



COMPARATIVE ANALYSIS OF POLYMER CONCRETE FORMULATED FROM LOW-DENSITY POLYETHYLENE POLYMERS

¹ Ikumapayi, C. M., ¹ Oyerogba A. O., ¹ Asotie D. I. and ^{1,2} Ajayi J. A.

¹ Department of Civil and Environmental Engineering, Federal university of Technology Akure, Ondo State, Nigeria.

² Department of Civil Engineering, Elizade University, Ilara-Mokin, Nigeria.

*Corresponding author: cmikumapayi@futa.edu.ng or josfeb01@gmail.com

Ikumapayi, C. M., Oyerogba A. O., Asotie D. I. and Ajayi J. (2026). Comparative analysis of Polymer Concrete formulated from Low-Density Polyethylene Polymers. FUTA Journal of Engineering and Engineering Technology 20(1), 21-28

Received Date: 15.01.2025

Accepted Date: 10.02.2026

Abstract

Research into the sustainable use of polymers as building materials in the construction sector has become necessary due to the growing costs associated with conventional building or construction materials and the issue of polymer waste management in Nigeria. Using recycled Low-Density Polyethylene (LDPE) and epoxy resin as polymer binders, the study investigates the creation and performance assessment of polymer concrete. A volumetric mix ratio of 1:1.5:2 for binder, fine aggregate, and coarse aggregate was used to create three concrete samples: LDPE-based, epoxy-based, and control sample. Fourier Transform Infrared Spectroscopy (FTIR) was used to perform standard tests to evaluate water absorption, surface electrical resistivity, compressive strength, and chemical composition. The results demonstrated that epoxy-based concrete had good mechanical and durability qualities, as evidenced by its high electrical resistivity values and high compressive strength value of 32 MPa. The compressive strength result reported by the LDPE samples was like the control samples, but the LDPE samples had a higher water absorption rate compared to the control samples. LDPE recorded a less value for resistivity which suggested that it has a reduced ability to withstand intrusion by moisture or water. The result of FTIR investigation showed unique chemical compositions in all the mixes confirming the influence and positive impact of the polymers on structural performance of the resulting concrete samples. The study, using recycling materials (polymers) promotes sustainable building methods and creates alternative for affordable building infrastructures.

Keywords: Building materials, compressive strength, electrical resistivity, epoxy resin, Low-Density Polyethylene (LDPE) and Polymers.

Introduction

A monumental increase in the cost of building materials has been noticed in Nigeria construction sector and the disposal of waste polymers is also a great challenge. This waste polymer can be effectively used in the production of polymer concrete. Polymer concrete is regarded as a type of concrete that utilizes polymer binders, water and aggregates. The exceptional qualities of polymer concrete such as high mechanical and durability properties have resulted in the wide adoption of the use of polymer concrete in the construction industry worldwide. Polymer concrete is regarded as a composite material with great mechanical and durability properties (Nodehi, 2022). The strength of polymer concrete largely depends on the quantity of

polymer, the type and shape of fine and coarse aggregates, and other additives used in the production of such concrete (Karamzadeh *et al.*, 2022). The study of Karamzadeh *et al.* (2022) reported that the addition of fibers greatly enhances the performance of polymer concrete.

Varieties of polymer resins such as vinyl ester, polyester, epoxy and others can be used in the production of polymer concretes as binders. The study of Zhao *et al.* (2021) reported that the use of vinyl ester resin in polymer concrete production as binder recorded better mechanical and durability results compared to polymer concrete produced with epoxy and polyester. Researchers such as Jafari *et al.* (2021) have reported that polymer concrete has high resistance to chemical attacks especially corrosion,

but investigation needs to be conducted on its ability to tolerate environmental factors such as UV radiation and others. It was documented in the research of Yelemessov *et al.* (2023) that the production technique, the mix proportions and the curing method have significant effects on the properties of the resulting polymer concrete. The study of Alhazmi *et al.* (2021) claimed that the use of appropriate production technique enhances the performance and utilization of polymer concrete in the construction sector. The study of Ceran *et al.* (2019) discovered that the flexural and compressive strength values of PVC concrete were higher than those produced with other types of polymers. The addition of filler enhances the mechanical properties of polymer concrete (Sokołowska, 2020).

