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Development and Experimentation of Hybrid Composite Gasket Using Sawdust Ash, Waste Glass Powder, and Polyester Resin

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Abstract

The increasing environmental burden caused by industrial wastes has prompted the development of sustainable alternatives to conventional engineering materials. This study utilized sawdust ash, waste glass powder, and polyester resin to develop composite gasket materials, aligning with the principles of sustainability and circular economy. Five composite formulations were prepared with constant polyester resin content (60 wt%) and varying filler ratios. Standard tests were conducted to evaluate density, porosity, Brinell hardness (BHN), tensile strength, impact strength, and thermal resistance. Results showed that filler composition significantly influenced the composite properties. The formulation containing 25% sawdust ash and 15% waste glass powder exhibited the best performance, with a tensile strength of 50.47 N/mm² and thermal resistance of 175°C. Density ranged from 2.05–5.03 g/cm³, porosity from 0.01–0.03%, and hardness from 6.70–14.63 BHN. All samples demonstrated zero impact strength, highlighting brittleness and limiting their application in dynamic environments. Compared with conventional rubber gaskets, which typically possess tensile strength of 16 N/mm², heat resistance of 150°C, density of 1.5 g/cm³, and hardness of 30 Shore A (≈ 4.8 BHN). The developed composites showed superior strength and thermal performance but lacked flexibility. To validate these results, advanced characterization was performed on the best sample. SEM analysis revealed uniform filler dispersion, strong matrix bonding, and minimal porosity, consistent with the improved mechanical properties. XRF analysis confirmed crystalline phases of silica (SiO_2) and alumina (Al_2O_3), which contributed to enhanced thermal stability and strength. This study demonstrates the potential of waste-derived fillers in producing cost-effective, high-performance gasket composites for static sealing applications, advancing eco-friendly polymer composite technologies.

Keywords: Hybrid Composite, Gasket, Sawdust Ash, Waste Glass Powder, Polyester Resin, Sustainability

INTRODUCTION

Gaskets, essential for sealing in industrial applications, are traditionally made from rubber or metal, but these materials face limitations including high cost, limited thermal resistance, and environmental impact [1]. This study explores the potential of hybrid SDA-WGP polyester composites as a sustainable alternative for gasket applications. As industries shift towards sustainable and cost-effective solutions, attention has turned to composite materials derived from waste products. Each material has their unique characteristics in this composite combination [2].

Composites are dependable replacements for traditional structural materials because of their flexibility [3]. Sawdust ash (SDA), a by-product of wood processing, provides lightweight and durable characteristics with pozzolanic activity [4]. Waste glass powder (WGP), rich in silica, enhances tensile strength, thermal resistance, and chemical stability [5]. Polyester resin (PR), an affordable thermosetting polymer, serves as a matrix that ensures structural integrity and effective load transfer [6]. When combined, these materials can yield high-performance composites that address waste disposal challenges while offering viable engineering applications. Several studies have explored the incorporation of SDA and WGP in construction and polymer composites. SDA has been shown to improve long-term strength and acid resistance in cementitious systems [6], while WGP enhances mechanical strength and durability when used as partial replacement for sand or filler [7].

However, limited research has focused on their combined use in gasket materials, particularly in optimizing mechanical and thermal properties for sealing applications. This study aims to develop and characterize hybrid composite gaskets using SDA and WGP as fillers in a polyester resin matrix.

MATERIALS AND METHODS

The study utilized sawdust ash (SDA), waste glass powder (WGP), and polyester resin with hardener. These materials were chosen for their availability, sustainability, and suitability for composite production.

Material preparation

Sawdust was sourced from a local sawmill at Camp Road, Alabata, FUNAAB. It was sun-dried for 72 hours to remove moisture and then subjected to controlled combustion in a furnace to obtain ash. The resulting ash was cooled and sieved through a fine mesh to achieve a uniform, fine particle size of 85µm powder which is suitable for composite formulation. Post-consumer glass wastes, such as bottles and broken glass, were collected, thoroughly washed to remove dirt and labels, and sun-dried. The dried glass was manually crushed with a hammer and further ground with a mechanical grinder. The resulting powder was sieved through a fine mesh to also obtain a uniform particle size of 75µm which is appropriate for use as reinforcement fillers [8].

