GREEN COMPOSITES- A Review

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ABSTRACT

Green composites, also known as eco-friendly or sustainable composites, are a type of composite material designed to have minimal environmental impact throughout their lifecycle. These composites are increasingly gaining attention and popularity as the world seeks more sustainable and environmentally friendly alternatives to traditional materials. Green composites are typically made from renewable, biodegradable, or recycled materials. These materials can include natural fibers like flax, jute, hemp, and bamboo, as well as biopolymers derived from sources such as corn starch or soy protein. Using these materials reduces the reliance on non-renewable resources like petroleum-based plastics. The production of green composites often generates fewer greenhouse gas emissions compared to traditional composites made from fossil fuels. This makes them a more environmentally friendly option, especially when considering their contribution to mitigating climate change. Green composites find applications in various industries, including automotive, construction, aerospace, and consumer goods. They are used to create products such as car components, building materials, packaging, and even furniture.

Keyword : - *composites, recycle, bio polymers, natural fibres, automotive*

1. INTRODUCTION

Green composites, also known as eco-friendly or sustainable composites, are a type of composite material designed to have minimal environmental impact throughout their lifecycle. These composites are increasingly gaining attention and popularity as the world seeks more sustainable and environmentally friendly alternatives to traditional materials. Green composites are typically made from renewable, biodegradable, or recycled materials. These materials can include natural fibers like flax, jute, hemp, and bamboo, as well as biopolymers derived from sources such as corn starch or soy protein. Using these materials reduces the reliance on non-renewable resources like petroleum-based plastics. The production of green composites often generates fewer greenhouse gas emissions compared to traditional composites made from fossil fuels. This makes them a more environmentally friendly option, especially when considering their contribution to mitigating climate change. Many green composites are designed to be biodegradable, meaning they can break down naturally over time, reducing the accumulation of non-degradable waste in landfills and ecosystems. The manufacturing processes for green composites often require less energy compared to conventional composites, further reducing their environmental impact. Green composites find applications in various industries, including automotive, construction, aerospace, and consumer goods. They are used to create products such as car components, building materials, packaging, and even furniture. Green composites can be engineered to offer good mechanical properties and durability, making them suitable for a wide range of applications. While green composites offer many environmental benefits, they also have some challenges. For instance, they may not always match the performance characteristics of traditional composites, and their cost can be higher due to the sourcing and processing of eco-friendly raw materials. Recycling green composites can be more complex than recycling traditional composites due to the variety of materials used. Researchers are working on developing efficient recycling methods for these materials. As green composites gain traction, there are efforts to establish standards and regulations to ensure their environmental claims are accurate and that they meet safety and quality requirements. Green composites are expected to continue growing in importance as sustainability becomes a focal point in various industries. Continued research and development are likely to improve their performance, cost-effectiveness, and recyclability. Green composites are a class of materials designed to reduce the environmental impact of traditional composites by using renewable, biodegradable, or recycled components. They offer several benefits, such as lower carbon emissions, biodegradability, and reduced energy consumption during production, making them a promising choice for a more sustainable future.

