ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue I, January 2026

Future of The City: Incorporation of Locust Bean Pod Ash and Groundnut Shell Ash in Self-Consolidating Concrete

[1]Dr. Timothy Oluseyi Odeyale and [2]Precious Ajayi

[1]Department of Architecture, University of Ibadan, Ibadan, Nigeria.

[2]Department of Civil Engineering, University of Ibadan, Ibadan, Nigeria.

DOI : https://doi.org/10.51583/IJLTEMAS.2026.150100043

Received: 16 January 2026; Accepted: 21 January 2026; Published: 29 January 2026

ABSTRACT

The research reports the inclusion of admixture to Self-Consolidating Concrete (SCC) to use locally sourced organic waste material as an alternative building material in reducing the burden of housing provision. Self-Consolidating Concrete (SCC) is a flowable type of concrete that doesn't require mechanical compaction. It uses high paste and fine aggregate content, small coarse aggregate size, and Supplementary Cementitious Materials (SCMs) to achieve this. SCC's adoption in construction projects has increased cement demand, which contributes to CO_2 emissions and environmental issues. SCMs like Locust Bean Pod Ash (LBPA) and Groundnut Shell Ash (GSA) are being studied to improve SCC's properties. In this study, LBPA and GSA were used to replace 20% of cement in SCC mixes. Results indicate that LBPA and GSA are effective pozzolans, but at 20% replacement, they didn't enhance mechanical performance significantly. However, a mix with 75% GSA and 25% LBPA showed comparable performance at 28 days, with compressive strength of 33.64N/mm^2 and split tensile strength of 3.91N/mm^2. The fresh properties of the SCC mixes met EFNARC standards.

Keywords: Eco-friendly materials; Groundnut Shell Ash (GSA), City futures; Housing provision; Locust Beans Pod Ash (LBPA); Self-Consolidating Concrete (SCC); Supplementary Cementitious materials (SCMs).

INTRODUCTION

Self-consolidating concrete (SCC) is a type of concrete made with selected aggregates and admixtures to have a flowability that allows it to fill spaces, no matter how tightly spaced the reinforcement bars are, without the use of mechanical compaction or vibration, making it very workable (Meena, Singh and Singh, 2023). Concrete, a composite material composed primarily of water, aggregate (gravel, sand, or rock), and cement, has been revered as one of the most influential building substances in human history. Its versatility, durability, and affordability have made it a cornerstone of modern construction, playing a pivotal role in the development of infrastructure, urbanisation, and architectural advancements across the globe. This makes the concrete achieve full consolidation in heavily reinforced members like bridge decks or abutments, tunnel linings or tubing segments, where it is difficult to vibrate the concrete (Faraj, Mohammed and Omer, 2022). As cities aspire to become smarter and more sustainable, concrete will play a crucial role in integrating technology and green practices into urban planning. The development of eco-friendly concrete alternatives and the adoption of smart concrete, equipped with sensors to monitor structural health, will contribute to safer and more efficient urban environments. Since the invention of SCC in the early 1980s due to labour shortage (Kiran and Nagaraja, 2019) and also to increase the uniformity and reliability of concrete (Hossain, Hossain and Manzur, 2020), it has found increased use in all European countries due to the EC funded multi-national project that promoted its use (Looney, Arezoumandi, Volz and Myers 2012). In 1994, five European organisations: the Federation of the European Precast Concrete Industry (BIBM), the European Cement Association (CEMBUREAU), Electrical company (ERMCO), the European Federation of Concrete Admixtures Associations (EFCA) and the European Federation of National Associations Representing Producers and Applicators of Specialist Building Products for Concrete (EFNARC), all dedicated to the promotion of

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue I, January 2026

advanced materials and systems for the supply and use of concrete, created a "European Project Group" to review current best practices and produce a new document covering all aspects of SCC (Murthy, Rao, Ramana and Vijaya, 2012). And there is a growing concern for the immediate impact of materials usage in the attainment of SDG goals in the developing world (Wang, Dang, Bai, et al. 2025; Han et al, 2022; Odeyale and Kehinde, 2015). In Nigeria, the use of this type of concrete is less pronounced due to the availability of labour force, little or no attention to noise pollution and the effect on the environment among others, the growing infrastructural development will necessitate the use of such concrete as heavy reinforcement will make the use of mechanical vibrators a bit difficult and also slow down casting operations and even the overall construction process. SCC helps to reduce construction time, noise pollution and promotes safety on site (Meko, Ighalo and Ofuyatan, 2021; Felekoglu, Turkel and Baradan, 2007). One sector that will immensely benefit from the full adoption of the use of SCC is the oil sector. The robustness of structures that are utilised in oil exploration and refinery, albeit concrete, demands being heavily reinforced. By being heavily reinforced, mechanical compaction becomes a bit difficult, and there will be a further need to prevent the ingress of corrosive seawater from damaging the reinforcements. Mangi et al. (2020 reported that natural seawater has good and bad effects on concrete and that using Supplementary Cementitious Materials (SCMs) can improve concrete resistance and increase concrete's strength and durability.

