CP301: DEVELOPMENT ENGINEERING PROJECT

Department of Mechanical Engineering,

Indian Institute of Technology, Ropar

MANUFACTURING OF HIGH-PERFORMANCE SAND AND NATURAL FIBRE REINFORCED COMPOSITE

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Acknowledgement

We extend our heartfelt gratitude to **Dr. Srikant Sekhar Padhee** for his unwavering guidance and support throughout our journey in Manufacturing of Sand and Natural Fiber Reinforced Composites. His expertise and insights were instrumental in helping us grasp the project objectives, and his invaluable feedback and suggestions played a pivotal role in crafting a high-quality project. We also express our sincere appreciation to Mr. Shiva (PhD Scholar) for his continuous assistance throughout the project and to Mr. Ram Kumar (Lab Assistant) for his expert guidance in composite production. Working alongside such exceptional mentors and role models has been a privilege.

Furthermore, we are deeply grateful to Dr. Srikant Sekhar Padhee for providing us with the opportunity to apply our project during Phase-2. This phase involved enhancing the Boat Assault Pneumatic Type (BAUT) utilized by the Indian Army for obstacle crossing in Ditch Cum Bund operations. By incorporating affordable bulletproof sheets on its front and sides, we addressed a critical need for protection against small arms fire, thereby enhancing troop safety during water obstacle crossings. The live testing experience at Pathankot, Mamun Regiment military place, not only provided us with invaluable insights but also enriched our practical knowledge significantly. We cherish this opportunity and the new experiences gained.

With heartfelt thanks and warm regards,

Bommiditha Jyothsnavi
Nishika Nakka
Sai Sahasra Surkanti

Table of Contents

1. Introduction

1.1 Origin of the Project Idea

The concept of manufacturing high-performance sand reinforced composite with incorporation of natural fibre originated from the pressing need for sustainable and eco-friendly materials in the field of mechanical engineering. The project was conceived through a thorough analysis of the limitations of traditional composite materials and the vast potential of sand as a reinforcement component. Sand, a ubiquitous material with unique properties, inspired the exploration of its potential in enhancing the mechanical properties of composites.

We recognized the untapped potential of sand as a reinforcement material in composite manufacturing. By leveraging the inherent strength and abundance of sand, the aim was to develop a novel composite material that not only exhibits superior mechanical properties but also addresses environmental concerns by incorporating natural fiber into the sand reinforced composite. The idea was further fueled by the desire to innovate and push the boundaries of traditional composite manufacturing processes, paving the way for sustainable and high-performance materials in mechanical engineering applications.

1.2 Problem Definition and Aim

The existing problem in the manufacturing of composite materials lies in the limited availability of sustainable and eco-friendly alternatives that can meet the performance requirements of various industries. Traditional composite materials, which are made from synthetic fibers and resins, have significant environmental drawbacks, including the generation of non-biodegradable waste and the use of non-renewable resources. The need for high-performance materials that are both sustainable and cost-effective has led to the development of innovative composite materials, such as those made from natural fibers and sand. In response to this imperative, innovative composite materials have emerged, leveraging natural fibers and sand as key constituents. These materials offer a compelling avenue towards addressing the environmental shortcomings of traditional composites while simultaneously delivering on performance requirements. By incorporating renewable resources and minimizing reliance on non-biodegradable components, these innovative composites present a promising solution to the prevailing problem of limited sustainable alternatives in the composite materials industry.

Our aim is to create one such reinforced composite which addresses the existing issues. This report outlines the manufacturing process for high-performance sand composites and incorporation of natural fiber, which offers a promising solution to the existing problem of limited sustainable alternatives in the composite materials industry.

2. Existing Studies

Sand-reinforced composites have gained significant attention in recent years due to their potential to enhance the mechanical, physical, and thermal properties of composite materials. The incorporation of sand particles and natural fibre into composite matrices can alter the properties of the resulting composites, making them suitable for various industrial applications. Several studies have explored the impact of sand and natural fibre reinforcement on different types of composites, including polyester, aluminum alloy, and epoxy composites.

1. Physical, Mechanical, and Thermal Properties of Sand Reinforced Polyester Composites

A study focused on preparing sand-reinforced polyester composites (SPCs) through compression molding methods, examining the effect of varying sand contents (from 0% to 60%). The results showed that SPCs exhibited lower compression strengths but increased hardness and decreased water absorption compared to non-sand reinforced counterparts. These findings suggested that sand reinforcement can alter the mechanical and physical properties of composites, highlighting the potential for tailoring composite properties through material composition adjustments. The study provided valuable insights into optimizing sand content ratios for enhanced material applications.

2. AA6061-Sea Sand Composite Analysis

This study explored the impact of electroless coating on sea sand prior to the stir-casting process for producing AA6061-based composites. The research aimed to analyze the physical and mechanical properties of the resulting composites with varying amounts of sea sand (2– 6 wt%) under both electroless-coated and non-electroless-coated conditions. The key findings were - Lower porosity in electroless-coated composites, Higher hardness and ultimate tensile strength in electroless-coated composites compared to non-electrolesscoated composites. These findings indicated that the electroless coating process improves the wettability of sea sand, leading to better bonding between the sand particles and the aluminum alloy matrix. As a consequence, the resulting composites displayed enhanced physical and mechanical properties, making them suitable candidates for various industrial applications.

3. Iron Sand/Epoxy Composite Modified with Carbon Powder

This study explored the impact of incorporating iron sand and varying concentrations of carbon powder (15 wt%, 20 wt%, 30 wt%) into epoxy composites. The research aimed to improve wear resistance and mechanical properties by optimizing the interfacial bond between iron sand and the epoxy matrix. Results indicated increased wear resistance and mechanical properties with the addition of carbon powder. The HCP composite with 30 wt% 5 | P a g e carbon powder exhibited enhanced wear resistance but reduced flexural properties, while the LCP composite with 20 wt% carbon powder demonstrated favorable flexural properties. SEM analysis confirmed improved dispersion and interfacial bonding in the composite matrix

4. Preparation and Properties of Natural Sand Particles Reinforced Epoxy Composites

This study focused on utilizing naturally occurring hydrophobic sand particles as filler material in epoxy composites to enhance their properties. The research demonstrated the preparation and characterization of these novel materials, showcasing improvements in flexural strength and modulus. Three-point bending tests revealed a 7.5% increase in flexural strength and an 8.7% increase in flexural modulus with the addition of 1 wt.% sand particles. Scanning electron microscopy (SEM) analysis indicated enhanced fracture toughness in the epoxy matrix due to the presence of sand particles. Dynamic mechanical analysis (DMA) and thermal mechanical analysis (TMA) showed increased storage modulus, glass transition temperature, and dimensional stability in the sand particles/epoxy composites compared to pristine epoxy. The study suggested promising applications for natural sand particles in composite materials

