"SYNTHESIS & CHARACTERIZATION OF EGGSHELL REINFORCED POLYMER COMPOSITES"

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Abstract-*The study investigates hybrid biodegradable polymer composites incorporating synthetic hydroxyapatite particulate (HAp) sourced from eggshells at varying weights (0%, 3%, 5%, and 7%), alongside fixed PLA (60%), E-Glassfibre (40%) compositions, fabricated via the hand lay-up method. HAp, akin to bone structure, is pivotal for bone repair and regeneration, while E-Glassfiber reinforces structural integrity. Test specimens adhere to ASTM standards for hardness, tensile, impact, and flexural tests, crucial for assessing suitability in medical applications. Enhanced mechanical properties are observed in the composite containing 7% eggshell powder particulate.*

Key Words*: *Eggshell, Hydroxyapatite (HAp), SEM, E-Glass fibrer, PLA, bio mineral.

1 INTRODUCTION

Composite materials blend different elements to create a unified structure with enhanced properties, often utilizing fibers, particles, or sheets alongside a polymer matrix. These composites leverage the superior strength and stiffness of fibers, whether metallic, ceramic, or polymer-based, to bear the primary load, complemented by the supportive matrix. The resultant synergy yields materials with superior mechanical traits, applicable across diverse industries like aerospace, automotive, and construction. An emerging trend involves hybrid composites, like E-Glass fiber reinforced polymer matrices, advancing material innovation further.

Hybrid composites blend multiple materials for superior mechanical properties, leveraging the shearing effect of fibers. They excel in aerospace, naval, civil, industrial, sporting, and automotive applications. E-Glass fiber, prized for strength and durability, enhances these composites' mechanical performance &versatility.

Biodegradable composites offer extensive potential across diverse industries, incorporating natural and synthetic fibers, nanoparticles, and other materials into biodegradable polymer matrices. E-Glass fiber is among the options for reinforcement. Notably, these composites hold promise for novel applications such as body implants.

Our composite utilizes Hydroxyapatite (HAp) as particulate reinforcement, a calcium phosphate mineral widely applied in biomedical fields like bone grafts and dental implants.

Eggshells, a rich calcium source, are employed for HAp synthesis due to their availability, cost-effectiveness, and biocompatibility. E-Glass fiber serves as the reinforcement alongside E-Glass Fiber. E-Glass fiber, composed of carbon atoms woven tightly with a polymer resin, offers exceptional mechanical properties, including high tensile strength, stiffness, and fatigue resistance. These reinforcing materials are seamlessly integrated into the polymer matrix.

The composite mentioned above is crafted using the hand-layup technique, a traditional and adaptable method in composite manufacturing. This process entails manually layering reinforcement materials like E-Glass fiber into a mold or onto a tool. Subsequently, each layer is infused with resin before undergoing natural or artificial curing to shape .

2 Materialsandmethods:

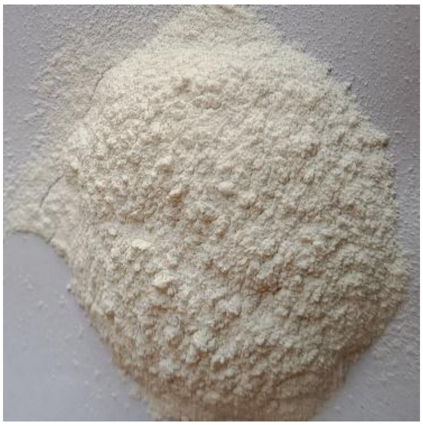


Fig2.1SynthesizedHAp

Fig2.2E-Glass Fibre

Fig2.3(1,2,3)Resin, catlyst, Accelerator

2.1 Hydroxyapatite (HAp), a biocompatible material derived from eggshells, undergoes a meticulous process. This involves collecting, cleaning, drying, and grinding the eggshells into fine 64µm particles. These particles are then heated at temperatures of 450℃and 900℃ to convert calcium carbonate into calcium oxide and Calcium phosphate (HAp) via chemical precipitation, yielding the desired HAp powder.

2.2 E-Glass fiber:E-Glass fiber: This material is extensively utilized in composite production owing to its exceptional strength-to-weight ratio, stiffness, and longevity. The fibers originate from a precursor substance, typically glass, which undergoes chemical treatment and heating to produce the E-Glass Fiber.

2.3.1 Cobaltaccelerator resin: In our composite, a cobalt accelerator is commonly utilized as an accelerator in the curing process of unsaturated polyester resins, alongside a peroxide initiator like MEKP. While typically added in trace amounts, in our composite,it constitutes approximately 10% of the total matrix weight. The cobalt accelerator plays a vital role by facilitating the decomposition of the peroxide initiator, which results in a quicker.