The design of Self Compacting Concrete is based on adding or partially replacing Portland cement with varying percentages of fine material known as admixtures, such as fly ash, blast furnace slag, and silica fume without modifying the water content compared to common concrete which changes the rheological behaviour of the concrete (Johansen and Hammer, 2002; Cook, 1981; Dunstan, 1980). These admixtures are pozzolanic. A pozzolan is a siliceous or alumino-siliceous (aluminous and siliceous) material which in itself, has little or no cementitious property but when in ground form and the presence of water, reacts chemically with alkali and alkaline earth hydroxide at ordinary temperatures to form or assist in forming compounds possessing cementitious properties (British Standards Institution BS EN 197-1 2000; Omoniyi and Akinyemi, 2012). Pozzolanic materials will form calcium silicate cement when they react with soil particles in the water. Pozzolans can be natural or artificial; the natural pozzolans are of volcanic origin, such as volcanic ashes, tuffs and other diatomaceous earth, agricultural and mine wastes. Artificial pozzolans, on the other hand, can be industrial by-products like blast furnace slag, fly ash and silica fume, which are available in large quantities or obtained from agriculture-based industries (Ikumapayi, 2018). The cementing agents are the same as in the case of Portland cement; however, in Portland cement, the calcium silicate gel is formed from the hydration of anhydrous calcium silicate (cement) (Akpenpuun et al. 2019). This research focuses on using natural pozzolans of two different classes, which are Groundnut Shell Ash (GSA) and Locust bean pod Ash (LBPA), as admixtures.

After the extraction of locust bean seed from the pod, the pod is usually discarded and burnt, and the ashes are dumped in landfills (Tangchirapat et al., 2009; Adama and Jimoh, 2012). For a by-product known to have cementitious properties, it is much better to have the waste pod burnt under controlled conditions to maintain these properties (Ogunbode et al, 2011). Research works have shown that despite the good pozzolanic properties of LBPA, it significantly hampers the strength of concrete with an increase in the percentage replacement of cement. Adejoh, Abubakar and Abubakar (2017). reported that the compressive strength reduced as the percentage replacement of cement with LBPA increased; thereby recommending 5-10% for different concrete grades and 15% replacement for lighter structures. Akpenpuun et al. (2019) studied the effect of cement replacement with locust bean pod ash (LBPA) as supplementary cementitious material on the mechanical and structural characteristics of mortars. They reported that LBPA is a suitable SCM for producing medium-strength concrete. Microstructural analysis revealed fewer voids and pores, and dense CSH gels helped maintain the optimum compressive strength at the 15% LBPA cement replacement level of the mortar. Auta and Kabiru (2020) recommended that a 5% replacement of cement with LBPA be adopted for concrete, having confirmed the good pozzolanic properties of the admixture.

Groundnut Shell Ash has been proven to be a good pozzolan in concrete. With the use of GSA in concrete, the cost of concrete production will decrease, and environmental pollution will be reduced. GSA has better pozzolanic properties as it contains oxides. The pozzolanic activity of ash increases with time, and the addition of GSA in cement concrete may reduce drying shrinkage and water absorption, but increase the setting time,

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue I, January 2026

which is because of the slow reactivity of GSA. The presence of GSA may block the existing pore structure of concrete and thereby increase its strength and reduce permeability (Nadiminti and Polinati, 2017). Ikumapayi's (2018) research showed that the application of 12% GSA blended OPC cement in concrete increases the resistance of such concrete to chloride ion penetration.GSA has been extensively used to improve the fresh and hardened properties of SCC. In mortar, as in the case of blocks, a 20% replacement of cement with GSA gives a strength within the standard limits (Mahmoud et al., 2012). Rathod and Mahure (2016) also reported satisfactory results after replacing cement partially with GSA based on the premise that GSA has the same chemical composition as Ordinary Portland Cement (OPC). Buari et al. (2019) reported the suitability of GSA as SCM in Self-Consolidating High-Performance Concrete (SCHPC) as it improved the fresh and hardened properties of concrete.

This research work aims to evaluate the rheological properties of SCC having GSA and LBPA as supplementary cementitious materials to partially replace cement in the mix, while also checking the mechanical properties. This is done with the ultimate goal of improving the performance of LBPA in SCC using GSA as a viable supplement.

MATERIALS AND METHODOLOGY

Materials

Cement: The cement used was Portland Limestone Cement CEM II grade 43. Usually with a Specific Gravity of 3.15.

Locust Beans Pod Ash (LBPA): The Locust Beans Pod was obtained from Iludun Ekiti, Ekiti State, Nigeria. It was sun-dried for days before being incinerated under controlled conditions at Federal Polytechnic, Ado-Ekiti, in a kiln to convert it to ash. The ash was later ground to get finer particles. The Specific gravity of GSA was determined using the specifications of BS 812:2, EN 12390-7.