5. Rice Husk as a Fibre in Composites:

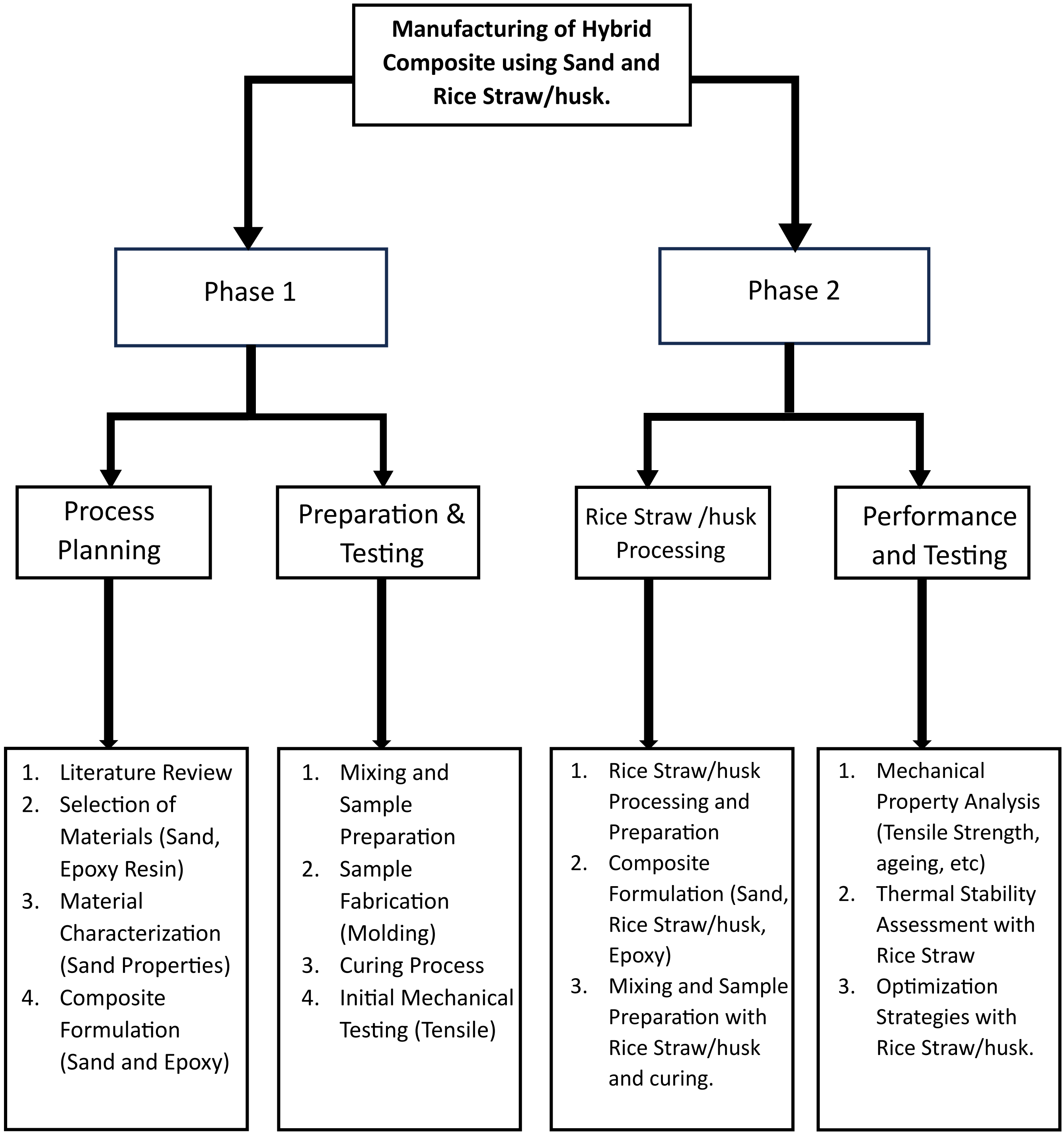
This review paper aims to study the physical, mechanical, and thermal behavior of rice husk (RH) as a reinforcing fiber in various polymer composites. The authors discuss the advantages of using RH, such as its low cost, abundance, and improved properties like reduced water absorption compared to other natural fillers. The review covers the impact of factors like RH particle size, polymer matrix type, and the use of compatibilizers on the performance of RH-reinforced composites. It also highlights the development of bio-composites using RH with polymers like polyethylene and polypropylene, as well as the utilization of RH in 3D printing applications. The review provides a comprehensive overview of the recent advancements in the field of RH-reinforced polymer composites, underscoring their potential as sustainable and cost-effective materials for various applications.

6. Bibliometric Analysis of Research Trends in Rice Straw/Husk Reinforced Polymer Composites

This paper presents a bibliometric analysis of research trends in rice straw/husk reinforced polymer composites. The authors have reviewed a wide range of studies that have explored the use of rice straw and rice husk as reinforcing fillers in various polymer matrices, including polyethylene, polypropylene, epoxy, and bio-based polymers like polylactic acid (PLA). The analysis covers the development of hybrid composites incorporating rice straw/husk along with other natural fibers, as well as the investigation of mechanical, thermal, and water absorption properties of these materials. The paper also discusses the application of techniques like design of experiments and artificial neural networks to optimize the performance of rice straw/husk reinforced composites. Overall, the bibliometric analysis provides a comprehensive overview of the research landscape in this field, highlighting the growing interest and advancements in the utilization of rice-based agricultural waste as sustainable reinforcements for polymer composites.

3. Overview

This project mainly involves 2 phases with 2 stages each:



4. Phase – 1

The first phase includes Process Planning, Preparation of Sand Reinforced Composites and Performing Tensile Testing

4.1 Preparation of Sand- Reinforced Composite

1. Separation of Sand Particles:

We obtained sand from the construction site and processed it using a sieving machine. Specifically, we selected sand particles with a size of 300 micrometers for our experiment.

Fig 1. Processing of Sand using Sieving Machine

Fig 2. Sand Particles of 300-micron size after sieving

2. Cutting of Dog-Bone Shaped Mold

We created an STL file of the dog bone-shaped mold for the tensile sample, adhering to ASTM standards, and used laser cutting to cut the shape from a 5mm silicone rubber sheet. Remove the shapes from between to get the mold. We also cut an 5mm acyclic sheet mold for trial.

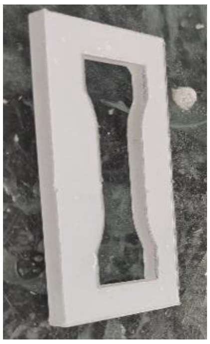


Fig 3. Laser Cutting of the shape on 5mm Silicone rubber sheet and 5mm acrylic sheet

3. Preparation of Mold for Use

i. First apply releasing agent PVA (Poly Vinyl Alcohol) evenly on an OHP Sheet and let it dry

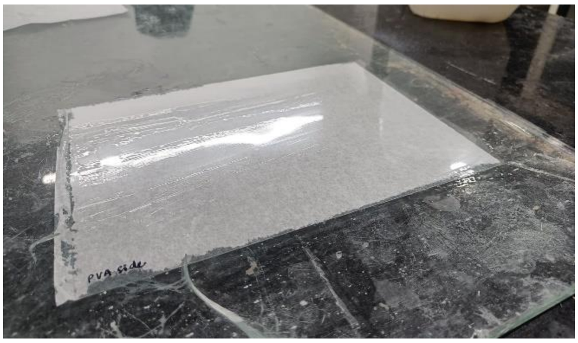


Fig 4. OHP sheet with releasing agent

ii. Next, stick double sided tape behind the silicone rubber mold and acylic mold and cut the tape only on outline of the shape.

