

## THE STUDY ON CHARACTERISTICS OF FLY ASH FILLER WITH GLASS FIBER REINFORCED POLYMER MATRIX COMPOSITES – A COMPREHENSIVE REVIEW

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### ABSTRACT

Fly ash, a byproduct of coal combustion in thermal power plants, has gained significant attention as a filler material in fiber reinforced polymer (FRP) matrix composites. Its utilization in composites offers numerous advantages, including cost-effectiveness, environmental sustainability, and improved mechanical properties. This paper reveals the review which focuses on the mechanical characterization of fly ash filler with glass fiber reinforced polymer (GFRP) matrix composites. The objective of this review is to provide a comprehensive analysis of the mechanical properties of composites containing fly ash as a filler material in a GFRP matrix and to understand the impact of fly ash on the overall performance of the composites.

**Keywords:** Fly ash, Fiber, Filler, GFRP.

### 1. INTRODUCTION

Composites are materials composed of two or more distinct constituents, where one phase acts as a reinforcement and the other as a matrix. The addition of fillers to composites can significantly enhance their properties. Fly ash, a byproduct of coal combustion in thermal power plants, has emerged as a promising filler material due to its abundance, cost-effectiveness, and environmental sustainability. This detailed report aims to provide a comprehensive overview of the utilization of fly ash as a filler material in composites, highlighting its impact on various properties and its potential applications.

The review surveys the existing literature, including research articles, conference papers, and patents, to gather insights into the advancements, methodologies, and findings in the field of fly ash-GFRP composites. It examines the motivation behind incorporating fly ash as a filler material in GFRP composites, considering factors such as its abundance, cost-effectiveness, and environmental sustainability. The fabrication processes and techniques used to achieve uniform dispersion of fly ash particles within the GFRP matrix are discussed. Special emphasis is placed on optimizing interfacial bonding and mechanical performance through appropriate surface treatment and processing conditions. The review investigates various mechanical properties, including tensile strength, flexural strength, impact resistance, hardness, and interlaminar fracture toughness.

The influence of fly ash content, particle size, surface treatment, and other parameters on these properties is thoroughly examined, providing valuable insights into the reinforcing effects of fly ash in the GFRP matrix. The findings from the reviewed literature reveal that the incorporation of fly ash in GFRP composites leads to improvements in mechanical properties, such as increased strength, stiffness, impact resistance, and fracture toughness. These enhancements can be attributed to the effective load transfer mechanisms, improved interfacial bonding, and unique properties of fly ash particles. Overall, this authentic review presents a comprehensive understanding of the mechanical characterization of fly ash filler with GFRP matrix composites.

It serves as a valuable resource for researchers, engineers, and industry professionals involved in composite material development, providing insights into the optimization of fly ash-GFRP composites for a wide range of applications, including automotive, aerospace, construction, and infrastructure.

**Ramakrishna et. al** investigated the use of fillers SiC and fly ash as secondary reinforcements have significant potential for enhancing the tensile and damping properties of glass fiber epoxy composites. The incorporation of SiC particles improves the mechanical strength, while fly ash particles enhance the damping characteristics of the composites. Combining these reinforcements in composites can lead to synergistic effects, resulting in improved overall performance.

**Raghavendra1 et. al** The evaluation of the mechanical behavior of woven bidirectional jute/glass hybrid nanocomposites filled with nanometer and micrometer fly ash particles demonstrated significant improvements in their tensile strength, flexural strength, and impact resistance. The size and concentration of the fly ash particles played a crucial role in determining the extent of improvement, with nanometer-sized particles showing superior reinforcement effects. These findings provide valuable insights into the potential application of fly ash-filled hybrid nanocomposites in various industries where enhanced mechanical properties are desired.

**Mohant et. al** The development of fly ash-based automotive brake lining showed promising results. The inclusion of fly ash as a primary component contributed to improved thermal stability, wear resistance, and frictional properties of the brake lining. The addition of fillers and additives further enhanced the mechanical strength, stability, and overall performance of the brake lining. Extensive testing and evaluation, including friction tests, wear tests, and thermal stability tests, confirmed the satisfactory performance of the fly ash-based brake lining.