Groundnut Shell Ash (GSA): The groundnut shell was obtained from Niger State and was sun-dried for days to ensure dryness, after which it was burnt in a kiln at Federal Polytechnic, Ado Ekiti. After that, the burnt shell was ground to derive finer particles. The Specific gravity of GSA was determined using the specifications of BS 812:2, EN 12390-7. Fine aggregate: River sand was obtained from a local sand deposit and was stored under a shade to ensure surface dryness of the material. Following BS812, tests were conducted to investigate the particle size distribution, specific gravity and water absorption. Coarse aggregate: Granite was used, and it was obtained from the quarry. The granite stones underwent sieve analysis, passing through a 20 mm sieve and retained in a 5mm sieve to ensure that the size range of 12mm - 16mm aggregates was used. In accordance with BS 812, tests were conducted to investigate the particle size distribution, specific gravity and water absorption.

High Range Water Reducer (HRWR): The Superplasticiser used was Conplast SP 430, which was purchased from Lagos, and 0.9% of the cement weight of the admixture was added for improved workability.Water: Potable water was obtained from the school premises (University of Ibadan). The water was clean and sure to be free of impurities and deleterious materials that could affect the strength and durability of the concrete.

Methodology

Mix design was developed according to specifications in the EFNARC standard and also following the empirical work done by Murthy et. al. (2012), and the mix design is shown in Table 2.1. The materials were batched by weight, after which each run was poured into the mixer and allowed to mix for about 2 minutes. The matrix was then poured into the V-funnel, L-Box and slump cone to get the flow time, passing ability and flow diameter, respectively, before being cast into cubes and cylinders. 24 hours after casting, the concrete cubes and cylinders were removed from the formwork. The weight of each specimen was taken before the samples were submerged in water for curing.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue I, January 2026

Table 1: Mix Design for Constituent Materials

Sample No.	Designation of Mix Proportion	Binder (Kg/ m^3)	Cement (Kg/ m^3)	LBPA (Kg/ m^3)	GSA (Kg/ m^3)	Sand (Kg/ m^3)	Granite (Kg/ m^3)	Water (l/ m^3)	SP (l/ m^3)
1	L0+G0	527	527	0	0	834	723.6	200.26	4.743
2	L20+G0	515	412	103	0	834	723.6	195.71	4.635
3	L15+G5	512	409.6	76.8	25.6	834	723.6	194.56	4.608
4	L10+G10	510	408	51	51	834	723.6	193.8	4.59
5	L5+G15	507	405.6	25.35	76.05	834	723.6	192.66	4.563
6	L0+G20	504	403.2	0	100.8	834	723.6	191.52	4.536

Source: Author's Fieldwork, 2025

The fresh and hardened properties of the experimental runs were tested by carrying out the slump flow, V-funnel, L-Box, compressive strength, split tensile strength and water absorption tests. After adding water and HRWR to each sample, the fresh properties were investigated to ascertain the conformation of the samples with the EFNARC standard. After 7 and 28 days, the compressive strength and split tensile strength were measured. Also, the water absorption test was conducted to check the permeability of each sample.