Fig 5. Stuck Double Sided Tape

Fig 6. Removed tape only in the place of the shape

iii. Stick the Mold onto the OHP Sheet.

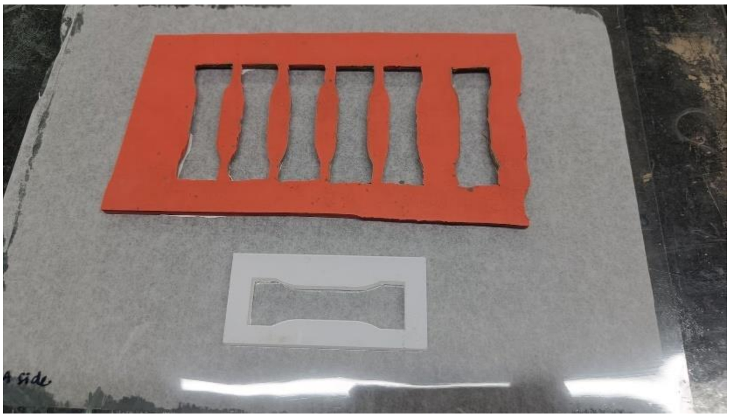


Fig 7. Mold is stuck on the OHP Sheet

iv. Take ER-099 SPL Epoxy and mix it with Hardener EH-150 in the ratio 2:1. We mixed them using Magnetic stirrer however it can be done by manual stirring also. Gradually add sand into the mixture according to the composition. First, we took 30% sand. Later we repeated the same process for 20% and 40% sand.

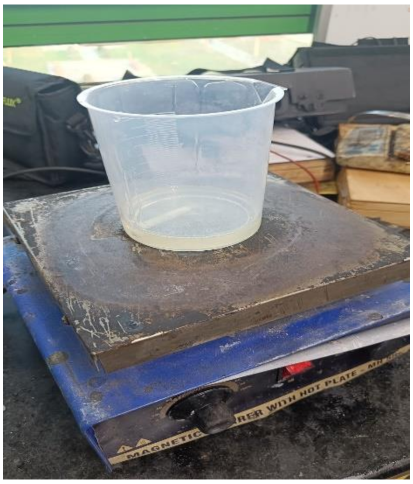


Fig 8. Epoxy mixture on magnetic stirrer

Fig 9. Mixing of Sand in the epoxy mixture.

v. Pour the mixture into the mold, remove the excess mixture and let it dry for about 24 hours.

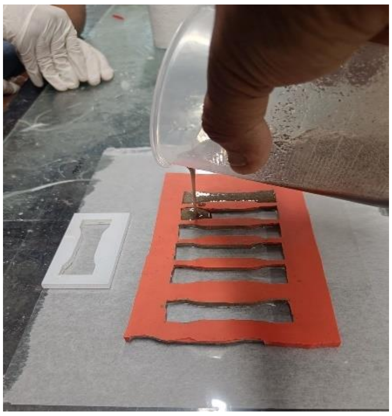


Fig 10. Pour the mixture into the mold

Fig 11. Removing the excess mixture

vi. The samples should be left for curing for a minimum of 24 hours. The samples can then be removed from the mold and filed accordingly if needed.

4.2 Sand- Reinforced Composite Tensile Samples

The finishing of the samples was done with the help of sand paper.

Fig 12. 20% Sand + 80% Epoxy

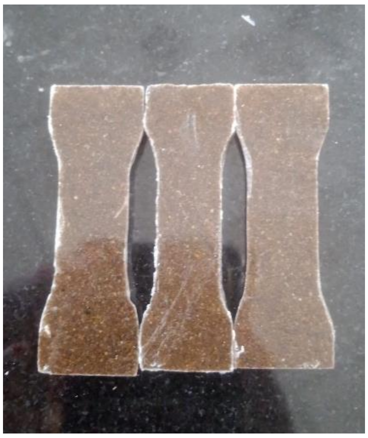


Fig 13. 30% Sand + 70% Epoxy

Fig 14. 40% Sand + 60% Epoxy

4.3 Tensile Test and Results

Tensile Test was performed using the Universal Testing Machine.

The load applied was 25 KN load and speed was 5mm/s

The Test samples dimensions are:
Width-15 mm
Thickness-5.06 mm
Gauge length-27 mm

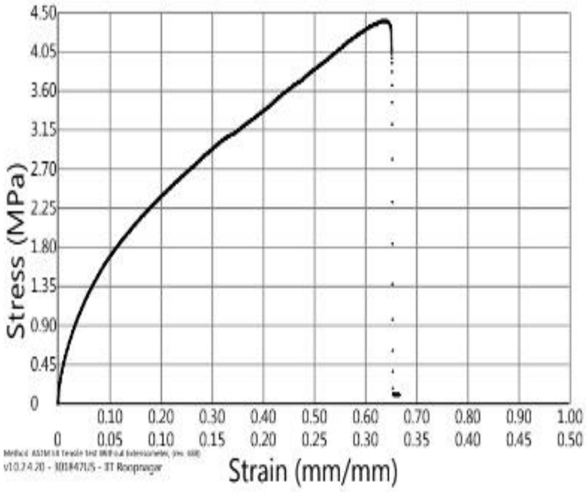
The results are as follows:

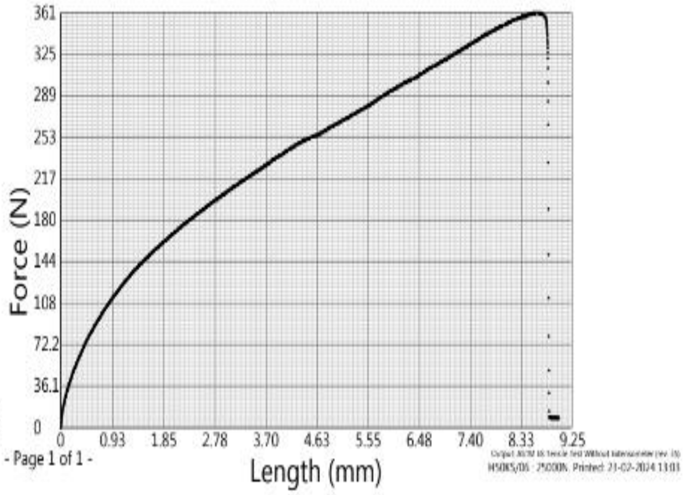
Fig 15. Tensile Testing using UTM

1. **Composition- 20% of sand and 80% of Epoxy**

Sample	Modulus (MPa)	Ultimate Force(N)	Ultimate Stress (MPa)
1	28.6	296	3.61
2	35.5	361	4.41
3	21.5	271	3.31

