed natural fibers were cleaned, dried at room temperature or atmosphere air and chemical treated using Isocyanate, washing with an alkaline solution and hardener were applied. After treatment, the natural fiber was dried in an oven at 500°C to1200°C for 1 to 24 hours or atmospheric air at 24 to 48 hours depending upon the method. And then to reduce the size in ball milled at 200 to 300 RPM for 5 to 6 hours. [3][4] The natural fiber and polymer matrix were mixing in the reactor or z-blade mixer or two-roll rheo mixer. [7]After the mixing composites were compressed under pressure from 10Mpa to 150Mpa at 1500°C to 1800°C for 5 to 10 minutes and finally dry the composites in dry air for proper curing.

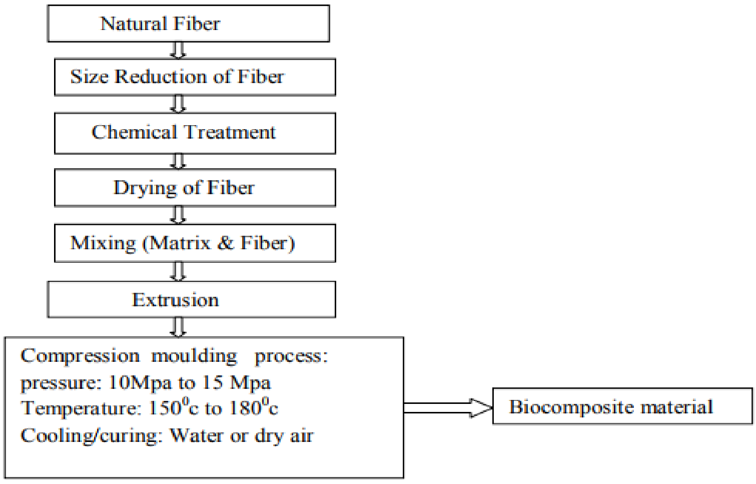


Fig 1: Work flow procedure to obtain the Biocomposite Material Extraction

[6] [7] Fibrous Composites Short fiber reinforced composites:

Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter). They are classified as Composites with random orientation of fibers. Composites with preferred orientation of fibers. Long-fiber reinforced composites: Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers. Unidirectional orientation of fibers. Bidirectional orientation of fibers (woven).Laminate composite when a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer composite.

[3][8] ***Fillers*** are the next materials in terms of volume that is required in the plastic industry apart from the base polymers. Thermoset commonly used fillers in plastic industries are mineral fillers and natural fillers. Presently, natural fillers are being used as alternative to conventional mineral fillers in compounding of plastics so as to enhance the properties of the plastics and reduce the over dependent on the petroleum-based resources due to high rate of depletion of the natural resources.

[8]In addition, to the overcome the other limitations associated with the use of mineral fillers(especially glass fiber, talc, asbestos, silica, mica, etc) in plastic industry which include high cost, non biodegradable, loss of energy during processing, abrading of processing equipment, and increase in the density of composite systems, nonrenewable and abundant resource and its hazardous effect on environment. However, the disadvantages of the natural fillers are summarized as follow; degradation by moisture, poor surface adhesion to hydrophobic polymers, non-uniform filler sizes, not suitable for high temperature application, susceptibility to

fungal and insect attack, etc .Polypropylene is a commodity thermo plastic the offers a combination of outstanding physical, chemical, mechanical, thermal and electrical properties not found in any other thermoplastic. It has a lower impact strength compared to low or high density polyethylene, but superior working temperature and tensile strength.

5. Coconut Shell Powder

Luo and Netravali, Ahmed, Faud and Schneider studied pineapple, filament wound cotton fiber, oil palm wood flour and jute & kenaf fiber based composite respectively. [10] Bhaskar J & V K Singh investigated the compressive properties of coconut powder composites. Coconut shell powder has various uses. The shell powder is manufactured from the coconut shell which is obtained as by-product from coconut oil industries and individual households. The powder has various uses as a filler in synthetic resin glues, filler and extender in phenolic moulding powders, mosquito repellent coils, mastic adhesives, resin casting, bituminous products etc. The coconut shells are available from all coconut producing States in India namely Kerala, Tamilnadu, Karnataka and Andhra Pradesh, which contribute more than 90% of the production in the country.

