Lafia Journal of Scientific & Industrial Research (LJSIR), Vol. 3(2), 2025
p-ISSN: 3026 – 9288 e-ISSN: 3027 – 1800 pages: 95 – 101
https://lafiascijournals.org.ng/index.php/ljsir/index ⇒ Published by the Faculty of Science,
Federal University of Lafia, Nasarawa State, Nigeria

Effect of S-glass Fibre and Nanoclay on the Tensile Properties of Epoxy Composites: A Comparative Study

Bisike Chidiebere Egere[1]*, Lawal Omeiza Yusuf[2], Philip Abubakar[3], Sunday Adaogoshi Eya[3] & Catherine Okaigbo Oseshi [1]
[1]Department of Chemical Engineering, Nasarawa State University, Keffi, Nigeria
[2]Department of Polymer and Textile Engineering, Ahmadu Bello University, Zaria, Nigeria
[3]Department of Civil Engineering, Nasarawa State University, Keffi, Nigeria

Abstract
In this research work, the effect of S-glass fibre and nanoclay loading on the tensile properties of epoxy material are comparatively studied. Two groups of composites were fabricated, glass fibre/epoxy composites A, B, C, D, E, and F, which contains 0, 10, 20, 30, 40 and 50 wt.% S-glass fibre reinforcements respectively and nanoclay/epoxy composites A, B, C, D, E, and F with 0, 1, 2, 3, 4, and 5 wt.% nanoclay content, respectively. Tensile property of the all the composites fabricated were analysed and findings reported. Glass fibre/epoxy composite E, which contains 60 wt.% epoxy, 40 wt.% glass fibre was found to be the overall best performing composite. It possesses the following qualities: 98.93 MPa tensile strength, 1336.90 MPa tensile modulus and 0.072 strain at break whereas the best result on the tensile properties for nanoclay/epoxy group composites was obtained from composite E, which contains 4 wt.% nanoclay and 96 wt.% epoxy. It has the following behaviour; 60.837 MPa tensile strength, 845.00 MPa tensile modulus and 0.072 strain at break. The composite fabricated are suitable for wide range of applications such as aerospace industry for aircraft panel and body parts, marine for ship and vessels body parts, automobile industry for car bumper and body parts and civil engineering or structural engineering for high rise building frames etc.

Keywords: Composite, S-glass fibre, nanoclay, epoxy, mechanical properties

Article History
Submitted
May 28, 2025
Revised
August 11, 2025
First Published Online
August 16, 2025

Correspondences
B. C. Egere ✉
egerebisike@nsuk.edu.ng

doi.org/10.62050/ljsir2025.v3n2.596

Introduction
Composites materials can be defined as engineered materials, which exist as a combination of two or more materials that result in better properties than when the individual components are used alone [1]. They can improve mechanical properties [2] such as stiffness [3], strength [4], toughness [5]. The resulting properties are largely dependent on the distribution [5], relative amounts [6] and geometries of constituents [7]. S-glass fibre is an inorganic fibre and has a unique combination of high strength, high modulus, toughness [8] and thermal stability [9]. Glass fibre reinforced composites have become attractive structural materials not only in weight sensitive aerospace industry [10] but also in marine [1], automobile, railways, civil engineering structures [4], sport goods [5]. This is attributed to high specific strength and specific stiffness of the glass fibre reinforced composites [6].

In the other hand, nanoparticles have received much attention as reinforcing materials for polymer because of their potentially high aspect ratio [1] and unique intercalation/exfoliation characteristics [4]. The small amount addition of nano particle into polymer matrix exhibits unexpected properties including reducing gas permeability, improved solvent resistance, being superior in mechanical properties [5] and thermal stability [6] and enhanced flame-retardant properties [3].

Nanoparticle reinforced epoxy composites result in an attractive combination of physical [9] and mechanical properties [2] which cannot be obtained by macro materials [11]. These are widely used due to ease of availability of clay [8] and economic processing techniques adopted for production of components [3].

Materials and Methods
Materials
The materials used for this research work, their specification and Source/manufacturer are listed in Table 1; whereas the equipment/apparatus used for this research work, their model/standard, capacity and manufacturer/source are listed in Table 2.

