

Research Article

Micro-GB: Truck Body Panel Composite- Basalt Fibre Reinforced Composite Filled with Micro Granite

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Abstract: Granite waste is becoming increasingly relevant as the global demand for granite increases. As demand rises, so does the amount of granite waste generated. The waste often contains large pieces of granite or small fragments, dust, and other debris. This waste can be challenging to manage and take up valuable landfill space. Additionally, granite waste can be hazardous if not handled and disposed of properly. This study aimed to develop a new composite using micro granite as filler and basalt fibre as the matrix. Composite fabrication process using hand layup and vacuum silicon mould. Mechanical testing that has been done were hardness, density, constituent volume fraction (burnt-off method) and tensile. A fibre fraction below 5% shows that the newly developed material is suitable because of less void in the newly developed composite. Analysis testing results show an increase in hardness, density, and tensile strength with the increase in weight percentage of micro granite. The maximum value of the weight percentage is in 3wt% in Hardness (BFRC-118.44HRR and GFRC-117.94HRR) and Tensile Strength (BFRC-318.58MPa and GFRC-281.58MPa). More than 5wt% micro granite will decrease the value of hardness and tensile strength. Sample with 5wt% micro granite will agglomerate, referring to the SEM. Replacement of using glass to basalt will increase by 25% in tensile strength. BFRC tensile strength is better than GFRC, and BFRC is greener than GFRC. Using micro granite in this application will help decrease the waste in granite industries and contribute sustainable resources.

Keywords: micro granite; basalt; polyester.



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1. INTRODUCTION

Trucks are important tools in industries like construction, transportation, and logistics, where they are used in tough situations and are put through a lot of stress. Manufacturers of trucks have turned to new materials and designs to meet the needs of heavy-duty applications while improving efficiency and lowering weight. Truck body panel composites use composite materials to make the roof, sides, doors, and front head of a truck. (Shelly et al., 2021) say that these composites are made by combining different materials, usually a matrix material and reinforcement fibres, to make light but strong and lasting structures. Most of the time, thermosetting resins like epoxy or polyester are used in

the core of truck body panel composites. These chemicals help the composite structure stick together well and last long. Reinforcing strands like fibreglass, carbon fibre, or aramid are mixed into the matrix material to make it stronger, stiffer, and less likely to break when hit (Temmink et al., 2018). When these materials are combined, they make composite panels with better mechanical qualities than materials like steel or aluminium. One of the main benefits of using composites for truck body panels is that they are much lighter than traditional materials. Because composites are light, they use less fuel and carry more weight, allowing truck drivers to move more goods while lowering operational costs. Truck body panel composites help reach the goals of reducing carbon emissions and supporting environmental stewardship. This is in line with the growing need for sustainable and eco-friendly solutions. Using less fuel and working better, these composites help make the transportation business greener and more sustainable. In conclusion, composites for truck body panels are a big step forward for the truck manufacturing business. Their low weight, high mechanical strength, resistance to rust, and ability to be shaped differently make them an excellent choice for building truck exteriors. With their ability to improve fuel economy, durability, and overall performance, truck body panel composites are set to change how trucks are made and used, giving the transportation industry a bright future.

Basalt fibre is produced through the extraction and processing of basalt rock, which is formed by the solidification of lava. The rock is crushed and melted at high temperatures, and the molten basalt is then extruded through small-diameter nozzles to form continuous fibres (Chaiyasarn et al., 2021). Basalt fibre also finds applications in the manufacturing of composite materials. It can be combined with various matrix materials, such as thermosetting resins or thermoplastics, to produce high-performance composites with enhanced mechanical properties (Doddi et al., 2021). These composites are utilised in industries ranging from automotive and aerospace to sporting goods and marine applications. Basalt fibre composites offer excellent strength-to-weight ratios, impact resistance, and thermal stability. Additionally, basalt fibre has gained attention in the textile industry. It can be processed into fabrics, yarns, and non-woven mats, offering excellent insulation properties, fire resistance, and chemical resistance (Haris et al., 2021). These characteristics make basalt fibre textiles suitable for heat and sound insulation, protective clothing, and automotive interior components. In conclusion, basalt fibre is a versatile and sustainable material with exceptional mechanical properties and diverse applications. Its manufacturing process involves extracting and processing basalt rock to form continuous fibres.

