A

Project Report

On

"ANALYSIS OF MECHANICAL PROPERTIES OF COIR/PORTLAND POZZOLANA REINFORCED POLYMER MATRIX COMPOSITES"

by

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in partial fulfillment of the requirements for the

degree of

Bachelor of Technology in

Mechanical Engineering

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MAY,2023

DECLARATION

I hereby declare that the project report titled **“ANALYSIS OF MECHANICAL PROPERTIES OF COIR/PORTLAND POZZOLANA REINFORCED POLYMER MATRIX COMPOSITES”** is an authentic record of the research work carried out by us under the supervision of **Dr. Ankit Asthana**, Department of Mechanical Engineering, for the period from August 2022 to June 2023 at BBDITM, Lucknow. No part of this project report has been presented elsewhere for any other degree or diploma earlier.

I declare that we have faithfully acknowledged and referred to the works of other researchers wherever their published works have been cited in the project report. we further certify that we have not willfully taken other's work, para, text, data, results, tables, figures etc. reported in the journals, books, magazines, reports, synopsis, theses, etc., or available at web-sites without their permission, and have not included those in B. Tech synopsis citing as my own work.

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CERTIFICATE

This is to certify that the Project Report entitled "**ANAYALSIS OF MECHANICAL PROPERTIES OF COIR/PORTLAND POZZOLANA REINFORCED POLYMER MATRIX COMPOSITES"** is a Bonafede record of the research paper work carried out by Nitesh Singh (1900540400029) under my supervision and guidance, in partial fulfilment of requirements, for the outcome Based education paradigm in Mechanical engineering, from BBDITM, Lucknow, for the academic year 2022-2023.

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I would like to pay my respect and special thanks to my parents who provided me with all the inventories and love throughout this project

ABSTRACT

The current analysis deals with the fabrication of the composite sheets with the epoxy reinforced with natural fiber coir and the Portland pozzolana. In today's time composite material plays a very important role in engineering application. we can replace the wood with the composite, even the composite is a recyclable. High mechanical properties can only be obtained by the complex structures such as coatings or the composites. Fields like the aerospace and automobiles they always need the lighter weight material with good strength. Many of the parts are complex which can be made by the forming process. It is made by using matrix and reinforcement material. A matrix is prepared by using epoxy resin and when it comes to the reinforcement material it could be the natural or artificial fibers. In this we have used the coir (coconut husk) and Portland pozzolana. To make the composite we have used the hand layup process method. At the end we performed the flexural strength test and impact strength test. Polymer matrix composite is light weight with the good strength and have mechanical qualities.

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LIST OF ABBREVIATIONS AND SYMBOLS

PMC: POLYMER MATRIX COMPOSITE

MMC: METAL MATRIX COMPOSITE

CFC: CARBON FIBER COMPOSITE

CMC: CERAMIC MATRIX COMPOSITE

UTM: UNIVERSAL TESTING MACHINE

ASTM: AMERICAN SOCIETY FOR TESTING AND MATERIALS

UTS: ULTIMATE TENSILE STRENGTH

LYP: LOWER YIELD POINT

DGEBA: DI GLYCIDYL ETHER OF BISPHENOL-A

TETA: TRIETHYLENETETRAMINE

CFRP: CARBON FIBER REINFORCED PLASTIC

NFRPC: NATURAL FIBERS REINFORCED POLYMER COMPOSIT

CHAPTER 1

INTRODUCTION

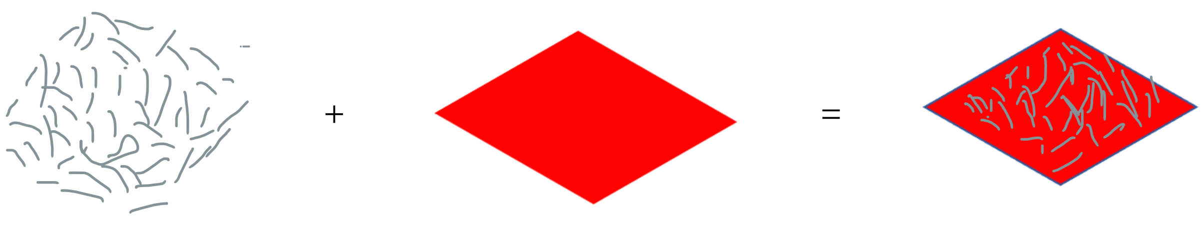
1.1 Introduction to composites

Composite material is defined as the material formed by combining two or more different materials/ constituents macroscopically that are distinct in the properties, and they do not dissolve into each other.

The combination of different constituents in the composites provides the composite material with unique properties which are different from the individual constituent.[1]

In composites, materials are combined in such a way as to enable us to make better use of them virtues while minimizing to some extent the effects of their deficiencies. This process of optimization can release a designer from the constraints associated with the selection and manufacture of conventional materials. He can make use of tougher and lighter materials, with properties that can be tailored to suit particular design requirements. And because of the ease with which complex shapes can be composites can often lead to both cheaper and better solutions [2].

Examples: Cement, Concrete, Fiber-reinforced polymer, etc.



Reinforcement Plate

Matrix

Composite

Figure 1.1 Formation of Composite

Some of the examples of man-made composites are:

- Concrete: Particulate composite of aggregates (lime stone and granite), sand, cement and water
- Plywood: several layers of wood veneer glued together
- Fiber glass: plastic matrix reinforced by glass fibers
- cements: Ceramic and metal composites
- Fibrous composites: variety of fibers (glass, Kevlar, graphite, nylon, etc.) bound together by a polymer matrix