The study of Ostad-Ali-Askari *et al.* (2018) indicated that the inclusion of aggregates enhances both thermal properties and electrical conductivity of polymer concrete. The mix proportion and the curing medium have great implications on the performance of polymer concrete (Józefiak and Michalczyk, 2020). The study of Ma *et al.* (2020) revealed that the use of recycled materials can significantly reduce the cost of polymer concrete without affecting the strength. The research of Sabău *et al.* (2020) revealed that incorporation of recycled materials into polymer concrete can lead to reduction in price as well as promoting waste management.

Numerous studies have focused their search light on the most appropriate quantity of epoxy as binder in polymer concrete that would enhance the durability and mechanical properties of the resulting concrete. The study of Ferdous *et al.* (2020) concluded that a 2:1 mix ratio for resin to aggregates should be adopted for use in epoxy polymer concrete design. Many studies have been conducted to evaluate the mechanical and disability properties of polymer concrete but not much have been documented concerning the comparison of the properties of polymer concrete produced with the use of vinyl ester, epoxy and polyester. The pore structures, surface resistivity and resistance to ion ingress under harsh environmental conditions have not been well studied.

Surface electrical resistivity is intimately related to pore structure and permeability, both of which play important roles in the durability and corrosion protection of reinforced concrete structures. The lack of an integrated assessment combining these characteristics represents a severe knowledge gap, preventing the optimal design of polymer concrete for long-term, performance-critical infrastructure in settings prone to salt attack and moisture penetration. By encouraging the use of polymer concrete as a long-lasting, low-emission substitute

for conventional concrete, this study supports SDGs 9 which is to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. The study also promotes SDGs 11 which is to make cities and human settlements inclusive, safe, resilient and sustainable.

Methodology

The materials used in this study are sand, gravel, polymer binder, water, and Portland limestone cement. For the polymer binder, epoxy resins and Low-density polyethylene (pure water nylon) from thermosetting resins and thermoplastic polymer are polymer binder used. Figures 1a and 1b show the picture of some of the material used.



Figure 1a: LDPE plastic wastes



Figure 1b: Epoxy resin Epoxy resin

Mix Ratio

For this study, a pre-design mix ratio of 1:1.5:2 was used to produce concrete samples. The batching was done by volume, and the water cement ratio was 0.5.

Sample production

The cement based concrete specimens were cast manually using the material proportions in Table 1. For the compressive test, surface electrical

resistivity and water absorption test, the moulds used were assembled and lubricated before casting to allow easy removal of the dried specimens. The steel moulds of sizes 150 mm x 150 mm x 150 mm x 150 mm were used for the compressive test and water absorption test, while for the surface electrical resistivity test, the moulds were hollow plastic pipes of 100 mm diameter and 200 mm height. The concrete was poured into three equal layers, and each layer was compacted thoroughly. The top surface of the mould was then levelled off with a trowel. All concrete specimens were demoulded after twenty-four hours and completely air cured. After the concrete specimens were cured in air for 28 days, they were tested in a compression testing machine having a capacity of 2000 kN.

LDPE based concrete

The specimens were produced using an industrial burner and gas. The LDPE (pure water nylon) was measured in respect to what was calculated in the materials proportions in Table 1 after which it was heated in a head pan at a temperature above 5000C and covered to allow the heat to circulate. The process continued for one hour and thirty minutes per batch and a liquid form was obtained. After the

liquid form was attained, sand and granite were measured and mixed thoroughly with the liquefied LDPE. The mix was covered and re-heated for another 10-15 minutes to allow the mixture to attain a paste like form. The mix was then poured inside the mould and allowed to cool in the air. Figure 2 displays the casting process of LDPE.