The graphs for one of the sample of 20% sand + 80% Epoxy are shown below

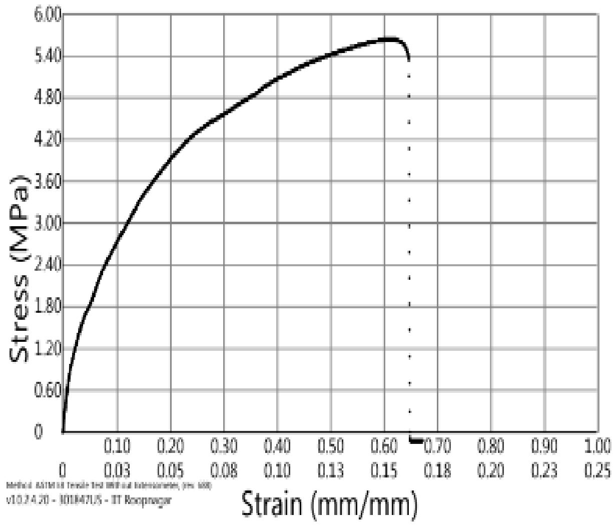


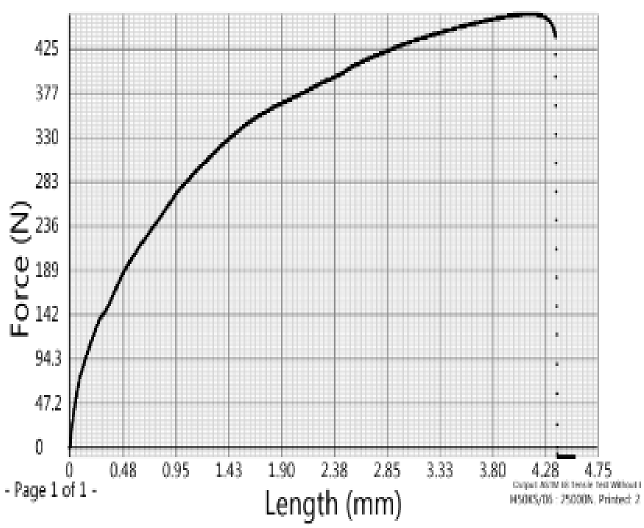


2. Composition- 30% of sand and 70% of Epoxy

Sample	Modulus (MPa)	Ultimate Force(N)	Ultimate Stress (MPa)
1	187	342	4.17
2	238	353	4.30
3	127	462	5.64

The graphs for one of the sample of 30% sand + 70% Epoxy are shown below

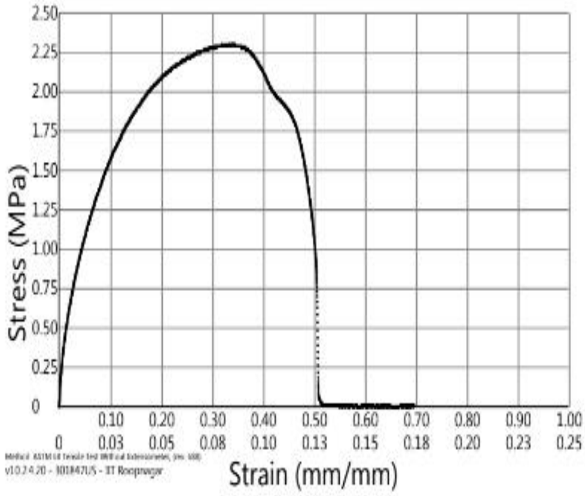


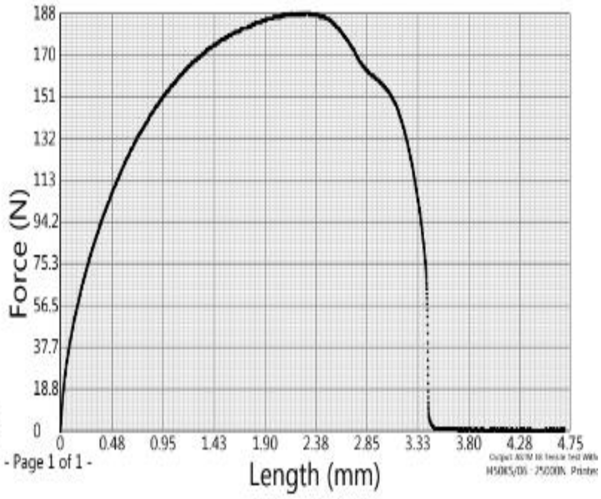


3. Composition- 40% of sand and 60% of Epoxy

Sample	Modulus (MPa)	Ultimate Force(N)	Ultimate Stress (MPa)
1	208	263	3.21
2	99.1	188	2.30
3	101	179	2.19

The graphs for one of the sample of 40% sand + 60% Epoxy are shown below





4.4 Conclusion of Phase -1

1. The 30% Sand sample demonstrated higher tensile strength. However, when compared with the 20% and 30%, the trend shows that with the increase in % of sand, the strength is expected to increase. This discrepancy in the strength of 40% sand sample might have occurred as it didn't get enough time to cure before performing the tensile test.

2. It was also observed that in all of these samples some sand particles have settled down due to their density. This settling phenomenon may have influenced the accuracy of strength values across samples of the same type.

The testing of 40% sand + epoxy sample should be performed again to crosscheck and ensure a proper pattern is achieved to make the further enhancements.

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5. Phase – 2

The second phase includes Enhancements, Performance Testing and Incorporation of Rice Straw into the sand-reinforced composite.

5.1 Preparation of Sand-Rice Straw Reinforced Composite

1. Preparation of Rice Straw

The rice straw is sun-dried and the outer layer is removed to obtain the part of the rice straw that contains rich-fibre content. The rice straw is further cut into small pieces inorder to use them for making the composite.

Fig 15. Dried Rice Straw

Fig 16. Size Reduction

2. Preparation of Mold for use

The Mold is prepared in a similar procedure as that of sand-reinforced composite. We used acrylic sheets and silicone rubber sheets for cutting the tensile and impact samples.

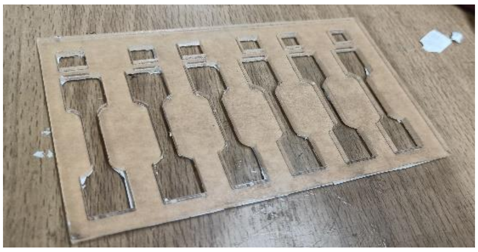


Fig 17. Tensile Samples are cut on the acrylic sheet

3. Preparation of Samples

Different types of samples are prepared with varied composition of sand and rice straw. We used ER099 Epoxy and Hardener in 2:1 ratio. The pure rice-straw and sand reinforced-rice straw composite samples were prepared for performing tensile and impact test. For the impact test the sand-reinforced composite samples were prepared again.

5.2 Samples

Fig 20. Rice Straw + Epoxy

Fig 21. Rice Straw + Epoxy + Sand

Fig 22. Impact samples of sand (40% ,50%) and pure rice straw

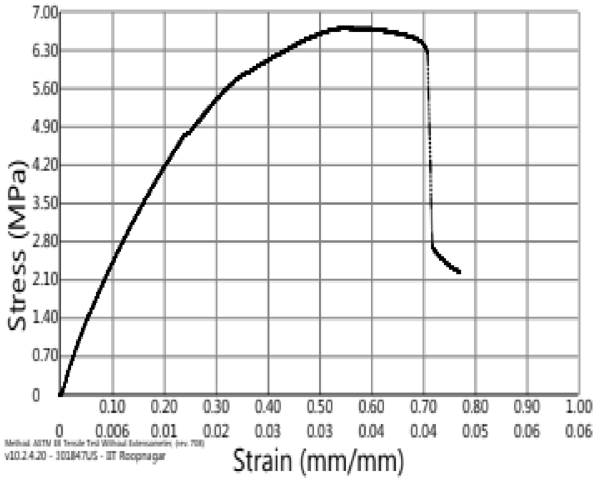
Fig 23. Impact samples of sand + rice straw + epoxy

