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Mechanical Properties of Epoxy Composites Reinforced with Granite Dust and Fly Ash

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ABSTRACT

This paper evaluates the mechanical behavior of epoxy-based composites reinforced with a hybrid filler system comprising granite dust and fly ash. Composites were fabricated with varying filler contents (0–40 wt.%) and subjected to compressive, tensile, flexural, and hardness testing. Compressive strength increased steadily from 80.8 MPa for neat epoxy to 97.4 MPa for the composite with 40 wt.% filler (EPGF40), indicating improved stiffness and reduced matrix deformability due to the rigid nature of both fillers. Tensile strength peaked at 42.7 MPa for 20 wt.% filler (EPGF20), then decreased to 36.2 MPa at 40 wt.%, likely due to particle agglomeration and interfacial debonding. Flexural strength also showed maximum improvement at 20 wt.% (70.5 MPa), with a slight decline at higher filler levels, though still outperforming neat epoxy. Shore D hardness increased consistently with filler content, reaching 84.5 at 40 wt.%, demonstrating enhanced surface resistance and wear durability. These findings suggest that a balanced addition of granite dust and fly ash significantly enhances the mechanical performance of epoxy composites, particularly in compressive and surface-loading applications, while offering an environmentally friendly solution through industrial waste utilization.

Keywords: Epoxy composites, Granite dust, Fly ash, Hybrid fillers, Mechanical properties, Industrial waste utilization, Sustainable materials.

1. Introduction

The increasing environmental concern surrounding waste management has prompted the exploration of industrial byproducts as reinforcements in polymer matrix composites. Among these, granite dust and fly ash are two prevalent fillers in the context of sustainable composite development. Granite dust, generated as a byproduct of stone cutting and polishing, and fly ash, a residue from coal combustion, both offer potential for improving the mechanical performance of polymer composites. Epoxy resins, known for their excellent mechanical properties and adhesive characteristics, are commonly used as the matrix material in these composites. This study investigates the mechanical properties of epoxy composites reinforced with varying amounts of granite dust and fly ash and compares their performance with neat epoxy.

2. Literature Review

Recent research has increasingly focused on enhancing the mechanical performance of polymer composites using industrial waste materials as fillers. Among these, granite dust, fly ash, marble dust, and other quarry byproducts have shown significant promise as sustainable reinforcements in epoxy and polyester matrices. Several studies have demonstrated the potential of granite dust and fly ash in hybrid formulations. Rajput et al. (2022) and Agrawal et al. (2023) reported that epoxy composites filled with Kota stone dust and fly ash exhibited notable improvements in compressive and flexural strength, attributed to improved filler dispersion and matrix–filler interlocking. Similarly, Murugan et al. (2022) found that fine granite particles enhanced the compressive behavior of epoxy-based hybrid biocomposites. Fly ash, due to its pozzolanic nature and spherical morphology, facilitates stress transfer and reduces void content, further improving mechanical properties.

Waste stone dusts, including marble, granite, and ceramic powders, have also been widely studied. Chyad (2011), Patnaik et al. (2023), and Awad et al. (2020, 2020) explored the reinforcement of thermoplastic and thermoset resins with ceramic, marble, and granite dust, reporting improved strength, modulus, and surface hardness. These benefits arise from the fillers' stiffness, fine particle size, and ability to restrict polymer chain mobility. Gomes et al. (2018) and Perim et al. (2023) further extended this approach by developing artificial stone using quarry and blast furnace dusts, noting not only enhanced mechanical performance but also potential for architectural applications.

Hybrid and bio-composites have also attracted attention. Studies by Karthikeyan et al. (2022) and Priyadarshini et al. (2023) evaluated combinations of marble dust with natural reinforcements like tamarind shell or glass fiber, finding improved tensile and flexural behavior up to an optimal filler threshold. Excessive filler loading, however, often led to agglomeration and interfacial debonding, which reduced mechanical integrity. Applications beyond structural reinforcement have also been explored. Igwe et al. (2021) and Odoala et al. (2021) studied the use of granite dust in coatings and tiles, observing improved anti-corrosion performance and reduced water absorption. Czarnecki & Sadowski (2021) and Kampa & Sadowski (2021) highlighted the role of granite powder in improving the bonding strength and durability of epoxy adhesives and cementitious composites.

