Nnamdi Azikiwe University Journal of Civil Engineering (NAUJCVE)

Volume-3, Issue-2, pp-132-144

www.naujcve.com

Research Paper Open Access

Structural Performance Evaluation Of Concrete Reinforced With Sponge Gourd (*LuffaAegyptiaca*) Fibre

[1]Christopher A. Fapohunda and [2]Samuel D. Oyediji

[1,2]Department of Civil Engineering, Federal University Oye-Ekiti, Nigeria.

Corresponding Author: [2]oyedijisamueldare64@gmail.com

Abstract: *In today's society, engineers and researchers are driven by the desire for sustainable lightweight structures. They are constantly looking into other materials to make up for the problems with concrete buildings. To improve efficiency, composite materials or fibers are often mixed into the concrete base. The fiber makes the concrete particles stronger against different kinds of stress. The study aims to examine the structural characteristics of concrete that has been reinforced with sponge gourd fibre (SGF) and the objectives are to determine the fresh state and hardened properties of concrete reinforced with SGF, and know the optimum addition in order to make appropriate recommendation. Different percentages by weight of cement (0.2%, 0.4%, 0.6%, 0.8%, 1.0%, and 1.2%) of the sponge gourd fibre were incorporate in a total of 125 cube and cylinder samples measuring 150mm x 150mm x 150mm, and 200mmlong x 100mm daimeter respectively and 70 beam samples measuring 100mm x 100mm x 500mm. A total of 18 cube samples, 18-cylinder samples, and 10 beam samples of identical sizes were cast as the control mix. The samples were cast, cured, and tested on specific days to evaluate various parameters such as workability, density, compressive strength, and tensile strength. Results showed that workability reduces with increase in the SGF content, (ii) specimens without fibre are lower in density, specimens containing SGF up to 0.4% developed higher compressive and tensile strengths, the deflection was higher. It can be concluded that the use of SGF up to 0.4% by weight of concrete will results in better concrete.*

***KEYWORDS*:** *Concrete, Fiber, Sponge gourd Fibre, concrete optimization*

Date of Submission: 25-04-2025 Date of acceptance:29-04-2025

1. INTRODUCTION

Throughout history, conventional building materials have been extensively employed and continue to hold a prominent position within the construction sector (Moghayedi et al., 2022). Frequently, these materials are selected due to their affordability, availability, and durability (Nouri et al., 2021). Brick, stone, timber, steel, and concrete are typical materials used in conventional construction (Psilovikos, 2023; Lee et al., 2021).Globally, concrete is the second most used material for construction (Meng, et al., 2019). On annual basis, 3.8tons of concrete is been used per person (Ali et al., 2023). The disadvantages of conventional concrete include:its inadequate discharge caused by impermeability, which results in the accumulation of water (Suryo et al., 2021); its content of fissures and microcracks in a feeble interfacial transition zone (ITZ), which can reduce its strength and durability (Alanazi, 2022);its heavy weight which pose challenge in transportation and handling (Suryo et al., 2021). Cement, which is the major component of concrete, also have various environmental effect (Jang et al., 2022). For instance, cement manufacturing is responsible for 7% of the total anthropogenic globalCO2emissions worldwide (Ali et al., 2023).To address the issues surrounding the usage of cement in concrete, efforts have been made to reduce CO2 emissions, recycle resources, and find permanent alternatives (Ali et al., 2023). One of the most cost-effective and long-lasting techniques utilized in the contemporary construction sector is fiber reinforced concrete (FRC), which utilizes waste fibers as a partial cement replacement to achieve the desired seismic performance at a reduced expense (Makara et al., 2022). FRC offers several advantages, such as increased tensile strength, higher resistance to cracking, and enhanced ductility, making it suitable for various civil engineering applications (Szpetulski et al., 2022). Using fibres/waste helps to lower cement usage, thereby supporting the building of affordable houses (Zhu et al., 2023). Among such industrial waste are polyester, rubber, cotton, plastic, rock wool, glass fibres, nylon, etc.(Sovják et al., 2021). These waste products naturally break down somewhat slowly (Kadac-Czapska et al., 2023). For rubber needs 50–80 years; rock wool requires 1–5 years; polyester takes roughly 20–200 years; glass fibres take 4000–5000 years (Ali et al., 2023). Particularly, Sponge gourd Fiber (SGF) is becoming increasingly popular as a natural concrete reinforcement (Alhijazi et al., 2020; Sahayaraj et al., 2022; Abd-Al Ftah et al., 2022). Sponge gourd Fiber (SGF) is a natural fiber derived from the fruit of the Luffa plant (Goudarzi et al., 2022). Known for its high cellulose content and low density, SGF offers advantages such as lightweight, high strength, and energy absorption capacity, making it suitable for applications in composite materials (Rao et al., 2023). Studies have shown that SGF can be effectively used as a reinforcement material due to its mechanical properties and compatibility with different matrices (Ighalo et al., 2020; Chakrabarti et al., 2020; Ashok &Kalaichelvan, 2021). These fibers have shown promise in improving the tensile strength, impact strength, and flexural properties of the resulting composites (Patra, 2021; Rao et al., 2023; Anbukarasi et al., 2020). Several studies have investigated the utilization of SGF in composite materials, including reinforcing concrete. Rao et al. (2023) examined the dynamic mechanical, ballistic, and tribological behavior of epoxy composites reinforced with Sponge gourd fiber. Sahayaraj et al. (2022) studied the properties of epoxy composites reinforced with Luffacylindrica fruit waste fiber and Tamarindusindica seed nano-powder. Yaro et al. (2021) investigated the influence of kaolin filler on the mechanical properties of Luffacylindrica/polyester composites and also explored the mechanical properties of polyester composites reinforced with Luffacylindrica fiber and kaolin particulate. Moreover, research has shown that Luffa fibers can enhance properties of composites beyond concrete reinforcement. Azaka et al. (2022) demonstrated the use of Luffacylindrica fiber as an additive for thermal insulation, while Jawad and Salih (2020) studied the potential of Luffa fibers in acoustic absorption performance. Additionally, Trung (2023) studied the impact of micro-sized Luffacylindrica fibers on the mechanical properties of epoxy epikote 828, demonstrating that incorporating Luffa-reinforced microfibers resulted in a more stable structure and enhanced resistance to impact forces. Nagarajaganesh and Rekha (2020) observed that increasing the weight percentage of Luffacylindrica fibers significantly enhanced the impact strength of hybrid composites. Furthermore, Anbukarasi et al. (2020) explored the thermal conductivity of Luffa and Luffa-coir reinforced epoxy composites, finding that Luffa fibers have the potential to improve the thermal properties of the resulting materials.But there appears to be little or no literature on the effects of sponge guard of the structural performance of concrete. Thus the aim of this work is to assess the structural performance of concrete containing sponge gourd. The specific objectives included the determination of the effects of sponge guard fibreon workability, density, compressive strength and tensile characteristics of concrete containing sponge gourdfibre.