Table 1: List of materials and chemicals

S/N	Material	Specifications
1.	Montmorillonite Nanoclay	≥20 nm, 10- 400 GPa, 1.72 gm/cm^3 (682608-500G)
2.	E-glass Fibre (fabric form)	300 GSM Specific gravity 2.6 gm/cc
3.	Epoxy Resin	Araldite LY 506 Specific gravity 1.15-1.20 gm/cc
4.	Epoxy Resin Hardner	Aradur HY 951 Specific gravity 0.97-0.99 gm/cc
5.	Mould Releasing Agent	Poly vinyl alcohol (PVA)

Table 2: List of equipment

S/N	Instrument	Model	Capacity	Manufacturer / Source
1	Instron Analyser for Tensile Test.	AUST/MT/004	5KN	Instron, 825 University Avenue Norwood MA 02062-2643 www.instron.com
2	Open Glass Moulds	-	-	Locally fabricated
3	Motorized Stirrer	-	1000 rev/min	-

Methods

The methods for preparation of the various composites are shown below.

Mould design and fabrication

The moulds used for fabricating all the composites were made of silicate glass and have the same dimensions of 200 x 200 x 3 mm dimension were fabricated locally using inert glass material. The glass sheets were marked and diamond glasscutter used to cut out the glass block from the sheet whereas the edges of the moulds were held together with adhesives.

Composites preparation

The formulated mixtures of nanoclay/epoxy of 99, 98, 97, 96 and 95-wt % epoxy with 1, 2, 3, 4 and 5-wt% nanoclay respectively were prepared. The ratios were mixed using high-speed motorised stirrer. Mould release agent PVA was applied on mould plates in order to have smooth removal of moulded composites after curing. Secondly, epoxy/E-glass fibre composites consisting mixtures of 90, 80, 70, 60 and 50-wt% epoxy with 10, 20, 30, 40, and 50-wt% E-glass fibre respectively were also fabricated. A roller was used to remove some of the entrapped air bubbles in order to reduce the development of voids. Hand layup method was used to prepare glass fibre/epoxy composites by placing one glass fabric (mat) over another and applying the epoxy matrix between the glass fabric alone and the glass fabric with the nanoclay (lamination) respectively while maintaining the thickness of the composite. Casting method was employed for nanoclay/epoxy composites of various ratios. The moulds were left undisturbed for 24 h and the samples were removed and cut into circular, dumbbell, square & rectangular shapes with diamond cutter according to ASTM standards for tensiletests.

S-glass fibre/ epoxy composites fabrication

Hand layup method was employed in the preparation of glass fibre/epoxy composites. The following weight ratio 50:50, 60:40, 70:30, 80:20, 90:10 and 100:0 (control) of compositions were prepared (Table 3). Glass fabric was weighed, Epoxy was measured out and poured into a beaker and epoxy hardener was measured and poured into the same beaker in the ratio of 2:1. The contents of the beaker were subjected to mechanical agitation using a high-speed motorized stirrer at 1000 rev/min. for a period of five minutes for proper mixing. Releasing agent (PVA) was applied on the mould, a little of the epoxy and hardener homogenous mixture were poured in, an E-glass fabric placed, matrix mixture applied again, E-glass fabric placed, matrix mixture poured in, this continued until the glass fabric was exhausted and the remaining mixture was poured, to form the outer covering of the composite. This method was used to fabricate all the varieties of E-glass/epoxy fabric composites produced in this research work.

Table 3: The compositions of epoxy and glass fibre in the composites

S/N	Composite Name	Composite Code	Epoxy (wt. %)	Nanoclay (wt. %)	Glass Fibre (wt. %)
1	EP100GF0NC0	A	100	0.00	0.00
2	EP90GF10NC0	B	90	0.00	10.0
3	EP80GF20NC0	C	80	0.00	20.0
4	EP70GF30NC0	D	70	0.00	30.0
5	EP60GF40NC0	E	60	0.00	40.0
6	EP50GF50NC0	F	50	0.00	50.0

Table 4: The compositions of epoxy and nanoclay in the composites

S/N	Composite Name	Composite Code	Epoxy (wt. %)	Nanoclay (wt. %)	Glass Fibre (wt. %)
1	EP100GF0NC0	A	100	0.00	0.00
2	EP99GF0NC01	B	99	1.00	0.00
3	EP98GF0NC02	C	98	2.00	0.00
4	EP97GF0NC03	D	97	3.00	0.00
5	EP96GF0NC04	E	76	4.00	0.00
6	EP95GF0NC05	F	75	5.00	0.00