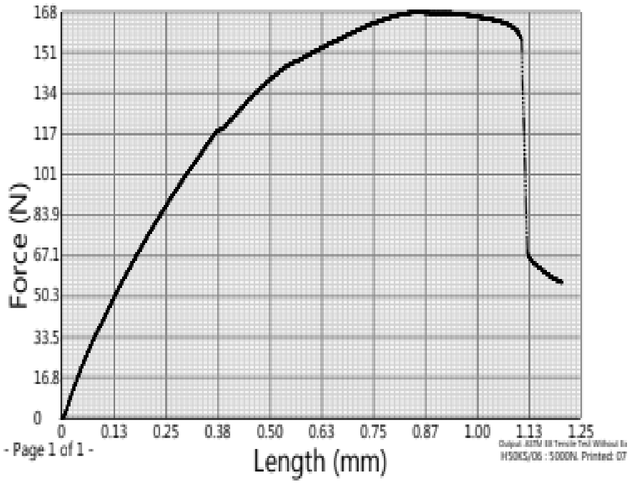
5.3 Tensile Test and Results

1. Rice Straw + Epoxy

Sample	Modulus (MPa)	Ultimate Force(N)	Ultimate Stress (MPa)
1	232	213	8.50
2	358	168	6.71
3	279	199	7.95

The graphs for one sample are shown below

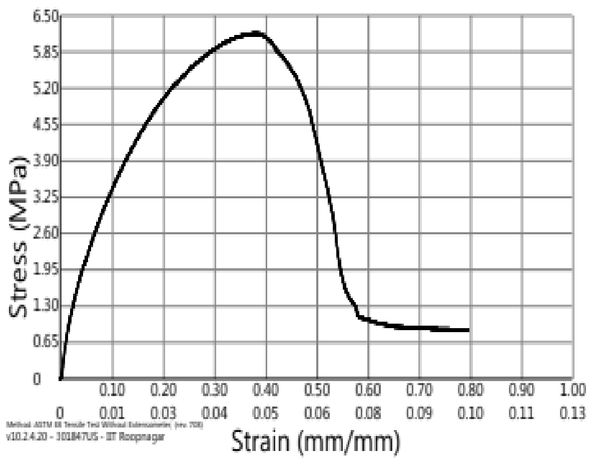


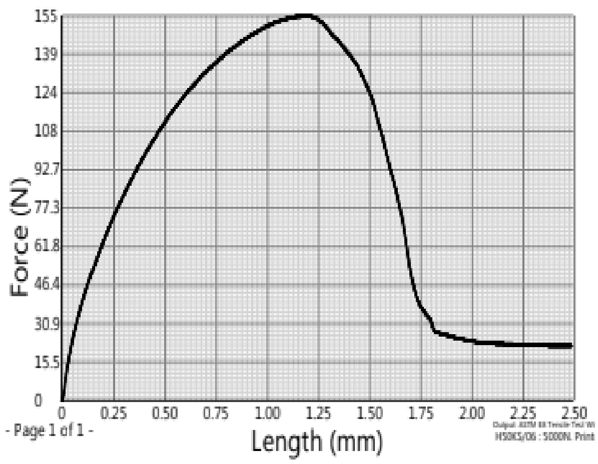


2. Rice Straw + Sand + Epoxy

Sample	Modulus (MPa)	Ultimate Force(N)	Ultimate Stress (MPa)
1	387	137	4.47
2	348	155	6.18

The graphs for one sample are shown below





5.4 Impact Test and Results

We performed the Izod Impact Test on our samples. Initially we placed a notch at the centre and then performed the testing. A pivoting arm is raised to a specific height and then released. The arm swings down hitting a notched sample, breaking the specimen.

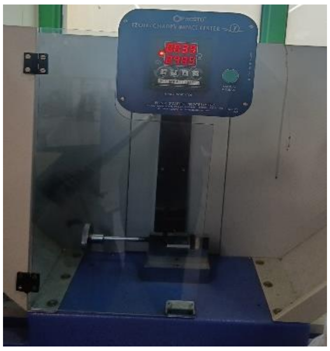


Fig 24. Izod Impact Testing Machine

The sample size for the impact test:

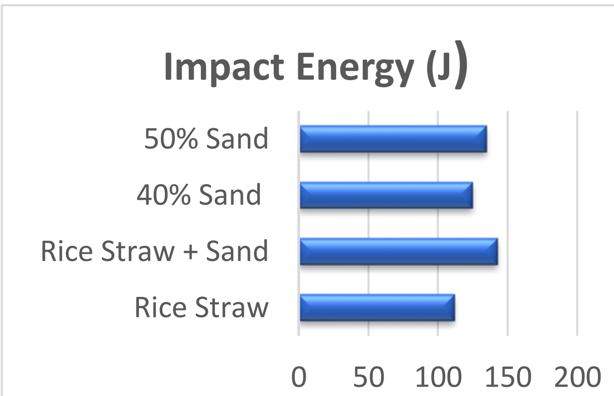
Length = 65mm
Width = 10mm
Thickness = 5mm

The Table below represents the results

S. No / Type	SAMPLE 1	SAMPLE 2	SAMPLE 3	AVERAGE
Rice Straw + Epoxy	**112**	**124**	**120**	**118.66**
50% Sand + Epoxy	**137**	**141**	**128**	**135.33**
40% Sand + Epoxy	**125**	**95**	**110**	**110**
Rice Straw+ Sand + Epoxy	**139**	**137**	**145**	**140.333**

5.5 Observations from the Tensile and Impact Test

1. The impact energy is higher for mixtures containing sand and rice straw compared to sample containing only sand or only rice straw.
2. Tensile Strength of Mixture is higher than only sand sample however only rice husk has highest tensile strength



6.Potential Application – Bullet Proof Material

6.1 Opportunity:

We got an opportunity to apply our project after Phase-1 where there was a requirement to enhance the BAUT (Boat Assault Pneumatic Type) utilized by the Indian Army for obstacle crossing in Ditch Cum Bund operations. The BAUT lacked protection against small arms fire from enemy forces, posing a significant threat to troops aboard during water obstacle crossings. Therefore, there was a need to modify the BAUT by installing affordable bulletproof sheets on its front and sides.

Fig 25. The side and front view of the BAUT which required protection on the front and sides

6.2 Our Proposed Solution:

We had just finished our Phase-1 Testing so we had thought of preparing the layered sand-reinforced composite as a low-cost solution for the problem which they had.

6.3 Initial Sample:

Initial Sample was prepared with the following specifications:

Specifications - The layers are filled on top of one another directly

Dimensions: Each Layer: 13cm x 13cm x 5 mm

Layer 1: 50% of 300 micrometers sand

Layer 2: 50% of 150 micrometers sand

The Procedure for preparing the sample was similar to that of preparing the tensile samples. Once the layer 1 was half cured the second layer was immediately poured onto it so that the entire curing process happens together ultimately.