1.2 History of Composites

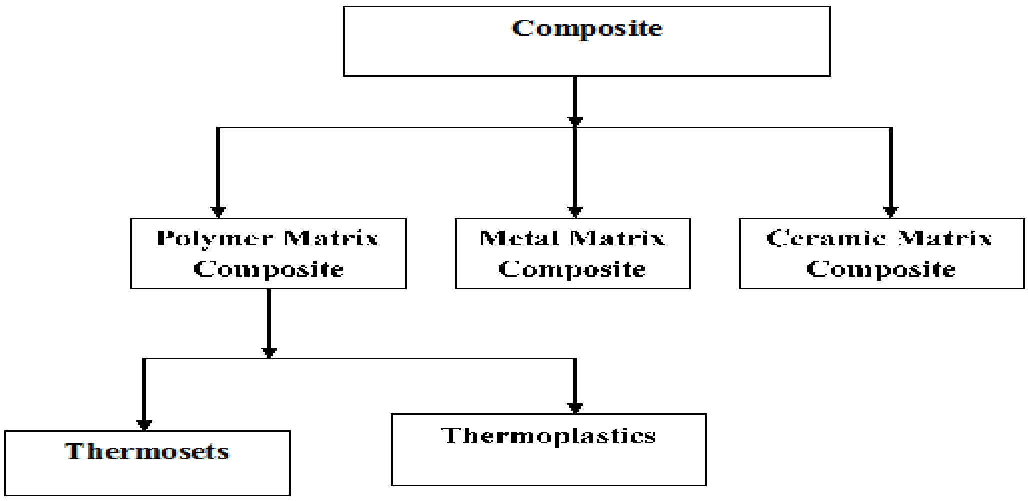
Over 5000 years ago, around the century 3500 BCE, we find the first uses of composites materials. The ancient Mesopotamians, one of the first civilizations found in present-day Iraq, Kuwait, and Syria, are the first people to produce a composites material. The Mesopotamian's early composites were made from pieces of wood glued together in different directions. This created an early form of plywood. The first resins were originated from plants and animals. For example, pine resin, a sticky syrup-like substance sealed bows and boats. Shortly after the 1870s and 1890s man-made, or synthetic, resins were invented. These resins could transform from liquid to solid by cross-linking molecules through a process known as polymerization. Composite materials have a long history of usage. The first uses of composites date back to the 1500 BC, when early Egyptians and Mesopotamian settlers used a mixture of mud and straw to create strong and durable buildings. The combination of mud and straw in a block of brick provides it a strong property against both squeezing and tearing or bending. The straw continued to provide reinforcement to ancient composite products, including pottery and boats. In 1200 AD, the Mongols invented the first composite bow using a combination of "animal glue", bone, and wood. The bows were pressed and wrapped with birch bark. These bows were powerful and accurate. Composite Mongolian bows helped to ensure Genghis Khan's military dominance. Due to their advantages such as being light weight and strong, many of the greatest advancements in composites were the result of wartime needs. During World War II, many composite materials were developed and moved from the laboratory into actual production [3].

1.3 Classification of Composites based on matrix

1. Polymer Matrix Composite (PMC): It is a composite material which is made of various continuous and the short fibres attached together with the matrix. They are made to distribute the loads between the fibres and the matrix. The main advantage of polymer matrix composite is they are light weight, high resistance, corrosion free.

2. Metal Matrix Composite (MMC): MMC is a composite material with fibres or particles dispersed in a metallic matrix and classified into discontinuous fibres and continues fibres, particulates by the type of reinforcement. In structural applications, matrix is usually a lighter metal and provides a complete support for the reinforcement.

3. Ceramic Matrix Composites (CMC): Ceramic matrix composites consider as the subgroup of composite material and subgroup of ceramics. Ceramic material is used as the reinforcement to make the composite. Carbon, silicon carbide, alumina is some reinforcement which can be used to make the ceramic matrix composite.



1.2 Types of Composite Material

1.4 Advantages of Composites over metallic materials

Composite materials have many advantages over the metallic materials which are listed below:

1. Light Weight: - Composites are light in weight, compared to most woods and metals. Their lightness is important in automobiles and aircraft, for example, where less weight means better fuel efficiency (more miles to the gallon). People who design airplanes are greatly concerned with weight, since reducing a craft's weight reduces the amount of fuel it needs and increases the speeds it can reach. Some modern airplanes are built with more composites than metal

2. High Strength: - Composites can be designed to be far stronger than aluminium or steel. Metals are equally strong in all directions. But composites can be engineered and designed to be strong in a specific direction.

3. Strength/ Weight ratio: - Strength-to-weight ratio is a material's strength in relation to how much it weighs. Some materials are very strong and heavy, such as steel. Other materials can be strong and light, such as bamboo poles. Composite materials can be designed to be both strong and light. This property is why composites are used to build airplanes—which need a very high strength material at the lowest possible weight.

4. Corrosion Resistance: - Composites resist damage from the weather and from harsh chemicals that can eat away at other materials. Composites are good choices where chemicals are handled or stored. Outdoors, they stand up to severe weather and wide changes in temperature.

5. High Impact Strength: - Composites can be made to absorb impacts—the sudden force of a bullet, for instance, or the blast from an explosion. Because of this property, composites are used in bulletproof vests and panels, and to shield airplanes, buildings, and military vehicles from explosions.

6. Design Flexibility: - Composites can be moulded into complicated shapes more easily than most other materials. This gives designers the freedom to create almost any shape or form. Most recreational boats today, for example, are built from fiberglass composites because these materials can easily be moulded into complex shapes, which improve boat design while lowering costs. The surface of composites can also be moulded to mimic any surface finish or texture, from smooth to pebbly.

7. Dimensional Stability: - Composites retain their shape and size when they are hot or cool, wet or dry. Wood, on the other hand, swells and shrinks as the humidity changes. Composites can be a better choice in situations demanding tight fits that do not vary. They are used in aircraft wings, for example, so that the wing shape and size do not change as the plane gains or loses altitude.

8.Non-Conductivity: - Composites are nonconductive, meaning they do not conduct electricity. This property makes them suitable for such items as electrical utility poles and the circuit boards in electronics. If electrical conductivity is needed, it is possible to make some composites conductive.

9. Non-Magnetic: - Composites contain no metals; therefore, they are not magnetic. They can be used around sensitive electronic equipment. The lack of magnetic interference allows large magnets used in MRI (magnetic resonance imaging) equipment to perform better. Composites are used in both the equipment housing and table. In addition, the construction of the room uses composites rebar to reinforced the concrete walls and floors in the hospital.

10. Low Thermal Capacity: - Composites are good insulators—they do not easily conduct heat or cold. They are used in buildings for doors, panels, and windows where extra protection is needed from severe weather.

11. Durable: - Structures made of composites have a long life and need little maintenance. We do not know how long composites last, because we have not come to the end of the life of many original composites. Many composites have been in service for half a century.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

Anthony Liu et al. (2012) **[4]** has studied the mechanical and dynamic properties of coconut fibre reinforced concrete and also, they have potential to be used as reinforcement in low-cost structures. The influence of 1%, 2%, 3% and 5% fibre contents by mass of cement and fibre lengths of 2.5, 5 and 7.5 cm is investigated. They concluded that by adding 5% fibre content by mass of cement and fibre length 5 cm improving the properties of concrete.

S. Mazan et al. **[5]** studied the viability of coir fibre reinforced composites in sound absorption panel. The composites are constructed as prescribed percentage of fillers and polyurethane as resin. Two microphone methods were used to investigate the acoustic the properties of the material. The result demonstrates good acoustic properties of the composites and highlight the potential of the coir fibre reinforced composites in sound absorption panel.