Figure 2: Casting of LDPE Based Concrete

Table 1: Material proportions used

Specimen	Material (kg)					
	Cement	Epoxy	LDPE	Sand	Granite	Water
LDPE Concrete	-	-	7.088	15.309	37.564	13.2
Epoxy Concrete	-	7.796	-	15.309	37.564	
Cement Concrete	57.024	-	-	85.536	209.88	

Epoxy based concrete

The epoxy resin and hardener were mixed in the ratio 2 to 1 as stated by the manufacturer ensuring a uniform blend. The aggregates, namely sand and gravel were then added and mixed thoroughly after which it was poured into clean and dried moulds. The mixture was allowed to harden naturally at room temperature for 24-72 hours without being disturbed before being cured in the air (open space). Figure 3 shows the casting process of epoxy-based concrete.

Water absorption test

This test was carried out in accordance with British standard as stated in BS 1881-122, (2011). Fifteen (15) samples were produced for this experiment.

Surface Electrical Resistivity

The surface electrical resistivity test method offers a fast, cost-effective, and non-destructive way to assess the quality and durability of concrete. By putting electrodes on the concrete's surface and applying a current, one can determine how resistant concrete is to electrical current flow. The electrical resistance between the electrodes is measured,

which is then converted into resistivity. Reduced permeability and improved durability against corrosion and chloride ion penetration are indicated by higher resistivity values (BS EN 12390-19 2023).

Compressive Strength Test

The Concrete Compression Testing Machine with a 2000 kN capacity depicted in Figure 4, was used in this study to estimate the compressive strength values of the concrete. The test was carried out in line with the British specification as captured in BS EN 206, (2013). A test for compressive strength determines a material's capacity to withstand compression forces.

FTIR (Fourier Transform Infrared Spectroscopy)

For FTIR analysis, crushed concrete from the compressive strength test was crushed into a fine powder. The chemical makeup of hydrated goods along with any additions in the concrete are examined using this test. FTIR provides information about the chemical reactions during curing and any changes after testing by identifying the functional groups and chemicals in the concrete, such as calcium silicate hydrates (BS EN 196-2:2013).

Table 2: values for corrosion probability supplied by the test apparatus

S/N	Resistivity (KΩ cm)	Corrosion possibility
1	≤ 5 KΩ cm	Very high
2	5-10 KΩ cm	High
3	10-20 KΩ cm	Secondary
4	20-199.9 KΩ cm	Good/ corrosive
5	>200 KΩ cm	Good/ corrosion probability is minimal



Figure 3: Casting of Epoxy Based Concrete



Figure 4: Concrete compression testing machine

Result and Discussion

Water Absorption

Figure 5 displays the outcome of water absorption. Figure 5 showed that the control sample had a water absorption rate of 3.38% which is in tandem with the result of water absorption on cement concrete as reported in the study of Mehta and Monteiro, (2006). The LDPE samples had a water absorption rate of 5.07%, which is slightly higher than the control sample. The study of ohama, (1995) showed that the

hydrophobic characteristics of LDPE may booth the performance of polymer concrete, but its permeability properties may be altered by poor mix design. The epoxy-based polymer concrete recorded a value of 5.35% for water absorption which is higher than both the control and LDPE samples. The study of Kumar Mehta, (1988) claimed that epoxy polymer concrete has low permeability and water absorption if the mix ratio is perfect.

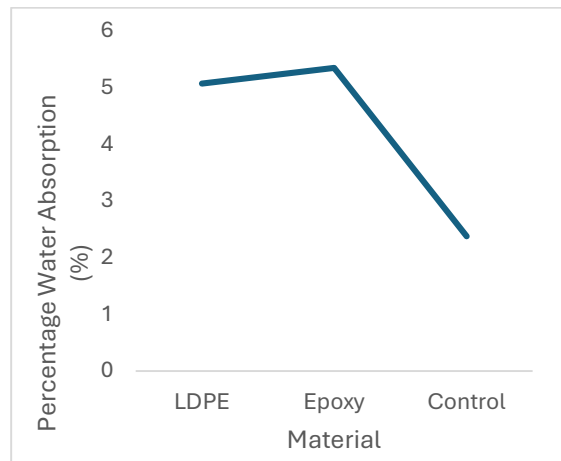


Figure 5: Combined chart of water absorption

Surface Electrical Resistivity Test

The results are shown in Figure 6, and Table 2 gives the corrosion possibility values as stated in the machine's handbook.