II. MATERIALS AND METHOD

2.1 Materials

The materials used for this research work are Portland limestone cement, sand, coarse aggregates, and sponge gourd fibre (SGF). The cement used in this research work, DANGOTE 3X brand,was the locally produced and it conformed to the requirement (BS 12, 1996). The fine aggregate used was the river sand having a maximum size of 4.75 mm. The coarse aggregate used was crushed granite obtained from a quarry in Ado-Ekiti with a maximum size of 20mm in accordance to the recommendations of BS 8110 (1997). The water used for this work was potable water that is suitable for drinking. The sponge gourd was obtained. Sponge gourd fibre (SGF) used in this present study was collected locally in Omuaran, kwara state and Ado Ekiti, Ekiti state. The outer layer (bark) and seeds of luffa fruit were removed carefully. Then the sponge fibres were cut carefully to separate the outer layer from the seed. Fibre expunge was treated by immering in water for 24 h to get rid of any impurities or sugary substances. The fibres was dried in air at room temperature for 24 h after being extracted from the water, and the fibres was then be cut. After cutting, the fibres was once again immersed in water for 24 h to get rid of any impurities or sugary substances Lastly, the samples was dried for 24 h, then, the fibres are ready to be used in concrete. Fig. 1 showed the procedure to obtain the fibre

(a) (b)

(c.) (d.) (e.)

Fig. 1: The process (a, b, c, d, e) of obtaining the sponge gourd fibre

2.2 Mix design and concreting

In order to model as much as possible the practice in the country, a mix ratio 1: 2: 4 was adopted with water/cement ratio of 0.50 were used for this investigation. The mix proportion arising from this was shown in Table 1.

Table 1: Mix design

% Fibre in the mix	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Water (kg)	Fibre content (kg)
0.0	1.16	2.31	4.36	0.58	0
0.2	1.16	2.31	4.36	0.58	0.00232
0.4	1.16	2.31	4.36	0.58	0.00464
0.6	1.16	2.31	4.36	0.58	0.00696
0.8	1.16	2.31	4.36	0.58	0.00928
1.0	1.16	2.31	4.36	0.58	0.0116
1.2	1.16	2.31	4.36	0.58	0.001392

Concreting was done by batching the ingredients by weight and then mixed properly. The sponge gourd fibre was added to the mix from 0.2 – 1.2% percentage by weight of cement at interval of 0.2%. The properly mixed concrete was then cast into specimens (cube, cylinders, and beams) and allowed to cured until the date of testing.

2.3 Methods

2.3.1 Materials Characterization

The physical properties of materials were determined for the aggregates. These were sieve analysis, moisture contents, specific gravity. Also, assessment of the physical and elemental properties of the fibre was carried out.

2.3.2 Workability test

The workability characteristics of concrete with fibre at different percentage were determined through slump test. The test was carried out in accordance to BS 12350-6 (2000).

2.3.3 Density and Compression test

Density and compression tests for concrete containing the sponge gourd fibre were carried out using 150mm x 150mm x 150 mm cube specimens. The cubes specimens were filled with thoroughly-mixed concrete and compacting with a tamping rod fills in layers. The specimens were allowed to wait for 24 hours before they were demolded and placed in a curing tank filled with water so that they can be cured until the day of testing. The compressive test was carried out in accordance to BS EN 12390-3 (2009) using a UTM machine shown in Fig. 2. Load was applied gradually until failure occurred, and the maximum load at failure was divided by the specimen's surface area to determine compressive strength. The compression testing at various intervals of sponge gourd was tested at 7, 14, 21, 28, 60, and 90 days.The Density of concrete was carried out according to BS 12390-3 (2009).

Before the testing, the mass of the cube specimens were determined and the density (D) determined by equation 1

$$D = \frac{M}{V} \qquad 1$$

Where D = density (kg/m^3), M = weight (kg) and V= Volume (m^3).