2. LITERATURE REVIEW

Rittin Abraham Kurien et.al [1] in their research aims to contribute to this field by conducting a review and outlining the potential applications of these materials in the automotive industry. The use of natural fiber composites in the automotive industry has gained interest due to their potential benefits, including reduced environmental impact, lower weight, and potentially lower manufacturing costs. This can be especially important as the automotive industry looks for ways to reduce its carbon footprint and adhere to stricter environmental regulations. Hafsa Jamshaid [2] in their work research indicates that the combination of basalt and jute fibers in the composite material results in improved mechanical properties, enhanced thermal stability, and better fiber-matrix interactions. Tufail Hassan et.al[3] in their study focuses on the investigation of acoustic, mechanical and thermal properties of natural fiber waste reinforced green epoxy composites. Three different types of fiber wastes were used, e.g., cotton, coconut and sugarcane with epoxy as the resin. Different fiber volume fractions, i.e., 10%, 15% and 20% for each fiber were used with a composite thickness of 3 mm. The sound absorption coefficient, impact strength, flexural strength, thermal conductivity, diffusivity, coefficient of thermal expansion and thermogravimetric properties of all samples were investigated. It has been found that by increasing the fiber content, the sound absorption coefficient also increases. The coconut fiber-based composites show a higher sound absorption coefficient than in the other fiber-reinforced composites. The impact and flexural strength of the cotton fiber-reinforced composite samples are higher than in other samples. . Echeverria et.al [4] in their research suggests that the composition of HFRC prototypes, particularly those with low density and natural fibers with intricate microstructures, can result in high sound absorption values. These findings have potential applications in industries where sound insulation or acoustic performance is crucial, such as automotive, construction, and architectural design. M.N. Mohammed et.al [5] in their research explores the development of coir/silk hybrid composites with varying fiber lengths and assesses the influence of alkali treatment on the mechanical properties. The findings suggest that these composites exhibit improved mechanical performance, making them potentially suitable for applications where strength and durability are important factors. SachinYadav et.al [6] in their research work states that the utilization of natural fibers like Bagasse in composite materials highlight the importance of sustainable and environmentally friendly approaches to material development, particularly in regions like India with abundant agricultural resources. These efforts have the potential to benefit various industries while reducing waste and environmental impact. . E.F. Cerqueira et.al [7] demonstrates that the chemical modification of sugarcane bagasse fibers and their incorporation into polypropylene composites led to significant improvements in the mechanical properties of the composites. This suggests that these modified natural fibers can be a viable and environmentally friendly alternative for reinforcing composite materials, aligning with the growing demand for sustainable and eco-friendly solutions in various industries. B.C. Mitra et.al [8] denotes that the development and use of biocomposites represent a significant step toward more environmentally friendly and sustainable materials. These materials have the potential to address the concerns related to petroleum-based composites and offer a more eco-friendly alternative, aligning with the principles of green technology and biodegradation. The future of biocomposites, including bio nanocomposites, holds promise, and innovation is key to unlocking their full potential. . Md Zahidul Islam et.al [9] explores that green composites are emerging as a promising solution to address environmental concerns and the demand for sustainable materials. Their versatility, biodegradability, and potential to replace non-environmentally friendly materials make them an important focus of research and innovation. Researchers and practitioners are actively working to advance the field of green composites to meet the growing global demand for eco-friendly alternatives. Deepa G. et.al[10] highlights the growing interest in natural fiber composites, with a specific focus on bagasse-based composites and found that these materials are seen as a sustainable solution, with various treatment methods and processing techniques being explored to enhance their properties. This research aligns with the broader goal of reducing waste and addressing environmental concerns while providing materials for diverse applications. H. Hajiha et.al [11] in their research work founds that bagasse sugarcane, which is typically used as fuel in sugar mills, is being explored for its potential in value-added applications, particularly as a reinforcement material in plastic and cement composites. The mechanical and thermal properties of bagasse make it a viable choice for improving the performance of composite materials. Additionally, various treatment techniques are used to enhance the compatibility between bagasse fibers and composite matrices, further improving their mechanical properties. This research aligns with the goal of reducing waste and optimizing the use of available resources. Sergio N. Monteiro et.al [12] in their study highlights the potential of utilizing bagasse waste in polymeric composites for ballistic resistance, making these materials more affordable and sustainable. The research suggests that bagasse-reinforced composites could serve as a cost-effective and environmentally friendly alternative to traditional materials like Kevlar™ in the development of protective armor systems. In the research by Paulo Pecas et.al [13] found that the natural fiber-reinforced polymeric composites is a dynamic field that involves the characterization of various fibers and the comparison of their properties with conventional materials. This research helps identify the most suitable natural fibers for specific industrial applications. It also explores emerging fiber types and provides insights into future trends and developments in this area. M.P. Staiger et.al [14] in their research findings found that the increasing importance of natural fibers in materials science and their potential to serve as sustainable alternatives to synthetic fibers in various applications. It particularly emphasizes their use in semi-structural and structural applications. R. Manohar Reddy [14] state that the silk is a versatile natural fiber with a wide range of applications, from food and cosmetics to medical and construction materials. Its biocompatibility, eco-friendliness, and various properties make it a valuable resource in modern applications, and continued research and awareness are essential to unlock its full potential. S. M. Darshan et.al [15] in their research work explores that the potential of waste silk fibers as a reinforcement in polymer composites and reviews the existing literature on their utilization in various processing methods. The research aims to enhance the development of automotive applications by utilizing waste silk fibers in FRPCs. Guravtar Singh Mann et.al [16] in their research work reveals that the emergence of green composites and their advantages, especially the use of natural fibers. Carl Zweben [16] in his research findings provides a statistical analysis of unidirectional hybrid composite materials and their tensile strength. It delves into various material properties that affect the failure process and explains the "hybrid effect" observed in such composites. The analysis serves as a valuable tool for understanding the mechanical behavior of these materials and may guide future research in this field. Santhanam Sakthivel et.al [17] explores the development of eco-friendly thermal and sound insulation materials for automotive applications using sugarcane bagasse and bamboo charcoal fibers. The materials show promising sound absorption properties, making them suitable for noise control and sound insulation in the automotive industry. Ibrahim Can Kaymaz et.al research work explains the the growing importance of composite materials in the transportation industry. It highlights the unique challenges and performance requirements in transportation and discusses the role of hybrid composites in meeting these demands. The railway sector is singled out as a promising component of the future of transportation due to its sustainability and efficiency.