RESULTS AND DISCUSSION

Slump flow, V-funnel and L-Box

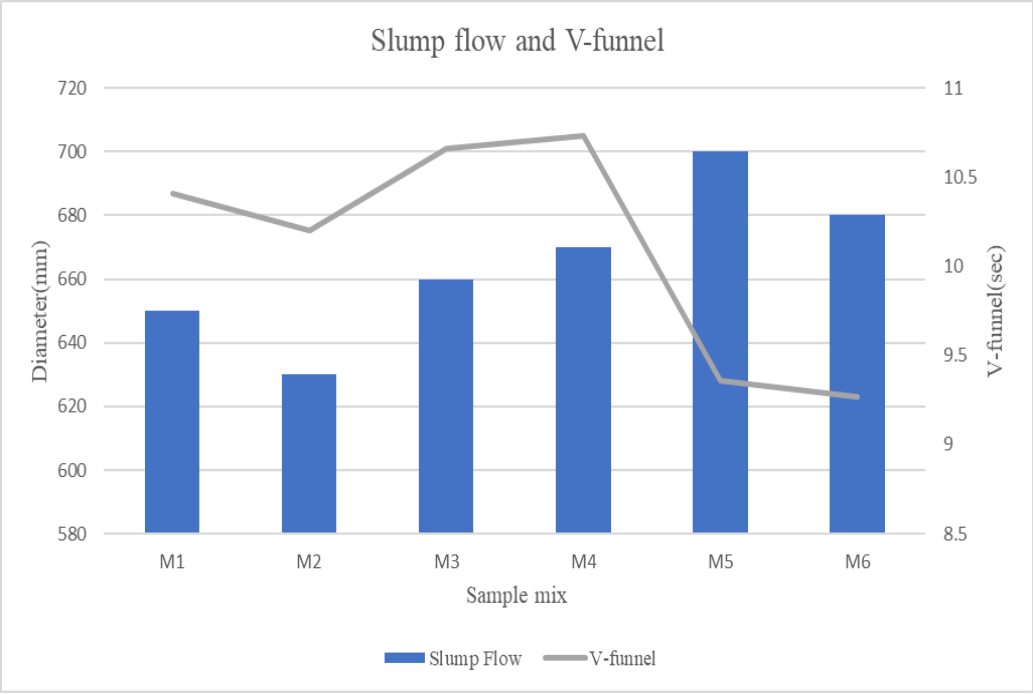


Figure 1: Slump flow and V-funnel result chart

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue I, January 2026

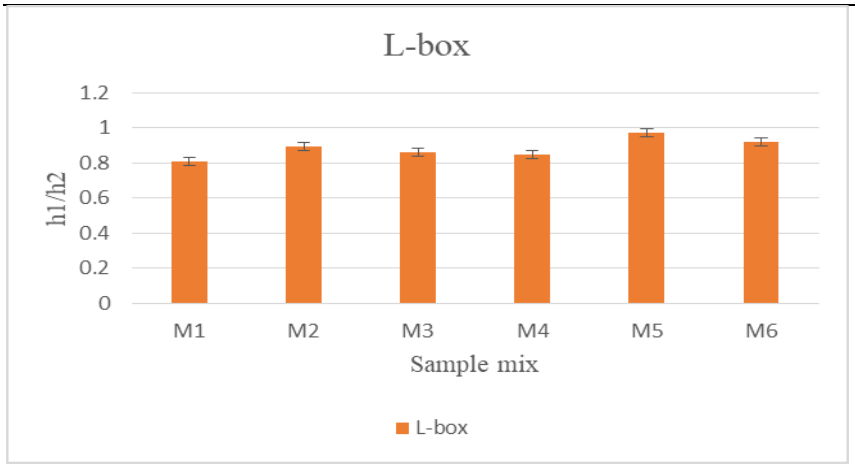


Figure 2: L-Box result chart

Figure 1 shows the slump flow and V-funnel time of the different mixes. With the slump flow ranging from 630mm to 700mm, it is within the EFNARC standard (shown in Table 1) and is therefore satisfactory. The control sample has a slump flow of 650mm, while M2 had the smallest flow of 630mm. This can be attributed to the increased water demand of the mix as the LBPA, which partially replaced cement, increased the surface area of the mix. The flowability of the concrete is reduced with increased LBPA content due to the large surface area of LBPA and the increased volume of binder as a result of the low specific gravity of LBPA, thereby resulting in higher water demand. However, the increase in GSA resulted in better flowability, albeit below the control mix, which had no SCM content. These findings corroborate those of Guneyisi and Gesoglu (2008), Mandandoust and Mousavi (2012), as they made use of Metakaolin (MK) and Ofuyatan *et al.* (2019). Conversely, Bheel *et al.* (2021) reported a reduction in slump flow as the percentage of SCM in the matrix increased. By use of High Range Water Reducer (HRWR), the flowability is improved by reducing yielding stress and plastic viscosity through liquefying action. All slump flow can be categorised under class 2 (SF2) as specified in the EFNARC standard. This flow class is used for walls and columns.

Similarly, the V-funnel test is presented in Table 1 above and charted in Figures 1 and 2 based on the results obtained. The V-funnel flow time ranges from 8.27 to 10.73 while varying the LBPA and GSA content. The range of the flow time is within the limit specified by EFNARC, thereby passing it as satisfactory. The minimum flow time was M6, which has a 20% replacement of cement with GSA. The maximum is M4, which shows that the incorporation of ashes, due to the reasons stated for the slump flow diameter, increases the flow time of the concrete through the V-funnel. The reduced workability properties are a result of the specific surface area of LBPA and GSA, which causes higher cohesiveness (Bheel et al, 2021). Arun *et al.* (2019 and Guneyisi and Gesoglu (2008 also discovered that the V-funnel flow time of SCC mixes increases with increasing SCMs in the mix. In this particular case, wherein the percentage replacement is the same, the volume of the ashes plays a role in the fresh properties of the concrete.