Production of binder

Commercial-grade Epochem 107 polyester resin and Epochem polyester hardener were procured from a local chemical supplier at Oshodi, Lagos. Polyester resin was selected as the matrix material due to its favorable mechanical properties and compatibility with fillers. The resin and hardener were mixed in a 3:1 ratio (resin: hardener) to initiate curing. All handling and storage procedures were carried out in accordance with safety standards to maintain the effectiveness of the materials [6].

Experimental design

A two-factor (2^2) factorial experimental design was adopted to evaluate the combined effects of sawdust ash (SDA) and waste glass powder (WGP) on the properties of the developed hybrid composites. The polyester resin content was kept constant at 60 wt.% across all formulations, while the remaining 40 wt.% consisted of varying proportions of SDA and WGP. In addition to the four factorial combinations, a central formulation with equal proportions of SDA and WGP was included, resulting in a total of five composite formulations. This central point was introduced to assess compositional balance and enhance the reliability of the experimental design. The selected factorial approach enabled efficient evaluation of the main effects of SDA and WGP, as well as their combined influence, while minimizing the number of experimental runs.

Table 1: Mixing ratios of the composite sample gaskets in percentage.

Sample No.	Sawdust Ash (%)	Waste Glass Powder (%)	Polyester Resin (%)
E1	30	10	60
E2	20	20	60
E3	25	15	60
E4	15	25	60
E5	10	30	60

COMPOSITE FABRICATION

Production process

The materials were accurately weighed and the waste glass powder and sawdust ash were first blended for uniformity. Polyester resin was then added gradually with continuous stirring to ensure proper wetting and avoid lumps. After forming a consistent paste, the hardener was introduced, and the mixture was gently stirred to prevent premature curing before being poured into prepared molds as shown in Plate 1. The hand lay-up technique was used in the preparation of the hybrid composite gasket. This method is widely used due to its simplicity and cost-effectiveness [7].

Plate 1: The Sample Composite In The Mold

Curing process

Before casting, the mold was lightly coated with a release agent to prevent adhesion. The mixture was poured and cured at room temperature for 24 hours in a dust-free environment, during which the resin hardened into a thermoset. The samples were then demolded and post-cured in open air for 24–48 hours to achieve full hardening and improved mechanical integrity before testing.

Characterization

The tests for the composite gaskets are divided into two segments which is the physical properties test which consist of density Test, porosity test, and heat resistance Test and the mechanical properties test which consist of hardness test and Tensile strength test after which the best is determined based on the tests. An advanced characterization (SEM and XRD test) was then performed on the best sample.

RESULTS AND DISCUSSION

Density

The density of the composite samples obtained were 5.03, 4.04, 3.05, 2.05, and 3.05 g/cm³ for samples E1, E2, E3, E4 and E5 respectively as displayed in Figure 1 Increasing the proportion of sawdust ash generally led to higher density, attributed to its greater packing efficiency and particle compactness compared to waste glass powder [8]. Compared to the standard rubber gasket density of about 1.5 g/cm³ (CR), all composites exhibited significantly higher values, indicating greater rigidity and dimensional stability. Overall, the density results highlight the strong influence of filler type and composition on the compactness and structural integrity of the polyester composite matrix [9].

Porosity

The porosity values of the composite samples obtained were 0.01, 0.02, 0.03, 0.03 and 0.03 % for samples E1, E2, E3, E4 and E5 respectively as presented in Figure 2. Although, there is a minimal variation in the porosity values, there was a subtle trend: Samples E3, E4, and E5, which contained higher proportions of waste glass powder, exhibited slightly elevated porosity. This can be attributed to the angular morphology and smooth surface of glass particles, which hinder resin wetting and dispersion, promoting micro-void formation during curing [5].

Compared to standard rubber gaskets with porosity of 0.005% the composites showed marginally higher void content, particularly in glass-rich formulations, indicating reduced packing efficiency that may affect tensile and impact performance [5]. However, the porosity levels remain low and acceptable for static gasket applications, as values below ~0.05% are considered tolerable in polyester-based composites for static loading conditions [10].