Bujang et al [6] studied the dynamic characteristics of coir fibre reinforced composites. Composites with volumetric amounts of coconut fibre up to 15% were fabricated and they were arranged in randomly oriented discontinues form. Tensile test was carried out to determine the strength of material, while experimental modal analysis was executed to obtain the dynamic characteristics of the composite material. The acquired results show that the tensile modulus changes with the fibre content. The strength of coconut fibre reinforced composites tends to decrease with the amount of fibre which indicates ineffective stress transfer between the fibre and matrix. The stiffness factor also gives the same effect to the dynamic characteristic of composite where the natural frequency decreased with the increase of coconut fibre volume. How ever the damping peak was found to be increased by the incorporation of the fibre. When higher fibre content of 10% was used, the damping peak shows the maximum value for almost all the frequency mode. It was observed that the effects of reinforcing polyester matrix with the coconut fibres caused the composites to be more flexible and easily deform due to high strain values and reduction of high resonant amplitude indicated that hybrid composites offer better resistance to water absorption. This work demonstrates the potential of the hybrid natural fibre composite materials for use in a number of consumable goods.

Sarocha Charoenvai et al [7] investigated the mechanical properties of coir based green composites were prepared using coir fibre treated with varying pre-treatment condition. The changes in the proportion of chemical composition and morphological properties of coir fibres with different coir pre-treatment condition were discussed. It is observed that the mechanical properties of coir-based green composites; modulus of rupture and internal bond, increase as a result of chemical composition modification and surface modification.

Rozman et al. [8] concluded that coir fibre packed with lignin-filled polypropylene composites perform better flexural characteristics than control composites. This study investigates the use of coir-based natural fibre composites strengthened with polypropylene for the automotive interior application panel.

A.Z., Ahmad mujahid et al [9] performed the experimental modal analysis on coir fiber reinforced composites. There are 4 percentages of the coir fibre that will be used to fabricate the composites which 40% wet, 50% wet, 60% wet and 70% wet of coir fibre. Dynamic characteristic of the composite is evaluated. For all the cases, the plate only experiences the global vibration where the whole structure is vibrating. The first five mode shapes of each percentage of coir fibre were observed which can be identified from 39.8 Hz until 985 Hz. From the result, the natural frequencies of 40% wet fibre are observed where can be identified from frequency 315 Hz until 985 Hz. The natural latex with the 40% volume of coir fibres shows a slightly higher frequency compared to 70% volume of coir fibres only for the second until five mode frequency. Somehow for the higher mode, it founds that the natural latex with 70% fibres volume prove to have a higher value. The results were found that the dynamic characteristics are greatly dependent on the volume percentage of fibres. From the result, it can be concluding that the sample with 40% coir fibre gives the highest value of natural frequency which is 315 Hz to 985 Hz compared the others composition. The increase of coir fibres will make the composite tend to have low stiffness and ductility.

Misra et al [10] investigated fire retardant coir epoxy micro-composites. The coir fibre is treated with saturated bromine water for increasing the electrical properties and then mixed with stannous chloride solution for improving the fire-retardant properties only 5% of fire-retardant filler reduces the smoke density by 25% and the LOI value increases to 24%. The mechanical properties of the composites were not affected much after the incorporation of fillers. Flexural strength and flexural modulus of the composite increased tremendously.

Multiquadric radial basis function (MQRBF) method is applied for static and dynamic analysis of coir epoxy

J.R.M. D. Almeida et al [11] investigated the structural characteristics and mechanical properties of coir fibre/polyester composites. The coir fibres were obtained from disregarded coconut shells that if not properly processed constitute an environmental hazard. The as-received coir fibre was characterized by scanning electron microscopy coupled with X-ray dispersion analysis. Composites prepared with two moulding pressures and with amounts of coir fibre up to 80 wt. % were fabricated. Up to 50 wt. % of fibre, rigid composites were obtained. For amounts of fibre higher than this figure, the composites performed like more flexible agglomerates.

Samia S. Mir et al [12] characterized brown single coir fibre for manufacturing polymer composites reinforced with characterized fibres. Adhesion between the fibres and polymer is one of factors affecting the strength of manufactured composites. In order to increase the adhesion, the coir fibre was chemically treated separately in single stage (with $Cr2(SO4)3•12(H2O)$) and double stages (with CrSO4 and NaHCO3). Both the raw and treated fibres were characterized by tensile testing, Fourier transform infrared (FTIR) spectroscopic analysis, scanning electron microscopic analysis. Mechanical properties of characterized fibre in this analysis were found to be better than the raw fibre and that of the double treated even better. Scanning electron micrographs showed rougher surface in case of the raw coir fibre. The surface was found clean and smooth in case of the treated coir fibre.

According to Elango KS and Revathi V, Pozzolana is artificial or natural material containing silica in a reactive form to produce cement [13]. The replacing of a conventional building to some extent such as fly ash bricks, PPC and lightweight aggregates. [14]. According to the author, the more fineness in cement increases both cement strength and workability [15]. Cement with higher fineness hydrate quickly to gain early strength [16]. The replacement of cement by pozzolana shows a decrease in the cement strength and disappear after 3 months [17]. According to NS and IS, the expansion carried out below 10 mm in the Le Chant test and 0.8% in the Autoclave test [18]. The development of the cement strength of Pozzolana cement is slightly slower than that of OPC, and it gains higher cement strength in the long run. If cement is stored in airtight conditions, it gives the expected strength up to 3 months [19].

Pofale, & Deo, 2010 [20] with their study indicated about 20% increase in compressive strength and about 15% increase in flexural strength of concrete over control concrete by replacing 27% of sand with low lime fly ash. In study fly ash-based Portland pozzolana cement was used. They had also reported about 25% increase in workability of the fly ash-based concrete over control concrete. Out of large number of papers studied papers only found very relevant are included for putting forward present objectives. Literature discussed has shown partial replacement of scarce sand with fly ash had shown higher strength from 3rd day as compared to control concrete. Long term strength was about 20% higher than the control concrete. Along with increase in strength, increase in workability and durability of concrete by partial replacement of sand with fly ash is very encouraging. Analysing the results, it may be seen that due to ball bearing and pore filling effect, dispersion of cement particles and pozzolanic reactivity of fly ash as partial replacement of sand workability and strength also increased. This additional strength and workability offered by partial replacement of sand with fly ash could offset loss of 28days strength of high-volume fly ash concrete.

Chatterjee, (2011) [21] reported that about 50 % of fly ash generated is utilised with present efforts. He also reported that, one may achieve up to 70% replacement of cement with fly ash when high strength cement and very high reactive fly ash is used along with the sulphonated naphthalene formaldehyde superplasticizer. He reported improvement in fly ash property could be achieved by grinding and getting particles in sub microcrystalline range.