[3][4] Coconut is a member of the palm family, which is one of the food crops in the world. It generates large amounts of waste material, namely coconut shell (CS). CS is non-food part of coconut which is one of the hard lignocellulosic agro wastes. Agro waste products such as CS is an annual increase every year and is available in abundant volume throughout the world. Particularly CS is one of the most significant natural fillers produced in tropical countries like India, Malaysia, Indonesia, Thailand and Srilanka. Several workers have been dedicated to use of other natural fiber in composite in the latest post and CS fiber is a potential candidate for the improvement of new composites because of their high strength and modulus properties. Composite fiber can be used in, the board range of application such as, building material, furniture and fishnets. [7]Coconut fiber is important reinforcement material in fabrication of various types of polymer based composites, due to cost effectiveness, high strength, etc. Presently 90% CS was disposed as waste and either burned in the open air or left Seattle in waste ponds. This way the coconut processing industries waste according to him contributed significantly to CO_2 and methane emissions. Based on economic as well as environmental related issues, this effort should be directed worldwide towards coconut management issues i.e. of utilization, storage and disposal. Different avenues of CS utilization are more or less known, but none of them have so far proved to be economically viable or commercially feasible. Coconut shell is low ash content. Conversion of coconut shells into activated carbons which can be used as adsorbents in water purification and municipal effluents would add value to these agricultural commodities, help reduce the cost of waste disposal and provide a potentially cheap alternative to existing commercial carbons .

Fig 2: Coconut Powder from the coconut shells (CS)

PRODUCT SPECIFICATION & USES There is no specification prescribed by Bureau of Indian standards for coconut shell powder. This is manufactured as per our requirement and the particle size varies depending upon its end uses.

The following specification is normally followed.

Appearance: Clear light brown free flowing powder
Moisture : Maximum 10% Apparent
Density : 0.6 to 0.7 gm/cc
Ash : Shall not exceed 1.5%

[2] Manufacturing Processes of Composite Material Manufacturing of a composite material is to combine the polymeric resin system with the fiber reinforcement. Since the orientation of the fibers is critical to the end properties of the composite, manufacturing process is utmost important to align the fibers in desired direction. A good manufacturing process will produce a higher, uniform fiber volume fraction along with a higher production of a large volume of parts economically and have repeatable dimensional tolerances.

[5][7]Hand lay-up is an open molding method suitable for making a wide variety of composites products from very small to very large. Production volume per mold is low; however, it is feasible to produce substantial

production quantities using multiple molds. Hand lay-up is the simplest composites molding method, offering low cost tooling, simple processing, and a wide range of part sizes. Design changes are readily made. There is a minimum investment in equipment. With skilled operators, good production rates and consistent quality are obtainable.

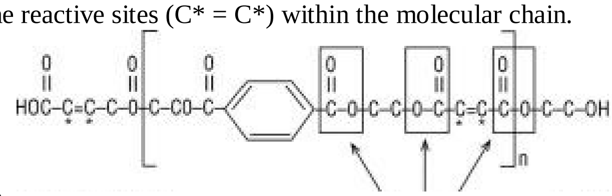
[5] Materials and methods:

This chapter deals with the materials that are used in the present study and the methods by Which these materials are processed. The materials that are used in the present concern of
Studies are:
1. Matrix material
 a. Coconut shell powder
 b. Walnut shell powder
2. Filler materials

Matrix material: The matrix is basically a homogeneous and monolithic material in which a fiber system of a composite is embedded. It is completely continuous. The matrix provides a medium for binding and holding reinforcements together into a solid. It offers protection to the reinforcements from environmental damage, serves to transfer load, and provides finish, texture, color, durability and functionality.
Polyester resin: [4] Polyester resins are the most widely used resin systems. Most polyester resins are viscous, pale colored liquids consisting of a solution of polyester in a monomer which is usually styrene. The addition of styrene in amounts of up to 50% helps to make the resin easier to handle by reducing its viscosity.

Fig 3: Polyester resin

The figure below shows the idealised chemical structure of typical polyester. Note the positions of the ester groups (CO - O - C) and the reactive sites (C* = C*) within the molecular chain.



***Denotes reactive sites Ester groups n= 3 to 6**

Fig 4: Chemical structure of polyester

These resins can therefore be moulded without the use of pressure and are called 'contact' or 'low pressure' resins. Often small quantities of inhibitor are added during the resin manufacture to slow this gelling action. For use in moulding, a polyester resin requires the addition of several ancillary products. These products are generally:

Fig 5: Polyester resin

Cobalt octoate being the most effective drier promotes polymerization of media, hardens the paint film, improves gloss and water resistance and reduces brittleness of film. The careful use of Cobalt octoate gives the paint film a good gloss, free from frosting tendency. This drier is a universal drier, which is essential in all the media and is capable of performing individually giving reasonable properties to the paint film. In air-drying type insulating varnishes use of Cobalt octoate increases water resistance. Cobalt octoate accelerates the catalytic action of Methyl ethyl ketone (M.E.K.) Peroxide to polymerize unsaturated polyester resin.