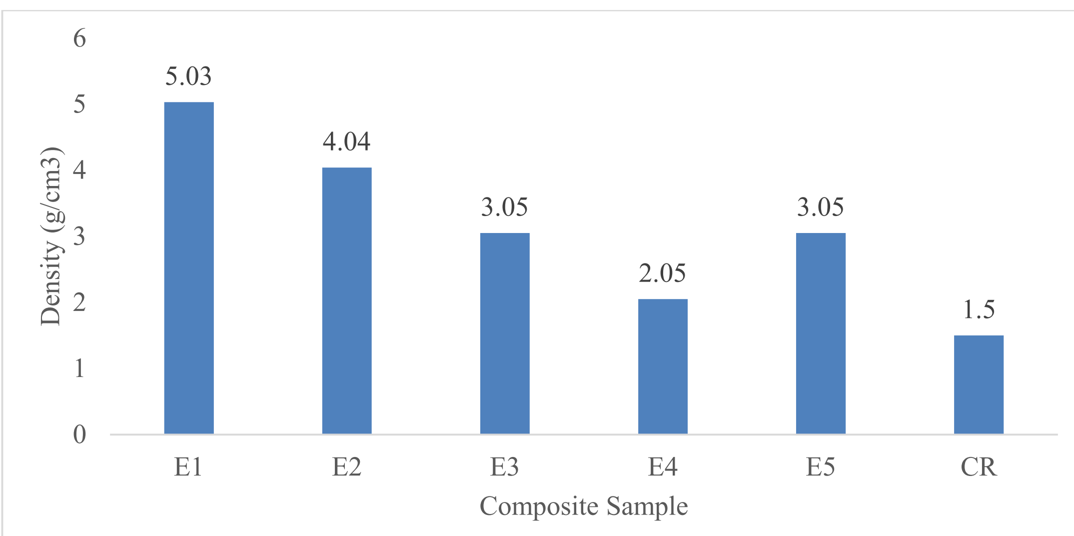

Fig. 1: Density Properties of the developed composite gasket Samples.

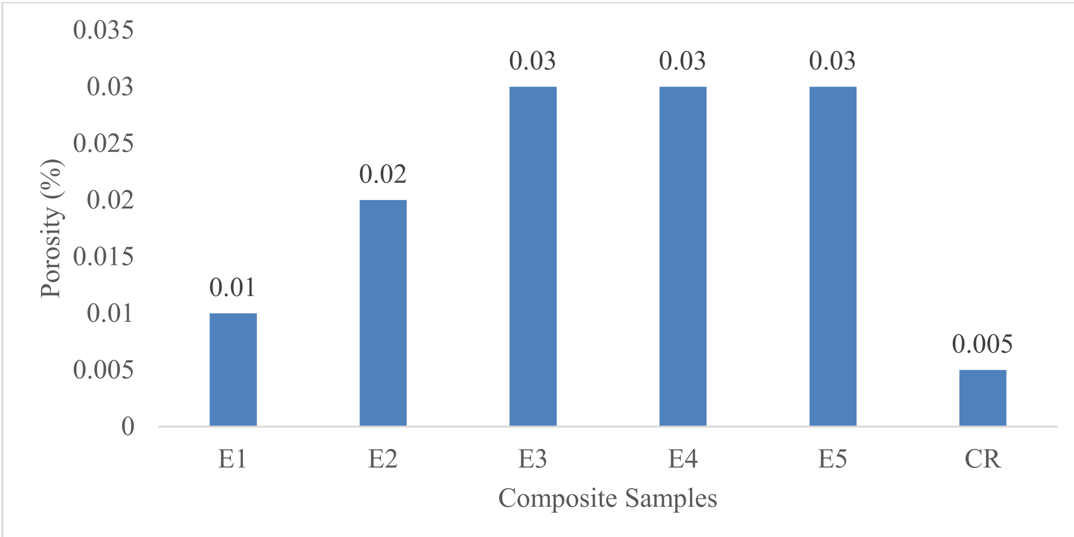

Fig. 2: Porosity Properties of the developed composite gasket Samples

Hardness

The Brinell Hardness Number (BHN) of the composite samples obtained were 6.94, 6.7, 14.63, 7.4, and 10.6 BHN for samples E1, E2, E3, E4 and E5 respectively as displayed in Figure 3. Sample E3, with intermediate proportions of sawdust ash and waste glass powder, recorded the highest hardness at 14.63 BHN, followed by Sample E5 at 10.60 BHN, indicating that a balanced dual-filler composition enhances surface resistance to indentation. In contrast, Sample E1, which contained predominantly sawdust ash and minimal glass powder, exhibited a comparatively low hardness of 6.94 BHN, suggesting that while sawdust ash can improve bulk properties such as density, it is less effective for enhancing surface hardness alone. This agrees with findings on hybrid particulate–polymer composites where optimal hardness was achieved with balanced dual fillers, as seen in PMMA composites containing both glass powder and nanoclay, while higher glass-only content reduced hardness [11]. The trend highlights that good filler dispersion, mechanical interlocking, and the angular morphology of glass particles enhance indentation resistance when complemented by sawdust ash, whereas sawdust alone cannot provide adequate hardness reinforcement.