3. BAGASS COMPOSITE

Bagasse composite materials are a type of green composite made from bagasse, which is the fibrous residue left over after sugarcane or other plants with a similar composition are processed for their juice. Bagasse is abundant in regions where sugarcane cultivation is prevalent, making it a readily available and renewable resource for composite material production.

1. **Raw Material**: Bagasse composites primarily use bagasse fibers as a reinforcement material. These fibers are extracted from the sugarcane plant's stalks after the sugar extraction process.
2. **Matrix**: The bagasse fibers are typically combined with a matrix material, which is often a biodegradable polymer. Common matrix materials include biopolymers like polylactic acid (PLA), polyhydroxyalkanoates (PHA), or thermoplastic starch. These matrices can be derived from renewable sources, making them environmentally friendly.
3. **Manufacturing Process**: Bagasse composites are typically produced using methods such as compression molding, injection molding, or extrusion. During the manufacturing process, bagasse fibers are mixed with the polymer matrix, and the mixture is shaped into the desired form.
4. **Properties**: Bagasse composites can exhibit a range of properties, depending on the choice of matrix and processing conditions. They can be engineered to have good mechanical strength, thermal stability, and biodegradability.
5. **Applications:**

- Packaging: Bagasse composites are often used to make biodegradable and eco-friendly packaging materials, such as food containers, plates, trays, and disposable cutlery.
- Construction: They can be used in construction materials, such as particleboards, ceiling tiles, and wall panels.
- Automotive: Bagasse composites can be used in automotive interior components, reducing the weight of the vehicle and increasing sustainability.
- Furniture: Bagasse composites can be used to create sustainable and lightweight furniture components.
- Consumer Goods: These composites are also used in the production of various consumer goods, including toys, pens, and household items.

6. Sustainability: Bagasse composites are considered sustainable because they utilize agricultural waste (bagasse) that would otherwise be discarded or burned, contributing to environmental pollution. By converting bagasse into useful composite materials, it helps reduce waste and reliance on non-renewable resources.
7. Biodegradability: Bagasse composites are often biodegradable, which means they can break down naturally over time, reducing their environmental impact and potential contribution to plastic pollution.
8. Challenges: While bagasse composites have several environmental benefits, they may have limitations in terms of mechanical properties when compared to traditional composites. Researchers continue to work on improving the properties and performance of these materials.

Bagasse composite materials are a sustainable and environmentally friendly option for a range of applications, including packaging, construction, automotive, and consumer goods. They leverage agricultural waste to create useful and biodegradable composite materials, contributing to efforts to reduce waste and promote sustainability.

4. SILK WASTE COMPOSITE:

Silk waste composites refer to composite materials that incorporate silk waste fibers or other components derived from silk production processes. Silk waste is the residue left over from various stages of the silk production cycle, and it can be repurposed and combined with other materials to create composite materials with unique properties. Here are some key aspects of silk waste composites:

1. **Raw Material:** Silk waste composites primarily utilize silk waste fibers, which are obtained from the byproducts of silk processing. These fibers may include cocoon shells, damaged silk threads, or other remnants from sericulture (silk farming).
2. **Matrix Material:** To create composite materials, silk waste fibers are typically combined with a matrix material. The matrix can be made of various materials, including polymers (both natural and synthetic), ceramics, or metals, depending on the desired properties of the composite.
3. **Manufacturing Process:** The production of silk waste composites involves mixing or blending the silk waste fibers with the matrix material. This can be done through processes such as compression molding, injection molding, or extrusion, depending on the intended application.
4. **Properties:** Silk waste composites can exhibit a range of properties, depending on the type and processing of silk waste fibers and the matrix material. Silk fibers are known for their strength, flexibility, and lightweight nature, which can be advantageous in composite materials. These composites may also benefit from the biodegradability and natural luster of silk fibers.
5. **Applications:**