A key trend across the literature is the existence of an optimal filler loading, generally around 20–30 wt.%, where mechanical properties such as tensile, flexural, and compressive strengths are maximized. Beyond this range, property degradation occurs due to poor dispersion, increased porosity, or filler–matrix incompatibility. In summary, the incorporation of industrial waste fillers like granite dust and fly ash into polymer composites offers a cost-effective and environmentally friendly route to enhance mechanical properties. These materials not only reduce the environmental burden of waste disposal but also improve the performance of composites for structural, surface, and protective applications.

3. Methodology

In this study, epoxy resin, along with its corresponding hardener, is chosen as the matrix material. The molecular chain structure of the epoxy resin used and it is commercially known as L-12. When combined with the hardener tri-ethylene-tetramine (TETA), which is an aliphatic primary amine with the commercial designation HY 951. Granite dust, a byproduct of stone processing industries, is chosen as the reinforcement material in this study due to its availability, cost-effectiveness, and potential environmental benefits. Granite dust is produced during the cutting, polishing, and grinding of granite stones, often accumulating in large quantities as industrial waste. Fly ash, a byproduct of coal combustion in thermal power plants, has emerged as a promising reinforcement material in epoxy-based granite dust composites. Its fine, spherical particles are rich in silica, alumina, and unburnt carbon, making it suitable for enhancing the mechanical and thermal properties of polymer composites.

4. Composite Fabrication

In the present investigation, marble dust-filled epoxy composites were fabricated using a simple hand lay-up technique. The fabrication process involves the following steps:

1. Room-temperature curing epoxy resin (L-12) and the corresponding hardener (HY 951) were mixed in a 10:1 weight ratio, as recommended by the manufacturer.
2. Micro-sized marble dust was then added to the epoxy-hardener mixture and thoroughly blended using manual stirring to ensure uniform dispersion.
3. Prior to pouring, a silicone release spray was applied to the mould to facilitate easy removal of the cured composite. The well-mixed epoxy/filler blend was then carefully poured into the mould to produce specimens conforming to ASTM standard dimensions.
4. The cast was allowed to cure at room temperature for 12 hours before being demoulded.

Composites were fabricated with different weight fractions of fillers. A total of 5 sets of composites are fabricated in the present investigation. The list of fabricated composites in the present work is tabulated in table 1.

Table 1 List of fabricated composites

Set	**Composition**
EP	Neat epoxy
EPGF10	Epoxy + 10 wt. % Granite dust & Fly Ash
EPGF20	Epoxy + 20 wt. % Granite dust & Fly Ash
EPGF30	Epoxy + 30 wt. % Granite dust & Fly Ash
EPGF40	Epoxy + 40 wt. % Granite dust & Fly Ash

5. Results and Discussion

5.1 Tensile Strength

The tensile strength of the epoxy–Granite dust fly ash composites demonstrates a non-linear behavior with increasing filler content. Neat epoxy exhibits a tensile strength of 35.5 MPa. This value increases to 42.7 MPa at 20 wt.% marble dust (EPGF20), indicating enhanced stress transfer and filler-matrix adhesion. The rigid marble particles likely restrict polymer chain mobility, contributing to better tensile resistance up to a certain threshold. Beyond 20 wt.%, tensile strength begins to decline, reaching 36.2 MPa at 40 wt.% (EPMD40). This reduction can be attributed to particle agglomeration and possible interfacial debonding, leading to stress concentration sites and premature failure under tension. The optimal strength at 20 wt.% suggests effective filler reinforcement without compromising matrix continuity.