2.3.2 MEKP catalyst: Methylethyl ketone peroxide (MEKP) serves as a common initiator in the curing process of unsaturated polyester resins. Within our composite material, it constitutes approximately 10% of the total matrix weight and is typically introduced into the resin system in minute quantities. MEKP is a clear, colorless liquid known for its ability to rapidly initiate polymerization reactions, particularly in the presence of anaccelerator.

- **2.3.3 PLA ISOMER resin:** ISO Resin is a medium viscosity, medium reactive polyester resin based on Isophthalic acid and superior glycols. It exhibits good mechanical and electrical properties together with good chemical resistance compared to general-purpose resins.

- ISO rapidly wets the surface of glass fiber in the form of cloth mat or chopped fiber to produce laminates and moldings

E-Glass fiber sheets measuring 200mm × 200mm served as the primary reinforcement in the composite. Hydroxyapatite (HAp) powder was introduced as secondary reinforcement at varying weight fractions: 0%, 3%, 5%, and 7%. The matrix consisted of Polyester Isoresin(80%).

E-Glass fiber is blended with the cobalt accelerator and MEKP catalyst 7% to create the matrix necessary for embedding the reinforcements.

Matrix table

Material	Matrix wt %	E-Glass Fibre wt %
Base	60	40
3% Egg shell	1.8	38.2
5% Egg shell	4.2	56.2
7% Egg shell	2.8	23

3 HAND LAY-UP TECHNIQUE

Hand lay-up is an open molding method suitable for making a wide variety of composites products from very small to very large. An initial preparation of all the materials and tools that are going to be used is a fundamental standard procedure when working with composites. This is mainly because once the resin and the hardener are mixed, the working time (prior to the resin mix gelling) is limited by the speed of the hardener chemically reacting with the epoxy producing an exothermic reaction.

Before starting with the lay-up process an adequate mold preparation must be done. Mainly, this preparation consists of cleaning the mold and applying a release agent in the surface of it to avoid the resin to stick.

The first step is to mix the resin and the hardener. The proportions are usually given by the supplier and can be found on the containers of the hardener or resin. The mixing is performed in the mixing containers with the mixing stick and should be done slowly so as to not entrain any excess air bubbles in the resin. Next an adequate quantity of mixed resin & hardener is deposited in the mold and a brush or roller is used to spread it around all surface along with reinforcement. It is important not to add too much resin, which will cause too thick of a layer, nor to add less than the necessary amount, which will cause holes in the surface of the part when it is cured. The first layer of fiber reinforcement is then laid. This layer must be wetted with resin and then softly pressing using a brush or a roller make the resin that was added in the previous step wick up through the fiberglass cloth. If the fiber is not completely wet, more resin can be added over the top and spread around. At this stage a second layer of glass fiber is added and special care must be taken to eliminate all air bubbles possible. This can be accomplished by either rolling any air bubbles out with a small hand rolling tool. This step is repeated until the desired thickness is obtained.

4 Material Preparation:

- E-Glass Fiber: Cut the E-glass fibers to thedesired length.
- Eggshell Powder: Clean and grind eggshells to produce a fine powder.

4.1 Mixing:

- Combine the E-glass fiber and eggshell powderin a mixing container.
- Stir or tumble the mixture to ensure uniform distribution.

4.2 Resin Preparation:

- Prepare the resin system suitable for E-glassfiber composite.
- Add the mixed E-glass fiber and eggshellpowder into the resin.
- Stir thoroughly to achieve a homogeneous mixture.