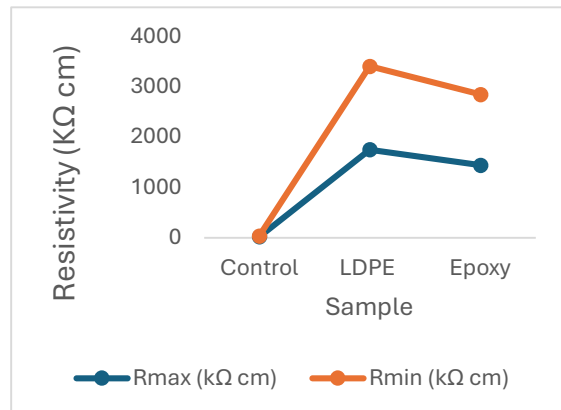


Figure 6: Surface Resistivity test results

The findings of the surface electrical resistivity test as depicted in Figure 6 demonstrate that both LDPE and epoxy polymer concrete perform better than control samples in terms of preventing ion penetration. Of the polymer concrete samples, LDPE had the highest resistivity, which may make it the best option for use in very corrosive settings; on the other hand, epoxy concrete also showed good durability and may be appropriate for several applications. A refined pore structure is shown by this decreased permeability, which lessens the entry of water and hostile ions like sulfates and chlorides that cause corrosion in reinforcement. Since LDPE showed the highest resistivity among the polymer concretes, its addition may result in a more irregular pore structure and reduced pore connectivity, which would improve resistance in extremely corrosive situations. Even while the epoxy polymer concrete's resistivity is marginally lower than that of LDPE, it nonetheless exhibits a far more refined pore structure than control concrete, providing exceptional durability.

Compressive strength

The result of compressive strength is presented in Figure 7.

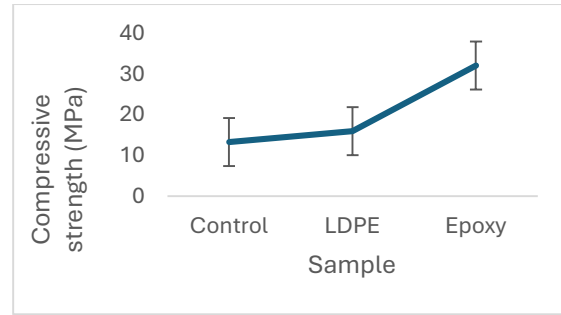


Figure 7: Compressive Strength graph

From figure 7, it was observed that the LDPE and Control samples showed similar strength results with the LDPE sample edging it and showing higher compressive strength. While the epoxy samples are the best results in terms of compressive strength being able to withstand a compressive force as high as 700 kN and producing an average compressive strength of 32 MPa.

FTIR Result

FTIR (Fourier-Transform Infrared Spectroscopy) analysis was performed to identify the chemical bonds, and functional groups present in the control, LDPE concrete, and epoxy concrete concretes. The results are presented in figure 8, 9 and 10 respectively for control, LDPE and epoxy samples.