Tensile Strength

The tensile strength of the composite samples (Figure 4) ranged from 23.943, 23.803, 50.47, 25.53, and 36.57N/mm² for samples E1, E2, E3, E4 and E5 respectively. Sample E3 (25% sawdust ash + 15% waste glass powder) exhibits the highest value of 50.47 N/mm². Similar trends were reported in polyester–glass composites, where strength improved up to an optimal filler level before declining [12]. Sample E2 (20% sawdust ash + 20% waste glass powder) showed the lowest strength (23.80 N/mm²), emphasizing that interfacial adhesion and dispersion quality are as critical as filler ratio [13]. A moderate dominance of sawdust ash with controlled glass content proved most effective, combining density and hardness benefits. Compared to standard rubber gaskets, CR, with 16 N/mm², the composites, especially Sample E3, offered superior tensile performance, making them suitable for static, high-stress sealing applications.

Heat Resistance

The heat resistance of the composite samples (Figure 5) ranged from 165,160, 175,170, 180 °C for samples E1, E2, E3, E4 and E5 respectively. Sample E5, which had the highest proportion of waste glass powder (30 %) and the lowest sawdust ash content, displayed the highest thermal resistance. Conversely, Sample E2, with an equal mix of sawdust ash and waste glass powder (20 % each), showed the lowest resistance at 160 °C. This suggests that waste glass powder plays a key role in enhancing thermal stability due to its inorganic, high-temperature-tolerant nature.