2.3.4 Tensile strength – Splitting Tensile test

Splitting tensile test were carried out on200mmlong x 100mmdaimetercylinder specimens of concrete containing sponge gourd fibre at various percentages. The cylinder specimens were positioned as showed in Fig. 2 for testing. While testing, the machine the load was applied gradually until failure, with the maximum load recorded in accordance to BS12390-6 (2009). The specimens were tested at 7, 14, 21, 28, 60, and 90 days. Splitting tensile strength wasthen calculated using equation 2.

$$T_s = \frac{2P}{\pi LD} \qquad 2$$

Where Ts represents the splitting tensile strength (N/mm^2), P is the maximum applied load (in Newtons), L is the specimen length (mm), and D is the specimen diameter (mm).

Fig. 2: Testing of the cylinder for splitting strength

2.3.5 Tensile strength- Modulus of rupture

The modulus of rupture test was performed on 100mm x 100mm x 500mm beams specimens of concrete containing the sponge gourd fibre at the specified percentages. Testing of specimens took place at 7, 14, 21, 28, 60, and 90 days of curing

Fig. 3: Testing of the beams for modulus of rupture

concrete specimens were cast and cured for 24 hours before testing, with load applied gradually until failure. The maximum load applied is recorded, and the modulus of rupture (Mr) is calculated using equation 3. The tensile strength test of concrete was carried out according to ASTM C1583 standard.

$$TMor = \frac{PL}{bd}2 \qquad 3$$

III. RESULT AND DISCUSSION

4.1 Materials characterisation

The results of mechanical analysis of the fine and coarse aggregate are shown in Figs. 4 and 5.

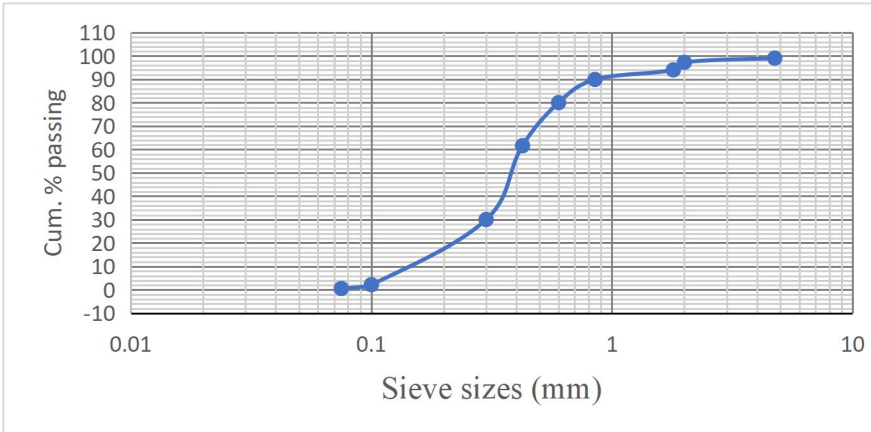

Fig. 4: Particle size distribution analysis of fine aggregate

Fig. 4 shows the Particle Size Distribution Analysis of Fine Aggregate. From the particle size distribution graph of fine aggregate (sand).The graph shows cumulative percentage against sieve sizes (mm). Fig. 4 shows that the fine aggregate is a well graded since the Coefficient of curvature and Uniformity coefficient falls within range.This means the sand is well graded.Fig. 5 shows the Particle Size Distribution Analysis of coarse Aggregate. From the particle size distribution graph of coarse aggregate (gravel)The gradation curve for coarse aggregate particles shows that the aggregate is within the lower and upper limits of the grading requirement for natural aggregates as set out in BS 882(1992).

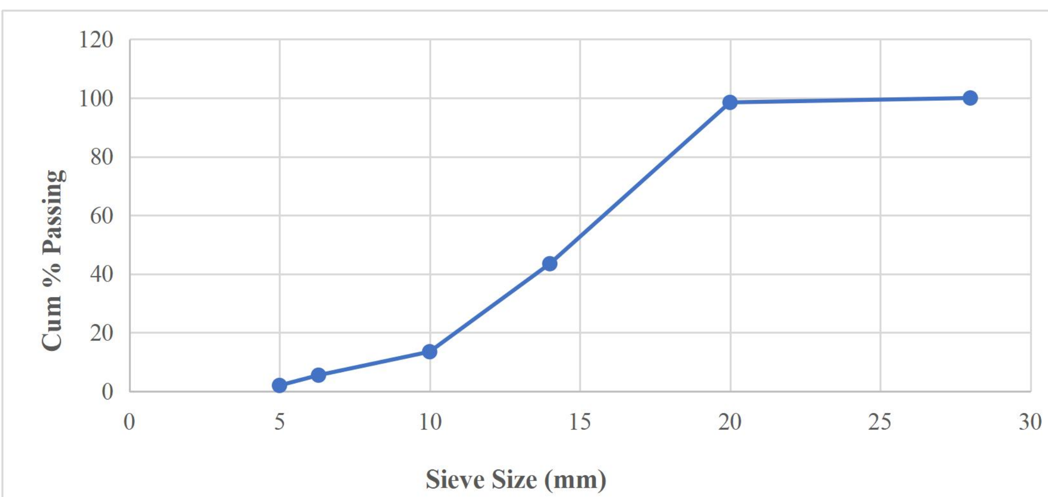

Fig. 5: Particle Size Distribution Analysis of coarse Aggregate

From Fig.5 the coarse aggregate particles are uniformly graded and it is therefore suitable for the production of concrete for construction.