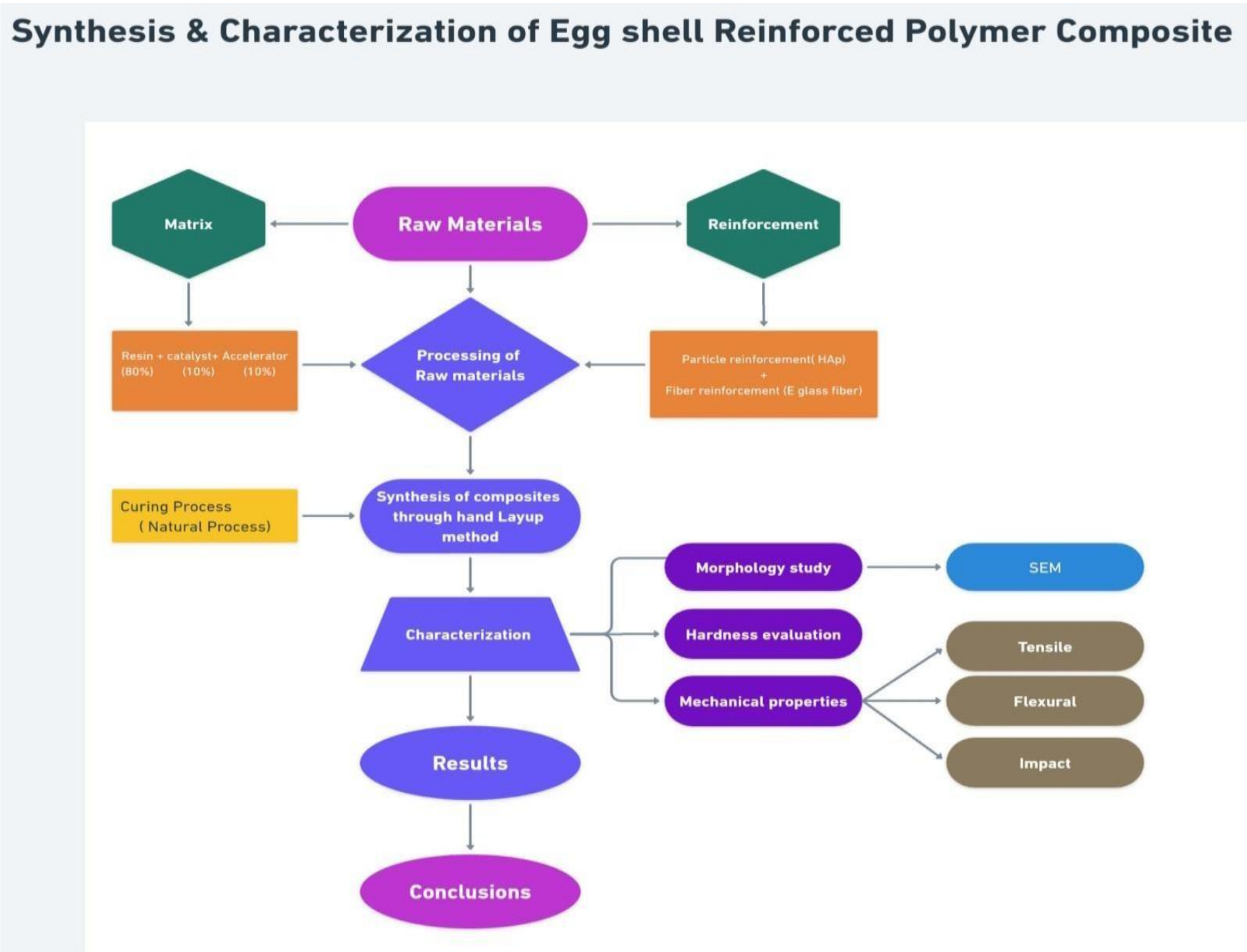
4.3 Molding:

- Pour the resin mixture into a mold of the desired shape and size.
- Use vacuum bagging or compression molding techniques to remove air bubbles and ensure proper compaction.
- Temperature and time for the resin system used.

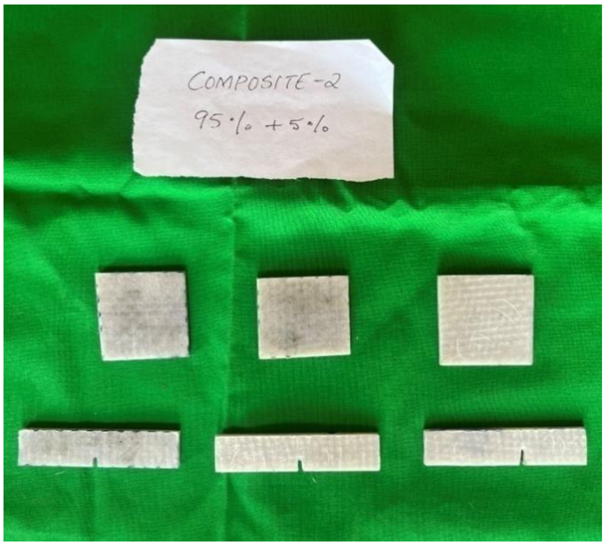
4.4 Testing:

- After curing, test the mechanical, thermal, and other properties of the composite material to evaluate the effects of eggshell powder on performance.

Compare these properties with those of composites made without eggshell powder for analysis.