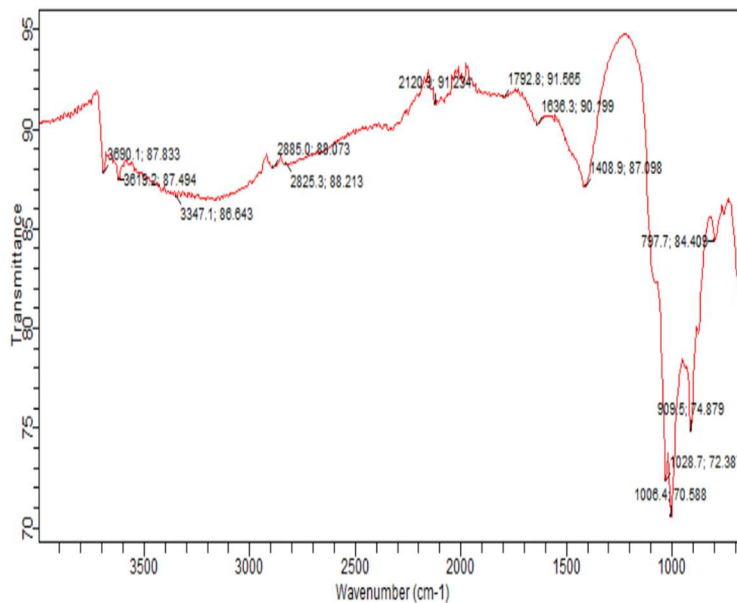


Figure 8: FTIR Spectra for Control Sample

FTIR result for Control Concrete

From figure 8, the FTIR spectrum for control concrete showed characteristic peaks associated with cement hydration products. Prominent peaks were observed in the region of 3400–3600 cm⁻¹,

corresponding to O–H stretching vibrations from water molecules and hydroxyl groups, indicative of calcium silicate hydrate (C-S-H). Peaks around 1400–1500 cm⁻¹ were assigned to the asymmetric stretching of carbonate (CO₃²⁻) groups, suggesting

carbonation during curing. These peaks are consistent with research by Yang *et al.* (2012) and Neville (2011), who highlighted the contribution of hydration products such as C-S-H to strength growth.

Result of FTIR for LDPE-Based Concrete

The FTIR results for samples produced with LDPE are shown in Figure 9.

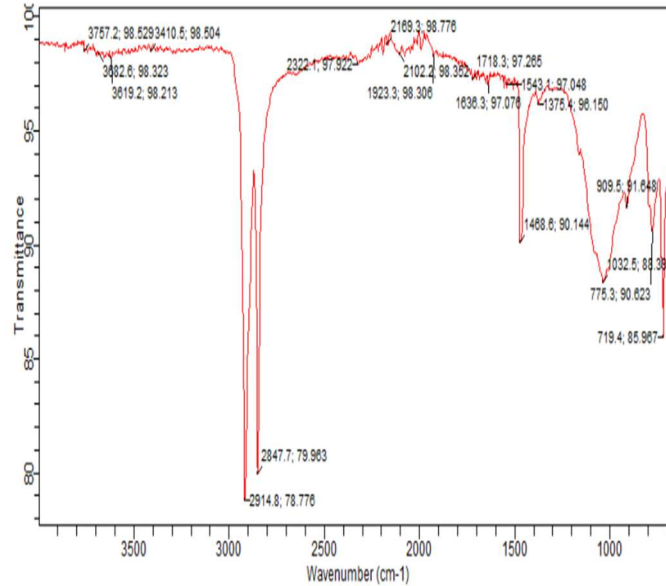


Figure 9: FTIR Spectra for LDPE Sample

The FTIR spectrum of the LDPE sample showed important features of the silicon-rich fillers and the polymer matrix, as shown in figure 9. The identification of peaks at 2800–3000 cm^{-1} as the aliphatic hydrocarbons' C–H stretching vibrations verified the existence of LDPE as the primary binder. At 1100–1200 cm^{-1} , significant Si–O–Si stretching vibrations were identified, suggesting that

silicon-based fillers or aggregates predominated in the SEM-EDS investigation. The lack of hydration-related peaks, like carbonate or O–H groups, confirms the absence of cementitious system-typical chemical processes. The results of Siddique *et al.* (2015), who noted that fillers are essential to the structural performance of thermoplastic matrices like LDPE, are in line with the findings of the study.