Micro granite is a specific type characterised by its fine-grained texture and compact structure. It is formed through the slow crystallisation of molten magma deep within the Earth's crust, resulting in a durable and visually appealing rock material. Microgranite finds extensive use in various applications, including construction, architecture, and decorative purposes. This introduction will provide an overview of micro granite, its properties, and its versatile applications. Micro granite has a fine-grained texture, with individual mineral grains typically less than one millimetre in diameter (Javanshour et al., 2022). This fine-grained structure distinguishes it from coarse-grained granite and gives it unique aesthetic qualities. The rock is primarily composed of minerals such as quartz, feldspar, and mica, which combine to create a beautiful, speckled appearance. One notable characteristic of micro granite is its exceptional durability and strength. Due to its dense composition and interlocking solid crystal structure, micro granite exhibits excellent resistance to abrasion, weathering, and impact. These properties make it highly suitable for indoor and outdoor applications, where durability is crucial. In the construction industry, micro granite is widely utilised for various purposes. It is commonly employed as a dimension stone in tiles, slabs, or blocks for flooring, wall cladding, and countertops. Micro granite's attractive appearance and durability make it popular among architects, designers, and homeowners. Furthermore, micro granite is extensively used to produce decorative items such as

sculptures, monuments, and gravestones. Its fine-grained texture allows for intricate carving and detailing, making it a preferred material for creating artistic and commemorative pieces. In recent years, micro granite has gained prominence in geotechnical engineering. Its excellent strength and stability make it suitable for construction projects, including bridges, tunnels, and retaining walls. The rock's resistance to weathering and erosion ensures its long-term performance and structural integrity in demanding engineering applications. In conclusion, micro granite is a unique and versatile rock material known for its fine-grained texture, durability, and strength. Its applications span various industries, including construction, architecture, and decorative arts. Micro granite provides a visually appealing and long-lasting solution for flooring, cladding, sculptures, or infrastructure projects. Its aesthetic qualities and inherent strength make it preferred for discerning designers and engineers seeking reliable and visually appealing natural stones.

2. MATERIAL & METHOD

2.1 Material

The basalt and glass composites were fabricated using varying loadings of micron-sized granite fine powder, woven roving glass fibre (WRGF), twill weave basalt fibre (TWBF), and polyester resin (PE) as the matrix material. The Polyester (CRYSTIC® 272E Isophthalic Polyester Resin), a low viscosity organic-mineral resin, and Butanox M60 hardener were supplied by Carbon Tech Global Sdn Bhd, located in Rawang Selangor. The resin and hardener were mixed in a 2:1 ratio, with the resin being twice the amount of the hardener. The woven basalt fibres were supplied by Zhejiang GBF Basalt Fibre Co. Ltd., located in Dongyang, China, while the woven roving glass fibres were supplied by Vistec Technology, situated in Puchong, Malaysia. The granite fine powder was obtained from the Kelantan Branch of Jabatan Kerja Raya (JKR), Malaysia as Figure 1.



Figure 1. Material: matrix, resin, hardener, filler

2.2 Method

The fabrication begins by cutting and measuring the fibre (woven roving glass fibre and twill weave basalt fibre) to the desired thickness. The fibres are then stacked layer by layer. The polyester resin is mixed with the filler (micron-sized granite fine powder) by weight percentage. A mechanical stirrer ensures proper dispersion, stirring for approximately 60 minutes at 400 RPM. The polyester resin is mixed with a hardener in a 2:1 ratio by weight. The supplier recommends this ratio to ensure complete curing of the composite. The mixed resin with filler and hardener was poured onto the fibre layers. This resin is applied layer by layer, ensuring thorough impregnation of the fibres. Once the resin is applied, the specimen sealed using a silicon mould. The vacuum was used to remove any entrapped

air inside the specimen, ensuring proper composite consolidation. The sealed FRP specimen is removed from the mould and left to cure at room temperature for approximately 8 hours. During this time, the resin undergoes a chemical reaction and hardens, resulting in a solid composite structure. After curing, the composite specimens are cut into 50mm × 50mm squares using a circular saw machine. These prepared specimens will be used for impact testing or other relevant analyses as Figure 2.