Fig 6: Cobalt Octoate

Methyl Ethyl Ketone Peroxide (MEKP)

MEKP is an organic peroxide, a high explosive. MEKP is a colorless, oily liquid; MEKP is slightly less sensitive to shock and temperature, and more stable in storage. Depending on the experimental conditions, several different adducts of methyl ethyl ketone and hydrogen peroxide are known. MEKP Catalyst for polyester resin including our GP Polyester Resin, Clear Polyester Gel Coat and Unmold system. MEKP Catalyst is typically added to polyester resin at a ratio of between 1 and 3%, according to the pot-life and cure speed required and the ambient temperature. Always follow the guidelines that accompany your specific resin system

Fig 7(a): Walnut Fiber Bio Composite

Fig 7(b): Coconut Fiber Bio Composite

Destructive Testing and Results:

Metallography Test:

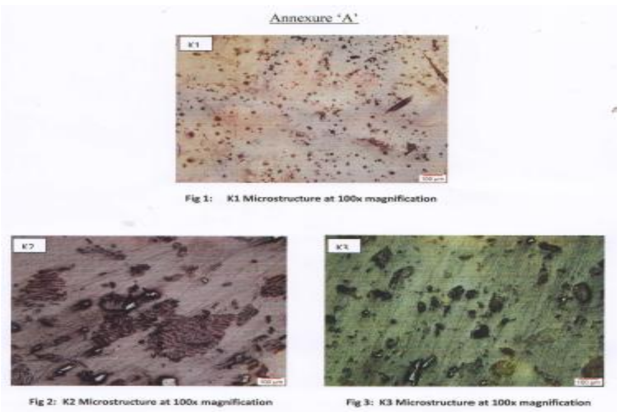


Fig 8: Microstructure of natural fibers

[9]Tensile Test:

Fig 9: Specimens Prepared for testing

Force is applied perpendicular to the cross sectional area of the test item. Two of the essential material properties that tractable tests decide are:

- Yield Strength, which is the anxiety required to for all time extend, or twist, a material a particular sum, normally 0.2% of aggregate extension.
- Ultimate Tensile Strength, which is the most extreme anxiety a material can withstand only preceding cracking

Table 1: Tensile test Reports

Specimen Parameters	**Coconut shell powder**	**Walnut shell powder**	**Steel Specimen**
Specimen type	Flat	Flat	Flat
Specimen width mm	13.75	14.02	14.33
Specimen width mm	13	13.05	13.2
Cross-section area,mm^2	178.75	182.961	189.156
Original Gauge, mm	50	50	50
Final gauge, mm	51.68	51.32	51.2
Ultimate load,KN	2.080	3.120	2.120
Ultimate Tensile Strength,N/mm^2	14.636	17.053	11.207
Elongation, mm	1.360	2.640	2.400
Yield Load, KN	1.080	2.920	1.820
Yield Stress, N/mm^2	9.042	15.960	6.621