Bhanu Mathias, &Kalidas, (2002) [22] with their research on Indian fly ashes reported that the increase in ground fineness by 52% could increase the strength by 13%. Whereas, with the increase in native fineness by 64% the strength was reported to increase by 77%. Looking in to the results it was proposed that no considerable improvement of reactivity could be achieved on grinding a coarse fly ash. Authors also uphold that the study on lime reactivity strength had more relevance when fly ash is used in association with lime but preferred pozzolanic activity index in case of blending with cement.

Reis [23] investigated the mechanical characterization (flexural strength, fracture toughness and fracture energy) of epoxy polymer concrete reinforced with natural fibres (coconut, sugarcane bagasse and banana fibres).

The study carried out by Castro and Naaman [24], concluded that it was possible to reinforce Portland cement mortars with maguey fibers, since this fiber has an adequate physical and mechanical properties.

The Portland pozzolana cements (Cements C3 and C5) consist of 77% and 65% clinker, 7.6% and 12.4% trass, and 11.4% and 18.6% volcanic slag, respectively [25].

In PPC concrete, the competition between chloride and hydroxide ions may result in severe corrosion of embedded steel if oxygen is available for cathodic reaction The use of PPC in important concrete structures such as bridges, multistorey building, off shore structure, etc., are very limited due to the increased corrosion of steel in concrete. So, the suitable admixture system should be incorporated during the construction stage itself in order to avoid the corrosion of steel in concrete [26].

2.2 Material Selection of Natural Fibre for Composites

Material selection has become a critical part of design for engineers, due to availability of diverse choice of materials that have similar properties and meet the product design specification. Implementation of statistical analysis alone makes it difficult to identify the ideal composition of the final composite.[27]

Materials Selection for Natural Fibre Composites covers the use of various tools and techniques that can be applied for natural fibre composite selection to expand the sustainable design possibilities and support cleaner production requirements. These techniques include the analytical hierarchy process, knowledge-based system, Java based materials selection system, artificial neural network, Pugh selection method, and the digital logic technique. Information on related topics, such as materials selection and design, natural fibre composites, and materials selection for composites are discussed to provide background information to the main topic. Current developments in selecting the natural fibre composite material system, including the natural fibre composites and their constituents (fibres and polymers) is the main core of the book, with in detailed sections on various technical, environmental and economic issues to enhance both environmental indices and the industrial sustainability theme. Focuses on materials selection for natural fibre composites.[27]

Materials selection of composite materials, compared to homogenous materials like metals and plastics is quite difficult to perform due to the anisotropic nature of the materials that required the tailored made consideration of products and materials. The real issues of materials selection for composites are the presence of large permutation of candidate materials based on the following: [28]

- Different types of composite materials such as polymer composites, metal matrix composites, and ceramic matrix composites. Different types of fibres such as glass, carbon, aramid, boron, and natural fibres.
- Different types of matrices and for polymer composites, the matrices comprise thermoplastic materials. Other variations in polymer matrices include polymer blends and the use of either synthetic or bio-based polymers. Please bear in mind that there are also different types of ceramic and metal matrices at our disposal

Different arrangements of fibres like continuous roving, woven roving, nonwoven fabrics, chopped strand mat, short fibres, and particulates.

- New advances in composite technology such as the emergence of nanocomposites, hierarchical composites, functional graded materials, smart and intelligent materials, biomimetic materials, and graphene-based composites.

CHAPTER 3

MATERIALS AND METHOD

3.1 Materials Required

Following materials are required for the preparation of sample

- Epoxy resin (LY-556)
- Hardener (HY-951)
- Coir (Coconut husk)
- Portland Pozzolana (Black cement)

1. **Epoxy resin (LY-556):** Epoxy resin is the basic component or end products of Epoxy resin it is also known as polyoxides, are a class reactive prepolymers. Epoxy resin has many industrial applications for a variety. It is a higher mechanical properties and thermal and chemical resistance. The Epoxy resin LY/556 is used for formation a composite material. The Epoxy resin LY556 is used as a reinforcing material due to its medium viscosity and chemicals resistivity. It is low cost it has been very well documented in the literature for hundred years that the incorporation of nanofiller to polymer glasses and semi crystalline polymer can remarkably improve the performance of polymer. For fabrication of component, diglyceryl-ether of bisphenol epoxy (DGEBA, LY556, specific gravity of 1.16) and triethylenetetramine hardener (TETA, HY951, specific gravity of 0.95) was used in 10:1 ratio.

Figure 3.1 Epoxy Resin

2. Hardener (HY-951)

A hardener is a component which is used with epoxy resin to achieve the result. In other words, we use the mixing hardener +epoxy resin to increase resilience of the mixture once it set hardener is work like as a catalyst in the chemical reaction that occurs during the mixing process. A Hardener also known as an accelerator. It is most important to make an epoxy resin to useful for its purpose. It we not mix Hardener in epoxy resin it is difficult to achieve the desired result Hardener is use its requirement of the application. It makes the fast process of solidification of wet composite material. Hardener is high viscous liquid material. If we will not use the hardener the epoxy resin will take long time to cure itself.

Figure 3.2 Hardener

3. Coir (coconut husk)

Coir is multilateral natural fibre extracted from mesocarp or husk of the coconut fruit generally fibre is of golden colour when cleaned after removing from coconut husk it is also known as golden fibre. this is the natural fibre and it is part of the coconut shell. The fibre protects the fruit enough to survive months floating on ocean it is grow on the tree of coconut. These features make the fibre quite useful in floor and outdoor mats, rope, and garden mulch. Fibre cells are parochial and hallow with thick walls made of cellulose. The coir fibre is used for various industrial purpose such as rope and mat making it is easily available. After the cleaned processed fibre ranging from about 10 to30cm (4to12inches) in length. They are resistant to abrasion and can be coloured. It is founded in two types of fibre white and brown fibre.

Figure 3.3 Coir (Coconut husk)

4. Portland Pozzolana (Black Cement)

Portland is an ash or eruptive powder. It is natural eco-friendly material. The Portland Pozzolana is found in near Italy. The material can be natural or synthetic which contain silica and aluminous in a reactive form. The material generally doesn't possess any cementing properties, however when it is mixed with water or lime to undergo reaction with calcium hydroxide to form compounds possessing cement properties.

Figure 3.4 Portland pozzolana

3.2 Methodology

1. Hand lay-up technique

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple.

STEP 1: First of all, a grease is applied on the mold surface to avoid the sticking of polymer composite to the surface.

STEP 2: Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after. And in the case of Portland pozzolana the powder is dropped.

STEP 3: Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of the mold.

STEP4: The polymer is uniformly spread with the help of brush. Second layer of reinforcement is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present.

STEP 5: The process is repeated for each layer of polymer and mat, till the required layers are stacked.

STEP 6: Then the mold is covered with some weight.