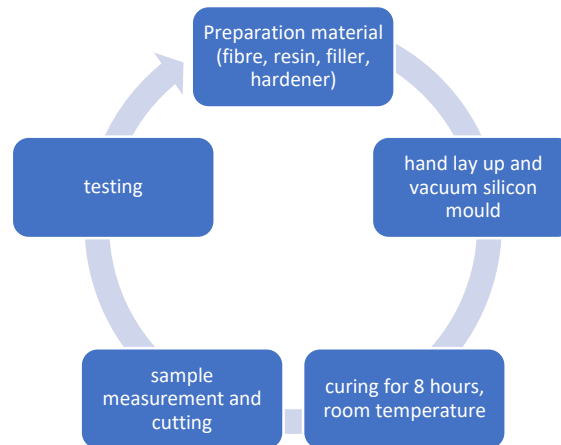


Figure 2. Fabrication process

2.2.1 Density

Density testing involves the comparison of an object's mass to its volume. The mass is typically measured using a balance or scale, while the volume can be determined through various methods depending on the nature of the material. The resulting density value provides critical information about the substance's compactness, concentration, or purity. The density test will be conducted to obtain the density of the specimens for each system according to ASTM D792. The liquid used was distilled water with a temperature of 25°C. The water level will be around 200ml to 250ml—the density of the liquid obtained from the table by referring to the temperature. The dimension of the specimens used in the density test will be 20mm × 20mm. Three samples will be tested for each system, and the final values will be determined by calculating the average.

2.2.2 Hardness Rockwell

The resistance to permanent local deformation can be characterised as hardness. It is frequently measured as the ease or difficulty of scratching, indenting, marring, cutting, drilling, or abrading a substance [174][175]. Where permanent deformation is measured, static indentation is most commonly used as a measure of hardness. The Rockwell hardness test was carried out in this work utilising an Instron Wilson Rockwell Series 600 hardness testing equipment, as shown in Plate 3.8, in accordance with ASTM 785-08 [176]. The Rockwell test scale R (HRR), which has a minor load of 10 kg and a major load of 60 kg, was chosen in accordance with the specification. With a 12.7 mm diameter sphere ball indenter, specimens of 25 mm × 25 mm × 5 mm were used. The specimens were sandwiched between the indenter and a fixture that held them in place during the test. Each specimen had five readings done, and the average hardness reading was calculated and reported. Furthermore, it provides repeatable and reliable results, allowing easy comparison and consistency in hardness measurements.

2.2.3 Constituent volume fraction- Burnt-off method

Constituent volume fraction refers to the volume ratio of a particular constituent to the total volume of the material. In this study, the matrix burnt-off method was used in accordance with ASTM D3171 to determine the constituent volume fraction and void content of the composites. The burnt-off test will determine the weight percentage of micro granite in polyester composite specimens. Three samples with a length-to-diameter ratio of 1:1 were created for each system. The samples were weighed to the closest 0.0001 g and then deposited in alumina crucibles. The crucibles were then placed in the Carbolite muffle furnace to finish the process. The furnace was heated to 550°C at a rate of 5°C/min and maintained at that temperature for half an hour. After that, the specimens were placed in a desiccator to cool to room temperature naturally. When the remaining samples were weighed, the volume fractions were finally calculated.

2.2.4 Tensile measurement

In the case of Basalt Fibre Reinforce Composite (BFRC), Glass Fibre Reinforce Composite (GFRC) and Polyester (PE) resin composites, the ASTM D-3039 standard is used for conducting tensile testing. The SHIMADZU 3366 machine is used for testing, and the specimen used for tensile testing has the following dimensions: Length of 80mm, width of 20mm, thickness of 4mm, and gauge length (distance between the grips) of 50mm. A standard sample size of five specimens is used in most testing methodologies to ensure statistical validity and to reduce any outliers' impact.

2.2.5 Scanning Electronic Microscope (SEM)

SEM is mainly used to examine the surface topography of a specimen and evaluate any particles, deposits, contaminations, failure or surface pitting on the material. It is one of the techniques in a damage monitoring program to provide insight into the types of damage experienced by the specimen. This study used SEM to examine the fracture surface of FRP composite materials after mechanical testing. This evaluation is necessary to identify the failure modes involved during the test. The splintered area on the specimen was sectioned and mounted on suitable holders before being treated with a thin coating of platinum via a Sputter Coater POLARON SC7620. The specimen was coated to provide a conductive surface and improve electron emission from the surface. The specimen was then adhered to the aluminium stubs with carbon adhesive tape before being placed in the SEM's vacuum chamber at the appropriate accelerating voltage and resolution.

3. FINDINGS

The results are the mean values of five samples tested for each type of composite laminate. The difference in the sample is the weight percentage of micro granite mixed in the resin before the pouring process during the hand lay-up fabrication process. The density, hardness, constituent volume fraction and tensile composite laminates, PE, BFRC, and GFRC were studied.