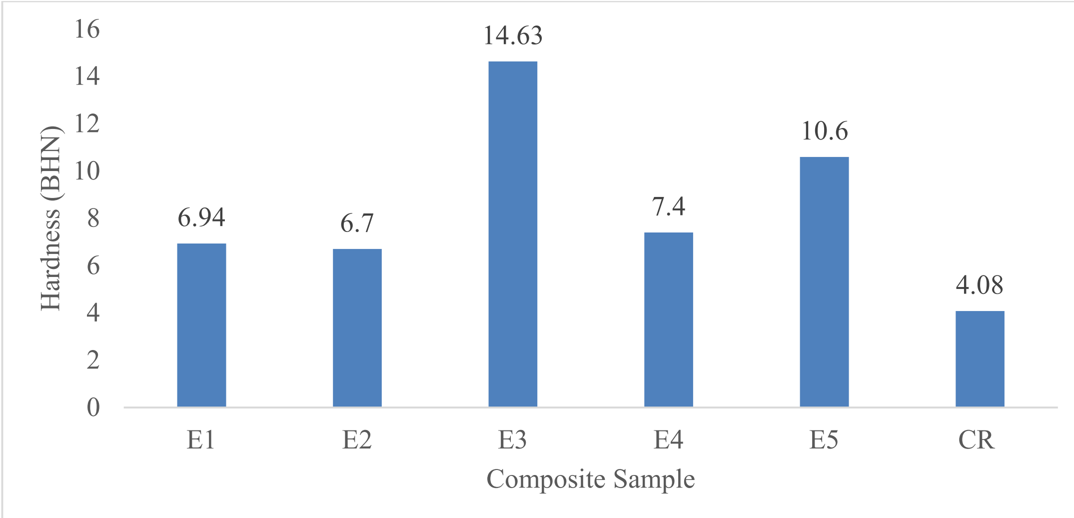

Fig. 3: Hardness Properties of the developed composite gasket Samples

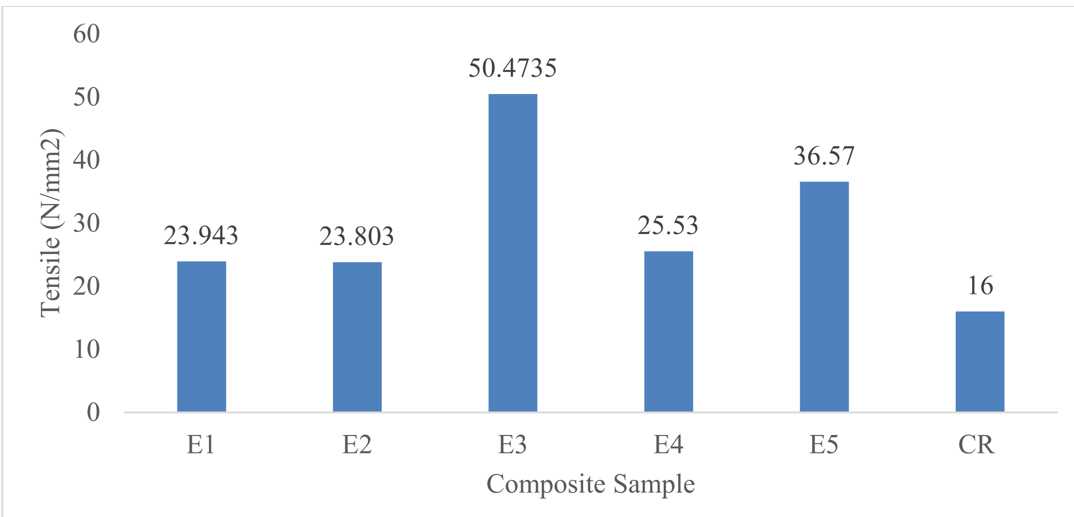

Fig. 4: The tensile properties of the developed composite gasket samples.

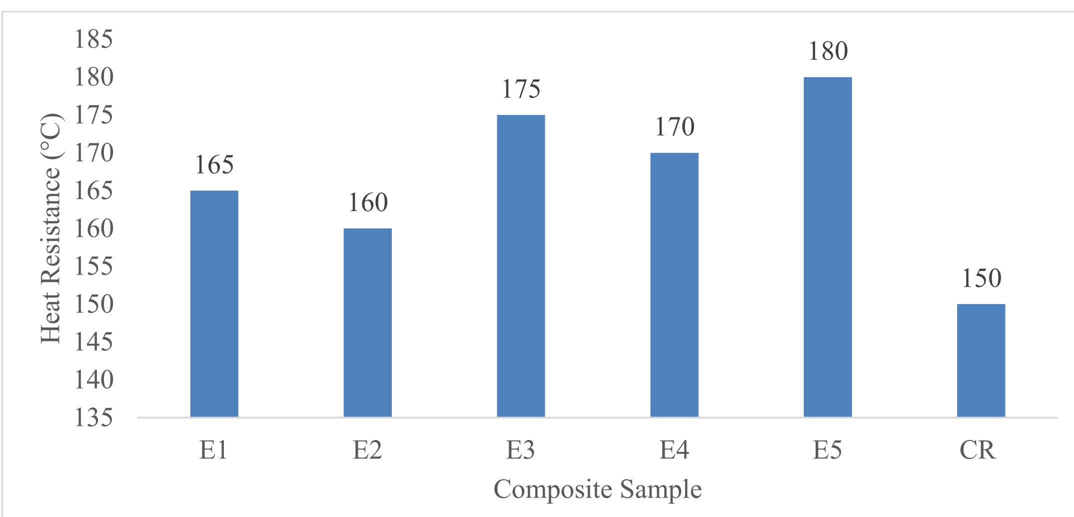

Fig. 5: Heat Resistance of the developed composite gasket samples

This highlights the role of waste glass powder in improving thermal stability due to its inorganic, high-temperature-tolerant nature. Similar findings were reported for HDPE–glass composites, where higher glass content (up to 30%) enhanced both mechanical and thermal performance [14]. Glass also improves fire resistance in geopolymer composites by melting at elevated temperatures, sealing pores and preserving integrity. While sawdust ash is inorganic, excess amounts can cause voids and weak dispersion, reducing thermal stability. Overall, greater waste glass content enhances thermal resistance, making such composites especially suitable for static sealing and applications requiring moderate to high heat tolerance.