Water Absorption

The water absorption test was carried out to investigate the durability performance of the concrete mixes. It is expected that well-consolidated concrete should have water resistance ability, which will prevent the influx of acid, sulphates and some soluble deleterious materials that will hamper the performance of the mix. Figure 3 shows the rate of water absorption of the mixed samples. M2 absorbed the largest percentage of water due to its porosity, as shown by the compressive strength result. M3 and M4 showed relatively similar characteristics in water absorption, with about a 1.2% increase in weight due to water gained. With a percentage absorption of 0.28% and 0.33% for M5 and M6, respectively, it shows a relatively low water absorption rate compared to M1, which has a percentage of 0.16%. It could be noticed from the trend that with the increasing composition of GSA in the matrix, the water absorption is reduced. This suggests that GSA is more capable of filling pore spaces in concrete than LBPA. M5 also reinforces that a combination of the two SCMs (at the 75% and 15% replacement ratio) is good for the compactness of SCC.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue I, January 2026

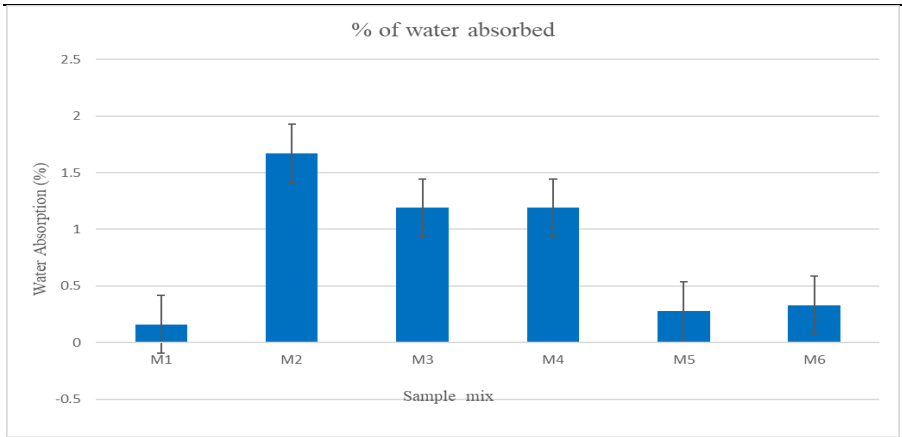


Figure 3: Water absorption of the sample mixes

Compressive Strength

Figure 4 shows the result of the compressive strength of the concrete mixes at 7 and 28 days. Outside the control mix, it was observed that the M5 and M6 mix gained rapid initial strength on day 7. This is in line with the observations of Rathod and Mahure (2016); M2 and M3, on the other hand, had a low initial strength. This may be due to the expansive swelling that occurred during the setting of the matrices; this swelling created air pore spaces in the concrete, which significantly weakened the concrete.

At 28 days, there is an increase in the strength of all the samples as expected. M2, being the pure LBPA incorporated mix, had the highest percentage of strength gain at 73%, while M5 had the least at 51%. Although M2 had the lowest compressive strength on day 28, just as on day 7, the percentage strength gain shows the quality of LBPA as a Class F pozzolan to gain strength over time by retarding the rate of hydration, thereby reducing cracks cause for heat emission, which, over time; this, in turn, helps the long-term performance of the concrete matrix. M6, which is the mix purely incorporated with GSA, can be seen to have the least percentage gain of strength at 28 days (37%). M6, the best-performing matrix among the SCM-incorporated matrices, has a strength gain of 51%, which is quite similar to the control mix. This result is quite different from the findings of Onuegbu *et al.* (2018 who made use of industrial wastes in pulverised fuel ash and carbide. At 20% replacement, pulverised ash and quarry dust increased the strength of the SCC, while carbide waste reduced the compressive strength of the SCC (Daczko and Vachon, 2006).

Overall, the blending of LBPA and GSA improved the structural performance of the SCM-incorporated sample. There was an increase in compressive strength with an increasing percentage composition of GSA until M5(15% GSA + 5% LBPA), making M5 the optimum combination of both SCMs.