STEP 7: After curing either at room temperature or at some specific temperature, mold is opened after 48 to 72 hours and the developed composite part is taken out and further processed.

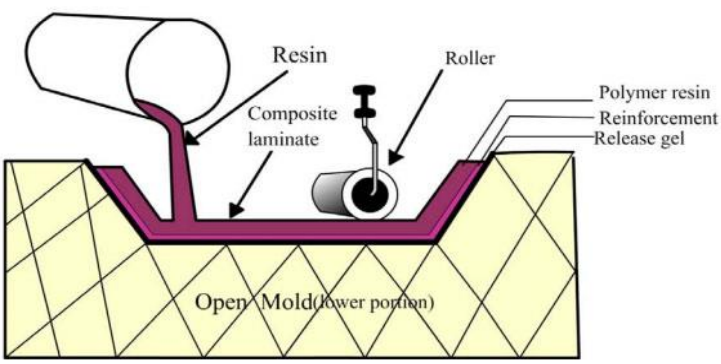


Figure 3.5 Schematic Diagram of hand lay-up process

2. Sample Preparation

- **Preparing the composite solution**

  For the preparation of solution epoxy and hardener are used. Hardener acts as a catalyst in the chemical reaction that occurs during the mixing process. A hardener may be also known as accelerator**.** The ratio of epoxy and hardener is taken as 10:1.

Figure 3.6 Mixing of epoxy and hardener

- **Applying Grease on the mould**

  As we know grease is a lubricant which reduce the adhesiveness of the composite plate with the mould. Grease is applied on the mould, so that the composite plate should not stick with the mould and can be easily removed from the mould.

Figure 3.7 Applying grease

- **Pouring the Solution into the mould**

After mixing the epoxy and hardener properly in a beaker by using stir, we poured the solution into the mould, in such a way that the solution is distributed through the mould equally, so that we can get a perfect composite plate.

Figure 3.8 pouring of epoxy & hardener solution on the mould

- **Bubble removing**

After pouring the whole solution into the mould, we waited for a while until bubbles came out on the top of the solution. We removed the bubbles by using a needle one by one so that maximum bubbles can be removed. Bubble removing helps to reduce the defect and irregularities in the composite plate.

Figure 3.9 Bubble Removing

- **Settling the mould by putting weight**

We covered the mould by the mould cover plate, on which grease was applied fist. Then a load is applied above the mould, so that the solution settles down properly.

Figure 3.10 External load applied on the mould

The time of curing is different for different composite processing, as it depends on the type of polymer used. For example, for epoxy-based composites normal curing time at room temperature is 48-72 hours.

CHAPTER 4
MECHANICAL ANALYTICAL TESTS FOR TESTING COMPOSITES

4.1 Impact Test

The resistance of a material to fracture under dynamic loads is characterized by impact strength, Impact strength of a material is a complex characteristic which takes into account both the toughness and strength of a material. Toughness is used to describe the ability of a material to withstand shock loads, the tougher the material the more it is able to withstand such loads without breaking, several engineering materials have to withstand impact or suddenly applied loads while in service. In S.I. units the impact strength is expressed in Mega Newtons per meter (MN/m). Impact strength is indicative of the toughness of the material, i.e., the ability of the material to absorb energy during plastic deformation. Impact strength tests are used considerably in some industries to know shock-absorbing property of the material under the given variations Izod Impact test specimens are prepared as per ASTM D256 standards. Standard specimens of length 13mm x 63 mm width, thickness 5-7 mm was cut from a fabricated sheet.

Factors which affect the impact strength of a material:

1. Impact strength increases if the dimensions of the specimen are increased.
2. To some extent the velocity of impact also affects impact strength. Impact strength can be measured using two tests, namely Izod and Charpy. We will be using Izod Impact Strength Test for this study.

4.1.1 Significance of Impact Strength

The fracture toughness of an engineering material is a very significant property. Composite materials, when they fail, tend to fail in a disastrous way. Unlike metals they suddenly fail with little yielding before totally collapsing. So, it is very important to have a minimum impact force needed to induce a crack into the composite material. Impact test determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition. It is to determine whether the material is brittle or ductile in nature [29]

4.1.2 Working of Izod Impact Test

An IZOD Impact Tester, as per figure 5, contains a pendulum type hammer with a striker and a mount to clamp the specimen into position. As the pendulum strikes the specimen, the breaking energy of the specimen is recorded. Impact Strength is calculated by dividing Impact Energy (absorbed) in Joules (J) (or ft-lb) by the cross-section area (area under the notch in m^3). Impact Strength is expressed in kJ/m^2. The standard specimen for ASTM D256 is 64 x 12.7mm, thickness is 3.2-3.5 mm.

Fig.4.1 Standard machine for impact testing (IZOD)

4.2 Flexural Test

Flexural or compressive strength is the mechanical measure of maximum load bearing capability of a material without undergoing any permanent deformation. In simple terms, it is the extent to which an object or any material may resist breakage when bent. In engineering mechanics, flexure or bending characterizes the behaviour of a slender structural element subjected to an external load applied perpendicularly to a longitudinal axis of the element. Flex modulus is indicative of how much the material can flex before permanent deformation. Flexural strength is also called as bend strength as well as modulus of rupture.

4.2.1 Significance of Flexural Strength:

Engineers often want to understand various aspects of material's behaviours, but a simple uniaxial tension or compression test may not provide all necessary information. As the specimen bends or flexes, it is subjected to a complex combination of forces including tension, compression, and shear. For this reason, bend testing is commonly used to evaluate the reaction of materials to realistic loading situations. [30] Flexural strength can be measured using two tests namely 3-point bend test and 4-point bend test. For our study, we will be using 3-Point Bend Test.

4.2.2 Working of Flexural Test

In this we have to place the specimen on the surface and the load is applied on it until it breaks down and the breaking point is measured. The standard specimen for ASTM D256 is 64 x 12.7mm, thickness is 3.2-3.5 mm.

Fig.4.2 standard machine for flexural test

CHAPTER 5

RESULTS AND DISCUSSION

The analytical tests performed in this study are:

1) Flexural Strength
2) Flexural Modulus
3) Impact Strength

After making samples of a primary epoxy, coir and Portland pozzolana composites, Flexural strength, Flexural Modulus and Impact Strength are evaluated using the Flexural and Impact tests according to international ASTM (American Society for Testing and Materials) standards. The ASTM D256 and D790 test methods are employed for the impact and flexural tests, respectively. The Central Institute of Plastic Engineering and Technology (CIPET), in Lucknow, has these testing devices available.