Table 2: properties of fine and coarse aggregates

Property	Fine aggregate	Coarse aggregate
Moisture content	0.0	0.0
Specific gravity	2.78	2.70
Coefficient of Curvatures (Cc)	1.23mm	1.6 mm
Coefficient of Uniformity (Cu)	1.6mm	4.1 mm

Table 2 shows the Properties of fine and coarse Aggregate. Both aggregates are in dry conditions, which could lead to water absorption during concrete mixing.The specific gravities are within the acceptable range for construction. Gradation analysis shows the fine aggregate is well-graded (more uniform in size), while the coarse aggregate is better graded, which is beneficial for concrete workability and strength. Also the physical properties of the sponge gourd fibre (SGF) are shown in Table 3.The physical properties of the sponge gourd fibre (SGF) are shown in Table 3. The table describes the physical properties of sponge gourd fiber (SGF), a natural fiber potentially used in construction or composites.

Table 3.0 : Physical properties of SGF

Properties	Value
Colour	Light brown
Length (mm)	14
Diameter (mm)	0.29
Aspect ratio	48.5
Density (g/cm)	0.63
Water absorption (%)	10.15
Moisture content (%)	5.85

Light brown indicates the natural appearance of the fiber. A light brown color suggests minimal processing and natural characteristics, which could affect aesthetic or compatibility in certain applications. The fiber length is an essential factor in determining the reinforcement properties in composites. A length of 14 mm is relatively short and suggests it may be suitable for reinforcement in small-scale or finely dispersed applications like mortar or thin cement panels. 0.29mm diameter provides better interfacial adhesion with the surrounding matrix in composite materials. Aspect Ratio Value: 48.5 indicate the ratio of length to diameter. Density 0.63 g/cm³ This low density indicates the fiber is lightweight, making it an excellent material for lightweight composite applications. It is much lower than synthetic fibers or aggregates, which contributes to weight reduction in construction materials. A water absorption rate of 10.15% reflects the fiber's ability to retain water. While relatively high, it is typical for natural fibers due to their porosity and cellulose content. High water absorption may affect dimensional stability and durability if not treated. A moisture content of 5.85% indicates the fibre retained moisture under normal conditions. It is critical for understanding drying behavior and compatibility with other materials. High moisture content could lead to swelling or microbial growth.The elemental properties of the sponge gourd fibre (SGF) are shown in Table 4. The table provides the elemental analysis of sponge gourd fiber (SGF), which highlights its chemical composition.

Table 4: The elemental analysis of SGF

Properties	Value
cellulose (%)	63.05
hemicellulose (%)	20.88
lignin (%)	11.69
Ash (%)	0.4

These properties are crucial in understanding its structural and mechanical behavior, especially in applications such as composites or construction materials. A cellulose content of 63.05% reflects a high level, indicating that sponge gourd fiber possesses strong mechanical properties, making it well-suited for use as a reinforcement material in composite applications.A hemicellulose content of 20.88% indicates a moderate level, suggesting a balanced fiber structure that contributes both strength and flexibility ideal for load transfer and impact resistance in composite materials. Hemicellulose is less crystalline than cellulose and can absorb water, which may contribute to the fiber's overall water absorption characteristics. Lignin Value: 11.69%A lignin content of 11% is typical for plant-based fibers and contributes to structural integrity. However, excessive lignin may make fibers brittle. This value suggests that sponge gourd fiber has adequate rigidity while still maintaining some flexibility. A low ash content of 0.4% indicates a minimal presence of inorganic materials, reflecting the sample's high purity which is desirable for applications requiring high purity or reduced thermal degradation. High cellulose content ensures good tensile strength and stiffness, making it suitable for reinforcement in composites. Moderate hemicellulose and lignin contents provide a balance between flexibility and rigidity. Low ash content suggests purity and minimal non-organic impurities.

4.2 Effect of sponge gourd on workability

The results of slump test to assess the effect of sponge gourd fiber on the concrete are presented in Fig. 6. From the Fig.6, it can be seen that the slump reduced with increasing addition of the fibre. Fig 4 shows a loss of 18mm, namely from 20mm to 2mm. This suggests that the level of moisture in the mixture has reduced. The addition of 0.2%-1.0% SGF results in a rather little decrease in slump. Therefore, when the SGF level increases, the more stiffened the mixture becomes. Higher SGF percentages result in a stiffer mix that is harder to work with. The addition of SGF significantly reduces slump height, indicating reduced workability. While this may pose challenges in handling, it can also enhance properties like durability and crack resistance. This is consistent with the findings of Fapohunda and Kilani (2023) and Muhammed (2006).