Scanning electron microscopy (SEM) analysis

SEM micrographs at 5,000×, 6,000×, and 7,000× magnification revealed a heterogeneous particulate morphology, with irregularly shaped filler particles dispersed within the polyester matrix (Figures 6-8). While most regions showed good particle embedding, localized micro-voids, cracks, and occasional agglomerates were observed, typical features of particulate-filled composites when compaction or degassing is incomplete. Such morphology indicates effective filler–matrix interaction overall but also highlights microstructural imperfections that may influence mechanical performance. These observations are consistent with reports on polymer and cement composites incorporating sawdust or other waste-derived fillers, where particle irregularity and incomplete interfacial bonding often result in localized porosity [15].

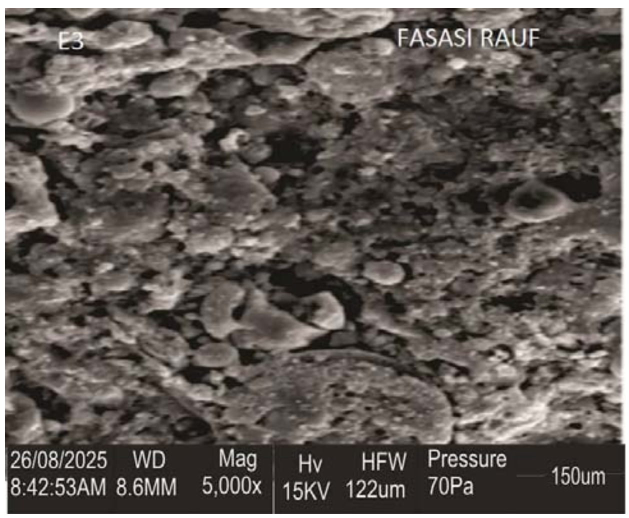

Fig. 6: Showing the Scanning Electron Microscopy (SEM) analysis at 5000× magnification

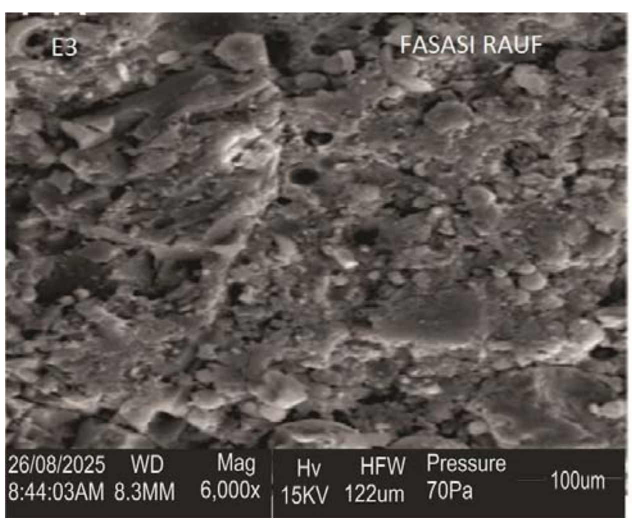

Fig. 7: Showing the Scanning Electron Microscopy (SEM) analysis at 6000× magnification

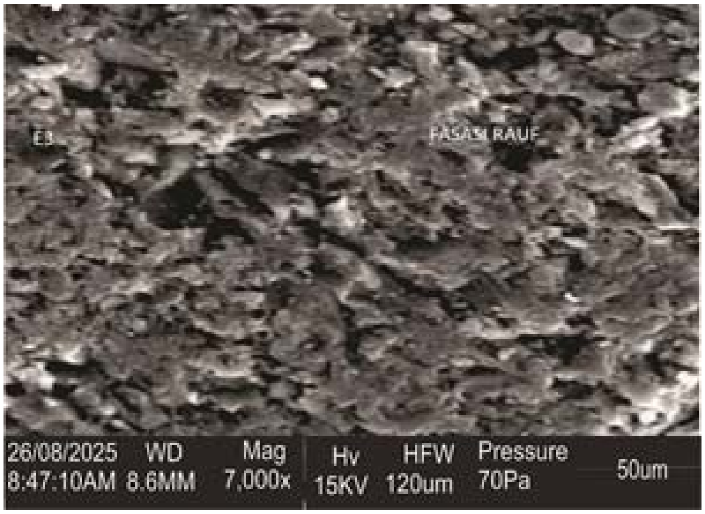

Fig. 8: Showing the Scanning Electron Microscopy (SEM) analysis at 7000× magnification

X-Ray Fluorescence (XRF)

XRF analysis of the optimized composite (Figure 9) revealed that silica (SiO_2) and alumina (Al_2O_3) are the predominant oxide phases, accounting for the majority of the composition. Minor oxides including TiO_2, Fe_2O_3, CaO, Na_2O, and K_2O were also detected. The dominance of silica and alumina confirms the incorporation of ash- and glass-derived fillers, which are known to significantly improve thermal resistance, hardness, and overall mechanical strength. The presence of these oxide phases provides direct evidence of the synergistic reinforcement effect achieved through the combination of sawdust ash and waste glass powder, consistent with earlier studies on hybrid composites [15].