3.1 Density

Density measurement was done to determine the mass per unit volume of each specimen to determine the effects of the micro granite content in the resin of the polyester polymer and FRP composites. As shown in Figure 3, which illustrates the density values of polymer composites, Neat-PE, with a density of 1.208 g/cm³ was set as a reference value to the other sample to differentiate the effect of the addition micro granite (MG) filled in polyester polymer. According to the values obtained, each system indicates an increasing value as the MG that is filled into polyester polymer increases in weight percentage (Chaves et al., 2023; Nayak et al., 2021; Plappert et al., 2020). 1MGPE, which has 1wt%

of MG, was recorded as having a 0.41% increment when compared to the Neat-PE. This shows that when the higher weight percentage of MG was filled into the polyester resin, the density values were increased too. Therefore, it was observed that neat polyester resin has the lowest density compared to resin that have been filled with MG. The density of composite will increase with increasing weight percentage of filler. Based on Figure 3, the result shows the density will increase with the increasing of the wt% of micro granite. Density of basalt fiber is higher than both glass fiber and unsaturated polyester (Aliyu et al., 2023).

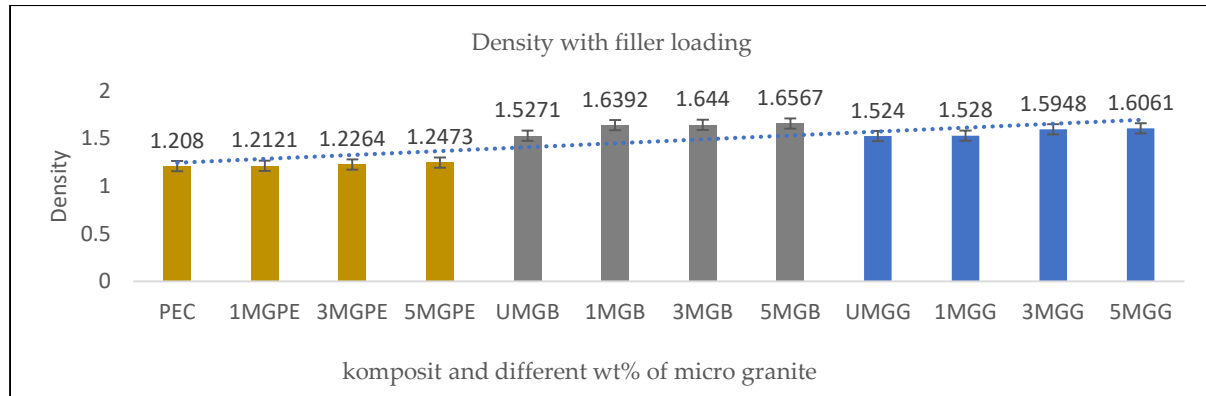


Figure 3. Density of composite

3.2 Hardness

According to the values obtained in Figure 4, each system indicates an increasing value as the MG that is filled into polyester polymer increases in weight percentage. 3MGPE, which has 3wt% of MG, was recorded as having the highest among PE composite with a 12.51% increment when compared to the Neat-PE. This shows that when the higher weight percentage of MG was filled into the polyester resin, the hardness values were increased too. Therefore, it was observed that neat polyester resin has the lowest hardness compared to resin that has been filled with MG. The hardness of the composite will increase with increasing weight percentage of filler. The hardness increases until 3wt% of filler and decreases at 5wt% for PE, BFRC and GFRC. The hardness of basalt composites is higher than glass composites (Keerthi Gowda et al., 2021; Nayak et al., 2021)