a.3%



b.5%

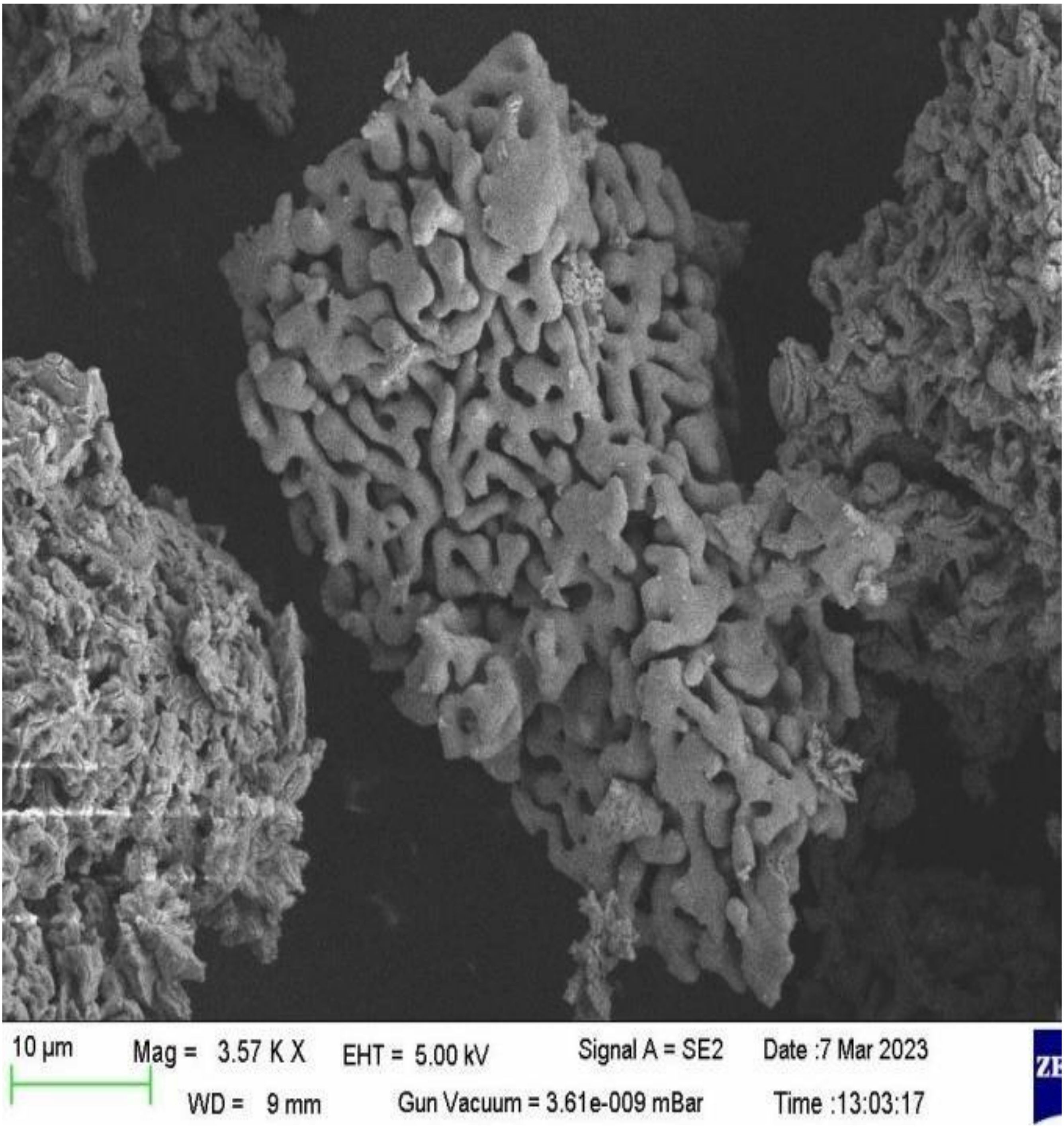
c. 7%

5 Hardness:

The Leeb hardness tester measured the hardness of the base composite and eggshell composites with 3wt%, 5wt%, and 7wt% eggshells using a 1 kg load for 10 seconds. Six readings were averaged for accurac

5.1 Impact Strength:

Fig4.1SEMMicrographofEggshellpowder Comparing the alloy and composites, the 7wt% eggshell composite showed higher hardness than the base composite, likely due to increased eggshell content. Adding E-glass fibers could boost the mechanical strength of these composites



6 Tensile test: The tensile test was performed on composite samples consisting of E-Glass fiber sheets, serving as the primary reinforcement. Alongside, Hydroxyapatite (HAp) powder was introduced into the matrix to act as a secondary reinforcement. The HAp was added at varying weight fractions: 0%, 3%, and 5%. The matrix material used for the composites was Polyester.

- In the testing process, the samples were prepared meticulously to ensure uniform dispersion of the E-Glass fibers and HAp particles within the Polyester matrix. This ensured that the mechanical properties of the composites were consistent and representative of the intended compositions.