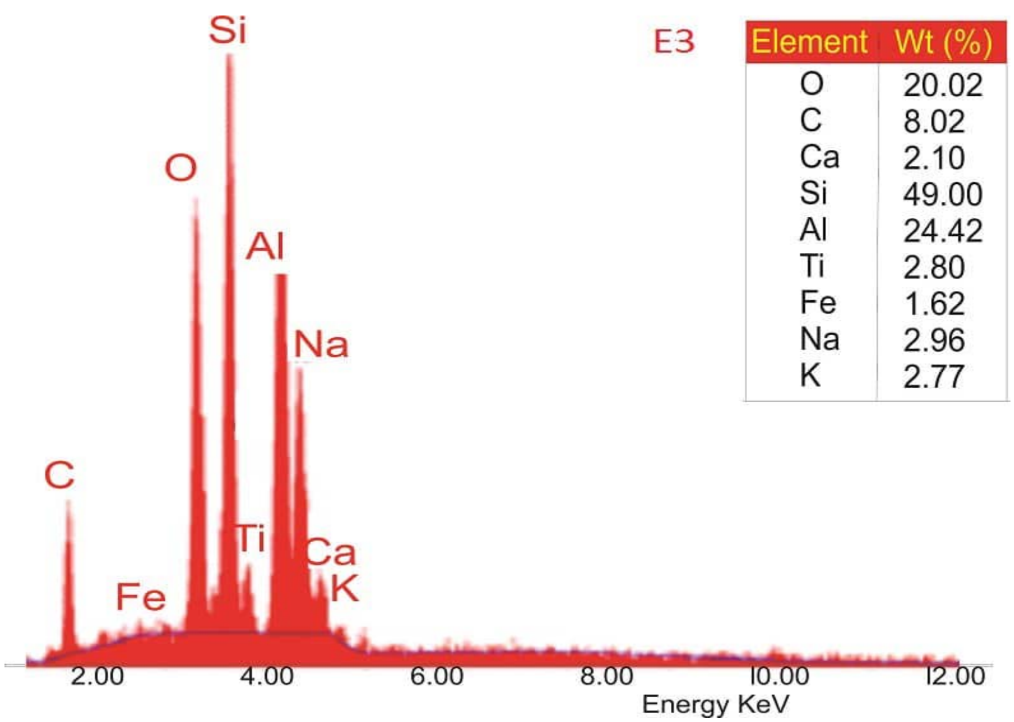

Fig. 9: Showing the Energy Dispersive X-ray Spectroscopy (EDS), and X-ray Diffraction

CONCLUSION

The study confirms that incorporating sawdust ash and waste glass powder as fillers in polyester resin can significantly improve tensile strength and heat resistance, with Sample E3 (25% sawdust ash, 15% waste glass powder) performing best at 50.47 N/mm² tensile strength and 175°C heat resistance. Compared to standard rubber gaskets (tensile strength of 16 N/mm², heat resistance of 150°C, density of 1.5 g/cm³, hardness of 30 Shore A (≈ 4.8 BHN, the composites displayed superior strength and thermal stability, making them promising for static applications requiring rigidity and heat tolerance. However, their lack of impact resistance and flexibility limits use in dynamic or vibration-prone settings, highlighting the need for flexible reinforcements such as natural fibers or elastomeric additives. Advanced characterization supported these results, with SEM showing uniform filler dispersion, strong matrix bonding, and low porosity, while XRF confirmed crystalline SiO_2 and Al_2O_3 phases, both of which reinforced the material's thermal stability and strength.