Nanoclay/epoxy composites fabrication

Nanoclay/epoxy composites with percentage weight composition of 99:1, 98:2, 97:3, 96:4, 95:5, and 100:0

(control) was fabricated with open moulds see Table 4. The moulds were cleaned and mould release agent applied on them. Proper weight percent of epoxy resin was measured and poured into a beaker and proper weight nanoclay was measured out and added to the beaker. The contents were mechanically agitated using high speed motorized stirrer at 1000 rev/min, for five minutes for proper mixing, then Epoxy hardener was measured and poured into the same beaker and the agitation continued for another about five minutes for homogenous mixing. The uniform mixture was then poured into the moulds and allowed to cure overnight. The composites were removed from the mould and the process repeated using with the various compositions as listed above.

Results and Discussion

Tensile properties of epoxy/glass fibre composites A, B, C, D, E and F with 0, 10, 20, 30, 40 & 50 wt.% glass fibre content respectively all displayed a typical viscoelastic stress-strain curves behaviour as shown in Fig. 1. From the chart, glass fibre is a reinforcing material because the increase in the quantity of it led to improved tensile properties such as stress and modulus. The control sample was cured epoxy. As the glass fibre content was increased from 10 wt.% to 50 wt.% at an interval of 10 wt.%, the stress factor experienced progressive increase until it reaches the optimal which was composite E with 40 wt.% S-glass fibre content. At 50 wt.% a decline in stress was experienced. The highest stress value of 98.93 MPa was recorded for sample E with 40 wt.% S-glass fibre. It showed about 32.83% better result when compared to the control sample A with 0 wt. % S-glass fibre. Composite F, which contains 50 wt. % S-glass fibre, showed a decline in stress value when compared with composite E with 40 wt.% S-glass fibre, this was so because the matrix in composite F was unable to wet properly the reinforcing S-glass fibre. Some research works [11, 1, 3] recorded similar results with about 22% improvement of stress value of 40 wt.% glass fibre reinforcement when compared with control. The highest strain value recorded was 0.082 for composite A (control sample), with 0 wt.% S-glass fibre reinforcement. The strain values continued to reduce from composite A to E and this was because of the stiffness caused by increment in S-glass fibre content across the composites. Furthermore, tensile modulus of the composites increases with the increase in S-glass fibre loading as witnessed in composites B-F. The reinforced composites are of higher tensile stress and modulus and are more brittle in nature when compared with the control sample. The works of some researchers [7, 9, 10] revealed similar trend.