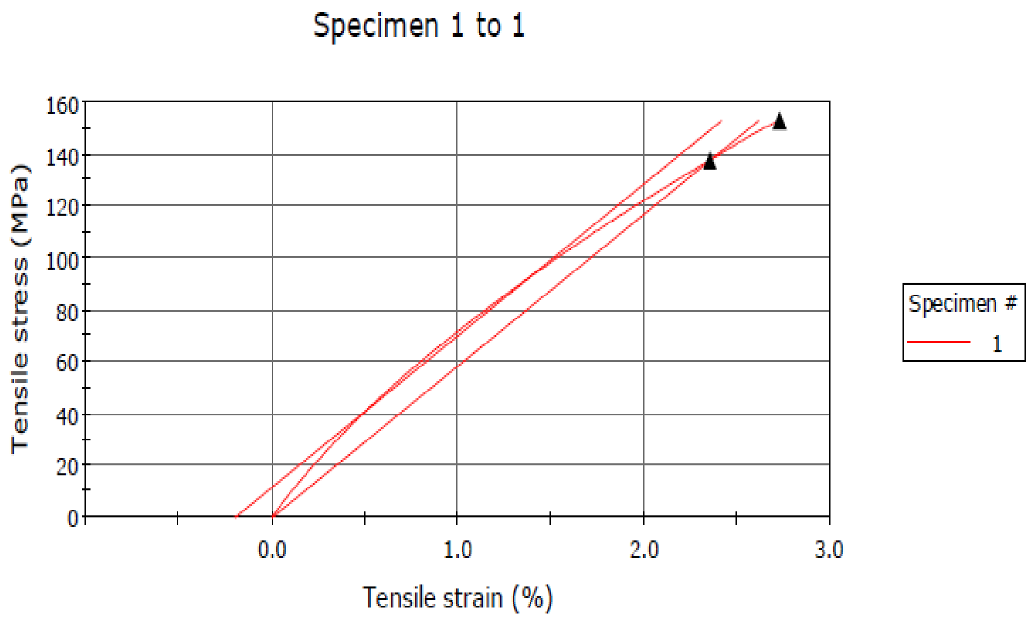
- The primary aim of incorporating HAp into the composite was to evaluate its influence on the tensile properties of the material. By varying the weight fractions of HAp, the study sought to identify the optimal content that would enhance the mechanical strength of the composite without compromising its other properties.

- Prior to the tensile testing, the composite samples underwent rigorous preparation and conditioning to eliminate any potential defects or inconsistencies. This involved careful cutting and shaping of the samples to ensure they met the required dimensions and specifications for testing.

- During the tensile test, each sample was subjected to a controlled tensile load using a universal testing machine. The load was applied gradually, and the corresponding elongation or deformation of the sample was measured in real-time. This allowed for the determination of the tensile strength, Young's modulus, and elongation at break of each composite sample.

- The results obtained from the tensile tests were then analyzed to assess the impact of HAp content on the mechanical properties of the composites. By comparing the tensile properties of the composites with varying HAp content to those without HAp (0% fraction), insights were gained into the role of HAp as a secondary reinforcement in enhancing the tensile strength and toughness of the Polyester-E-Glass composite.

- In conclusion, the tensile testing on the Polyester-E-Glass-HAp composites provided valuable data on the mechanical behavior of the materials. The findings from this study contribute to the understanding of how secondary reinforcements like HAp can be effectively incorporated into composites to optimize their mechanical properties for specific applications.



7 FLEXURAL STRENGTH

- A flexural test, also referred to as the modulus of rupture or bending test, is utilized to assess the strength and behavior of materials when subjected to bending or flexural forces. This test is conducted using a universal testing machine and employs a three-point or four-point bend fixture.

- During the test, samples containing varying concentrations of eggshell powder (3%, 5%, and 7%) are evaluated alongside a control sample for comparison. The sample is positioned on two support pins set at a specific distance apart. The three-point bending setup offers advantages in terms of specimen preparation and testing simplicity.

- The three-point bending flexural test provides valuable data on parameters such as the modulus of elasticity in bending, flexural stress, flexural strain, and the material's flexural stress–strain response. However, it's important to note that the results obtained from this testing method can be influenced by factors such as specimen and loading geometry, as well as the rate of strain.

- Flexural strength, which signifies the maximum stress encountered within the material at the point of yield, is a key parameter measured during the test. This strength is expressed in terms of stress.