Table 1.The analytical test as per ASTM Standards

S. No	Types of tests	ASTM standards
1	Flexural Strength	ASTM 790 D
2	Flexural Modulus	ASTM 790 D
3	Impact Strength	ASTM 256 D

Table 2. Test result of composite samples

Material	Flexural strength (MPa)	Flexural Modulus (MPa)	Impact Strength (Izod)(KJ/m^2)
Sample 1 (epoxy and hardener)	23.32	3091.1	1.64
Sample 2 (epoxy and Coir)	88.01	3814.9	3.28
Sample 3 (epoxy and Portland pozzolana)	35.74	5344.8	1.48

Results: Flexure Strength Test

The Flexure Test (also called the 3-Point bend test) was performed on an Instron UTM machine, model: 3382, at CIPET, Lucknow. The machine used a support span of 96 mm on a 100kN capacity machine, with a cross head testing speed of 50 mm/min. Specimen dimensions were prepared and method of testing were used in accordance to ASTM D790 standards. Image of the actual equipment used for this test is shown in.

Table 3. Flexural Strength of Samples

Sample	Sample Description	Flexural strength (MPa
1	epoxy and hardener	23.32
2	epoxy and Coir	88.01
3	epoxy and Portland pozzolana	35.74

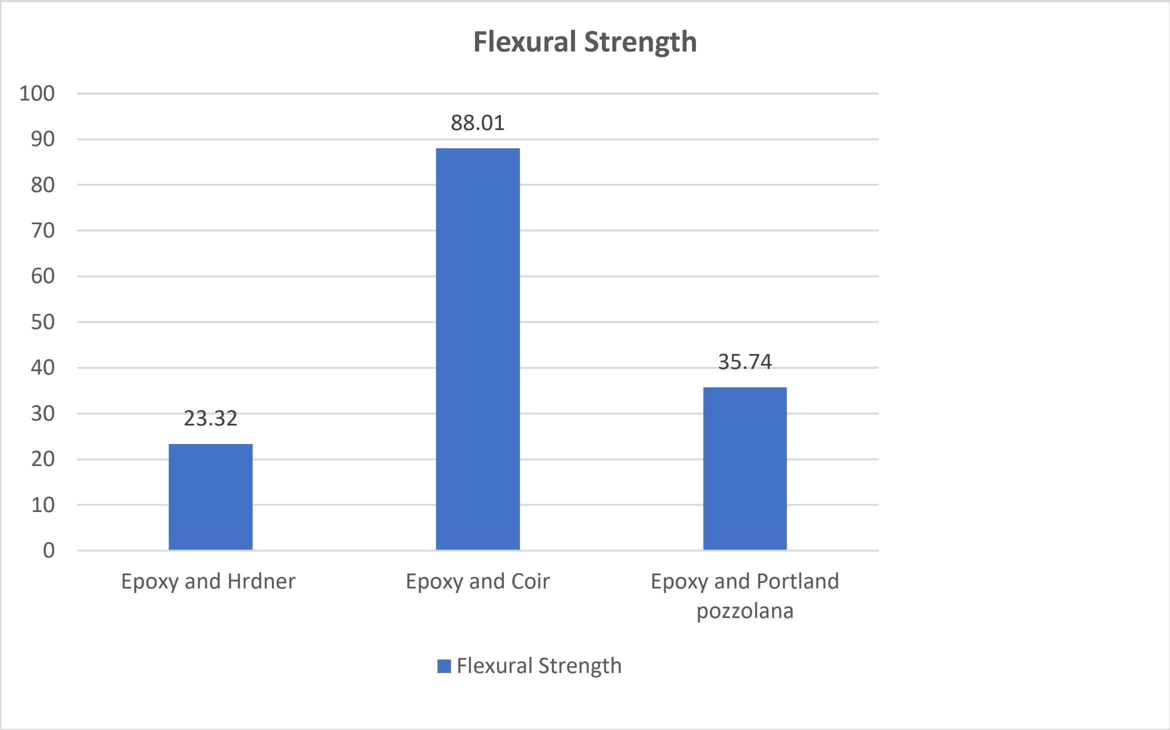


Figure 5.1 Flexural strength of Samples

During flexural (3-point bend) test, specimens were mounted on the UTM machine with clams and holders for flexural tests. Tension was applied to the test specimen until it fractured on the testing machine. The deflection of the specimen was measured using the crosshead position. Deformation and flexural strength were also assessed. Measured values were reported as per Table, showing the comparison of flexural strengths of the composites obtained experimentally from the 3-point bend tests as per figure It was interesting to note that composite samples exhibited a higher flexural strength compared to the epoxy neat matrix sample.

We get to know that the flexural strength of coir composite is more than the other two composites i.e., 88.01MPa. The coir fibre contains cellulose, hemi cellulose and lignin (the fibre contains 30 to 300 or more cells in its total cross-section) and its cross-section is polygonal or round [31]

Results: Flexural modulus

Flexural modulus is a convenient measure of composite stiffness. Fillers can contribute significantly to a stiffness increase.

The flexural modulus (sometimes referred to as the bending modulus or tangent modulus) of a material is a mechanical property. It describes its stiffness or resistance to a bending action or its ability to deform in bending.

Table 4. Flexural Modulus

Impact Strength (Izod) (KJ/m^{2}sample	Sample description	Flexural Modulus
1	epoxy and hardener	3091.1
2	epoxy and Coir	3814.9
3	epoxy and Portland pozzolana	5344.8

It was observed that the flexural modulus of coir and Portland pozzolana composites is higher than primary epoxy composite (sample 1). it indicates that Coir (sample 2) and Portland Pozzolana (sample 3) composites have higher tendency to bend when a given amount of bending stress is applied.