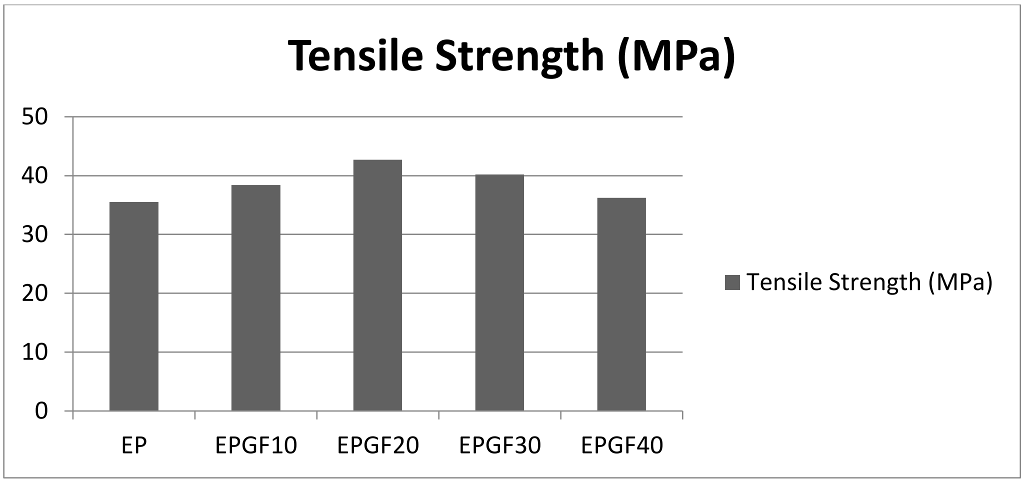

Fig 1 Tensile Strength of Epoxy- Granite Dust fly ash Composites

5.2 Compressive strength

The compressive strength of the composites steadily increases with the addition of Granite dust, from 80.8 MPa for neat epoxy to 97.4 MPa for EPGF40. This continuous rise is attributed to the filler's inherent stiffness and its ability to restrict matrix deformation under compressive loads. Marble dust particles act as micro-reinforcements that distribute applied loads more uniformly across the composite, reducing localized strain. The increased packing density with higher filler content enhances the resistance to compressive failure. Moreover, the absence of a strength drop at higher filler levels, unlike in tensile strength, indicates that compressive behavior is less affected by interfacial debonding or filler agglomeration. This suggests that marble dust-filled composites are particularly suitable for applications requiring high compressive resistance, such as structural supports, mounting bases, or flooring tiles. The data highlights that filler addition up to 40 wt.% remains beneficial in compressive loading scenarios without degrading performance