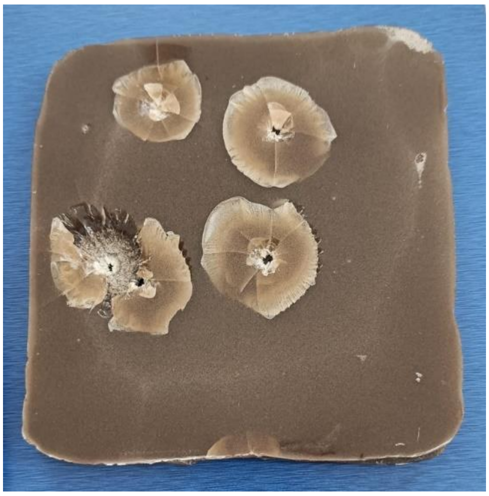
6.4 Testing:

The testing of the samples was performed with the INSAS 5.6mm Rifle from 50 and 100 meters.

Speed of Bullet is 1km/s

Bullet part that actually hits the sample.

6.5 Result of Testing the Initial Sample and Observation:



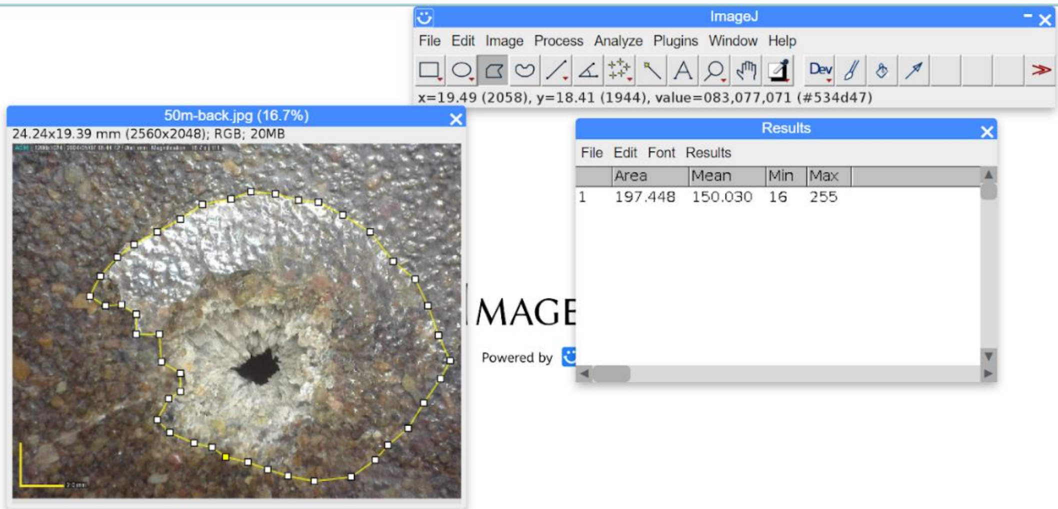
It was observed that the bullet has penetrated through the sample from 50m and 100m but the sample was able to withstand 5 bullets energy as it didn’t fully break.

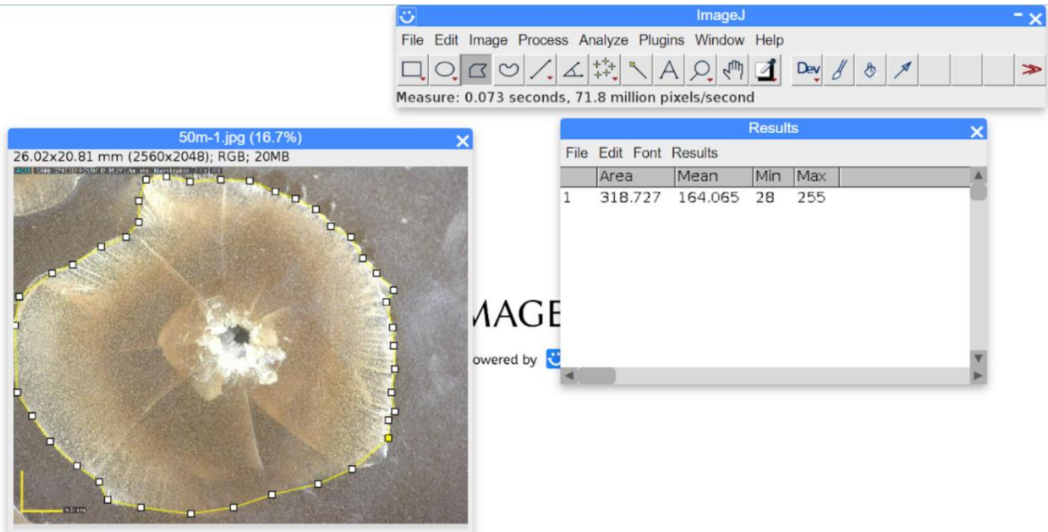
6.6 Analysis:

The Microstructures of the samples were captured using Optical Image Microscope

The above images are bullet from **50 meters distance**. The bullet has penetrated through the sample.

Using Image-J software, the impacted area was found out.