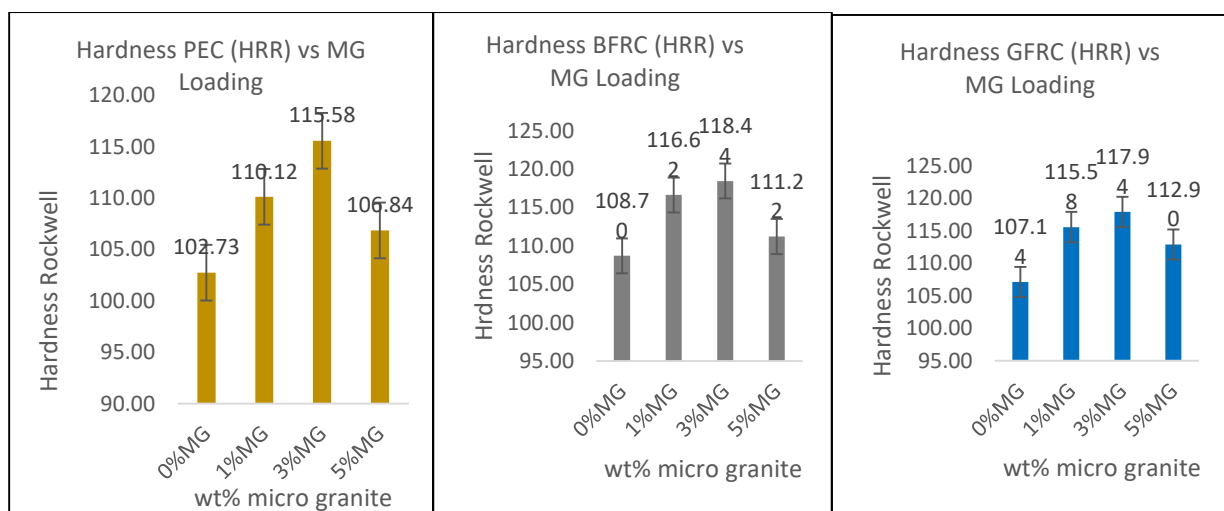


Figure 4. Hardness of composite with different wt% of micro granite

3.3. Constitent volume fraction - Burnt-off method

The volume fraction of filler in polyester resin was determined using burnt-off method—the result of the volume fraction as shown in Table 1. As we can see, the void is between 0.77% - 4.86%. The void contents are critical in typical aerospace-grade composites, allowing only 1% of voids for maximum performance. Meanwhile, in other grades of composites, it can have a range of void content between of 3% to 5%, .

Table 1. Volume fraction.

SAMPLE	WEIGHT (G)				SPECIMEN AFTER BURNT OFF	RESIN	FIBER	DENSITY	FIBER WEIGHT RATIO	MATRIX WEIGHT RATIO	FIBER VOLUME FRACTION	MATRIKS VOLUME FRACTION	VOID
	SPECIMEN BEFORE	CRUCIBLE	COMPOSITE										
UMG	190.6401	186.9755	3.6646	188.9594	1.6807	1.9839	1.5975	0.5414	0.4586	42.39%	54.27%	3.33%	
1MGG	151.0017	148.1700	2.8317	149.7149	1.2868	1.5449	1.6392	0.5456	0.4544	43.84%	55.18%	0.99%	
3MGG	146.4158	142.8790	3.5368	145.0964	1.3194	2.2174	1.644	0.6270	0.3730	50.53%	45.43%	4.04%	
5MGG	149.8650	146.8160	3.0490	148.5264	1.3386	1.7104	1.6567	0.5610	0.4390	45.56%	53.88%	0.57%	
UMB	130.3939	128.0340	2.3599	129.0355	1.3584	1.0015	1.524	0.4244	0.5756	32.34%	64.98%	2.68%	
1MGB	152.8361	149.8870	2.9491	151.3096	1.5265	1.4226	1.528	0.4824	0.5176	36.85%	58.59%	4.56%	
3MGB	151.3053	148.2490	3.0563	149.9203	1.3850	1.6713	1.5948	0.5468	0.4532	43.60%	53.53%	2.86%	
5MGB	153.2593	147.8634	5.3959	151.1282	2.1311	3.2648	1.6061	0.6051	0.3949	48.59%	46.99%	4.42%	

3.4 Tensile

Based on Figure 5, we can see a pattern in each composite, PE, GFRC and BFRC. The highest tensile strength value of each composite was at 3wt% of micro granite. The highest tensile strength was at BFRC, which is 337.75 Mpa. Meanwhile, the highest value for GFRC was 291.31Mpa, with a difference of 15.9%. The increasing percentage of unmodified composite with the highest tensile strength in BFRC is 7.4%.