- Textiles and Apparel: Silk waste composites can be used in textiles and clothing to create fabrics with enhanced properties, such as improved strength, moisture management, and breathability.
- Construction: They may be employed in construction materials, such as lightweight panels, insulation, or reinforcements.
- Automotive and Aerospace: In these industries, silk waste composites can be used to create components requiring both strength and lightweight characteristics.
- Biomedical: Some silk waste composites have been explored for medical applications, such as wound dressings, due to their biocompatibility.

6. **Sustainability:** Using silk waste in composite materials is considered sustainable because it repurposes a byproduct of silk production that might otherwise go to waste. This can reduce waste in the silk industry and minimize the environmental impact of discarded silk waste.
7. **Challenges:** While silk waste composites offer several advantages, they may have limitations in terms of cost and availability of silk waste fibers. Additionally, the performance of these composites can vary depending on the quality and processing of the silk waste.
8. **Innovation:** Researchers continue to explore new ways to optimize silk waste composites and expand their applications. Innovations in processing techniques and the development of new matrix materials are ongoing.

Silk waste composites are a sustainable and potentially valuable material option that leverages the byproducts of silk production to create composite materials with various applications. These composites can offer a combination of strength, lightweight properties, and biodegradability, making them appealing for a range of industries.

5. COTTON HUSK COMPOSITE:

Cotton husk composite materials are composite materials that incorporate cotton husk fibers or other components derived from cotton husks. Cotton husks are the outer layer of the cottonseed and are typically considered waste or byproducts of the cotton ginning process. However, these husks can be repurposed and combined with other materials to create composite materials with unique properties. Here are some key aspects of cotton husk composites:

1. **Raw Material**: Cotton husk composites primarily use cotton husk fibers, which are obtained from the outer layers of cotton seeds. These fibers are often considered agricultural waste and can be collected after the cotton ginning process.
2. **Matrix Material**: To create composite materials, cotton husk fibers are typically combined with a matrix material. The matrix can be made of various materials, including polymers (both natural and synthetic), such as polypropylene, polyethylene, or biodegradable polymers like polylactic acid (PLA).
3. **Manufacturing Process**: The production of cotton husk composites involves mixing or blending the cotton husk fibers with the matrix material. This can be done through processes such as compression molding, injection molding, or extrusion, depending on the intended application.
4. **Properties**: Cotton husk composites can exhibit a range of properties, depending on factors such as the type and processing of cotton husk fibers and the matrix material used. Cotton husk fibers are known for their lightweight nature, biodegradability, and thermal insulation properties.
5. **Applications:**

- Construction: Cotton husk composites can be used in construction materials, such as particleboards, ceiling tiles, and insulation products.
- Automotive: They may be employed in automotive interior components to reduce weight and enhance sustainability.
- Furniture: Cotton husk composites can be used to create sustainable and lightweight furniture components.
- Packaging: They can be used to create biodegradable packaging materials, such as trays, containers, and disposable cutlery.

6. **Sustainability:** Using cotton husks in composite materials is considered sustainable because it repurposes a byproduct of cotton production that might otherwise go to waste. This can reduce waste in the cotton industry and minimize the environmental impact of discarded cotton husks.
7. **Challenges:** While cotton husk composites offer several advantages, they may have limitations in terms of mechanical properties compared to traditional composites. The performance of these composites can vary depending on the quality and processing of the cotton husk fibers.
8. **Innovation:** Researchers continue to explore new ways to optimize cotton husk composites and expand their applications. Innovations in processing techniques and the development of new matrix materials are ongoing.

Cotton husk composites are a sustainable and potentially valuable material option that repurposes byproducts of the cotton ginning process to create composite materials with various applications. These composites can offer benefits such as reduced waste, biodegradability, and thermal insulation properties, making them appealing for industries seeking more sustainable material alternatives.