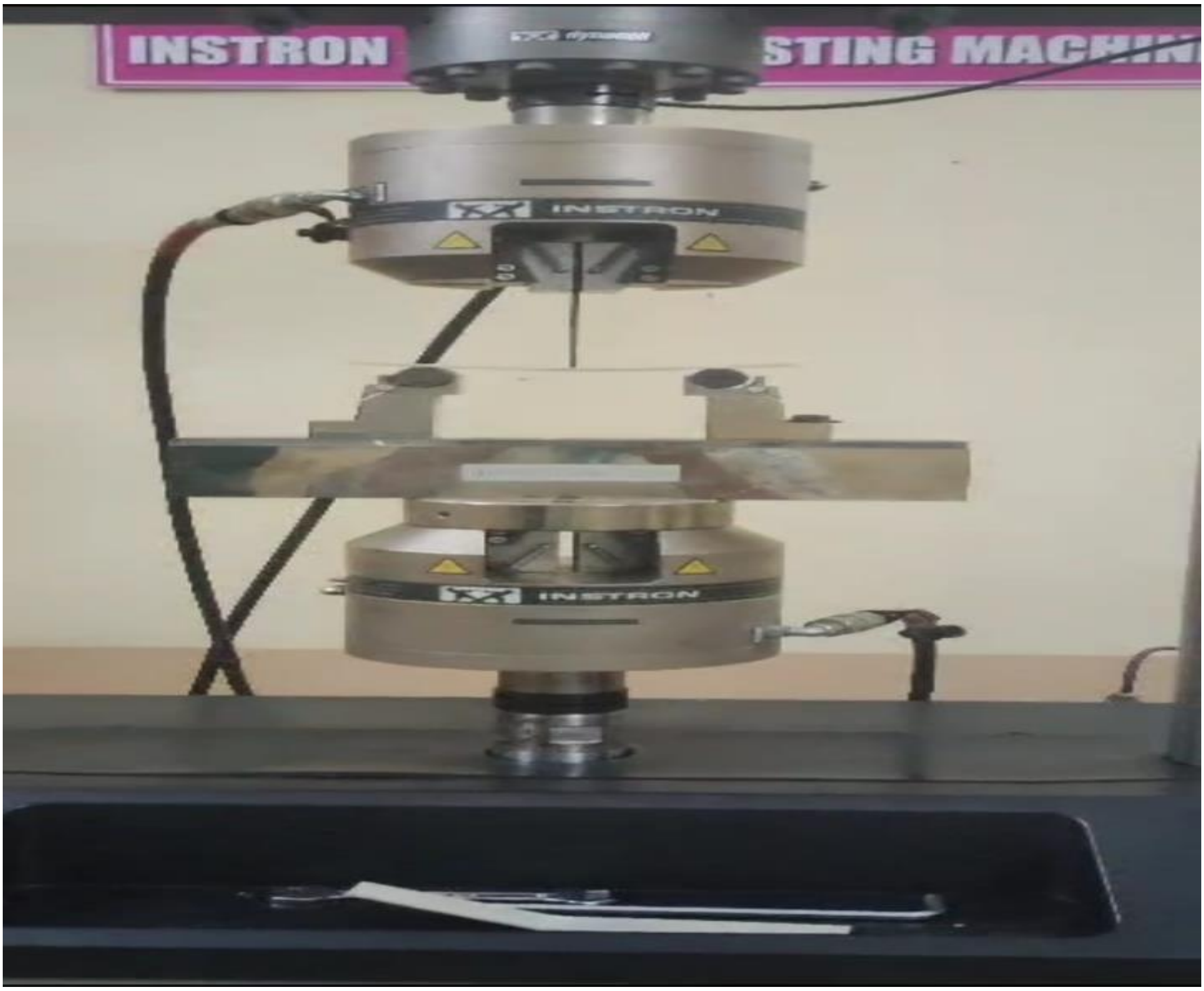


Plate.4.6 Flexural test on UTM

Flexural strain measures a material's deformation under bending forces, expressed as a ratio or percentage. It gauges the material's ability to bend without breaking and is vital for assessing its mechanical behavior. This parameter is crucial in materials testing and engineering design, predicting a material's response to bending forces.

	Specimen Label	Width (mm)	Thickness (mm)	Length (mm)
1	composite-7	13.50000	4.00000	100.00000

	Maximum Load (N)	Load at Break (Standard) (N)	Ultimate Tensile Strength (UTS) (MPa)	Tensile stress at Yield (Offset 0.2 %) (MPa)
1	8252.48	8252.48212	152.82	137.51927

In the case of comp-7, when maximum load is 8252.48N

The specimen labelled as "composite-7" had dimensions of 13.5 mm in width, 4.0 mm in thickness, and a length of 100.0 mm. During testing, it experienced a maximum load of 8252.48N, with a load at break (standard) of 8252.48212 N. The ultimate tensile strength (UTS) recorded for this specimen was 152.82MPa. Additionally, the tensile stress at yield, calculated with an offset of 0.2%, was found to be 137.51927MPa.

This data provides a comprehensive overview of the mechanical properties exhibited by the "composite-7" specimen under tensile loading conditions. Similarly, 7%ESP has highest UTS (169.965MPa). The ultimate tensile strength represents the maximum stress the material can withstand before failure, while the tensile stress at yield indicates the stress at which the material begins to exhibit permanent deformation. Such information is vital for evaluating the performance and suitability of the composite material for various engineering applications.