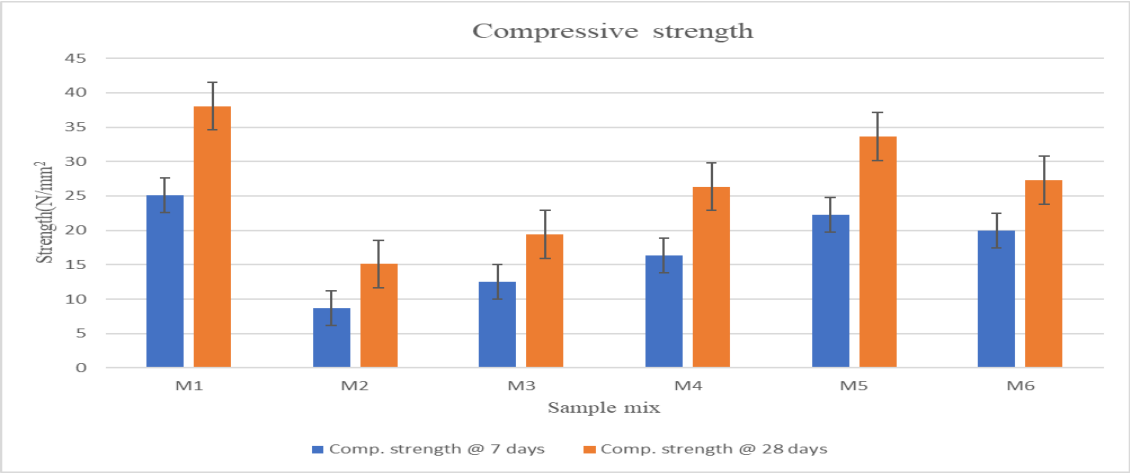


Figure 4: Compressive strength at 7 and 28 days

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue I, January 2026

Split Tensile Strength

According to the split tensile strength results presented in Figure 5, the concrete mixes incorporating supplementary cementitious materials (SCMs) such as GSA and LBPA exhibited lower strengths compared to the control mix (M1), which did not contain any SCMs. The control mix achieved a maximum split tensile strength of 4.33 N/mm^2, while the lowest value of 2.42N/mm^2 was recorded for M2. Among the concrete mixes containing SCMs, M5 exhibited the highest split tensile strength of 3.91 N/mm^2.

It is worth noting that M5, which comprised 75% GSA and 25% LBPA as partial replacements for 20% of cement, demonstrated the best overall performance. Hence, it can be inferred that this mix proportion is optimal for utilising these pozzolanic SCMs. In summary, the addition of SCMs to concrete can impact its mechanical properties, as observed from the split tensile strength results. Nevertheless, the use of GSA and LBPA as partial replacements for cement can enhance the overall performance of concrete, with M5 exhibiting the best results. These findings can inform future concrete mix designs that aim to utilise these pozzolanic materials as SCMs.