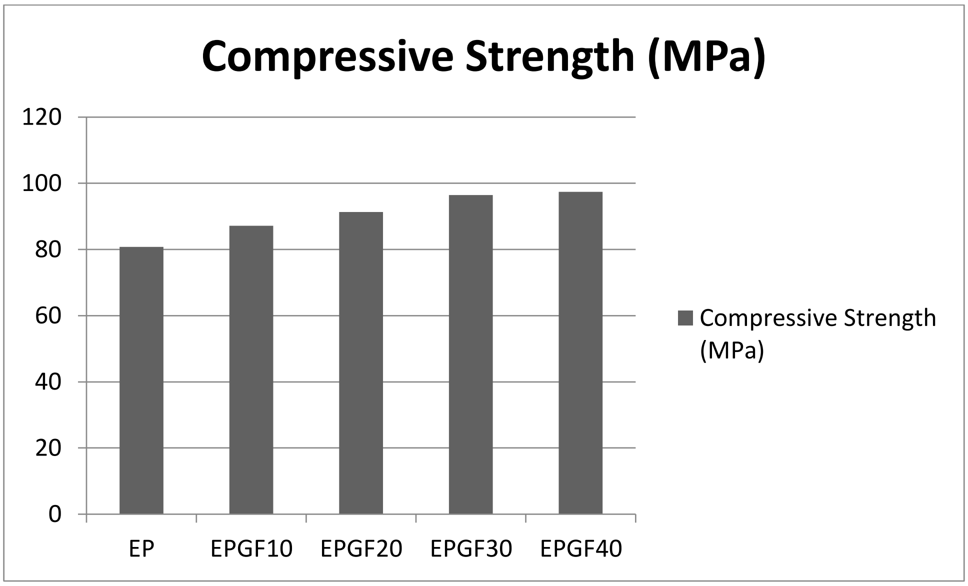

Fig 2 Compressive Strength of Epoxy- Granite Dust/fly ash Composites

5.3 Flexural Strength

Flexural strength results show an increasing trend up to 20 wt.% Granite dust, peaking at 70.5 MPa for EPGF20 compared to 62.6 MPa for neat epoxy. This indicates enhanced resistance to bending due to the reinforcing effect of the stiff Granite particles. The improvement is likely due to better load distribution and reduced matrix mobility under flexural stress. However, further increase in filler content causes a slight reduction in strength, with values of 68.7 MPa and 67.8 MPa for EPgf30 and EPGF40, respectively. At higher filler levels, poor particle dispersion and possible voids or stress concentrators may initiate early failure during bending. Nevertheless, the flexural performance remains superior to neat epoxy at all filler levels tested. These results confirm that marble dust contributes positively to the composite's stiffness and bending strength, particularly at 10–20 wt.%, making it a viable candidate for structural applications subject to flexural loads.

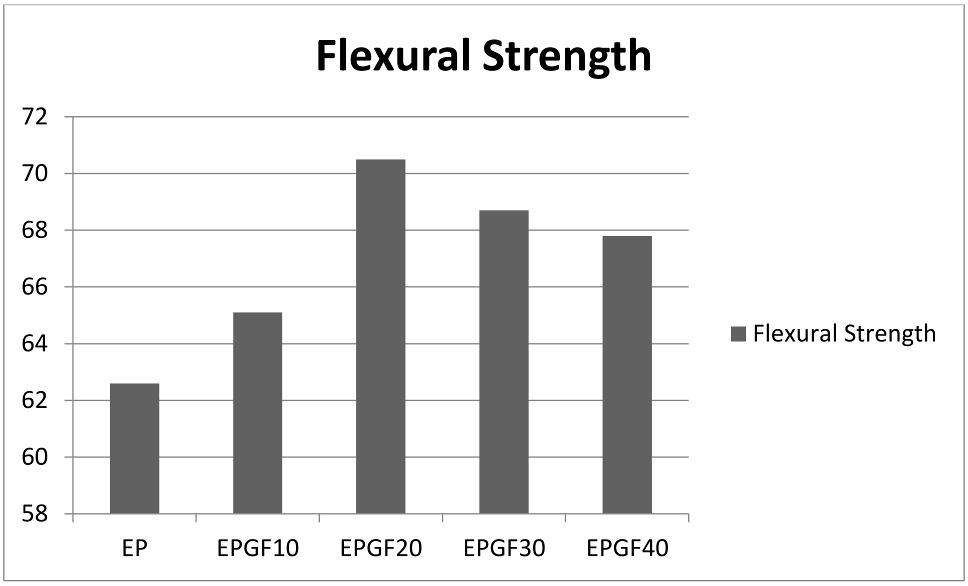

Fig 3 Flexural Strength of Epoxy- Granite Dust/fly ash Composites

5.4 Hardness Test

Shore D hardness values exhibit a consistent increase with rising Granite dust content, from 76.4 for neat epoxy to 84.5 for EPGF40. This enhancement is directly related to the increased rigidity and reduced deformability imparted by the inorganic filler. Marble dust particles reinforce the surface and bulk of the composite, making it more resistant to indentation. The steady rise in hardness reflects improved surface strength and better wear resistance, which is beneficial in abrasive or contact-heavy applications. Unlike mechanical strength, Shore D hardness does not show a decline at higher filler levels, suggesting that surface properties are less sensitive to internal filler agglomeration or voids. The improved hardness values affirm the utility of these composites in areas where high surface durability is essential, such as tooling surfaces, panels, and flooring materials. These findings highlight the filler's effectiveness in enhancing the hardness without significantly compromising other mechanical properties.