**Vijay Baheti et. al** have discusses crucial factors such as tensile strength, flexural strength, impact resistance and the influence of different fly ash content on these properties. They have illustrated, that, how the addition of fly ash can improve or compromise the performance of the composites, providing valuable insights for material selection and optimization.

**Ayse Bicer** have explored the impact of fly ash particle size on the mechanical properties of the composites, including compressive strength, flexural strength, and tensile strength. The influence of particle size on the packing density, interfacial bonding, and microstructure of the composites, which directly affects their mechanical performance. By examining these factors, the review highlights the potential to tailor the mechanical properties of fly ash-cement composites by manipulating the particle size distribution.

**Dharmalingam et. al** have provided a comprehensive evaluation of the mechanical and thermal properties of surface-treated fly ash filled modified epoxy composites. the improvements achieved in properties such as tensile strength, flexural strength, impact resistance, and thermal stability. By enhancing the interfacial bonding between fly ash particles and the epoxy matrix through surface treatment, these composites exhibit superior mechanical performance and enhanced resistance to thermal degradation.

**R. Satheesh et. al** conducted study on the effect of fly ash filler size on the mechanical properties of polymer matrix composites provides valuable insights into an important aspect of composite materials research. The comprehensive analysis of the relationship between filler size and mechanical performance enhances our understanding of the key factors influencing composite behavior. Despite the suggestion to provide more critical comparisons, this review serves as a valuable resource for researchers, engineers, and practitioners involved in the design and optimization of polymer matrix composites.

**Shyamkumar Shah et. al** have discussed in their work on the effect of coal ash as a filler on the mechanical properties of glass fiber reinforced materials offers a comprehensive analysis of an important aspect of composite materials research. This review aims to explore the influence of coal ash as a filler on the mechanical performance of glass fiber reinforced composites, providing valuable insights for material development and optimization. The key mechanical characteristics, including tensile strength, flexural strength, impact resistance, and hardness, and evaluates how the incorporation of coal ash impacts these properties. By synthesizing findings from various studies, the review provides a comprehensive overview of the effects of coal ash filler on the mechanical behavior of glass fiber reinforced materials.

**Seshaiah et. al** studied the effect of fiber orientation on the mechanical behavior of E-glass fiber reinforced epoxy composite materials provides a comprehensive analysis of a crucial aspect in composite materials research. This review aims to explore the influence of fiber orientation on the mechanical properties and performance of E-glass fiber reinforced epoxy composites, offering valuable insights for material design and optimization. One of the strengths of this review lies in its thorough examination of the mechanical properties affected by fiber orientation. Mechanical characteristics, including tensile strength, flexural strength, interlaminar shear strength, and impact resistance, and evaluates how varying fiber orientations impact these properties.

**Pritish Shubham at. al** investigated the effects of varying fly ash content on key mechanical characteristics such as tensile strength, flexural strength, impact resistance, and hardness. By synthesizing findings from various studies, the review provides a comprehensive overview of the relationship between fly ash concentration and mechanical behavior. Various surface modification methods, such as chemical treatment, silane coupling agents, and plasma treatment, and their effects on the dispersion and adhesion of fly ash particles. The author emphasizes how surface modification influences the mechanical properties by enhancing the interfacial bonding and reducing the presence of voids or defects in the composite structure.

**Chauhan et. al** conducted the evaluation of mechanical and tribological properties of E-Glass fiber reinforced vinyl ester composites filled with SiC, Al<sub>2</sub>O<sub>3</sub>, and fly ash particulates provides valuable insights into an important aspect of composite materials research. The comprehensive analysis of the relationship between filler type, concentration, and the mechanical and tribological performance enhances our understanding of the key factors influencing composite behavior.

**Gupta et. al** evaluated the effect of filler addition on the compressive and impact properties of glass fiber reinforced epoxy offers valuable insights into an important aspect of composite materials research. This review aims to explore

the influence of filler incorporation on the compressive strength and impact resistance of glass fiber reinforced epoxy composites, providing valuable knowledge for material optimization and performance enhancement.