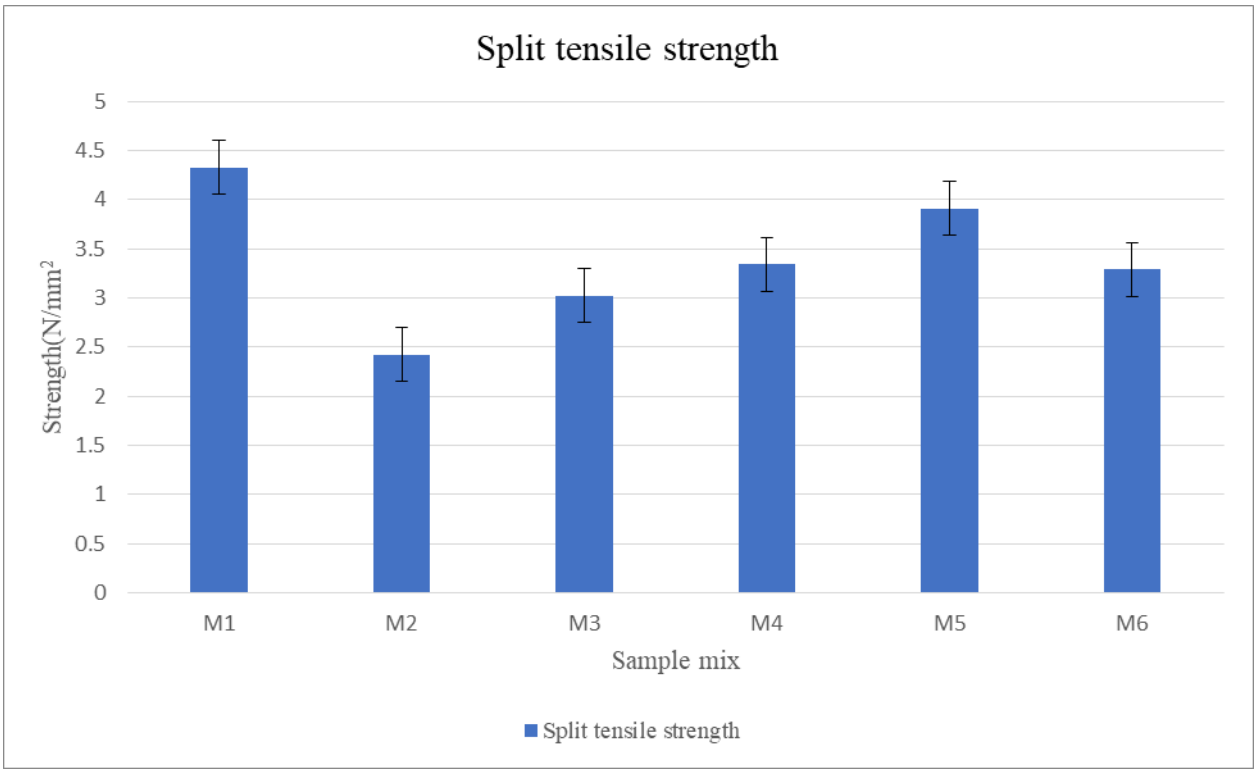


Figure 5: Split tensile strength result

CONCLUSION

Concrete's significance as a global material cannot be overstated. Its adaptability, resilience, and economic value have cemented its role as an indispensable component of modern civilisation. As the world continues to evolve, so too will the applications and innovations surrounding concrete, ensuring it remains a foundational element in building a sustainable and prosperous future. However, LBPA and GSA are good pozzolans that improve the fresh properties of concrete. At 20%, LBPA significantly weakens the concrete. A combination of LBPA and GSA in concrete improves its performance, as seen with an increasing percentage composition of GSA; the mechanical properties of concrete improved. The optimum mix proportion of LBPA and GSA is M5 (75:25), which produced the highest strength for the SCM-incorporated mixes compared to the control mix. Due to its early strength gain properties, GSA can be used for works that require quick initial strength as retrofitting. Mixing with LBPA allows for better acquisition of strength in the long term, as evidenced in M5 and M6. LBPA, on the other hand, gains strength slowly over time, making it a good recommendation for long-term work as it continues to strengthen with longer days.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue I, January 2026

REFERENCES

1. Adama, A. Y., and Y. A. Jimoh. 2012. Effect of locust bean pod ash on strength properties of weak soils. AU Journal of Technology, 16.1: 21–35.
2. Adejoh, B.O., Abubakar M.A., Abubakar S.K. 2017. Suitability Of Locust Beans Waste Ash as a Replacement for Cement in Concrete. Journal of Physical Science and Innovation ISSN: 2277-0119, 9. 4.
3. Akpenpuun, T.D., Akinyemi B., Olamide, O., Aladegboye, J.O., Adesina, O.I. 2019. Mechanical and structural characteristics of cement mortars blended with locust bean pod ash; Journal of Applied Sciences and Environmental Management.
4. Arun B.R., Nagaraja P.S. and Srishaila J.M. 2019. An Effect of NaOH Molarity on Fly Ash—Metakaolin-Based Self-Compacting Geopolymer Concrete, Springer, Singapore. pp. 233–244.
5. Auta, S.M. and Kabiru, A. 2020. Effect of Locust Bean Pod Epicarp Ash (LBPEA) on the Compressive Strength of Revibrated Concrete; Construction of Unique Buildings and Structures, 90.9002.
6. Bheel N., Paul Awoyera P., T. Tafsirojjaman T., Sor N.H., Sohu S. 2021. Synergic effect of metakaolin and groundnut shell ash on the behaviour of fly ash-based self-
7. British Adopted European Standard BS EN 197-1: (2000). Cement. Composition, Specification and Conformity Criteria for Common Cements, United Kingdom.
8. Cook J. E. 1981. A Ready-Mixed Concrete Company's Experience with Class C Ash. National Ready-Mix Concrete Association, Publication No. 163, Silver Spring, Maryland.
9. Daczko, J., and Vachon, M. 2006. ‘‘Self-consolidating concrete (SCC)’’, significance of tests and properties of concrete and concrete-making materials STP 169D (pp. 637–645). West Conshohocken: ASTM International.
10. Dunstan E. R., Jr. 1980. A Possible Method for Identifying Fly Ashes That Will Improve Sulfate Resistance of Concrete. Cement, Concrete and Aggregates, Volume 2, No. 1, American Society for Testing and Materials, West Conshohocken, Pennsylvania.
11. Faraj R.H., Mohammed A.A., Omer K.M. 2022. Self-compacting concrete composites modified with nanoparticles: A comprehensive review, analysis and modelling. Journal of Building Engineering. 2022; 50:104170. https://doi.org/10.1016/j.jobe.2022.104170.
12. Felekoglu B, Turkel S, Baradan B. 2007. Effect of water/cement ratio on the fresh and hardened properties of self-compacting concrete. Build Environ; 42: 1795–802.
13. Guneyisi E, Gesoglu M. 2008. Properties of self-compacting mortars with binary and ternary cementitious blends of fly ash and metakaolin. Mater Struct; 41:1519–31.
14. Han, L., Lu, L., Lu, J., Liu, X., Zhang, S., Luo, K., He, D., Wang, P., Guo, H., & Li, Q. 2022. Assessing spatiotemporal changes of SDG indicators at the neighbourhood level in Guilin, China: A geospatial big data approach. Remote Sensing, 14(19), 4985. https://doi.org/10.3390/rs14194985.
15. Hossain K.M.A., Hossain M.A. and Manzur T. 2020. Structural Performance of Fibre-reinforced lightweight self-compacting concrete beams subjected to accelerated corrosion. Journal of Building Engineering Vol 30, 101291.https://doi.org/10.1016/j.jobe.2020.101291.
16. Ikumapayi, C. M. (2018). Properties of Groundnut Shell (Arachis Hypogaea) Ash Blended Portland cement; J. Appl. Sci. Environ. Manage, 22.10: 1553–1556 https://dx.doi.org/10.4314/jasem.v22i10.03
17. Johansen, K. and Hammer, T. A. 2002. Drying Shrinkage of Norwegian Self-Compacting Concrete, SINTEF Trondheim.
18. Kiran B., Nagaraja P.S. 2019. Fresh Properties of Self-Consolidating Concrete Using SCM. International Journal of Engineering and Applied Sciences (IJEAS) ISSN: 2394-3661, 6.4.
19. Looney T.J., Arezoumandi M., Volz J.S., and Myers J.J. 2012. An Experimental Study on Bond Strength of Reinforcing Steel in Self-Consolidating Concrete International Journal of Concrete Structures and Materials Vol 6, No.3, pp.187–197. DOI 10.1007/s40069-012-0017-9.
20. Madandoust, R. and Mousavi, S. 2012). Fresh and hardened properties of self-compacting concrete containing metakaolin. Construction and Building Materials 55. pp 752-760.
21. Mahmoud H., Belel Z.A. and Nwakaire C. (2012). Groundnut shell ash as a partial replacement of cement in sandcrete blocks production. International Journal of Development and Sustainability.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue I, January 2026