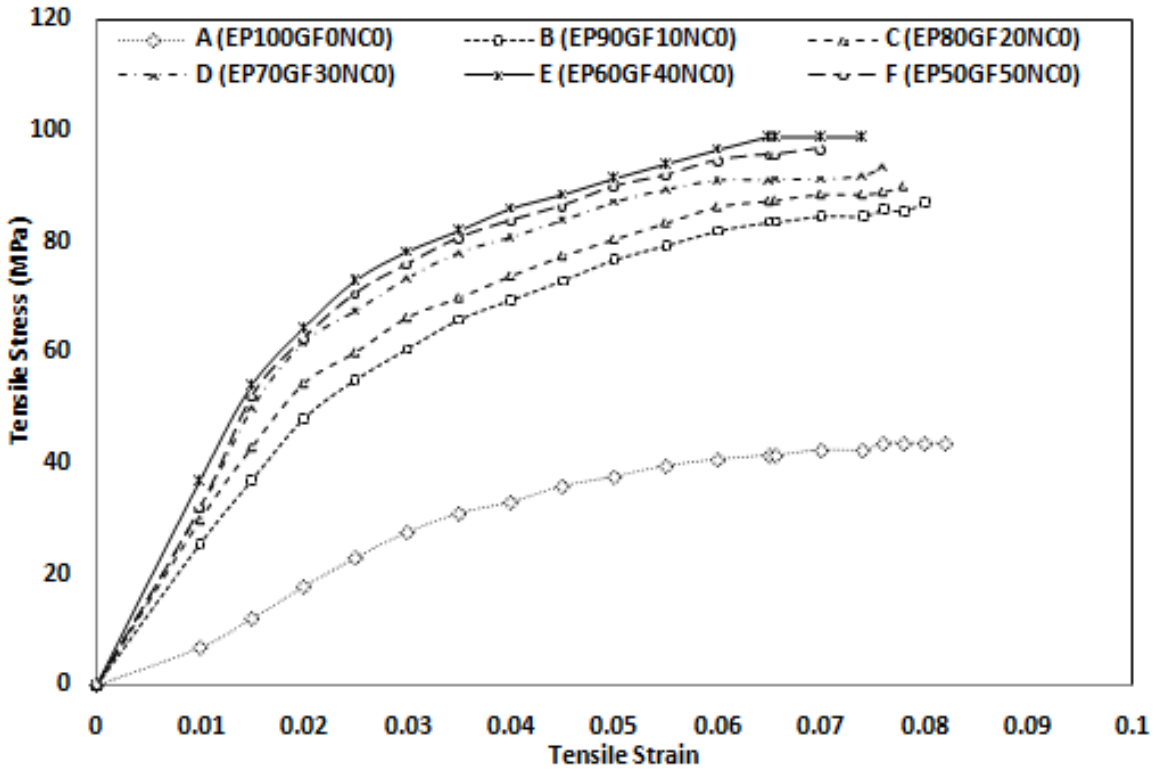

Figure 1: Tensile stress-strain Curves of glass fibre/epoxy composites at different fibre loadings

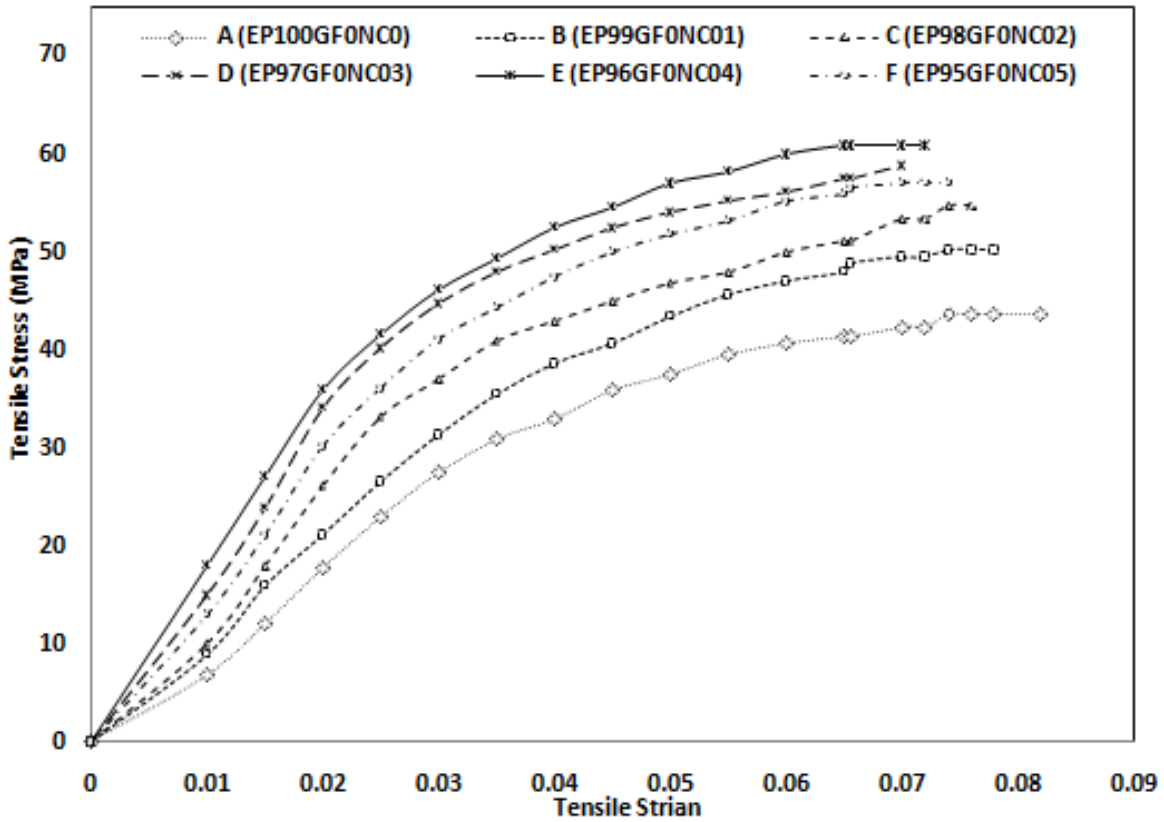

Figure 2: Tensile stress-strain curves of nanoclay/epoxy composites at different filler loading