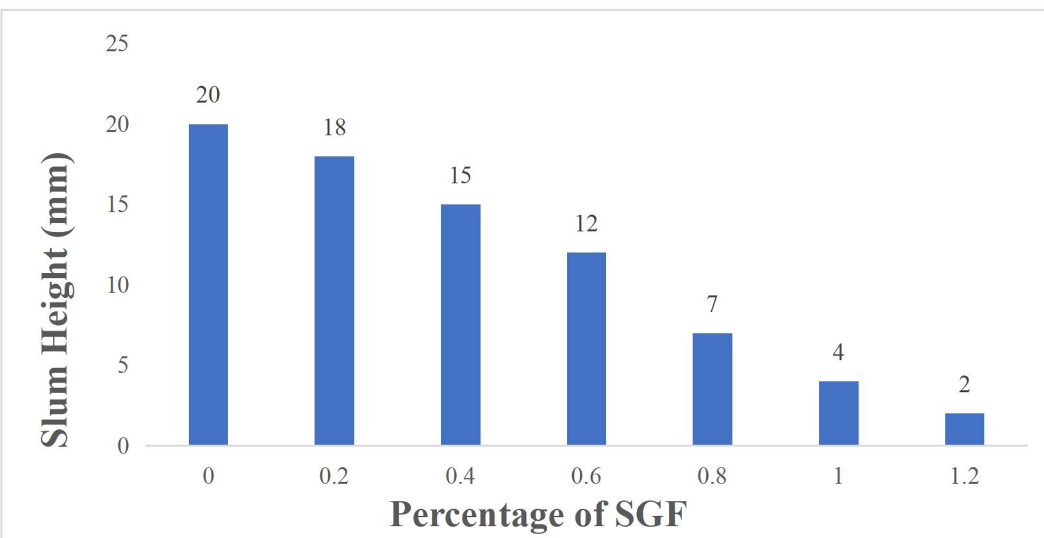

Fig. 6: Slump Height for different levelof SGF

4.3 Effect of sponge gourd on density of concrete

The results of density test to assess the effect of sponge gourd fiber on the concrete are presented in Fig.7. From the Fig.7, it can be seen that SGF Reinforced Concrete Samples gave density within the range of 2252 - 2402 kg/m3, meaning that it is suitable for Normal Weight Structural Concrete production. Above findings are in agreement with Fapohunda and Kilani (2021), Ismail and Yacoob (2011), Ramli and Dawood (2010), Ismail (2009), Mohammed et al (2008). Also since the density of standard concrete is 2,200 - 2,400 kg/m3 according to ACI (American concrete institute), this shows that the concrete can be commonly used for most construction purposes.

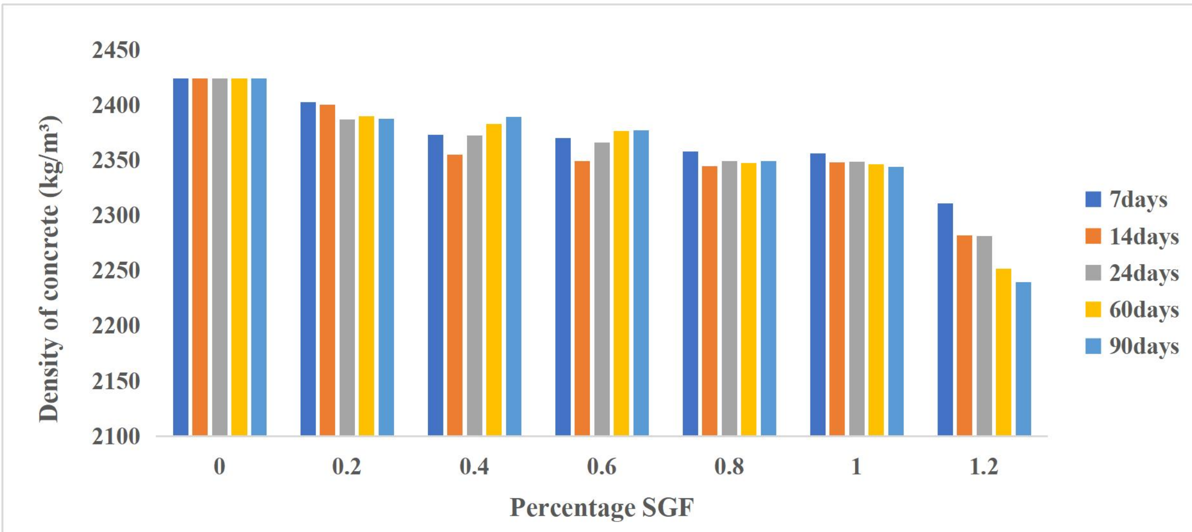

Fig. 7: Density of Concrete Specimen for various percentage of SGF

4.4 Effect of SGF on Compressive strength of concrete

The results of Compressive strength test to assess the effect of sponge gourd fiber on the concrete are presented in Fig.8. One sample with a SGF content of 0.2% achieved the highest compressive strength result of 23.03 MPa after 90 days. Nevertheless, the findings indicated that the inclusion of SGF had a noticeable impact on the concrete sample. Specifically, the samples containing 4% SGF content exhibited the most similar comprehensive strength value (22.65MPa at 28 days) to the Control Sample.This is useful for Foundation elements that won't bear heavy structural loads (such as isolated footings or light retaining walls). It's strong enough for components that aren't exposed to heavy weight, making it more cost-effective (ACI, 2019).