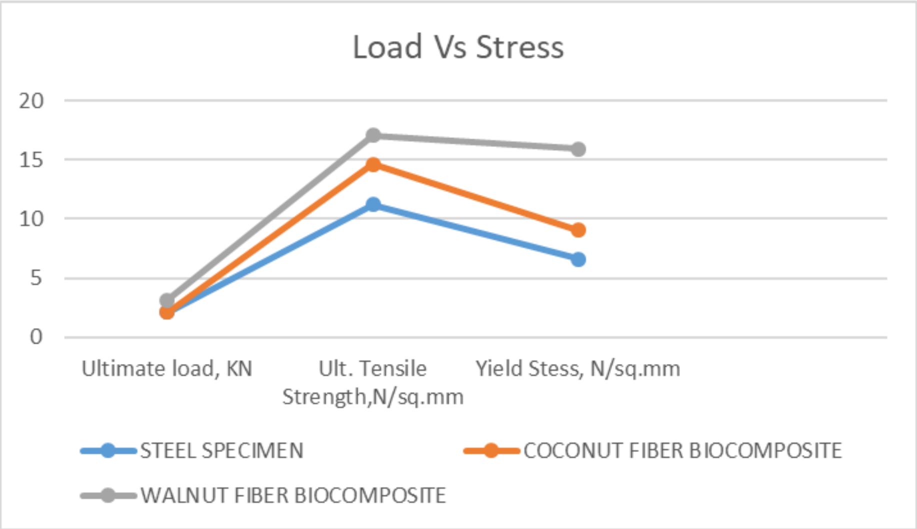


Fig 10: Mechanical Behavior of three specimens under loading

[9]Hardness Test

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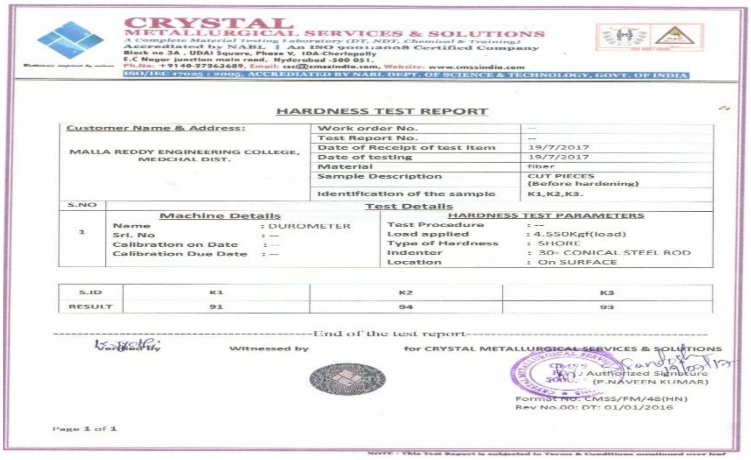
Hardness is a normal for a material, not a basic physical property. It is characterized as the protection from space, and it is dictated by measuring the perpetual profundity of the space. This test is completed with understanding of ASTM D 2240.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ISO/IEC 17025 : 2005, ACCREDIATED BY NABL DEPT. OF SCIENCE & TECHNOLOGY, GOVT. OF INDIA

HARDNESS TEST REPORT

Customer Name & Address:		
MALLA REDDY ENGINEERING COLLEGE, MEDCHAL DIST.	Work order No.	--
	Test Report No.	--
	Date of Receipt of test Item	19/7/2017
	Date of testing	19/7/2017
	Material	fiber
	Sample Description	CUT PIECES (Before hardening)
	Identification of the sample	K1,K2,K3.

S.NO	Test Details: Machine Details	Test Details: HARDNESS TEST PARAMETERS
1	Name : DUROMETER Srl. No : -- Calibration on Date : -- Calibration Due Date : --	Test Procedure : -- Load applied : 4.550Kgf(load) Type of Hardness : SHORE Indenter : 30◦ CONICAL STEEL ROD Location : On SURFACE

S.ID	K1	K2	K3
RESULT	91	94	93

-----End of the test report-----

Verified by   Witnessed by   for CRYSTAL METALLURGICAL SERVICES & SOLUTIONS

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Rev No.00: DT: 01/01/2016

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Fig 11: Reports of Hardness Test

[9]Impact Test

Amid the testing procedure, the example must be stacked in the testing machine and permits the pendulum until the point when it cracks or breaks. Utilizing the effect test, the vitality expected to break the material can be measured effectively and can be utilized to gauge the durability of the material and the yield quality. Impact tests measure resistance to shock loading or impact by determining the amount of energy absorbed by the test specimen. There are two basic types of impact tests:


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IMPACT TEST REPORT

Customer Name & Address:		
MALLA REDDY ENGINEERING COLLEGE, MEDCHAL DIST.	Work Order	--
	Report No/Date	--
	Date of Receipt of test Item	16/07/2017
	Date of testing	16/07/2017
	Material	FIBER
	Sample Description	55X10X10
	Identification of the sample	K1,K2,K3.

S.NO	Test Details: Machine Details	Test Details: IMPACT TEST PARAMETERS
1	Name : FIE (IT-30D) Srl. No : 1357 Range: 0-300J Calibration on Date : 06-04-2017 Calibration Due Date : 05-04-2018	Test Procedure : IS 1757 -2014 Type of Impact : CHARPY - V Notch Depth : 2mm Notch Angle : 45° Specimen size : 10 x 5x 55mm Test Temperature : 20° C

Location	Observed Values in (Joules)		
	K1	K2	K3
LONGITUDINAL DIRECTION	0.5	0.5	0.5

-----End of the test report-----

Verified by   Witnessed by   for CRYSTAL METALLURGICAL SERVICES & SOLUTIONS

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Fig 12: Reports of Impact Test

Conclusion:

- From the Metallography test, it has been observed that the uniform dispersion of fibers in both Bio composites made with walnut & coconut powder.
- With the help of universal testing machine, tensile test is done and it is determined that the ultimate tensile strength of coconut fiber bio composite and walnut fiber bio composite are 23.42% & 34.28 % higher than the steel specimen.
- Also, the yield stress shows drastic change in walnut fiber bio composite of 58.51% and coconut fiber bio composite has 26.77% as compared steel specimen.
- As per hardness test, coconut fiber shows 91 as its hardness number whereas walnut fiber shows 94.
- Finally, impact test shows only a sustainable value of 0.5 Joules.

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