The tensile properties of nanoclay/epoxy composites A, B, C, D, E, and F with 0, 1, 2, 3, 4, and 5 wt.% nanoclay concentrations were studied and analysed respectively. The stress/strain curves of the composites are shown in Fig. 2. As the nanoclay content of the composites was increased from 0 to 5 wt.% at an interval of 1 wt.%, the stress values increased. The optimum stress value of 60.837 MPa was registered against composite E with 4 wt.% nanoclay. A reduction in stress value of 58.78 MPa was recorded against composite F with 5 wt. % nanoclay. This may be so, because nanoparticles do best in composite enhancement in very minute quantity between 3-4 wt.% [1]. The highest strain value of 0.82 was recorded against the control sample followed by 0.078 for Composite E, which is 7.03% less when compared to the control i.e. composite A with 0 wt.% nanoclay content. Generally, the strain values showed marginal reductions on addition of 1, 2, 3 and 4 wt.%. Composite E with 4 wt.% nanoclay is the stiffest composite with 845 KPa tensile modulus, the stiffness value increased from composite A to E. Composite F witnessed a reduction in stiffness value. The works of [6] showed similar trends.

Effect filler loading on tensile strength of composites

The tensile strength of the three groups of composites epoxy/glass fibre composites, epoxy/nanoclay composites and epoxy/glass fibre/nanoclay hybrid composites were compared in Fig. 3, the following deductions made. The results show that tensile strength of glass fibre/epoxy composites vary from 43.56 MPa (control) to 98.93 MPa while the tensile strength of nanoclay/epoxy composites ranges from 43.56 MPa (control) to 60.837 MPa. The tensile strength increases with increase in filler loading in all the composites. S-glass fibre/epoxy composites gave better results when compared to the nanoclay/epoxy composites. S-glass fibre/epoxy composite Eis the composite with the overall best tensile strength. The increase in tensile strength as the filler loading increase can be attributed to the glass fibre and nanoclay ability to improve the tensile strength independently. As the S-glass fibre content increased beyond 40 wt.% the epoxy matrix could no longer wet S-glass fibre properly hence the tensile strength decreased as in composite F with 50 wt.% GF: 50 wt.% epoxy. Likewise tensile deceased for nanoclay as in sample composite F with 5 wt.% nanoclay: 95 wt.% epoxy. In the other hand the effect of the glass fibre loading on the tensile strength as can also be seen, the tensile strength varies from 43.56 MPa to 98.93 MPa. The tensile strength increases with increase in glass fibre up to 40 wt.% as in composite E and thereafter decreases as seen in composite F. The increase in tensile strength with increase in glass fibre can be attributed to good interfacial bonding between the glass fibre and the epoxy matrix giving the glass fibre ability to serve as good reinforcing filler. As the glass fibre content was further increased as in composite F with 50 wt.% S-glass fibre, the epoxy matrix could no longer wet the S-glass fibre properly hence the tensile strength decreased marginally. This

conforms to the work [9] that recorded tensile strength of GF reinforced epoxy composites variation from 34.13 MPa to 79.47 MPa, and the tensile strength increases with increase in glass fibre up to 30 wt.% and thereafter decreases. Likewise, a study [4] recorded similar trends of results in graphene/epoxy composites tensile strength analysis. In like vein, the effect of the nanoclay loading on the tensile strength of the nanoclay/epoxy composites ranges from 43.56 MPa to 60.837 MPa. The tensile strength improves with increase in the quantity of nanoclay added up to 4 wt.% as in composite A to E. Thereafter, the tensile strength decreased as seen in composite F with stress 58.78 MPa. The increase in tensile strength from samples A to E can be attributed to the abilities of nano fillers to mix thoroughly forming no clusters and lumps in the epoxy matrix. When nanoclay content was further increased beyond 4 wt. % as in composite E with 5 wt.% nanoclay content, the tensile strength reduced due to formation of clusters by the nano filler. This conforms to the work of [8].