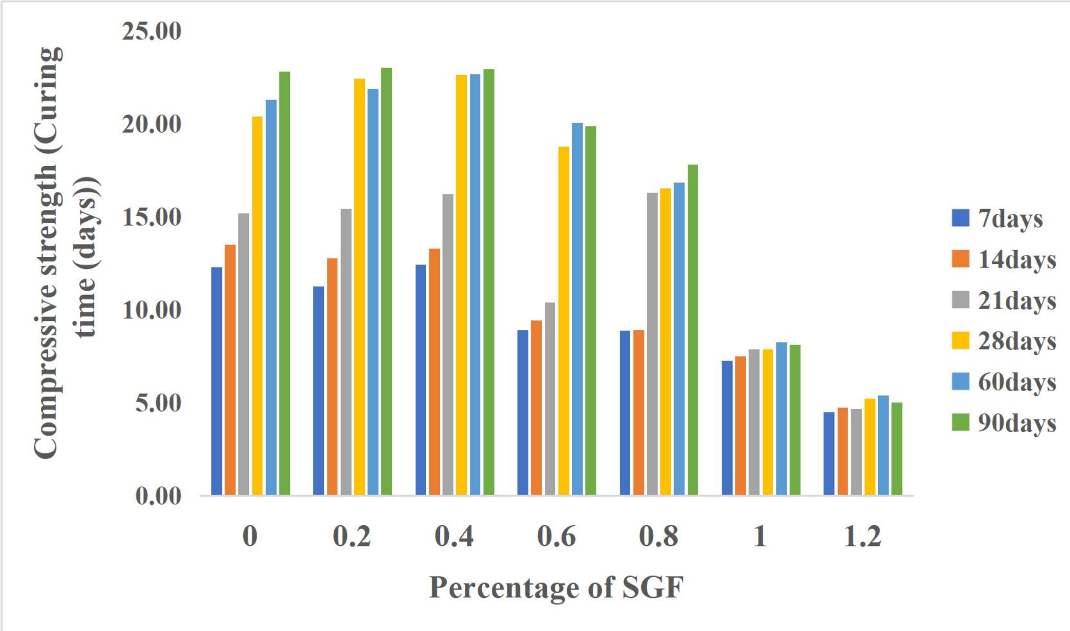

Fig. 8: Compressive test result for cube for various SGF percentage

4.4 Effect of SGF on SplittingTensile Strength of concrete

The results of Splitting Tensile Strength test to assess the effect of sponge gourd fibre on the concrete are presented in Fig.9.The result showed that percentage content of incorporated SGF have influence on concrete sample up to value of 0.4% fibre addition. Concrete samples with SGF have higher Tensile strength of 2.55mpa at 90days with value of 0.4% percentage content than the Control sample. From ASTM C496 Splitting Tensile Strength value for M20 ranges from 2.0 – 2.5 Mpa, SGF can be useful where the concrete is subject to both compressive and tensile stresses to prevent cracking and failure.

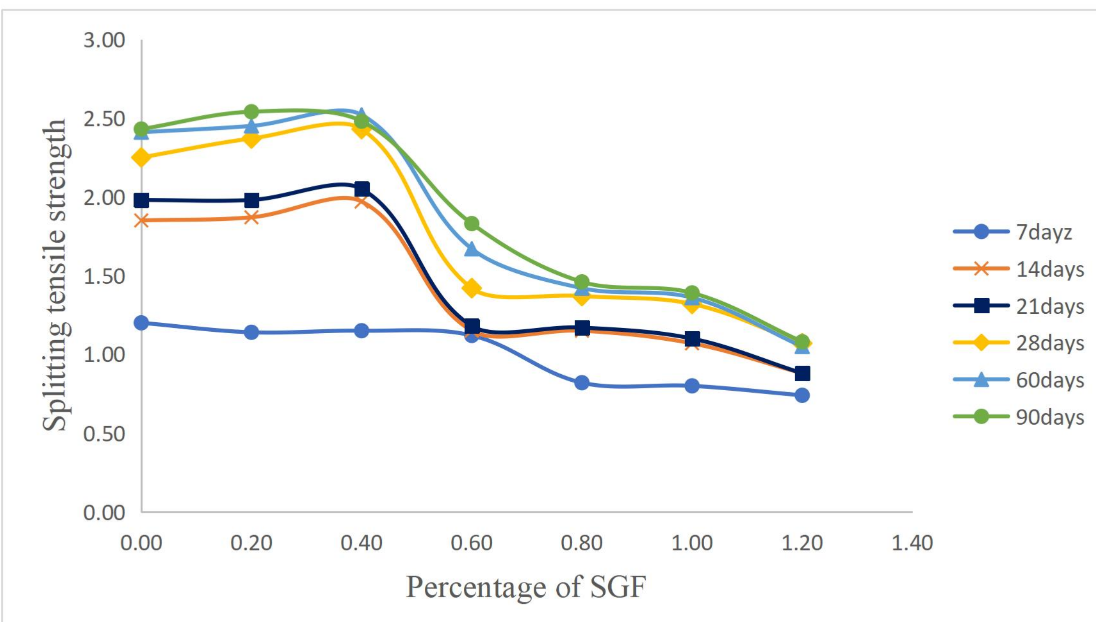

Fig. 9: Splitting tensile strength at different Percentage of SGF for different curing days