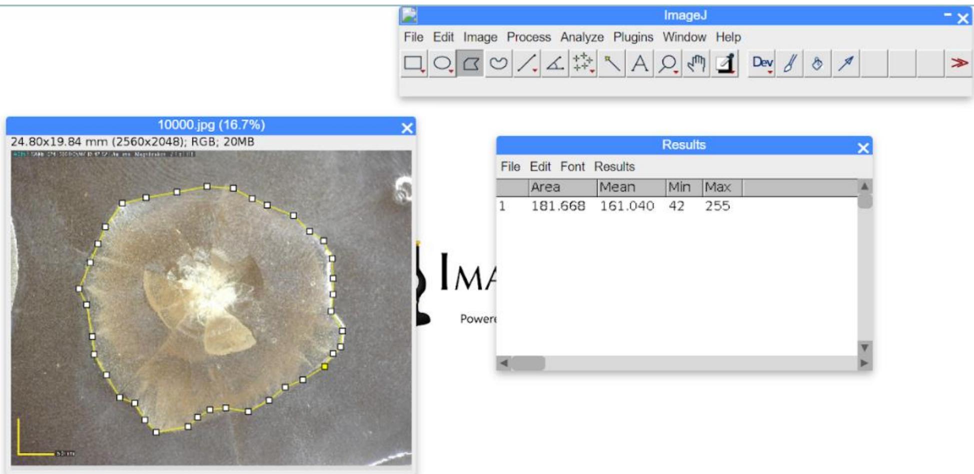


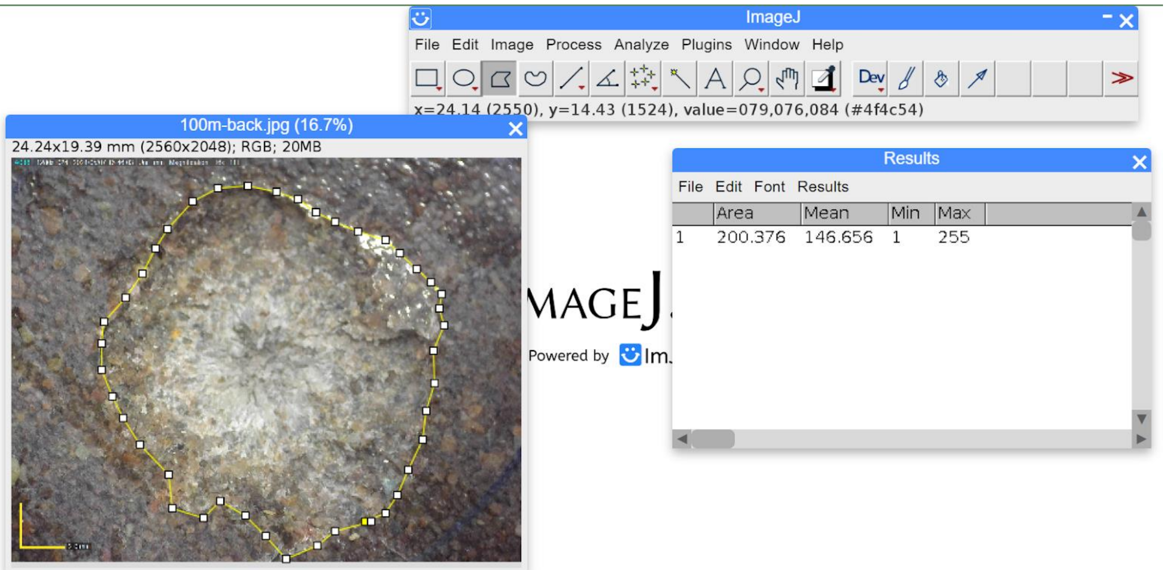


The above images are bullet from **100 meters distance**. The bullet has penetrated through the sample. However, a very small hole was made which was probably covered with a small sand grain due to which the hole was not observed.

Using Image-J software, the impacted area was found out.





When a bullet impacts a sand-reinforced composite material, the initial bullet facing area measures 197 mm², 200mm², while a larger area of energy dissipation (318 mm²,315.576mm²) and on the opposite side indicates effective energy absorption and dissipation. This showcases the material's capacity to withstand and mitigate bullet impact forces by spreading and dissipating energy effectively.

6.7 Further Samples:

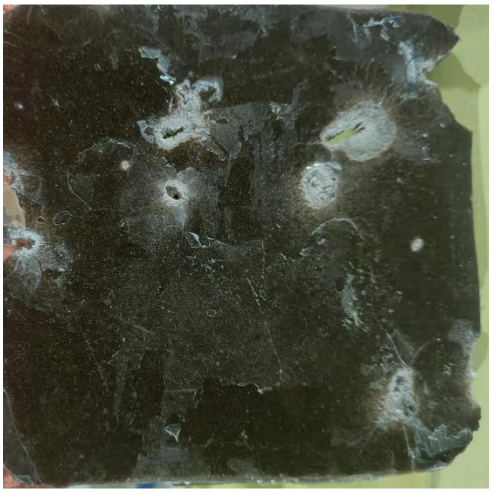
Further samples were made with varied compositions and tested

1. **Sand Fiber Reinforced Sample**
   Specifications - The layers are stuck using Epoxy Resin
   Dimensions: 1st Layer: 13 cm x 13 cm x 5mm; Other: 13cm x 13cm x 2.5mm
   Layer 1: 50% of 300 micrometers sand
   Layer 2: 50% of 300 micrometers sand
   Layer 3: 35% of 150 micrometers sand
   Layer 4: 40% of 300 micrometers sand
   Layer 5: 30% of 150 micrometers sand

   1 Bullet was hit onto this sample

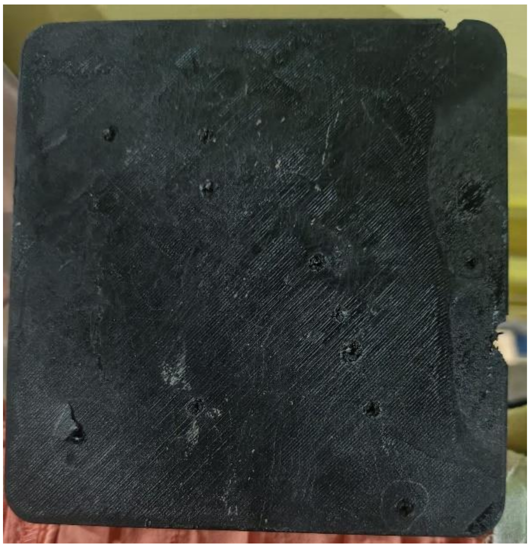
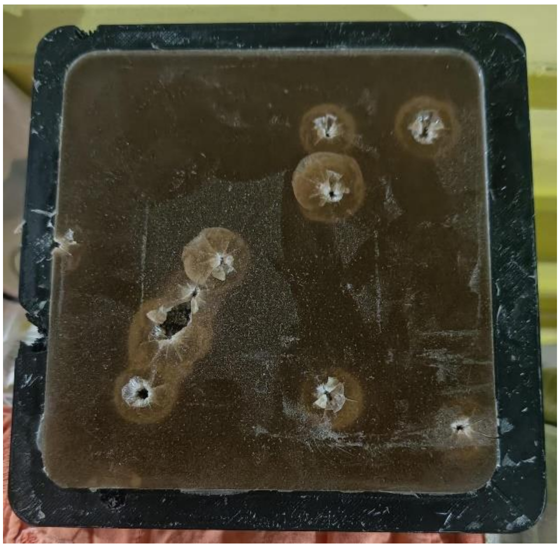
   The bonding between the layers was not perfect since we attached them after curing using epoxy.

2. **Sand Fibre Reinforced Sample alternately Heat Treated (HT)**
   Specifications - The layers are stuck using Epoxy Resin
   Dimensions : 1st Layer: 13 cm x 13 cm x 5mm ; Other: 13cm x 13cm x 2.5mm
   Layer 1: 50% of 300 micrometers sand
   Layer 2: 50% of 300 micrometers sand (HT)
   Layer 3: 35% of 150 micrometers sand
   Layer 4: 40% of 300 micrometers sand (HT)
   Layer 5: 30% of 150 micrometers sand

8 bullets were hit onto the sample. Due to heat- treatment, the samples became more brittle which led to them breaking easily since there is no yielding and direct fracture phase is reached

3. **Sand Filled - 3D Printed Mold Sample**
   Specifications - 3D printing is done using PLA (Poly Lactic Acid)
   The outer dimensions of the 3D printed mold are : 15 x 15 x 2.25 cm
   The inner dimensions of the cavity (sand filling) : 13 x 13 x 1.5 cm
   Each Sand Layer Thickness : 0.375 cm
   Layer 1: 50% of 300 micrometers sand
   Layer 2: 40% of 150 micrometers sand
   Layer 3: 35% of 300 micrometers sand
   Layer 4: 30% of 150 micrometers sand

8 Bullets were hit

The 3D printed mold was first printed and different layers of different compositions were poured similar to the initial sample.
This was a sample which was proposed keeping in mind that this can be upgraded to a sliding door of the BAUT.

4. **Sand and Glass Fibre Reinforced Sample**

   Specifications - Glass Fibre is stuck between each layer using Epoxy Resin
   Dimensions: 1st Layer: 13 cm x 13 cm x 5mm ; Other: 13cm x 13cm x 2.5mm
   Layer 1: 50% of 300 micrometers sand
   Layer 2: 50% of 300 micrometers sand
   Layer 3: 35% of 150 micrometers sand
   Layer 4: 40% of 300 micrometers sand
   Layer 5: 30% of 150 micrometers sand


2 bullets were hit
The glass fibre addition was not effective since the glass fibre didn't absorb any amount of energy.