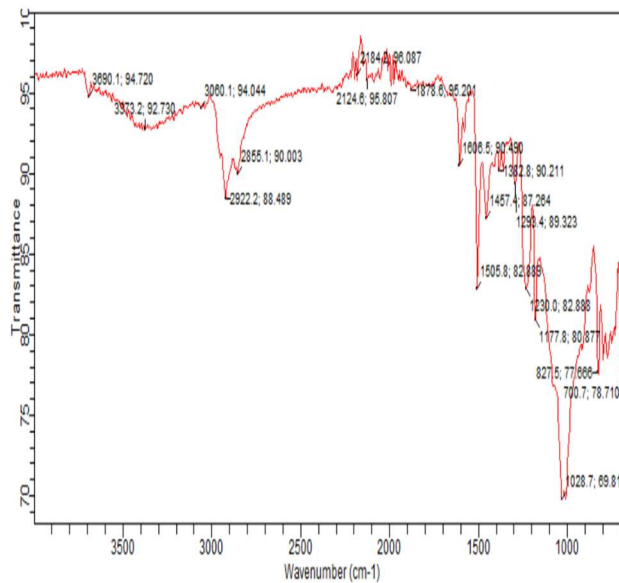


Figure 10: FTIR spectra for Epoxy Sampl

Epoxy-Based Concrete

The FTIR spectrum of epoxy sample revealed peaks characteristic of both epoxy resins and aggregates, as shown in Figure 10. C–O stretching is associated with vibrations in the 1250–1300 cm^{-1} range, while aromatic C=C stretching is associated with peaks in the 1600–1500 cm^{-1} range. These features confirm that the epoxy matrix is present. Additionally, there were noticeable peaks between 1100 and 1200 cm^{-1} that were associated with Si–O–Si bonds and matched the silicon-rich aggregates or fillers found in the SEM-EDS investigation. The absence of hydration-related peaks indicates that the structural strength of epoxy-based concrete is dependent on chemical encapsulation and strong matrix-aggregate bonding rather than hydration products. These findings support those of Ohama (1997) and Colangelo *et al.* (2020), who emphasized epoxy's exceptional chemical stability and endurance.

Conclusion

The investigation leads to the following conclusions:

- The water absorption test revealed that LDPE concrete absorbed the most water, which could potentially make it susceptible to moisture-related damage. Control concrete showed a significant level of water absorption, as is typical of traditional cement-based materials. Interestingly, epoxy-based concrete's water absorption rate was higher than expected, which may indicate issues with mix proportions or curing conditions.
- Epoxy-based concrete had the strongest resistance to electrical conductivity and moisture penetration in terms of electrical resistivity. Control samples had the lowest resistivity, whilst LDPE samples showed a typical intermediate resistivity. This lower resistivity suggests that control sample is more electrically conductive and susceptible to penetration of aggressive materials like chloride ions, sulfate attack, acid attack etc making it less suitable for situations requiring high resistivity
- The compressive strength test showed that epoxy-based concrete had the highest strength, surpassing both control and LDPE concrete.
- The FTIR study revealed that control concrete had hydration and carbonation products, LDPE concrete had non-reactive polymer properties, and epoxy-based concrete had strong chemical connections

and interactions with aggregates, which improved its strength and stability.

- The use of Epoxy-based concrete and LDPE concrete is a potential and alternative way to fully replace cement in the production of concrete with better performance in terms of compressive strength and resistivity to aggressive ions.

Acknowledgement

The authors appreciate the tertiary Education Trust fund (TETFund) in Nigeria for funding this research from National Research Fund (NRF) 2021 with reference number TETF/ES/DR&DCE/NRF2021/CC/EHU/00081/VOL.1. The host Institution, Federal University of Technology, Akure is also well appreciated.