4.6 Effect of sponge gourd fibre on Modulus of rupture of concrete

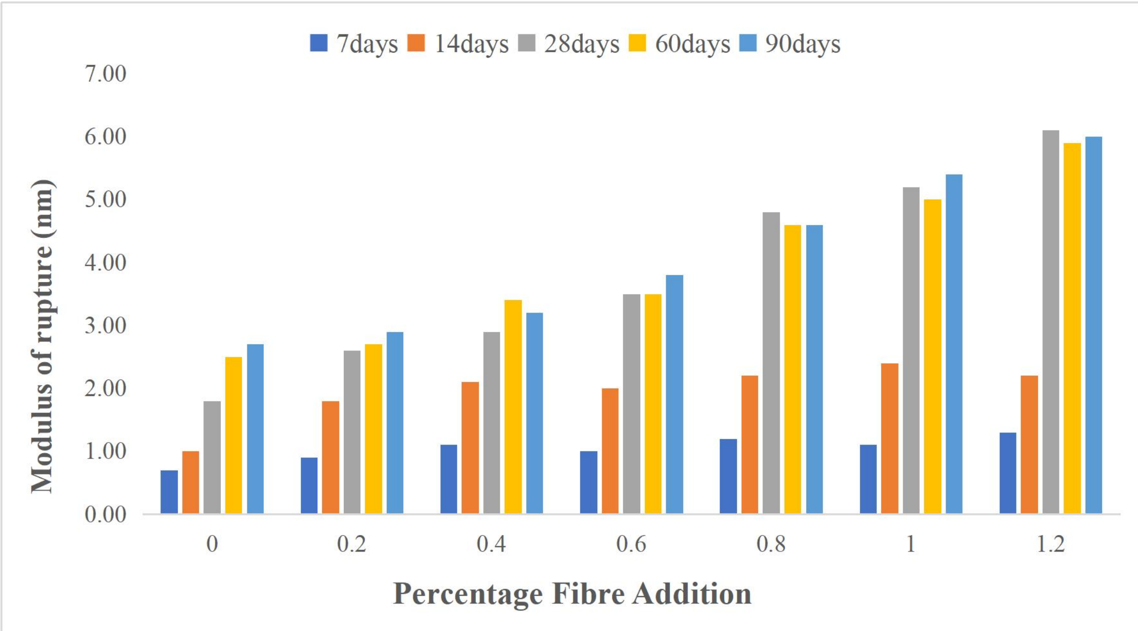

Fig 10: Modulus of rupture of concrete at various fibre addition

The results of Modulus of rupturetest to assess the effect of sponge gourd fibre on the concrete are presented in Fig. 10. Modulus of rupture result shows increase strength, Concrete samples with SGF have higher Tensile strength than the Control samples up to the optimum value of 1.2% percentage content.This shows that the SGF helped in limiting the development of the micro cracks in concrete.

IV. CONCLUSION AND RECOMMENDATION

From the results of this investigation, the followings conclusions are made:

i. Workability of the concrete decreases with increasing proportion of fibre inclusion.
ii. For density the higher the fibre content the lighter the weight of the concrete.
iii. Concrete is weak in compression the fibre increases concrete strength by up to 0.4%
iv. The fibre improves tensile strength by bridging cracks and enhancing materials strength

RECOMMENDATIONS

This study has its own limitations and the following recommendations are made for further studies to improve the current work on SGF.

1. Future study should extend beyond the 90 days experimental period and focus more on the bio-structural behaviour of the incorporated fibre in the concrete.
2. Mechanical properties of fibre in concrete has been established. Experimental focus should be shifted to the influence of SGF on durability properties of incorporated concrete composite.
3. It is advisable that SGF should be chemically treated before incorporating in production of structural concrete for best performance.
4. Optimization of fibre Aspect Ratio is a strong factor in the production of fibre reinforced concrete for best structural performance.
5. Effect of exposure to elevated temperature in concrete containing SGF should be studied.

References

Abd-Al Ftah, R.O., Tayeh, B.A., Abdelsamie, K., & Abdel-Hafez, R.D. (2022). Assessment on structural and mechanical properties of reinforcement concrete beams prepared with luffa cylindrical fibre. Case Studies in Construction Materials, 17(e01283): 1-14. https://doi.org/10.1016/j.cscm.2022.e01283

Alanazi, H. (2022). Study of the interfacial transition zone characteristics of geopolymer and conventional concretes. Gels, 8(2), 105. https://doi.org/10.3390/gels8020105

Ali, H., Jamshaid, H., Mishra, R., Chandan, V., Jirku, P., Kolar, V., Muller, M., Nazari, S., &Shahzada, K. (2023). Optimization of seismic performance in waste fibre reinforced concrete by TOPSIS method. Scientific Report, 13(8204): 1-15. https://doi.org/10.1038/s41598-023-35495-9

Anbukarasi, K., Hussain, S., &Kalaiselvam, S. (2020). Investigation of thermal conductivity of luffa and luffa-coir reinforced epoxy composites. International Journal of Research -Granthaalayah, 8(12), 69-79. https://doi.org/10.29121/granthaalayah.v8.i12.2020.2534

Ashok, K. and Kalaichelvan, K. (2021). Experimental studies on interlaminar shear strength and dynamic mechanical analysis of luffa fiber epoxy composites with nanopbo addition. Journal of Industrial Textiles, 51(3_suppl), 3829S-3854S. https://doi.org/10.1177/15280837211052317

Azaka, O., Umeobi, H., &Obika, E. (2022). Thermophysical properties and grain size effects in luffacylindrica-modified clay composites for thermal insulation. Proceedings of the Institution of Mechanical Engineers Part E Journal of Process Mechanical Engineering, 237(4), 1168-1178. https://doi.org/10.1177/09544089221114507

Chakrabarti, D., Islam, S., Jubair, K., &Sarker, R. (2020). Effect of chemical treatment on the mechanical properties of luffa fiber reinforced epoxy composite. JEA, 01(02), 37-42. https://doi.org/10.38032/jea.2020.02.002

Dong, Y. (2018). Performance assessment and design of ultra-high-performance concrete (UHPC) structures incorporating life-cycle cost and environmental impacts. Const. Build. Mater. 167, 414–425. https://doi.org/10.1016/j.conbuildmat.2018.02.037.