6. ACOUSTIC PROPERTIES OF GREEN COMPOSITES

The acoustic properties of green composites, like any composite materials, depend on various factors, including the composition, structure, and manufacturing processes used. Green composites are typically engineered to have specific acoustic characteristics, making them suitable for various applications where sound control and acoustic performance are important. Here are some key aspects of the acoustic properties of green composites:

1. **Sound Absorption**: Green composites, particularly those using natural fibers as reinforcement, can have good sound absorption properties. The porous and fibrous structure of natural fibers allows them to dissipate sound energy effectively, reducing sound reflection.
2. **Density:** The density of the composite material plays a crucial role in its acoustic properties. Lower-density green composites tend to be more effective at absorbing sound. Lightweight materials, such as those using natural fibers or biopolymers, can provide good acoustic performance.
3. **Frequency Response**: The acoustic behavior of green composites can vary with the frequency of sound. Some composites may be more effective at absorbing certain frequency ranges, while others may perform better at different frequencies. Engineers and designers must consider the specific application's frequency requirements.

4. **Damping Properties**: Green composites can exhibit damping properties that help reduce vibrations and noise transmission. This is particularly valuable in applications where noise control and vibration damping are essential, such as automotive components or building materials.
5. **Moisture Sensitivity**: Green composites, especially those with natural fiber reinforcements, can be sensitive to moisture. Moisture absorption can change the material's density and mechanical properties, potentially affecting its acoustic performance. Proper sealing or protective coatings may be necessary in moisture-prone environments.
6. **Resonance and Thickness**: The thickness of the green composite material can impact its acoustic performance. Thicker materials may offer better sound absorption properties, especially for lower frequencies. Engineers may adjust the thickness to match the desired acoustic performance.
7. **Manufacturing Techniques**: The manufacturing process used to create green composites can affect their acoustic properties. Factors such as fiber orientation, resin distribution, and compaction can influence how sound is transmitted through or absorbed by the material.

7.APPLICATIONS OF GREEN COMPOSITES WITH ACOUSTIC PROPERTIES INCLUDE:

- **Automotive**: Green composites can be used in car interiors, door panels, headliners, and acoustic insulation materials to reduce cabin noise levels and improve passenger comfort.
- **Construction**: Green composites can be used in building materials, such as acoustic panels, wall claddings, and flooring, to enhance sound insulation and reduce noise pollution in residential and commercial buildings.
- **Aerospace**: In aircraft interiors, green composites can contribute to noise reduction and improved passenger experience by serving as structural components with sound-damping properties.
- **Consumer Electronics**: Green composites can be used in the casings of electronic devices to dampen vibrations and reduce noise emissions.
- Industrial Equipment: Green composites can be employed in industrial machinery to mitigate noise generated during operation. To optimize the acoustic performance of green composites, designers and engineers may conduct testing, modeling, and analysis to tailor the materials to the specific requirements of their applications. This often involves adjusting the composite's composition, thickness, and manufacturing processes to achieve the desired acoustic characteristics.

8. CONNCLUSION

Green composites represent a promising avenue for more sustainable and environmentally friendly materials. Their potential is particularly important in a world where sustainability and responsible resource management are paramount. Green composites are seen as a sustainable alternative to traditional composite materials. They are made from renewable resources, often natural fibers, which are readily available and biodegradable. This makes them environmentally friendly and reduces reliance on fossil-based materials. Continued research and innovation in this field will further enhance the capabilities and applicability of green composites. Green composites are expected to see increased adoption in various industries as environmental concerns grow. Research and development efforts are likely to focus on improving their properties and expanding their range of applications. Green composites can offer competitive mechanical properties when appropriately designed. Their performance can match or surpass that of traditional composites, depending on the application. Green composites are versatile materials with a wide range of applications. They can be used in various industries, including automotive, aerospace, construction, and consumer goods. Their properties can be tailored to meet specific requirements.

9. REFERENCES

[1] Rittin Abraham Kurien, D Philip Selvaraj, M Sekar and Chacko Preno Koshy, “Green composite materials for green technology in the automotive industry” IOP Conference Series: Materials Science and Engineering, 2020.
[2] Hafsa Jamshaid, Rajesh Mishra, Jiri Militky, Miroslava Pechociakova & Muhammad Tayyab Noman, ”Mechanical, thermal and interfacial properties of green composites from basalt and hybrid woven fabrics”, November 2016.
[3] Tufail Hassan,Hafsa Jamshaid,Rajesh Mishra,Muhammad Qamar Khan,Michal Petru,Jan Novak,Rostislav Choteborsky andMonika Hromasova,“Acoustic, Mechanical and Thermal Properties of Green Composites Reinforced with Natural Fibers Waste” March 2020.