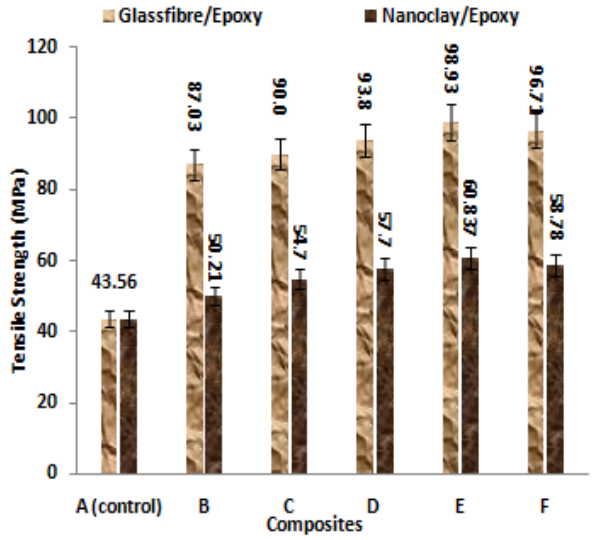

Figure 3: Comparison of the effect of filler loading on tensile strength of glass fibre/epoxy and nanoclay/epoxy composites

Effect of filler loading on the tensile modulus of composites

The Fig. 4 compares the tensile modulus of glass fibre/epoxy composites and nanoclay/ epoxy composites. The tensile modulus of elasticity varies from (control) 531.2 MPa to 1343.2 MPa. The optimum tensile modulus of 1343.2 and 845 recorded for glass fibre/epoxy composites & nanoclay/epoxy composites respectively. The tensile modulus increases with the in fillers content in the three scenarios until saturation point is reached. The saturation point is the point at which the matrix (epoxy) could no longer properly wet the fillers (nanoclay or glass fibre) in the composite, at that point nano clusters begins to form for nanocomposites. These are experienced in glass fibre/epoxy composites F and nanoclay/epoxy composites F. The effects of glass fibre loading on the tensile modulus for various epoxy composite varies from 531.2 to 1343.2 MPa. The tensile modulus increased from sample A (control) with 531.2 MPa to composite F (50 wt.% GF) with 1343.2 MPa. The composite becomes stiffer as the glass fibre contents were increased from 0 to 40 wt.% at interval of 10 wt.% as in composites A to E. A study [5] recorded similar trends with maximum tensile modulus between 1314 MPa - 1252.5 MPa for 50 wt.% fibre content. The effect of nanoclay loading on the tensile modulus for various formulations of epoxy/nanoclay composites varies from 531.2 MPa to 845 MPa. The optimum tensile modulus of 845 MPa was obtained for the sample E with 4 wt.% of nanoclay, the tensile modulus decreases to 839.7 MPa for composite F with 5 wt.% nanoclay content. The improvement in tensile modulus with increase in nanoclay from sample A to E was because of homogenous mixing of the nanoclay in the matrix system leading to a good interfacial relationship between the nano filler and the epoxy matrix. As the filler content increased, further, clusters of nanoclay begins to form hence reduces the cohesion between the epoxy and nanoclay causing the tensile modulus of composite F to decreased. The works of Yang *et al.* [2] reported similar results and trends.

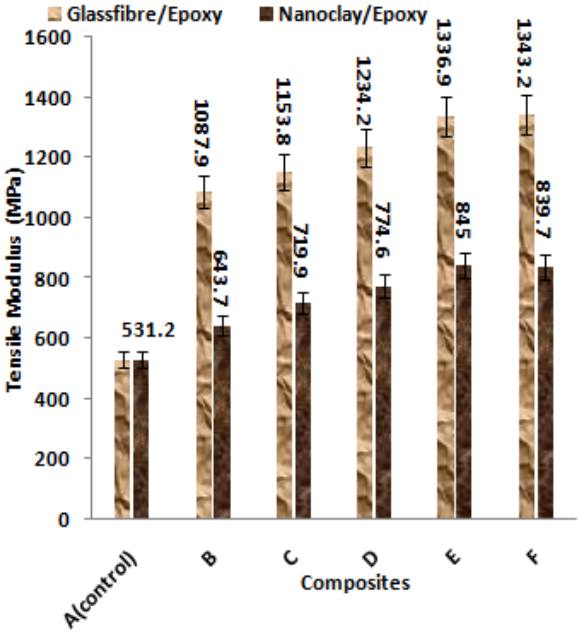

Figure 4: Comparison of the effect of filler loading on tensile modulus of glass fibre/epoxy & nanoclay/epoxy composites