**Rameshkumar** effectively highlights the role of fly ash and E-glass fibers in enhancing the mechanical properties of the composites. The interactions between the epoxy matrix, fly ash particles, and E-glass fibers, emphasizing the improvement in interfacial adhesion and load transfer mechanisms. The influence of filler content, aspect ratio, and particle size distribution on the mechanical properties, providing valuable insights into the optimization of composite formulations.

**Patra et. al** have examined the key mechanical characteristics such as tensile strength, flexural strength, impact strength, and hardness and evaluates how the addition of fly ash influences these properties. By synthesizing findings from various studies, the review provides a comprehensive overview of the effects of fly ash reinforcement on the mechanical behavior of the composites. Factors such as fly ash particle size, distribution, and content, as well as the processing techniques employed, and their impact on the final mechanical and physical properties of the composites. This critical assessment enhances the practical relevance of the review by addressing potential limitations and providing insights into the optimization of composite formulations.

**Devendra et. al** have conducted the examination of the strength characteristics affected by the addition of filler materials in E-Glass fiber reinforced epoxy composites. The work explores key strength parameters, including tensile strength, flexural strength, compressive strength, and interlaminar shear strength, and evaluates how the incorporation of filler materials influences these properties. By synthesizing findings from various studies, the review provides a comprehensive overview of the effects of different fillers on the strength behavior of the composites.

**Singla et.al** studied the mechanical characteristics, including tensile strength, flexural strength, impact strength, and hardness, and evaluates how the addition of fly ash influences these properties. By synthesizing findings from various studies, the review provides a comprehensive overview of the effects of fly ash reinforcement on the mechanical behavior of the composites. Role of fly ash in enhancing the mechanical properties of the composites. The interactions between the epoxy matrix and the fly ash particles, emphasizing the improvements in interfacial adhesion and load transfer mechanisms. The author also addresses the influence of fly ash content, particle size, and distribution on the mechanical properties, providing valuable insights into the optimization of composite formulations.

**Mayana et. al** studied the mechanical characterization of the GFRE composites is carried out through various tests, such as tensile, flexural, and impact strength measurements, as well as hardness and fracture toughness evaluations. It also investigates the influence of CFA and SiC content on these properties, allowing for a comprehensive analysis of the material's performance. The addition of CFA and SiC leads to improved mechanical properties compared to the conventional GFRE material. The tensile and flexural strength of the composites increase with the addition of CFA, resulting in enhanced resistance to deformation. Furthermore, the incorporation of SiC particles contributes to increased hardness and fracture toughness, making the material more resistant to damage and crack propagation.

**Manimaran et. al** provides a comprehensive analysis of the mechanical properties of fly ash composites. Fly ash, a byproduct of coal combustion in power plants, has gained significant attention in recent years due to its potential as a reinforcing filler in composite materials. A fly ash as a filler material and its potential applications in composite materials. The author highlights the importance of fly ash as a sustainable and cost-effective alternative to traditional fillers due to its abundance and environmental benefits. He also examines the influence of different factors, such as fly ash content, particle size, and surface treatment, on the mechanical performance of the composites. The review also discusses the effects of incorporating other additives or reinforcements in combination with fly ash to further enhance the mechanical properties.

**Mohan kumar et. al** studied the mechanical properties of fly ash-filled GFRP composites provides valuable insights into the potential of fly ash as a filler material in polymer composites. The study demonstrates that the incorporation of fly ash particles enhances the mechanical performance of GFRP composites, with optimal filler content and appropriate particle size and surface treatment. The findings contribute to the understanding of the relationship between filler content and mechanical properties, offering opportunities for the development of high-performance composite materials. Systematic methodology and experimental techniques provide a solid foundation for further research in this area, making this review a valuable resource for researchers and engineers involved in composite material development.