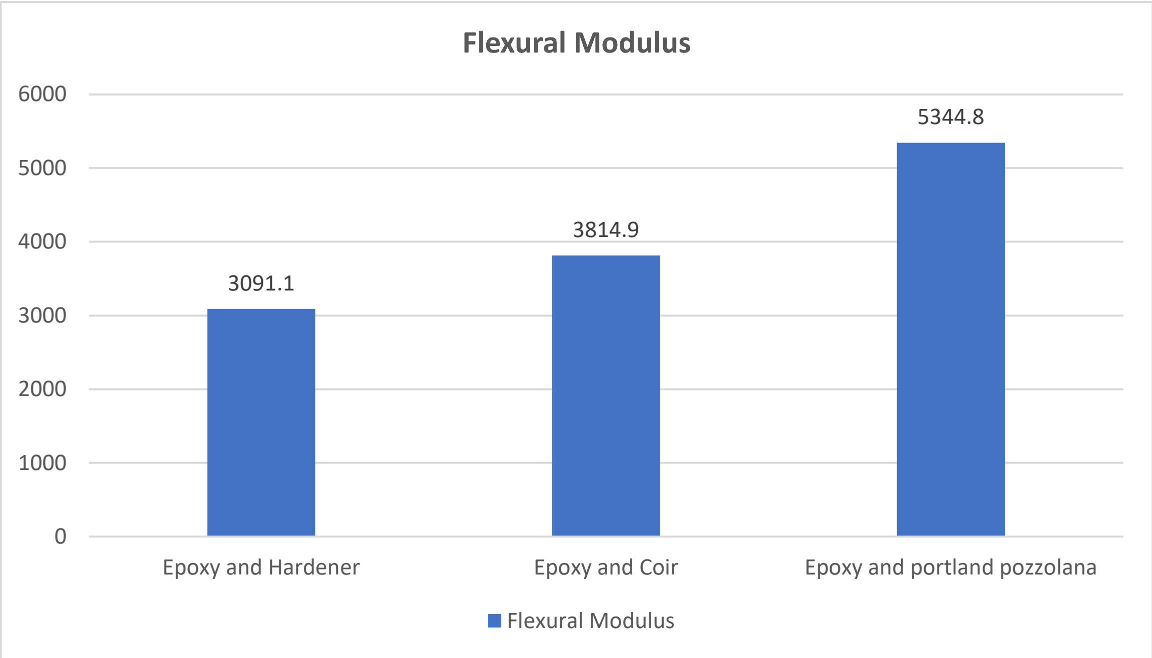


Figure 5.2 Flexural Modulus of Samples

Results: Impact Strength

The Impact Strength Test were performed on the CEAST Torino, model RDNL, at CIPET, Lucknow. Specimen dimensions prepared and method were used according to ASTM D256; image of the equipment used is shown in Appendix.

Table 5. Impact Strength of Samples

Sample	Sample description	Impact Strength (Izod) (KJ/m^2)
1	epoxy and hardener	1.64
2	epoxy and Coir	3.28
3	epoxy and Portland pozzolana	1.48

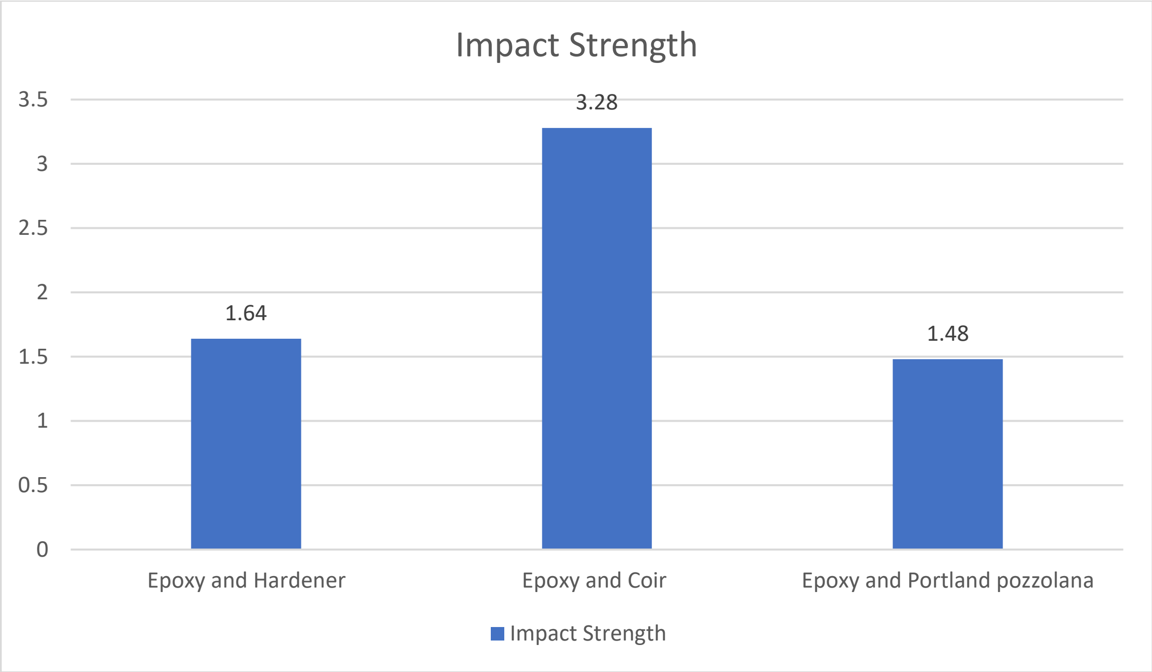


Figure 5.3 Impact Strength of Samples

During testing, the specimen was loaded into a device and the pendulum was allowed to swing until it broke. Impact tests were used to measure the energy necessary to break the material, and this energy was used to determine the toughness and yield strength of the material.

we have got that the impact strength of coir composite (sample 2) is higher than the other two composites. The impact strength of Coir Composite is found to be 3.28kj/m² which is the highest among the three samples.

केंद्रीय पेट्रोरसायन अभियांत्रिकी एवं प्रौद्योगिकी संस्थान (सिपेटः आई.पी.टी.)
(पूर्व में केंद्रीय प्लास्टिक इंजीनियरिंग एवं तकनीकी संस्थान)
रसायन एवं पेट्रोरसायन विभाग,
रसायन एवं उर्वरक मंत्रालय, भारत सरकार
बी-२७, अमौसी इण्डस्ट्रियल एरिया, लखनऊ-२२६ ००८
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CIPET सिपेट

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PLASTIC TESTING CENTRE
TEST CERTIFICATE

S.No. 0412

ULR-TC595523000000807F

Date: 22.05.2023

Issued to: **Mr. Nitesh Singh,**
Student of Mechanical Engineering (4th Year)
Babu Banarasi Das Institute of Technology & Management,
Sector-I, Dr. Akhilesh Das Nagar,
Faizabad Road, Lucknow

TC-6956

Your Ref.No. & Date : MED/BBDITM/PROJECT/A/04/02 **dated : 20.04.2023**

TEST REPORT AS PER STANDARD AND AMEND WITH DATE : As per party requisition
TEST REPORT NO: 0416 **Page 1 of 2**

PART – A :- PARTICULARS OF SAMPLE SUBMITTED

a)	Name of the sample	:	Primary Composite, Coir Composite, Portland Pozzolona Composite as stated by the party
b)	Grade / Variety / type / size / class	:	—
c)	Declared value, if any &	:	—
d)	Code No.	:	—
e)	Batch No. & Date of Manufacture	:	—
f)	Quantity	:	1 No. each prepared sample
g)	Mode of Packing	:	Packed in polythene
h)	Sealed or not	:	Not sealed
i)	Date of receipt of sample	:	09.05.2023
j)	Date of starting of the testing	:	10.05.2023
k)	Date of completion of testing	:	22.05.2023
l)	Any other information	:	Payment received on 09.05.2023

PART - B :- SUPPLEMENTARY INFORMATIONS

a)	Reference to sampling procedure	:	Not Applicable.
b)	Supporting document for the measurement taken & result derived	:	Not Applicable.
c)	Deviation from the test method as prescribed in relevant work instructions, if any	:	Not Applicable.