REFERENCES

[1] Adaway M., and Wang Y. (2015). Recycled glass as a partial replacement for fine aggregate in structural concrete- Effects on compressive strength. *Electronic Journal of Structural Engineering, 14*(1), 116-122. DOI: https://doi.org/10.56748/ejse.141951

[2] Ayyagari S., and Marwan A. (2024) Mitigating Crack Propagation in Hybrid Composites An Experimental and Computational Study. *Journal of composites science*. 8(4):122. DOI: https://doi.org/10.3390/jcs8040122

[3] Munonyedi K. E. (2012) A fundamental review on composite materials and some of their applications in biomedical engineering. *Journal of King Saud University - Engineering Sciences*, 98, 45-56. DOI: https://doi.org/10.1016/j.jksues.2020.07.007

[4] Olutoge, F.A. (2010) Investigations on Sawdust and Palm Kernel Shells as Aggregate Replacement. ARPN Journal of Engineering and Applied Sciences, 5, 7-13.

[5] Abbas A.H., Al-Deen M.F., and Abdullah R.M. (2011). Using of glass wastes as a fine aggregate in concrete mix. *Trikit Journal of Engineering Sciences, 18*(3), 81-87. DOI: https://doi.org/10.25130/tjes.v18i3.513

[6] Awham M.H., EntihaaGateaDaway and ShymaHameed M. (2018) Investigation the properties of polyester polymer mortar reinforced with recycled glass powder. Volume 9, Issue 13 , pp. 34–44. Article ID: IJMET_09_13_005.

[7] Fiveable (2022). Hand lay-up technique – (Intro to Civil Engineering).

[8] Kaewpruk C., Supparoek B., Choosak P., Pongdhorn S., Chomsri S., (2021) Utilization of Sawdust and Wood Ash as a Filler in Natural Rubber Composites *ChemistrySelect 6(3):264-272*
DOI: https://doi.org/10.1002/slct.202004109

[9] J. G. de Castro, R. Zargar, M. Habibi, S. H. Varol, S. H. Parekh, B. Hosseinkhani, M. Adda-Bedia, and D. Bonn (2015). Nonmonotonic fracture behavior of polymer nanocomposites. *Applied Physics Letters* 106:221904 DOI: https://doi.org/ 10.1063/1.4922287

[10]Tcherdyntsev, V.V.(2023) Reinforced Polymer Composites III. Polymers. DOI: https:// doi.org/10.3390/polym13040564

[11] A. Almansoori, R.A. Ghadban , M.H. Ali , M.M. Sabri (2023). Studying the influence of waste glass and montmorillonite powders on the thermal conductivity and hardness of poly(methyl methacrylate) polymer matrix. *Journal of Achievements of Materials and Manufacturing Engineering*118(2):49-56DOI: https://doi.org/10.5604/01.3001.0053.7661

[12] Bhaskar K., Sourabh J., Shaleen S., Nikunj K.J., (2020) Construction and demolition waste recycling: Investigating the role of theory of planned behavior, institutional pressures and environmental consciousness. Journal of Cleaner Production. Volume 263 DOI: https://doi.org/10.1016/j.jclepro.2020.121405

[13] Rahman, A.; Khondoker, M.A.H. Effect of Treatment Methods on Material Properties and Performance of Sawdust-Concrete and Sawdust-Polymer Composites. *Polymers 2024*, 16, 3289. DOI: https:// doi.org/10.3390/polym16233289

[14] Wagih A.S. , Abdel-Ghaffar M.E., Abdelrahman E.A., Noha A.E. (2020). Innovative high-density polyethylene/waste glass powder composite with remarkable mechanical, thermal and recyclable properties for technical applications. DOI: https://doi.org/10.1016/j.heliyon.2021.e06627.

[15] Olaiya, B. C., Lawan, M. M., & Olonade, K. A. (2023). Utilization of sawdust composites in construction — a review. SN Applied Sciences, 5, Article 140. DOI: https://doi.org/10.1007/s42452-023-05361-4

[16] Emmanuel O. Achukwu (2023). Development of Waste Glass Particle-Reinforced Unsaturated Polyester Composites. ResearchGate. DOI: https://doi.org/10.3390

[17] Sadik, W. A., El-Demerdash, A.-G. M., Abokhateeb, A. E. A., and Elessawy, N. A. (2021). Innovative high-density polyethylene/waste glass powder composite with remarkable mechanical, thermal and recyclable properties for technical applications. *Heliyon*, *7*(4), e06627. DOI: https://doi.org/10.1016/j.heliyon.2021.e06627