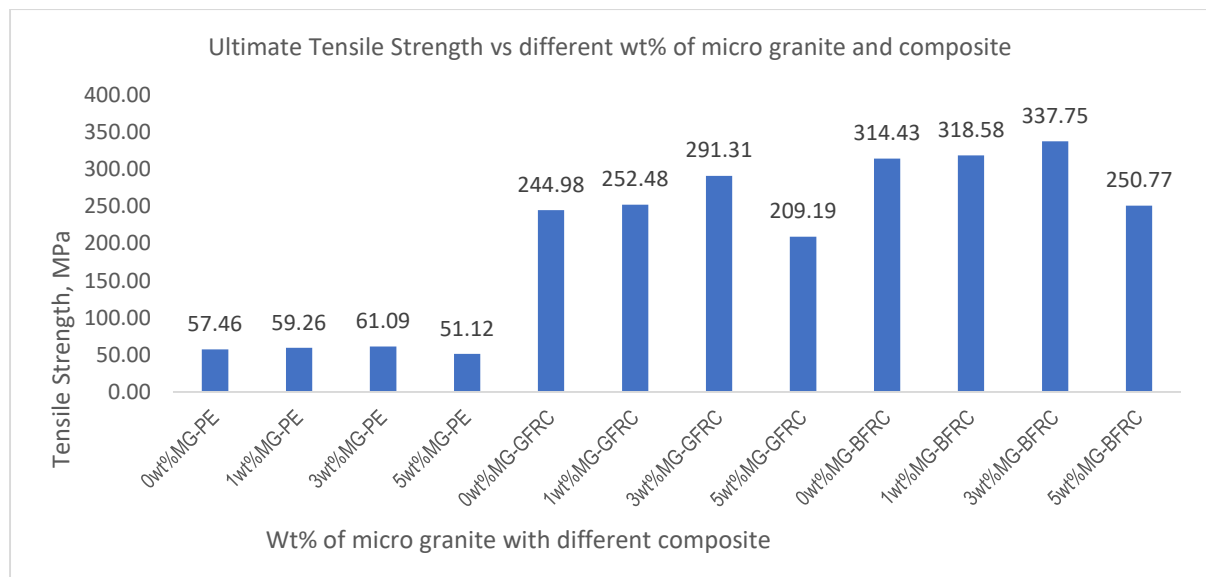


Figure 5. Tensile strength vs different wt% of micro granite and composite

The addition of micro granite showed the result of improvement in the tensile strength of the composite material. (Cionita et al., 2022; Ganesan et al., 2021; Jaafar et al., 2022; Muslim et al., 2022;

Sharma et al., 2020) discussed the effect of various fillers on the mechanical properties of polymer composites, including granite dust in polyester resin composites reinforced with glass and basalt fibres. They reported that adding granite dust as filler improved the mechanical properties of the composites, such as tensile and flexural strength, with the optimum weight percentage varying between 1-5%.

3.5 Scanning Electronic Microscope

In this study, SEM was used to examine the fracture surface of FRP composite materials after mechanical testing as shown in Figure 6. In the case of both BFRC and GFRC, the addition of 3wt% of micro granite can lead to the formation of agglomerates within the material.