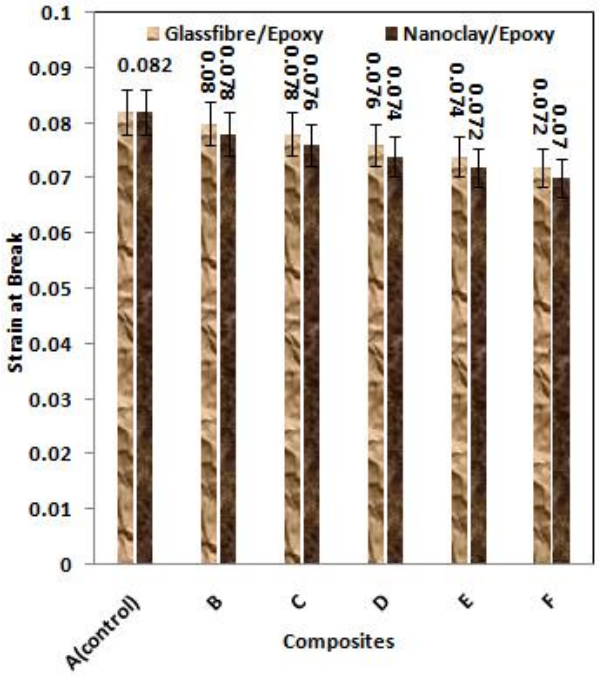

Figure 5: Comparative studies on strain at break for the two groups of composites formulated

Effect of filler loading on the strain at break of composites

In Fig. 5, the strain at break of the two groups of composites glass fibre/epoxy composites and nanoclay/epoxy composites were compared. The result shows that strain at break of glass fibre/epoxy composites vary from (control) 0.082 to 0.072 and strain at break of nanoclay/epoxy composites ranges from 0.082 to 0.07. The strain at break decreases with increase in filler loading in all the composites. S-glass fibre/epoxy composites gave the optimally least stress at break value followed by nanoclay/epoxy composites when compared to the control sample A. The increase in strain at break as the filler loading increased can be attributed to the glass fibre and nanoclay ability to independently serve as good reinforcements for epoxy composite [9, 7, 3]. The strain at break for various GF/epoxy composites varies from 0.072 to 0.082. The maximum is obtained for (control) Sample A with 0 wt.% glass fibre and decreases on addition of glass fibre as shown in composite B to F with 10, 20, 30, 40 and 50 wt.% of glass fibre. The decrease in strain at break (elongation) can be ascribed to increase in brittleness and reduction in ductility of the composites as the glass fibre content increased from 10 to 50 wt.%. Yang *et al.* reported similar results with maximum strain at break of 0.79 and minimum 0.68 reported for glass fibre/polyester and glass fibre/polythene composites respectively [2]. In nanoclay/epoxy composites, the strain at break for various varies from 0.07 to 0.082. The maximum strain at break of 0.082 was obtained for (control) sample A with 0 wt.% of nanoclay. The strain at break decreases with increase in nanoclay content from 1 to 5 wt.%. The decrease in strain at break as the nanoclay content increase as in composite samples A to F was because the increase nano filler makes them to be more brittle and less elastic, in the other hand, the association between the nano filler and epoxy matrix reduces on increments in nanoclay quantities hence reducing the elongation at break. Zhao *et al.* reported similar results against grapheme oxide/epoxy composite [4].