22/05/2023 22/05/2023

सिपेट : आईपीटी, लखनऊ *Continuation Sheet* **CIPET : IPT, LUCKNOW**

ULR-TC595523000000807F **G- 0412**

Issued to : Mr. Nitesh Singh, Student of Mechanical Engineering (4th Year)
Babu Banarasi Das Institute of Technology & Management,
Sector-I, Dr. Akhilesh Das Nagar, Faizabad Road, Lucknow

Your Ref.No. & Date : MED/BBDITM/PROJECT/A/04/02, dated : 20.04.2023

TEST REPORT No. – 0416 Date: 22.05.2023

PART – C:- TEST RESULTS as per Party requisition **Page 2 of 2**

S. No.	Name of the Test	Test Method	Unit	Test Value Obtained
1.	Impact Strength	ASTM D 256	kJ/m^2	1.64
			kJ/m^2	3.28
			kJ/m^2	1.48
2.	Flexural Strength	ASTM D 790	MPa	23.32
			MPa	88.01
			MPa	35.74

PART – D : REMARKS - NIL

22/05/2023 22/05/2023

AUTHORIZED SIGNATORY
Dr. V. H. Sangeetha
Technical Manager

AUTHORIZED SIGNATORY
Rajiv Kumar Lilhare
Quality Manager

NOTE :
(i) This Test Report/ Certificate is issued only for the samples submitted to CIPET.
(ii) The results stated above related only to the items tested.
(iii) The quality of the subsequent production lot has to ensured by the purchaser.
(iv) The test certificate shall not be reproduced in full except without the written approval of the laboratory.
(v) Statement of conformity of a specification or standard is provided by laboratory taking into account the level of risk associated/borderline cases with the decision rule employed.

Figure 5.4 Test Results

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

Coir/epoxy resin and Portland Pozzolana/epoxy resin, based composites were fabricated by hand lay-up method by mixing 30% coir and 30% Portland Pozzolana as a reinforcement, we found that the coir, which is a natural reinforcement has higher mechanical properties than synthetic reinforcement like Portland Pozzolana which resulted in higher flexural and impact strength of coir composite. The value obtained from the test of flexural strength is 88.01 MPa, and the impact strength value is $3.28 KJ/m^2$ of the coir composite. Coir/epoxy may perform better than Portland Pozzolana when choosing a material having high flexural and impact strengths, compared to Portland pozzolana composites coir composite would make an effective reinforcement for creating composites. The desire for bio composites in various applications due to the need for green composites in automobile, packaging, electronics, health, and structural industries has further increased the interest of researchers in the use of bio fibres. Composite materials are used extensively in the automobile, aerospace, and wind energy industries. industries include electrical, sports, household use, civil construction, pharmaceuticals, and chemicals, etc. Composite materials have a wide range of possible uses in structures that are predominantly exposed to compression loads. The comparatively high compressive strength, good adaptability in creating thick composite shells, low weight, low density, and corrosion resistance of composite materials make them appealing. Due to their excellent mechanical and chemical characteristics, composite materials are used in a wide range of sectors. Due to their advantageous qualities, composite materials are used to make a variety of automotive and aeronautical components. For home purposes, such as in furniture, windows, doors, mending, civil building, etc., composite materials are employed. We can employ composite material for greater performance in the maritime, chemical, and sporting industries.

6.2 Future scope

The present research works leave a wide scope for future investigators to explore many other aspects of such composite materials.

There are several potential areas of improvement that could make coir composites even better. Here are a few examples:

Coir composites have good mechanical properties, they can be further improved by using additives or coatings to increase their strength, stiffness, and durability.

Enhancing mechanical properties: While coir composites have good mechanical properties, they can be further improved by using additives or coatings to increase their strength, stiffness, and durability.

Improving water resistance: Coir composites have relatively low water resistance, which limits their use in applications exposed to moisture. Research could focus on developing methods to increase water resistance without compromising other properties.

Investigating alternative processing methods: Currently, coir composites are mainly produced using compression moulding or hand lay-up methods. Research could investigate alternative processing methods, such as injection moulding or 3D printing, to increase efficiency and reduce waste.

Portland Pozzolana Cement (PPC) composites have gained popularity in the construction industry due to their high strength, durability, and ability to reduce the environmental impact of cement production. However, there are still several potential areas of improvement that could make PPC composites even better. Here are a few examples:

PPC composites are currently made using a combination of Portland cement and pozzolanic materials such as fly ash or silica fume. Research could focus on identifying new pozzolanic materials that could improve the properties of PPC composites, such as natural pozzolans like volcanic ash or calcined clay.

Investigating new raw materials: PPC composites are currently made using a combination of Portland cement and pozzolanic materials such as fly ash or silica fume. Research could focus on identifying new pozzolanic materials that could improve the properties of PPC composites, such as natural pozzolans like volcanic ash or calcined clay.

Developing new processing techniques: Currently, PPC composites are mainly produced using traditional methods such as casting or moulding. Research could investigate alternative processing techniques, such as extrusion or 3D printing, to increase efficiency and reduce waste.

Improving durability: While PPC composites are known for their durability, there is always room for improvement. Research could focus on developing methods to increase resistance to chemical attack, temperature fluctuations, and other environmental factors that can degrade the material over time.

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APPENDIX

Specimen’s For Mechanical Testing As per ASTM methods

Figure (a) Specimens cut to dimensions as per ASTM for Flexural Testing

Figure (b) Specimens cut to dimensions as per ASTM for Impact Testing

APPENDIX

Specimen’s For Mechanical Testing As per ASTM methods

Figure (c) Specimens of Portland Pozzolana Composite

Figure (d) Specimens of coir Composite

Figure (e) Specimens of Primary Epoxy Composites

APPENDIX

Some pictures While making of Composites

Figure (f) Making of Composites through hand lay-up process

Figure (g) Coconut Coir (Husk)

Figure (h) Portland Pozzolana

Figure (I) Epoxy Resin (LY554) and Hardener (HY951)

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Certificate of Acceptance & Publication

This is to certify that **"Nitesh Singh"** has successfully published their paper **"Analysis of Mechanical Properties of Coir/Portland Pozzolana Reinforced Polymer Matrix Composites"** in International Journal of Advanced and Applied Sciences, Volume-**1**, Issue-**2**, 2023, allotted DOI Number: **10.5281/zenodo.7956020**

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