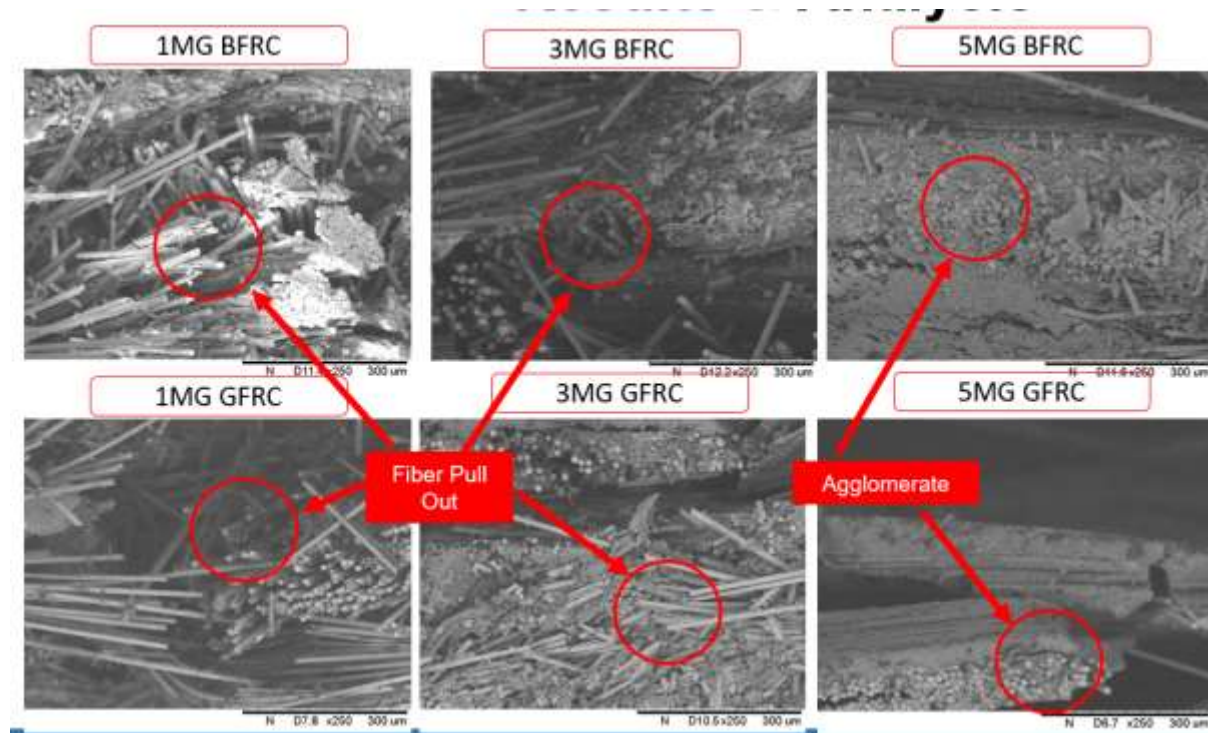


Figure 6. SEM result based on wt% of micro granite

4. DISCUSSION

Overall, agglomerates in BFRC and GFRC with 5wt% of micro granite can affect the composite material's dispersion, distribution, and bonding characteristics. Understanding and addressing these issues are crucial for achieving the desired mechanical properties and performance of fibre-reinforced composites. Agglomerates are clusters or aggregates of particles that are bound together due to various factors such as particle size, shape, and interparticle forces (Huang et al., 2022; Saba et al., 2018). The presence of agglomerates can have several implications for the properties and behaviour of the composite material. Firstly, agglomerates can affect the dispersion and distribution of the micro granite particles within the matrix.

Poor dispersion can result in uneven distribution of the reinforcing particles, leading to localised variations in properties such as strength and stiffness. Additionally, agglomerates may hinder the bonding between the matrix and the reinforcing fibres. This weakens the interface between the fibres and the matrix, reducing the load transfer capability and potentially leading to fibre pull-out during material failure. Fibre pull-out refers to the phenomenon of the reinforcing fibres being pulled out from the matrix without significant debonding or fracture. Fibre pull-out indicates that the bonding

between the matrix and resin has been compromised or weakened. This can happen due to inadequate adhesion between the fibres and the matrix material or due to the presence of agglomerates that create areas of weak bonding. Fibre pull-out is a visible sign of the loss of load transfer between the fibres and the matrix, which can negatively impact the composite's overall mechanical properties and performance. Various strategies can be employed to mitigate the issues related to agglomeration and fibre pull-out (Karimi et al., 2020). These include optimising the dispersion of the micro granite particles during the mixing process, ensuring proper adhesion between the fibres and the matrix through appropriate surface treatments or coatings, and adjusting the composition and processing parameters to enhance the interfacial bonding strength.

5. CONCLUSION

Based on the findings, adding micro granite as filler in the polyester resin can improve hardness, density, and tensile strength in PEC, BFRC and GFRC. The increase in filler will increase the density of PEC, BFRC and GFRC. The optimal value of the weight percentage is 3wt% in Hardness and Tensile Strength. More than 5wt% micro granite will decrease the value of hardness and tensile strength. Sample with 5wt% micro granite will agglomerate, referring to the SEM. The increasing value of 18.91% from UMGFRC to 3MG GFRC and 7.4% increase from UMBFRC to 3MG BFRC. Replacement of using glass to basalt will increase by 28.35% in tensile strength. BFRC tensile strength is better than GFRC, and BFRC is greener than GFRC. The addition of micro granite will increase tensile strength until 3wt%. Using micro granite in this application will help decrease the waste in granite industries and contribute sustainable resources.

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References

- Chaiyasarn, K., Hussain, Q., Joyklad, P., & Rodsin, K. (2021). New hybrid basalt/E-glass FRP jacketing for enhanced confinement of recycled aggregate concrete with clay brick aggregate. *Case Studies in Construction Materials*, 14. <https://doi.org/10.1016/j.cscm.2021.e00507>
- Chaves, Y. S., da Silveira, P. H. P. M., Neuba, L. de M., Junio, R. F. P., Ribeiro, M. P., Monteiro, S. N., & Nascimento, L. F. C. (2023). Evaluation of the density, mechanical, thermal and chemical properties of babassu fibers (*Attalea speciosa*.) for potential composite reinforcement. *Journal of Materials Research and Technology*, 23, 2089–2100. <https://doi.org/10.1016/j.jmrt.2023.01.100>
- Cionita, T., Siregar, J. P., Shing, W. L., Hee, C. W., Fitriyana, D. F., Jaafar, J., Junid, R., Irawan, A. P., & Hadi, A. E. (2022). The Influence of Filler Loading and Alkaline Treatment on the Mechanical Properties of Palm Kernel Cake Filler Reinforced Epoxy Composites. *Polymers*, 14(15). <https://doi.org/10.3390/polym14153063>
- Doddi, P. R. V., Dora, S. P., & Chintada, S. (2021). Investigations on the impact of laminate angle on the damping performance of basalt-epoxy composite laminate. *Reinforced Plastics*, 65(3), 137–141. <https://doi.org/10.1016/j.repl.2021.04.013>
- Ganesan, K., Kailasanathan, C., Rajini, N., Ismail, S. O., Ayrilmis, N., Mohammad, F., Al-Lohedan, H. A., Tawfeek, A. M., Issa, Z. A., & Aldhayan, D. M. (2021). Assessment on hybrid jute/coir fibers reinforced