Conclusion

Two groups of composites were fabricated: glass fibre/epoxy composites B, C, D, E, and F, which contains 0, 10, 20, 30, 40 and 50 wt.% S-glass fibre reinforcements respectively and nanoclay/epoxy composites B, C, D, E, and F with 0, 1, 2, 3, 4, and 5 wt.% nanoclay content respectively. Tensile property of the all the composites fabricated were analysed and findings reported. Glass fibre/epoxy hybrid nanocomposite E, which contains 60 wt.% epoxy, 40 wt.% glass fibre was found to be the overall best performing composite. It possesses the following qualities; 98.93 MPa tensile strength, 1336.90 MPa tensile modulus and 0.072 Strain at break whereas the best result on the tensile properties for nanoclay/epoxy group composites was obtained from composite E, which contains 4 wt.% nanoclay and 96 wt.% epoxy. It has the following behaviour; 60.837 MPa tensile strength, 845.00 MPa tensile modulus and 0.072 strain at break. Based on the findings and scope of this research work, the following are recommended, research should be done on the hybrid nanocomposites in the area of electrical and thermal properties of the composites and biodegradability test should be investigated.

References

[1] Shah, A. & Bakhshi, P. (2020). Recycling of plastic wastes: Challenges and future opportunities. *Polymer Journal*, 52(7), 639-648. https://doi.org/10.1038/s41428-0200331-7.

[2] Yang, L., Zhou, Q., & Li, H. (2023). Enhancing the performance of recycled polyethylene and polystyrene blends. *Journal of Applied Polymer Science*, 140(, 2, e53347. https://doi.org/10.1002/app.53347

[3] Wu, C., Li, X. & Zhang, J. (2022). Mechanical properties of LDPE/PS polymer blends: A review of recent advances. *Polymer Engineering & Science*, 62(1), 45-52. https://doi.org/10.1002/pen.25814

[3] Zhao, H., Wang, Y. & Liu, X. (2021). Recent developments in polymer blends for sustainable materials: Focus on polyethylene and polystyrene. *J. of Polymer Res.*, 28(9), 275-290. https://doi.org/10.1007/s10965-02102701-x

[5] Zhu, W., Li, Y. & Wang, H. (2022). Mechanical properties and phase behaviour of polyethylene/polystyrene blends: Effects of composition and processing conditions. *Polymer Composites*, 43(6), 1579-1588. https://doi.org/10.1002/pc.26202

[6] Ruiz, Alain E. Mera, Júlio C. Santos & Silvio S. da Silva (2023). Valorisations of corn cobs for xylitol and bioethanol production through column reactor process. *Energies*, 16(13), 4841 https://doi.org/10. 3390/en16134841

[7] Choi, J. Y., Nam, J., Yun, B. Y., Kim, Y. U. & Kim, S. (2022). Utilization of corn cob, an essential agricultural residue difficult to disposal: Composite board manufactured improved thermal performance using microencapsulated PCM. *Ind. Crops and Products*, 183, 114931. https://doi.org/10.1016/j.indcrop.2022.114931

[8] Arhik, B, Gabriella, R, Rhoda, A. M. & Oisik, D. (2020). A review on the flammability propertiesof carbon-based polymeric composites: state of the art and future trends. *Journal of Polymer Science*. 12(7), 1518. https://doi.org/10.3390/polym12071518

[9] Obasi, H. C. (2015). Peanut husk-filled polyethylene composites: Effects of filler content and compatibilizer on properties. *Journal of Polymers*, http://dx.doi.org/10.1155/2015/18928

[10] Aiyejagbara, M., Ejiogu, K., Ibeneme, U., Shekari, T. N. B., Musa, E., Egere, B. C. & Okeke, C. (2025) A study on the effect of corn cob nano particles on the physic mechanical properties of waste expanded polystyrene. *J. of Communication in Phys. Sci.*, 12(4), 1311-1320. https://dx.doi.org/10.4314/cps.v12i4.13

[11] Gelande, P. & Zarakar, S. E. (2016). Effect of various filler on mechanical properties of glass fibres reinforced polymer composites: A review. *Int. J. Emerg. Trends in Sci. & Techn.*. http://dx.doi.org/10.18535/ijetst/v3i04.04

Citing this Article

Egere, B. C., Yusuf, L. O., Abubakar, P., Eya, S. A. & Oseshi, C. O. (2025). Effect of S-glass fibre and nanoclay on the tensile properties of epoxy composites: A comparative study. *Lafia Journal of Scientific and Industrial Research*, *3*(2), 95 – 101. https://doi.org/10.62050/ljsir2025.v3n2.596