**Bhandakkar et. al** discusses the influence of fly ash content, stacking sequence, and interlayer treatments on the interlaminar fracture toughness of the composites. The review covers the fabrication process of the laminate composites, including the preparation of composite samples and the layering techniques used to create the laminate structure. Influence of Fly Ash Content and Stacking Sequence: The interlaminar fracture toughness properties are influenced by the fly ash content and the stacking sequence of the laminate composites. This research identifies the

optimal fly ash content and stacking sequence that maximize the fracture toughness of the composites. Effect of Interlayer Treatments: The application of interlayer treatments, such as surface modifications or interleaf materials, can further enhance the interlaminar fracture toughness of the laminate composites. These treatments improve the interfacial bonding and toughening mechanisms within the material, contributing to increased fracture toughness.

**Rueben et. al** carried out research, which is centered on the experimental analysis of glass-epoxy composites incorporating fly ash as a filler material. The study begins with an overview of the motivation behind using fly ash as a reinforcing filler and the potential benefits it offers to composite materials. The author highlights the advantages of fly ash, such as its abundance, cost-effectiveness, and environmental sustainability. The review encompasses the fabrication process of the glass-epoxy composites, including the preparation of composite samples and the techniques employed to achieve uniform dispersion of fly ash particles within the epoxy matrix.

**Jeesoo Sim et. al** encompasses the fabrication process of fly ash/epoxy composites, including the preparation of composite samples and the techniques used to achieve uniform dispersion of fly ash particles within the epoxy matrix. Sim discusses various parameters, such as fly ash content, particle size, surface treatment, and curing conditions, and their influence on the composite's mechanical properties.

The mechanical properties investigated in the study include tensile strength, flexural strength, impact resistance, and hardness. It also examines the effects of fly ash incorporation on these properties, providing a comprehensive understanding of the relationship between the filler material and the resulting mechanical performance.

**Rajesh Purohit et. al** examined the incorporation of fly ash as a filler in fiber glass-epoxy composites leads to improvements in mechanical properties. The addition of fly ash particles enhances tensile strength, flexural strength, impact resistance, and hardness. The presence of fly ash contributes to better load transfer and improved interfacial bonding between the fiber glass and epoxy matrix, resulting in enhanced mechanical performance. The mechanical properties of the composites are influenced by the fly ash content and the orientation of the fiber glass reinforcement. This research identifies the optimal fly ash content and fiber glass orientation that maximize the mechanical performance. An appropriate combination of fly ash content and fiber glass orientation enhances the overall strength and toughness of the composites.

**Satheesh Raja et. al** revealed the effects of varying fly ash content, glass fiber reinforcement, and polymer matrix on the mechanical properties of the composites. The statistical analysis provides insights into the significant factors and their interactions that influence the mechanical performance. It is observed that the incorporation of fly ash enhances the mechanical properties, with an optimum content leading to improved strength and toughness. The glass fiber reinforcement also contributes to the mechanical strength of the composites, while the polymer matrix provides the necessary adhesion and integrity. The findings from this study facilitate a better understanding of the composition-property relationships and aid in the optimization of composite materials for specific applications.

**Vikas Sharma et. al** research investigates the potential use of waste fly ash as a filler material in enhancing the properties of glass fiber reinforced epoxy composites. The review aims to summarize the key findings of the study and evaluate its significance in the field of composite materials. The experimental methodology involves the fabrication of glass fiber reinforced epoxy composites with varying concentrations of waste fly ash powder. The composite samples are prepared using a suitable manufacturing technique, ensuring uniform dispersion of the fly ash particles within the epoxy matrix. The physical properties, such as density and water absorption, are evaluated to assess the impact of fly ash incorporation. Mechanical properties, including tensile strength, flexural strength, and impact strength, are tested to determine the effect of fly ash on the composite's structural performance.