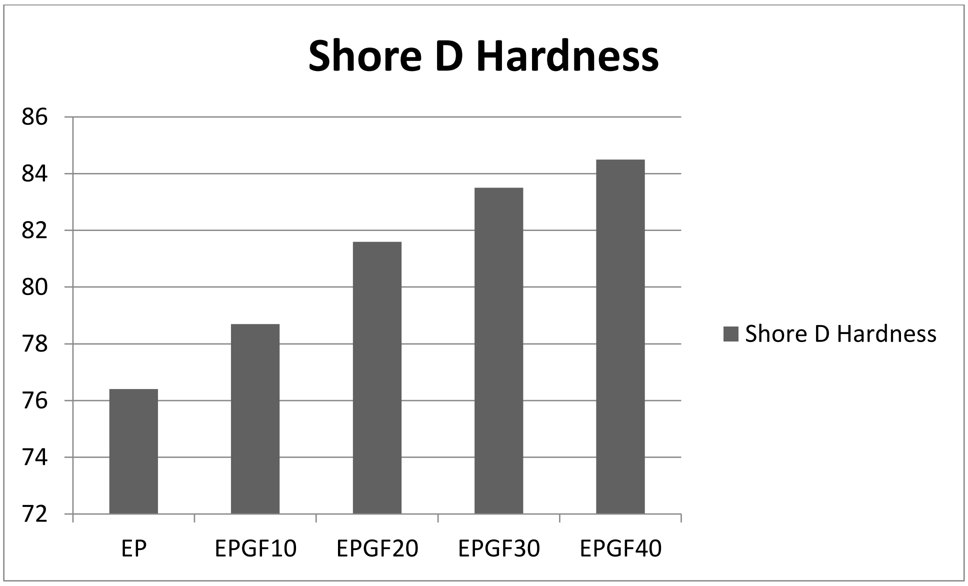

Fig 4 Shore D Hardness of Epoxy-Granite/Fly ash Dust Composites

6. Conclusion

This paper investigated the mechanical performance of epoxy composites reinforced with granite dust and fly ash, highlighting their potential as sustainable fillers in polymer matrix composites. The results demonstrate that both fillers enhance the compressive strength, flexural strength, and surface hardness of the epoxy composites. Notably, the compressive strength increased steadily with the filler content, reaching a maximum of 97.4 MPa at 40 wt.% filler, indicating the effectiveness of granite dust and fly ash in improving stiffness and resistance to deformation under compressive loads. Flexural strength also showed notable improvements, peaking at 70.5 MPa at 20 wt.% filler, although a slight decline occurred at higher filler contents due to agglomeration and debonding. The Shore D hardness increased progressively with filler content, reflecting improved surface durability. Overall, the findings suggest that epoxy composites filled with granite dust and fly ash offer a promising solution for structural applications requiring enhanced mechanical properties, particularly in compressive and surface-loading scenarios. Further optimization of filler dispersion and content could further improve the performance and applicability of these composites.

References

1. Rajput, V., Sahu, N. K., Agrawal, A., & Gupta, G. (2022). Physical and mechanical properties of epoxy/Kota stone dust/fly ash hybrid composites for light duty structural applications. *Polymer Composites*, *43*(3), 1566-1576.

2. Rajput, V., Somani, S. K., Agrawal, A., & Pagey, V. S. (2021). Mechanical properties of epoxy composites filled with micro-sized kota stone dust. *Materials Today: Proceedings*, *47*, 2673-2676.

3. Gomes, M. L. P., Carvalho, E. A., Sobrinho, L. N., Monteiro, S. N., Rodriguez, R. J., & Vieira, C. M. F. (2018). Production and characterization of a novel artificial stone using brick residue and quarry dust in epoxy matrix. *Journal of materials research and technology*, *7*(4), 492-498.

4. Chyad, F. A. (2011). The effect of waste ceramic materials (Iraqi stones dust powders) on the mechanical properties of epoxy resin. *Engineering & Technology Journal*, *29*(16).

5. Priyadarshini, S., Soren, S., & Durga, G. (2023). Effect of waste marble dust powder as a filler material on mechanical properties and water uptake capacity of Epoxy/glass fiber composites. *Materials Today: Proceedings*.

6. Agrawal, A., Gupta, G., Pati, P. R., & Nayak, S. K. (2023). Dry-sliding wear analysis and prediction using response surface method and fuzzy logic for Kota stone dust–fly ash–epoxy hybrid composites. *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering*, 09544089231158902.