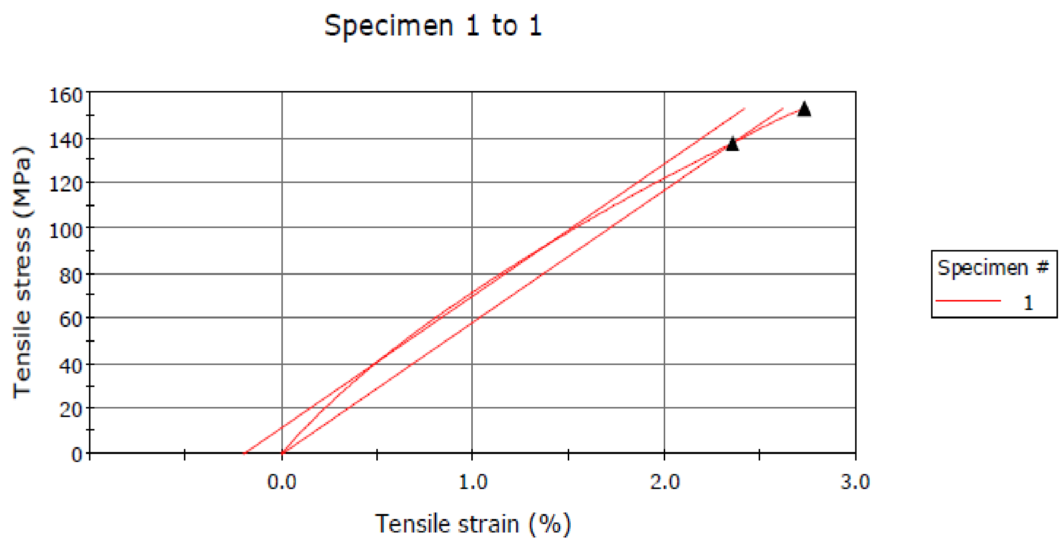


Fig.4.3 Graph representing tensile stress vs strain of S-1

4

Plate.4.7 (a,b,c) Prepared Composites for flexural test

Analysis

Specimen 1 results:

At the first point, the applied load was 0N.

The maximum load observed during the test was 202.68457kN.

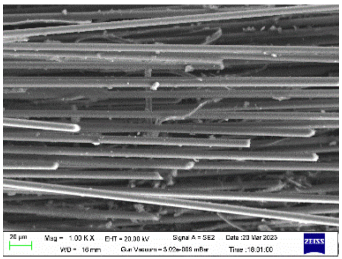
The specimen's dimensions were as follows

Width: 24.00mm

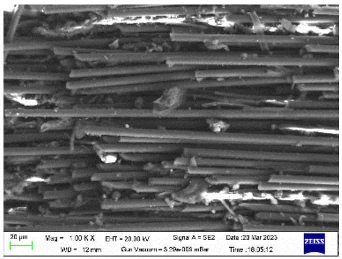
Thickness: 24.00mm

8 Morphology study:

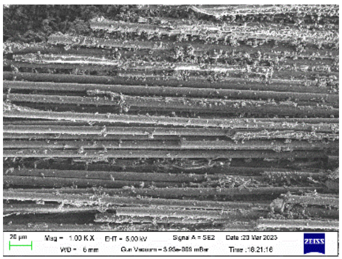
Morphology tests provide valuable insights into the structural and physical properties of materials. By examining the combination of eggshell and E-glass fiber, we can better understand how these materials interact and whether they can enhance each other's properties. This research could lead to innovative uses for these combined materials in various engineering applications, offering both environmental and functional benefits Hap particulates has significantly improved its mechanical properties.



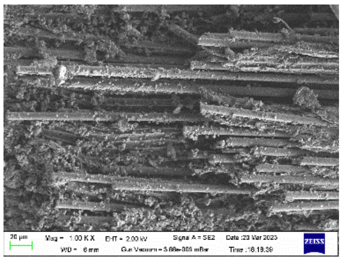
(a)Base Composite



(b)3%EggShell



(c)5%EggShell



(d)7%EggShell

Fig4.9 (a,b,c,d) Shows the SEM Micro Graphs of 4CompositematerialsRespectively.

9 Conclusion:

The study focuses on characterizing a composite comprising Eggshell particulate and E-Glass fiber reinforced PLA. SEM images show the particulate's high toughness, with evaluations conducted on PLA resin-reinforced E-Glass fiber composites, with and without eggshell powder. SEM analysis confirms uniform distribution of eggshell particulates within the PLA matrix. Overall, the use of hybrid biodegradable polymer composites, incorporating synthetic hydroxyapatite particulate from eggshells and E-Glass Fiber reinforcement in PLA matrix, exhibits enhanced mechanical properties, including maximum tensile and impact strength. upto35.9%&111%respectively.