[4] A. Echeverria , Farshid Pahlevani , Wilson Handoko , Chaoyang Jiang , Con Doolan , Veena Sahajwalla , " Engineered hybrid fibre reinforced composites for sound absorption building applications "Resources, Conservation and Recycling Volume 143, April 2019, Pages 1-14.
[5] P. Noorunnisa Khanam, G. Ramachandra Reddy, and S. Venkata Naidu "Tensile, Flexural, and Compressive Properties of Coir/Silk Fiber-reinforced Hybrid Composites" Journal of Reinforced Plastics and Composites, Volume 29, Issue 14.
[6] SachinYadav, Gourav Gupta, Ravi Bhatnagar, "A Review on Composition and Properties of Bagasse Fibers" International Journal of Scientific & Engineering Research, Volume 6, Issue 5, May-2015.
[7] E.F. Cerqueira a, C.A.R.P. Baptista b, D.R. Mulinari , "Mechanical behaviour of polypropylene reinforced sugarcane bagasse fibers composites" Procedia Engineering Volume 10, 2011, Pages 2046-2051.
[8] B.C. Mitra," Environment Friendly Composite Materials: Biocomposites and Green Composites", Defence Science Journal, Vol. 64, No. 3, May 2014, pp. 244-261.
[9] Md Zahidul Islam , Md Emdad Sarker and Md Syduzzaman "Green composites from natural fibers and biopolymers: A review on processing, properties, and applications" Journal of Reinforced Plastics and Composites, Volume 41, Issue 13-14.
[10] Deepa G. Devadiga,K. Subrahmanya Bhat& GT Mahesha "Sugarcane bagasse fiber reinforced composites: Recent advances and applications", Materials engineering, June 2020.
[11] H. Hajiha, M. Sain "The use of sugarcane bagasse fibres as reinforcements in composites", Biofiber Reinforcements in Composite Materials 2015, Pages 525-549.
[12] Sergio N. Monteiro a, Veronica S. Candido a, Fabio O. Braga a, Lucas T. Bolzan a, Ricardo P. Weber a, Jaroslaw W. Drelich "Sugarcane bagasse waste in composites for multilayered armor" ,European Polymer Journal Volume 78, May 2016, Pages 173-185.
[13] Paulo Peças, Hugo Carvalho, Hafiz Salman and Marco Leite "Natural Fibre Composites and Their pplications: A Review" Journal of Composites Science, November 2018.
[14] M.P. Staiger, N. Tucker "Natural-fibre composites in structural applications", Properties and Performance of Natural-Fibre Composites2008, Pages 269-300.
[15] R. Manohar Reddy "Innovative and Multidirectional Applications of Natural Fibre, Silk - A Review", Academic Journal of Entomology 2 (2): 71-75, 2009.
[16] S. M. Darshan, B. Suresha, G. S. Divya "Waste Silk Fiber Reinforced Polymer Matrix Composites: A Review ", Indian Journal of Advances in Chemical Science, May 2016.
[17] Guravtar Singh Mann, Naved Azum*, Anish Khan, Malik Abdul Rub, Md Imtaiyaz Hassan, Kisa Fatima and Abdullah M. Asiri "Green Composites Based on Animal Fiber and Their Applications for a Sustainable Future" Polymers (Basel), January 2023.
[18] Carl Zweben "Tensile strength of hybrid composites", Journal of Materials Science volume 12, pages1325–1337 (1977).
[19] Santhanam Sakthivel, Selvaraj Senthil Kumar and Fasika Abedom "Sound absorbing and insulating properties of natural fiber hybrid composites using sugarcane bagasse and bamboo charcoal" Journal of Engineered Fibers and Fabrics, Volume 16, January-December 2021.
[20] V. G. Babashov, A. S. Bespalov, A. V. Istomin & N. M. Varrik "Heat and Sound Insulation Material Prepared Using Plant Raw Material "Refractories and Industrial Ceramics(Vol. 58, Issue 2), July 2017.
[21] Ibrahim Can Kaymaz,Alperen Dogru,Mehmet Ozgur Seydibeyoglu "Hybrid Composites for Railway and Transportation Uses – A Review", Applied science and engineering progress, Published: volume 15 December 2022.