References

- Nodehi M. (2022). Epoxy, polyester and vinyl ester-based polymer concrete: a review. *Innovative Infrastructure Solutions*, 7(1), 64.
- Karamzadeh N. S., Aliha M. R., and Karimi H. R., (2022). Investigation of the effect of components on tensile strength and mode-I fracture toughness of polymer concrete. *Arabian Journal of Geosciences*, 15(13), 1213.
- Zhao C., Yi Z., Wu W., Zhu Z., Peng Y., and Liu J., (2021). Experimental study on the mechanical properties and durability of high-content hybrid fiber-polymer concrete. *Materials*, 14(21), 6234.
- Jafari K., Heidarneshad F., Moammer O., and Jarrah M., (2021). Experimental investigation on freeze-thaw durability of polymer concrete. *Frontiers of Structural and Civil Engineering*, 15, 1038-1046.
- Yelemessov K. K., Baskanbayeva D. D., Sabirova L. B., and Akhmetova S. D., (2023). Justification of an acceptable modern energy-efficient method of obtaining sodium silicate for production in Kazakhstan. In IOP Conference Series: Earth and Environmental Science (Vol. 1254, No. 1, p. 012002). IOP Publishing.
- Alhazmi H., Shah S. A., Anwar M. K., Raza A., Ullah M. K., and Iqbal F., (2021). Utilization of polymer concrete composites for a circular economy: A comparative review for assessment of recycling and waste utilization. *Polymers*, 13(13), 2135.
- Ceran Ö. B., Şimşek B., Uygunoğlu T., and Şara O. N. (2019). PVC concrete composites: comparative study with other polymer

- concrete in terms of mechanical, thermal and electrical properties. *Journal of Material Cycles and Waste Management*, 21, 818-828. <https://doi.org/10.1007/s10163-019-00846-0>.
- Sokołowska J. J., (2020). Long-term compressive strength of polymer concrete-like composites with various fillers. *Materials*, 13(5), 1207.
- Ostad-Ali-Askari K., Singh V. P., Dalezios N. R., and Crusberg T. C., (2018). Polymer concrete, *international Journal of Hydrogen Energy*, 2, 630-635.
- Józefiak K. and Michalczyk R., (2020). Prediction of structural performance of vinyl ester polymer concrete using FEM elasto-plastic model. *Materials*, 13(18), 4034.
- Ma, W., Zhao, Z., Guo, S., Zhao, Y., Wu, Z., & Yang, C. (2020). Performance evaluation of the polyurethane-based composites prepared with recycled polymer concrete aggregate. *Materials*, 13(3), 616.
- Sabău M. O., Chețan O. T., Țica O. V., Comănescu A., Antal L., and Bidian C., (2020). Real life anticoagulant treatment for stroke prevention in patients with nonvalvular atrial fibrillation. *Farmacia*, 68(5), 1-7.
- Ferdous W., Manalo A, Wong H. S., Abousnina R., AlAjarmeh O. S., Zhuge Y., and Schubel P., (2020). Optimal design for epoxy polymer concrete based on mechanical properties and durability aspects. *Construction and Building Materials*, 232, 117229.
- BS 1881-122, (2011). Testing Concrete. Method for Determining Water Absorption.
- BS EN 12390-19, (2023). Testing hardened concrete. Part 19: Determination of electrical resistivity.
- BS EN 206 (2013). Concrete Specification, Performance, Production and Conformity.
- BS EN 196-2:2013. Method of testing cement. Chemical analysis of cement.
- Mehta, P. K., and Monteiro, P. J. (2006). *Concrete microstructure, properties, and materials*. McGraw-hill.
- Ohama, Y. (1995). Handbook of polymer-modified concrete and mortars: properties and process technology. William Andrew.
- Kumar Mehta, P. (1988). Polymer Concrete: Properties and Applications.
- Yang, K. H., Cho, A. R., Song, J. K., & Nam, S. H. (2012). Hydration products and strength development of calcium hydroxide-based alkali-activated slag mortars. *Construction and Building Materials*, 29, 410-419.
- Neville, A. M. (2011). Properties of Concrete, Pearson Education Limited. Edinburgh Gate, Harlow England, 58-661.
- Siddique, R., Khatib, J., & Kaur, I. (2015). Use of recycled plastic in concrete: A review. *Waste Management*, 28(10), 1835–1852.
- Ohama, Y. (1997). Polymer-based admixtures for concrete. CRC Press.
- Colangelo, F., Roviello, G., Tarallo, O., & Cioffi, R. (2020). Epoxy polymer concrete: Mechanical properties and microstructure. *Construction and Building Materials*, 263, 120198.