- The study revealed that increasing the weight percentage of E-Glass fiber (up to 7%) effectively enhanced the mechanical properties of the composites.
- Utilizing the hand lay-up method in composite development resulted in a significant percentage increase in hardness, reaching 73.22 for the 7 wt% E-Glass fiber composite.
- Overall, the findings suggest that bio composites incorporating E-Glass fiber exhibit promising mechanical properties, rendering them suitable for various medical applications.
- Employing E-Glass fiber as a reinforcement in composites represents an innovative approach that could potentially offer a cost-effective and sustainable solution for biodegradable composite production.

RESULTS AND DISCUSSIONS

Material	Base	3% ES	5% ES	7% ES
Hardness (RHN)	42.3	53.6	59.8	67.2
Impact Strength (J)	9.5	11.8	14.2	15.9
Tensile Strength (MPa)	89.2	131.88	144.66	169.965
Flexural Strength (MPa)	95.94	107.59	110.14	128.6
%Rise in Hardness	75	100.52	100.76	102.6
%Rise in Impact Strength	67.89	108.36	104.96	104.78
%Rise in Tensile Strength	150	100.52	40.56	75.23
%Rise in Flexural Strength	50.62	68.23	25.62	56.02

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A special note of appreciation goes to our esteemed Project Guide, Mr. M Mouli Kumar. His expertise, unwavering support, and insightful guidance have been the cornerstone of this research endeavor. His constructive feedback and mentorship have greatly enriched our understanding and have played a crucial role in shaping the direction and quality of this study.

Furthermore, we would like to acknowledge the invaluable contributions of our dedicated lab assistants and fellow students. Their diligent efforts in assisting with experimental work, data collection, and collaborative discussions have been pivotal to the success of this research. Their commitment, teamwork, and enthusiasm have truly made this journey both productive and enjoyable.

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Last but not least, we express our deepest gratitude to our families and friends for their unwavering support, encouragement, and understanding throughout this academic journey. Their love, patience, and motivation have been our constant source of strength and inspiration.

In conclusion, we extend our sincere thanks to each and every individual who has contributed to this research study. Your support, guidance, collaboration, and contributions have been invaluable, making this endeavor a truly rewarding and enriching experience.

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BIOGRAPHIES

M.Mouli Kumar :- M. Mouli Kumar, an assistant professor at Sanketika Polytechnic, serves as our invaluable guide for this project in Mechanical Engineering. With over 6 years of experience in to he field and holding a Master's degree in Mechanical Engineering, Kumar's expertise greatly contributes to the project's success. Under his mentorship, we have conducted tests and obtained results with significant potential for future applications. Mouli Kumar not only provides guidance but also extends extensive support throughout the project, ensuring its smooth progress. Our case study specifically revolves around synthesizing and exploring the applications of innovative materials and technologies in Mechanical Engineering, benefiting from Kumar's profound knowledge and guidance

D. Satya Athreya :- The student in mechanical engineering has actively engaged in case studies on integrating NAS (Network-Attached Storage) into mechanical CNC (Computer Numerical Control) systems to enhance cost-effectiveness. Their enthusiasm for research is evident in their involvement in various activities across the field. Additionally, they have undertaken a project titled "Synthesis & Characterization of Eggshell Reinforced Polymer Composites." This project underscores their commitment to exploring novel materials and their applications in Mechanical Engineering. As a final year student at Sanketika Vidya Parishad Engineering College, they have showcased remarkable dedication and initiative in both academic pursuits and practical research endeavors, positioning themselves as a promising contributor to the field of Mechanical Engineering.

J. *Phalguni* :- *J Phalguni is a dedicated 4th-year Mechanical Engineering student at Sankethika Vidya Parishad Engineering College, showcasing an unwavering passion for the field of mechanical engineering and research. Throughout their academic journey, Phalguni has actively engaged in various research initiatives, demonstrating a keen interest and commitment to expanding their knowledge and skills in the discipline.*

In addition to their academic pursuits, Phalguni has also undertaken a significant project on the "Design and Detailing of Excavator Bucket." This project not only reflects their technical proficiency but also their practical understanding of mechanical design principles and their application in real-world scenarios.

D.Sai :- *D Sai is a dedicated 4th-year Mechanical Engineering student at Sankethika Vidya Parishad Engineering College, demonstrating a strong commitment to the field of mechanical engineering and research. Throughout their academic journey, Sai has exhibited a keen interest and passion for research, actively engaging in various research projects and initiatives*

In addition to their academic achievements and research activities, Sai has undertaken a significant project focused on the "Design and Detailing of Excavator Bucket." This project highlights their technical skills, practical knowledge of mechanical design principles, and ability to apply theoretical concepts to real-world engineering challenges.