Ighalo, J., Adeniyi, A., Oke, E., Adewoye, L., &Motolani, F. (2020). Evaluation of fibers in a biomass packed bed for the treatment of paint industry effluent before environmental release. European Journal of Sustainable Development Research, 4(4), em0132. https://doi.org/10.29333/ejosdr/8302

Jang, H., Ahn, Y., & Tae, S. (2022). Proposal of major environmental impact categories of construction materials based on life cycle impact assessments. Materials, 15(14), 5047. https://doi.org/10.3390/ma15145047

Jawad, L. and Salih, T. (2020). Theoretical and experimental study to investigate the acoustic absorption performance of natural luffa fibers. ATMPH, 23(13). https://doi.org/10.36295/asro.2020.231305

Kadac-Czapska, K., Knez, E., Gierszewska, M., Olewnik-Kruszkowska, E., &Grembecka, M. (2023). Microplastics derived from food packaging waste—their origin and health risks. Materials, 16(2), 674. https://doi.org/10.3390/ma16020674

Lee, B., Ponraj, M., Widyasamratri, H., & Wang, J. (2021). Green building practices on waste minimization in china construction industry. Industrial and Domestic Waste Management, 1(1), 12-25. https://doi.org/10.53623/idwm.v1i1.36

Makara, Y., Combrinck, R., &Fataar, H. (2022). Behaviour of steel fibre reinforced concrete pavements on a single fibre level. Matec Web of Conferences, 364, 05018. https://doi.org/10.1051/matecconf/202236405018

Meng, Q., Wu, C., Su, Y., Li, J., Liu, J., & Pang, J. (2019). A study of steel wire mesh reinforced high performance geopolymer concrete slabs under blast loading. J. Clean Prod. 210, 1150–1163. https://doi.org/10.1016/j.jclepro.2018.11.083.

Moghayedi, A., Massyn, M., Jeune, K., &Michell, K. (2022). Evaluating the impact of building material selection on the life cycle carbon emissions of south African affordable housing. IOP Conference Series Earth and Environmental Science, 1101(2), 022021. https://doi.org/10.1088/1755-1315/1101/2/022021

Nouri, H., Safehian, M., &Hosseini, S. (2021). Life cycle assessment of earthen materials for low-cost housing a comparison between rammed earth and fired clay bricks. International Journal of Building Pathology and Adaptation, 41(2), 364-377. https://doi.org/10.1108/ijbpa-02-2021-0021

Patra, S. (2021). Effect of gamma irradiation on mechanical properties of poly (lactic) acid–luffa fiber composites. Advanced Materials Proceedings, 3(4), 284-288. https://doi.org/10.5185/amp.2018/403

Psilovikos, T. (2023). The use and re-use of timber structure elements, within a waste hierarchy concept, as a tool towards circular economy for buildings. IOP Conference Series Earth and Environmental Science, 1196(1), 012040. https://doi.org/10.1088/1755-1315/1196/1/012040

Rao, H., Nagabhooshanam, N., Kumar, D., Sahu, S., Indian, R., Jyothirmai, G., &Mohanavel, V. (2023). Dynamic mechanical, ballistic and tribological behavior of Sponge gourd Fiber reinforced coco husk biochar epoxy composite. Polymer Composites, 44(3), 1911-1918. https://doi.org/10.1002/pc.27215

Sahayaraj, A., Muthukrishnan, M., & Ramesh, M. (2022). Influence of tamarindusindica seed nano-powder on properties of luffacylindrica (l.) fruit waste fiber reinforced polymer composites. Polymer Composites, 43(9), 6442-6452. https://doi.org/10.1002/pc.26957

Sovják, R., Fládr, J., Stastka, J., &Frydrýn, M. (2021). Impact response of various concretes at 2.8-second drop shaft. Matec Web of Conferences, 352, 00005. https://doi.org/10.1051/matecconf/202135200005

Suryo, E., Arifi, E., &Zaika, Y. (2021). Study on sliding stability of porous-concrete retaining wall model test subjected to rainfall infiltration. Iop Conference Series Earth and Environmental Science, 930(1), 012101. https://doi.org/10.1088/1755-1315/930/1/012101

Szpetulski, J., Stawiski, B., &Witkowski, P. (2022). Tests regarding the effect of dispersed reinforcement made with a prototype device from pet beverage bottles on the strength properties of concrete. Energies, 15(7), 2415. https://doi.org/10.3390/en15072415

Yaro, A., Kuburi, L., &Moshood, M. (2021). Influence of kaolin filler on the mechanical properties of luffacylindrica/ polyester composite. https://doi.org/10.21203/rs.3.rs-270130/v1

Yaro, A., Kuburi, L., &Moshood, M. (2021). Influence of kaolin particulate and luffacylindrica fiber on the mechanical properties polyester matrix. The International Journal of Advanced Manufacturing Technology, 116(1-2), 139-144. https://doi.org/10.1007/s00170-021-07442-3