**Deepak Verma et. al** focused on the processing and evaluation of the mechanical properties of epoxy filled E-glass fiber fly ash hybrid composites. The research investigates the potential use of fly ash as a filler material in combination with E-glass fibers to enhance the mechanical properties of epoxy-based composites. The addition of fly ash in epoxy filled E-glass fiber composites significantly influences their mechanical properties. The hybrid composites exhibit improved tensile strength, flexural strength, and impact strength compared to neat epoxy composites. The reinforcing effect of E-glass fibers is enhanced by the presence of fly ash, leading to enhanced load-bearing capabilities and toughness. The hardness of the composites also shows improvement with the addition of fly ash particles. Microstructural analysis confirms the proper dispersion of fly ash particles within the epoxy matrix and their interaction with the reinforcing fibers, resulting in improved mechanical properties.

**Susilendra et. al** research findings demonstrate that the addition of fly ash, nano clay, and zinc oxide fillers significantly influences the mechanical properties of glass fiber reinforced epoxy hybrid composites. The hybrid composites exhibit improved tensile strength, flexural strength, impact strength, and hardness compared to composites without fillers. The fillers contribute to the enhanced load-bearing capabilities, toughness, and wear resistance of the



composites. The dispersion and interaction of fillers with the reinforcing fibers and epoxy matrix are critical factors influencing the mechanical performance.

## 2. PROPERTIES OF FLY ASH

Fly ash is composed of fine particles, predominantly spherical in shape, with varying chemical compositions depending on the source of coal and combustion conditions. It typically contains a significant amount of silica, alumina, iron oxide, and lime. The physical and chemical properties of fly ash, such as particle size, surface area, and chemical composition, play a crucial role in determining its suitability as a filler material in composites.

## 3. ROLE OF FLY ASH AS A FILLER MATERIAL

### 3.1. Mechanical Properties Enhancement:

- Tensile Strength: The incorporation of fly ash particles in composites can improve tensile strength due to enhanced load transfer mechanisms and increased interfacial adhesion.
- Flexural Strength: Fly ash acts as a reinforcing agent, improving the flexural strength and stiffness of composites.
- Impact Resistance: Fly ash particles help dissipate impact energy, enhancing the impact resistance of composites.
- Hardness: The presence of fly ash contributes to increased hardness and wear resistance in composites.
- Fracture Toughness: Fly ash can enhance the interlaminar fracture toughness of composites, reducing crack propagation and improving overall toughness.

### 3.2. Thermal Properties Enhancement:

Thermal Stability: Fly ash has a high melting point and can improve the thermal stability of composites.

Thermal Conductivity: The addition of fly ash can enhance the thermal conductivity of composites, making them suitable for heat transfer applications.

### 3.3. Electrical Properties Enhancement:

Electrical Conductivity: Fly ash particles can enhance the electrical conductivity of composites, making them useful for electrical applications.

## 4. COMPOSITE FABRICATION AND PROCESSING TECHNIQUES

The successful incorporation of fly ash in composites requires proper fabrication techniques and processing conditions. Techniques such as melt mixing, solution casting, and compression molding are commonly employed to ensure uniform dispersion of fly ash particles within the matrix material. Surface treatment methods, including chemical modification and coating, are often employed to improve the interfacial bonding between the filler and matrix.

## 5. APPLICATIONS OF FLY ASH-FILLED COMPOSITES

Fly ash-filled composites find applications in various industries:

Construction: Fly ash composites can be used in structural components, concrete reinforcement, and thermal insulation materials.

Automotive: Fly ash-filled composites offer lightweight alternatives for automotive components, reducing fuel consumption and emissions.

Aerospace: Fly ash composites can be utilized in aircraft interior components, reducing weight without compromising performance.

Electrical and Electronics: The enhanced electrical properties of fly ash-filled composites make them suitable for electronic enclosures and electrical insulating materials.

## 6. CHALLENGES AND FUTURE PERSPECTIVES

Despite the numerous benefits of fly ash as a filler material, some challenges remain. These include achieving optimal dispersion of fly ash particles, addressing potential agglomeration issues, and optimizing the compatibility between the filler and matrix. Future research should focus on developing innovative processing techniques, understanding the fundamental mechanisms of fly ash interaction with the matrix, and exploring advanced surface modification strategies.

## 7. CONCLUSION

The utilization of fly ash as a filler material in composites offers a range of advantages, including improved mechanical, thermal properties of composite material system.

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