5. **Sand Fibre Reinforced Sample varied thickness**

   Specifications - The layers are stuck using Epoxy Resin
   Dimensions: Each Layer: 13cm x 13cm x 5 mm
   Layer 1: 50% of 300 micrometers sand
   Layer 2: 50% of 300 micrometers sand
   Layer 3: 50% of 300 micrometers sand
   Layer 4: 50% of 150 micrometers sand


4 bullets were hit

6.8 Analysis:

The potential failure reasons associated with the sand-reinforced composite include:

1. Fiber pullout
2. Fiber rupture
3. Epoxy cracking

These failure modes were observed through visual inspection and scanning microscopy analysis of the impacted composite samples.

To mitigate the failure mechanisms associated with sand-reinforced composite materials, several strategies can be employed:

1. <u>Enhanced Fiber-Matrix Bonding</u>: Improving the bond strength between the fibers (such as sand particles) and the epoxy matrix can reduce fiber pullout and rupture. This can be achieved through surface treatments on the fibers or using coupling agents that enhance adhesion between the fibers and the matrix.
2. <u>Optimized Fiber Orientation:</u> Controlling the orientation and alignment of the fibers within the composite can enhance their load-bearing capacity and reduce the likelihood of fiber pullout or rupture under impact. Strategic fiber placement and orientation can distribute stresses more evenly throughout the material.
3. <u>Epoxy Resin Modification:</u> Modifying the epoxy resin formulation to enhance its toughness and impact resistance can help mitigate epoxy cracking. This can involve using additives or modifiers that improve the resin's ability to withstand impact loads without fracturing.
4. <u>Composite Design and Thickness</u>: Designing the composite structure with appropriate thickness and layering can improve its overall strength and resistance to failure mechanisms. Reinforcing critical areas or using multilayered composites with varying fiber orientations can enhance impact resistance.
5. <u>Testing and Validation</u>: Conducting thorough testing, including ballistic tests and impact simulations, can help identify potential failure modes and validate the effectiveness of mitigation strategies. Iterative testing and refinement of composite designs can lead to improved performance and reliability.

6.9 Advantages:

1. <u>Impact Resistance</u>: Epoxy and sand reinforced composites can absorb and dissipate the energy from bullet impacts effectively due to their toughness and resilience.
2. <u>Lightweight</u>: Compared to traditional bulletproof materials, epoxy and sand composites can be much lighter while still providing adequate protection. This is particularly advantageous for applications where weight is a concern, such as in body armor or vehicle armor.
3. <u>Cost-Effectiveness</u>: While the initial cost of epoxy and sand composites may vary depending on the specific formulation and manufacturing process, they may offer long-term cost savings compared to traditional materials due to their durability and lightweight nature.
4. <u>Customization</u>: The composition of epoxy and sand composites can be adjusted to achieve specific ballistic protection requirements.

7.Conclusion

1. **The incorporation of Rice Straw into the Sand reinforced composite has shown better results for impact resistance which validates that utilizing this mixture is beneficial. This is observed due to:**

    1.1 Improved Energy Absorption Capacity: The rice straw fibers act as reinforcements in the composite, enhancing its ability to absorb and dissipate energy during impact events.

    1.2 Increased Toughness and Ductility: The addition of rice straw fibers to the sand-reinforced composite increases the overall toughness and ductility of the material.

    1.3 Fiber-Matrix Interaction: The rice straw fibers form a strong interface with the epoxy resin matrix, enhancing the load transfer mechanism between the fibers and the matrix.

    1.4 Microstructural Changes: The incorporation of rice straw fibers into the sand-reinforced composite leads to changes in the microstructure, such as the formation of a more uniform and dense structure.

2. **One potential reason for less tensile strength of the sand reinforced composite can be bonding issues between epoxy and sand particles. The bonding issues were potentially due to:**

    2.1. Insufficient Coverage: Inadequate epoxy resin coverage on sand particles results in weak or non-existent bonding points within the composite. These uncovered areas act as stress concentration points during tension, leading to premature failure and decreased tensile strength.

    2.2 Critical Particle Volume: As sand particle volume exceeds a critical threshold, overcrowding reduces epoxy bonding surface area. This leads to reduced adhesion and tensile strength, potentially causing increased porosity and delamination.

    2.3. Shape of Sand Particles: Irregularly shaped sand particles pose challenges for uniform epoxy coverage due to sharp edges and varying sizes. These irregularities may require more epoxy to fill gaps, increasing resin-to-filler ratio and impacting mechanical properties.

    2.4. Frictional and Interlock Forces: Irregular sand particles create interlocking structures, enhancing shear resistance but causing variations in bonding strength. Strong interlock areas may exhibit higher tensile strength, while weaker regions may experience premature failure, affecting overall composite strength.

3. **The inclusion of rice straw fibers enhances mechanical properties, while the high silica content of rice straw ash provides excellent thermal insulation properties.**

    3.1 Enhanced Mechanical Properties: Rice straw fibers reinforce the composite matrix, boosting tensile strength, flexural strength, and impact resistance, while their fibrous structure enhances toughness by bridging cracks and resisting fractures. Additionally, these fibers aid in distributing stresses evenly across the material, improving overall mechanical performance.

    3.2 Thermal Insulation Properties: Rice straw ash, rich in silica, offers excellent thermal insulation by reducing heat transfer and forming a barrier within composites that hinders heat transfer effectively. Moreover, silica's temperature stability ensures consistent insulation performance across varying thermal conditions.

4. **The increased water absorption observed with the addition of these materials can provide benefits such as improved moisture regulation and dampening effects, which may be advantageous in specific climates or environments.**

   4.1 Optimized Composition: Adjusting how much epoxy and sand are mixed together can make the material better at handling heat and stop it from melting when hit hard. By adding special ingredients to the resin or changing how it's made, we can make sure it stays strong even when it gets really hot

   4.2. Post-Processing Techniques: After making the material, we can use different methods like curing or adding heat to make it even stronger and more resistant to melting. These extra steps help make the material tougher and last longer when it's hit hard.

   4.3. Enhanced Thermal Conductivity: Making the material better at moving heat away helps prevent it from melting in one spot. We can do this by adding certain things to the mix that can carry heat away more effectively, like special fillers or additives.

   4.4. Structural Reinforcement: Adding extra layers or making certain parts of the material stronger can help stop it from melting in the areas where it's hit the hardest. This reinforcement makes sure the material stays solid even when under a lot of pressure.

8.Future Work

1. Exploring different combinations of sand particles and epoxy through comprehensive testing procedures to identify the most effective composition that enhances both strength and impact resistance. This involves analyzing the bonding characteristics and performance of each combination to ensure optimal results in strengthening materials.
2. Assessing the feasibility of integrating alternative natural fibers alongside rice straw to determine their potential for augmenting impact resistance and strength, particularly in applications requiring bulletproof capabilities. This entails evaluating various natural fiber options and their compatibility with existing materials to identify synergistic combinations that offer enhanced protective properties.
3. Fine-tuning multiple parameters, including post-processing techniques and treatments, to further enhance the overall performance of materials. This includes experimenting with different methods to refine the structural integrity and durability of composite materials, aiming to achieve superior results in terms of strength, resilience, and resistance to external forces.

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