Online ISSN: 2186-8662 – www.isdsnet.com/ijds. Volume 1 Number 3. pp 1026-1032. ISDS Article ID: IJDS12092703.

22. Mangi, S.A., Makhija, A., Raza, M.S., Khahro, S.H. and Jhatial, A.A 2020. A Comprehensive Review on Effects of Seawater on Engineering Properties of Concrete. Silicon 13, 4519–4526 (2021). https://doi.org/10.1007/s12633-020-00724-7.
23. Meena A., Singh N., Singh S.P. 2023. High-volume fly ash Self-Consolidating Concrete with coal bottom ash and recycled concrete aggregates: Fresh, mechanical and microstructural properties. Journal of Building Engineering 63 105447.
24. Meko, B., Ighalo, J.O., Ofuyatan, M.O., 2021. Enhancement of Self-Compatibility of Fresh Self-Compacting Concrete: A Review. Cleaner Materials 1, 100019.
25. Murthy N. K., Rao N. A., Ramana I.V. and Vijaya S. M. 2012 Mix Design Procedure for Self-Compacting Concrete; IOSR Journal of Engineering (IOSRJEN) e-ISSN: 2250-3021, p-ISSN: 2278-8719, www.iosrjen.org, 2. 9: 33-41.
26. Nadiminti V.L., Polinati S.S., 2017. Study on partial replacement of groundnut shell ash with cement; Challenge Journal of Concrete Research Letters 8 (3). pp 84–90.
27. Odeyale, T.O. and Kehinde, O. 2015 "Millennium Development Goals: Impact of Sustainability Discourses, Conflict and Inter-Governmental Actions in the Built Environment", International Journal of Engineering and Technology Research (IJETR), 5 (2): 95-108. (ISSN 2329-7309).
28. Ofuyatan O.M., Olowofoyeku A.M., Edeki S.O., Oluwafemi J., Ajao A. and David O. 2019. Incorporation of Silica Fume and Metakaolin on Self-Compacting Concrete; International Conference on Engineering for Sustainable World Journal of Physics: Conference Series. doi:10.1088/1742-6596/1378/4/042089.
29. Ogunbode, E.B., Hassan, I.O., Isa, R.B. 2011. An Evaluation of Compressive Strength of Concrete made with Rice Husk Ash obtained by Open-Air Burning. Environmental Technology and Science Journal, 4.1: 137-147.
30. Omoniyi, T. E., and B. A. Akinyemi. 2012. Durability-based suitability of bagasse-cement composite for roofing sheets. Journal of Civil Engineering and Construction Technology, 3.11: 280–290.
31. Onuegbu. O. U, Nwoji C. U., Onyia, M.E., Gber, A., Tarzomon, T.T. and Ogbo E. H, 2018. Development of Self-Compacting Concrete using Industrial Waste as Mineral and Chemical Additives; IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 15, Issue 5 Ver. III pp 45-58.
32. Rathod, S. U. and Mahure, S. H. 2016. Study of Effects of Groundnut Shell Ash (GSA) on Fresh and Hardened Properties of Self-Compacting Concrete; IJSRD - International Journal for Scientific Research & Development| Vol. 4, Issue 06, ISSN (online): 2321-0613.
33. Tangchirapat, W., Jaturapitakkul, C., and Chindaprasirt, P. 2009. Use of palm oil fuel ash as a supplementary cementitious material for producing high-strength concrete. Construction and Building Materials, 23.7: 2641–2646.
34. Wang, K., Dang, X., Bai, J., Jing, H and Guilong T. 2025. The relationship between urban land expansion and spatiotemporal dynamics of SDG 11.7: evidence from Xi'an, China. Environmental Development and Sustainability. https://doi.org/10.1007/s10668-025-05982-2.