- polyester composite with hybrid fillers under different environmental conditions. *Construction and Building Materials*, 301. <https://doi.org/10.1016/j.conbuildmat.2021.124117>
- Haris, N. I. N., Ilyas, R. A., Hassan, M. Z., Sapuan, S. M., Afdzaluddin, A., Jamaludin, K. R., Zaki, S. A., & Ramlie, F. (2021). Dynamic mechanical properties and thermal properties of longitudinal basalt/woven glass fiber reinforced unsaturated polyester hybrid composites. *Polymers*, 13(19). <https://doi.org/10.3390/polym13193343>
- Huang, J., Tan, V. B. C., Chew, E., Chan, K. J., Tay, T. E., Guo, L., & Liu, J. L. (2022). A new partially-infused fiber reinforced thermoplastic composite for improving impact resistance. *International Journal of Impact Engineering*, 168. <https://doi.org/10.1016/j.ijimpeng.2022.104293>
- Jaafar, M. A., Abdullah, S. A., Jumahat, A., Muslim, M. A., Sapiai, N., & Teng Loy, R. S. (2022). Effect of stacking sequence on tensile properties of glass, hemp and kenaf hybrid composites. *Physical Sciences Reviews*. <https://doi.org/10.1515/psr-2022-0052>
- Javanshour, F., Prapavesis, A., Pournoori, N., Soares, G. C., Orell, O., Pärnänen, T., Kanerva, M., Van Vuure, A. W., & Sarlin, E. (2022). Impact and fatigue tolerant natural fibre reinforced thermoplastic composites by using non-dry fibres. *Composites Part A: Applied Science and Manufacturing*, 161. <https://doi.org/10.1016/j.compositesa.2022.107110>
- Karimi, D., Crawford, B., & Milani, A. S. (2020). Manufacturing process and mechanical properties of a novel acrylonitrile butadiene styrene-based composite, with recycled natural granite micro-particles. *Manufacturing Letters*, 23, 79–84. <https://doi.org/10.1016/j.mfglet.2020.01.004>
- Keerthi Gowda, B. S., Naresh, K., Ilangoan, S., Sanjay, M. R., & Siengchin, S. (2021). Effect of Fiber Volume Fraction on Mechanical and Fire Resistance Properties of Basalt/Polyester and Pineapple/Polyester Composites. *Journal of Natural Fibers*. <https://doi.org/10.1080/15440478.2021.1904479>
- Muslim, M. A., Jumahat, A., Abdullah, S. A., Jaafar, M. A., Sapiai, N., & Teng Loy, R. S. (2022). Investigation on impact properties of different type of fibre form: Hybrid hemp/glass and kenaf/glass composites. *Physical Sciences Reviews*. <https://doi.org/10.1515/psr-2022-0053>
- Nayak, S., Jesthi, D. K., Saroj, S., & Sadarang, J. (2021). Assessment of impact and hardness property of natural fiber and glass fiber hybrid polymer composite. *Materials Today: Proceedings*, 49, 497–501. <https://doi.org/10.1016/j.matpr.2021.03.079>
- Plappert, D., Ganzenmüller, G. C., May, M., & Beisel, S. (2020). Mechanical properties of a unidirectional basalt-fiber/epoxy composite. *Journal of Composites Science*, 4(3). <https://doi.org/10.3390/jcs4030101>
- Saba, N., Jawaaid, M., & Sultan, M. T. H. (2018). An overview of mechanical and physical testing of composite materials. *Mechanical and Physical Testing of Biocomposites, Fibre-Reinforced Composites and Hybrid Composites*, 1–12. <https://doi.org/10.1016/B978-0-08-102292-4.00001-1>
- Sharma, M., Sharma, R., & Chandra Sharma, S. (2020). A review on fibres and fillers on improving the mechanical behaviour of fibre reinforced polymer composites. *Materials Today: Proceedings*, 46, 6482–6489. <https://doi.org/10.1016/j.matpr.2021.03.667>
- Shelly, D., Nanda, T., & Mehta, R. (2021). Addition of compatibilized nanoclay and UHMWPE fibers to epoxy based GFRPs for improved mechanical properties. *Composites Part A: Applied Science and Manufacturing*, 145(February), 106371. <https://doi.org/10.1016/j.compositesa.2021.106371>
- Temmink, R., Baghaei, B., & Skrifvars, M. (2018). Development of biocomposites from denim waste and thermoset bio-resins for structural applications. *Composites Part A: Applied Science and Manufacturing*, 106, 59–69. <https://doi.org/10.1016/j.compositesa.2017.12.011>