7. Perim, T. B., Carvalho, E., Barreto, G., da Cruz Silva, T. L., Monteiro, S. N., Azevedo, A. R. G. D., & Vieira, C. M. F. (2023). Characterization of Artificial Stone Produced with Blast Furnace Dust Waste Incorporated into a Mixture of Epoxy Resin and Cashew Nut Shell Oil. *Polymers*, *15*(20), 4181.

8. Awasthi, T., Bharti, M. S., Agrawal, A., & Pati, P. R. (2024). Development of the Polyester/Kota Stone Dust Composite and their Characterization. *The Journal of Solid Waste Technology and Management*, *50*(3), 512-521.

9. Karthikeyan, R., Girimurugan, R., Sahoo, G., Maheskumar, P., & Ramesh, A. (2022). Experimental investigations on tensile and flexural properties of epoxy resin matrix waste marble dust and tamarind shell particles reinforced bio-composites. *Materials Today: Proceedings*, *68*, 2215-2219.

10. Patnaik, A., Agarwal, P., Sharma, A., Shekhawat, D., & Patnaik, T. K. (2023). Marble Dust Reinforced Epoxy Structural Adhesive Composites. *Structural Adhesives: Properties, Characterization and Applications*, 105-133.

11. Odoala, C., Igwe, I. O., & Chike, K. O. (2021). Sorption properties of granite quarry dust reinforced unsaturated polyester resin tiles. *AJST*, *5*(4), 729-733.

12. Ray, S. (2022). Effect of control parameters on erosion wear performance of glass-epoxy composites filled with waste marble powder.

13. Murugan, G., Loganathan, G. B., Sivaraman, G., Shilaja, C., & Mayakannan, S. (2022). Compressive behavior of tamarind shell powder and fine granite particles reinforced epoxy matrix based hybrid bio-composites. *ECS Transactions*, *107*(1), 7111.

14. Awad, A. H., Abdel-Ghany, A. W., Abd El-Wahab, A. A., El-Gamasy, R., & Abdellatif, M. H. (2020). The influence of adding marble and granite dust on the mechanical and physical properties of PP composites. *Journal of Thermal Analysis and Calorimetry*, *140*, 2615-2623.

15. Igwe, I. O., Acha, F. N., Agwu, G. I., Ifeacho, V. C., Okonkwo, S. N., Ekwueme, C. C., & Igboanugo, U. I. (2021). Utilization of granite quarry dust extender in formulating anti-corrosive paints for the protection of steel. *AJST*, *5*, 631-7.

16. Awad, A. H., El-Gamasy, R., Abd El-Wahab, A. A., & Abdellatif, M. H. (2020). Assessment of mechanical properties of HDPE composite with addition of marble and granite dust. *Ain Shams Engineering Journal*, *11*(4), 1211-1217.

17. Bekeshev, A., Mostovoy, A., Kadykova, Y., Akhmetova, M., Tastanova, L., & Lopukhova, M. (2021). Development and analysis of the physicochemical and mechanical properties of diorite-reinforced epoxy composites. *Polymers*, *13*(15), 2421.

18. Czarnecki, S., & Sadowski, L. (2021, October). Utilization of waste granite powder in cementitious composites: perspectives and challenges in Poland. In *F-EIR Conference on Environment Concerns and its Remediation* (pp. 33-42). Cham: Springer International Publishing.

19. Choudhary, M., Singh, T., Dwivedi, M., & Patnaik, A. (2019). Waste marble dust-filled glass fiber-reinforced polymer composite Part I: Physical, thermomechanical, and erosive wear properties. *Polymer Composites*, *40*(10), 4113-4124.

20. Kampa, Ł., & Sadowski, Ł. (2021). Engineering technology and preparation of coating systems made with epoxy resin-based bonding agents modified with the addition of granite powder sourced from quarry wastes. In *6th International Conference on Adhesive Bonding 2021: Selected Contributions of AB 2021* (pp. 17-31). Springer International Publishing.