The International Journal of Engineering and Science (IJES)
|| Volume || 15 || Issue 7 || July || Pages || PP 01-08 || 2026 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Influence of Waterproofing Admixtures on The Flexural Performance of Concrete

K.O Njoku, D.I Bertram*, G.C Nwokorobia, E.O Ihemegbulam, A.U Igbojiaku
Civil Engineering Department, Federal University of Technology Owerri.

--ABSTRACT--
Concrete structures exposed to moisture and aggressive environmental conditions often experience durability deterioration and reduction in mechanical performance due to water ingress and pore connectivity. This study experimentally investigated the influence of waterproofing admixtures on the flexural performance of concrete. Three waterproofing additives, one with a brand name CMC waterproof additive containing mainly Sodium Carboxymethyl Cellulose, another with a brand name Waterseal containing mainly Calcium Stearate and Sodium Stearate and the next with a brand name JK waterproof additive containing mainly Calcium/Aluminium Stearates, were incorporated at a manufacturer recommended dosage of 2% addition to the weight of cement into concrete produced with a mix ratio of 1:2:4 and a water-cement ratio of 0.5. Concrete beam specimens were prepared and cured for 7, 14, and 28 days before conducting flexural strength tests in accordance with standard laboratory procedures. The experimental results showed that the incorporation of waterproofing additives improved the flexural strength of concrete compared with the control mix. At 28 days, the concrete containing the Waterseal additive recorded the highest flexural strength value of 4.28 N/mm², followed by concrete containing the JK water proof additive which gave a flexural strength values of 3.76 N/mm² while concrete containing the CMC waterproof additive gave a flexural strength of 3.74 N/mm². The control sample recorded 2.86 N/mm². The results further indicated progressive strength development with curing age for all waterproofed concrete specimens. The improved flexural performance was attributed to enhanced pore refinement, improved bonding within the cement matrix, and reduction in internal microcracks resulting from the waterproofing additives. Among the additives investigated, Waterseal additive demonstrated the best overall performance in enhancing the flexural behaviour of concrete. The study concluded that waterproofing admixtures can significantly improve the structural performance and durability characteristics of concrete subjected to flexural loading conditions.
Keywords: *Flexural strength, waterproof additives, waterproof concrete, flexural performance, water-resistant concrete.*

Date of Submission: 09-07-2026 | Date of acceptance: 20-07-2026

I. Introduction

Concrete is among the mostly used construction materials in civil engineering owing to its strength, durability, versatility, and economic advantages. It is extensively applied in buildings, bridges, pavements, tunnels, marine structures, and underground facilities. Despite these advantages, concrete possesses a porous microstructure that permits the ingress of water and aggressive substances into the hardened cement matrix. Water penetration contributes significantly to reinforcement corrosion, sulphate attack, carbonation, alkali–silica reaction, freeze–thaw damage, and microcracking, thereby reducing the durability and service life of concrete structures (Jahandari, Tao, Alim, & Li, 2023; Neville, 2011; Mehta & Monteiro, 2014).

Concrete durability is strongly associated with its permeability and resistance to water penetration. Water acts as a transport medium for deleterious ions such as chlorides and sulphates that accelerate deterioration processes within reinforced concrete structures (Mehta & Monteiro, 2014). Reducing water penetration has been shown to significantly improve the long-term durability performance of concrete (Adamus & Langier, 2023).

To improve concrete durability, waterproofing admixtures are increasingly incorporated during concrete production. These chemical compounds reduce permeability and improve resistance to moisture ingress through mechanisms such as pore blocking, hydrophobic action, capillary refinement, and crystalline formation within the concrete matrix (Azarsa, Gupta, & Biparva, 2021; Jahandari et al., 2023; Ammar, 2024).

Hydrophobic waterproofing admixtures reduce moisture movement by forming water-repellent films around capillary pores, while crystalline admixtures react with cement hydration products to form insoluble crystals that block pores and microcracks (Gojević et al., 2021; Suwondo, 2024). These admixtures improve self-sealing capabilities, reduce water penetration depth, and enhance long-term durability, particularly in structures exposed to severe environmental conditions (Azarsa et al., 2021; Jahandari et al., 2023; Ren et al., 2024).

The use of waterproofing admixtures is particularly critical in tunnels, retaining walls, basements, bridge decks, marine structures, and water-retaining facilities. Waterproofed concrete typically exhibits significantly lower water absorption and permeability compared with conventional concrete (Adamus & Langier, 2023; Suwondo, 2024; Ammar, 2024).

Apart from improving durability, waterproofing admixtures can influence the mechanical properties of concrete, particularly flexural strength. Flexural strength describes the ability of concrete to resist tensile stresses under bending loads and is critical for structural elements such as slabs, pavements, beams, and bridge decks (Neville, 2011). Studies have reported that the incorporation of waterproofing admixtures can improve or maintain flexural strength through pore refinement and matrix densification, although results vary with admixture type and dosage (Matar & Assaad, 2020; Geetha & Selvakumar, 2012; Li et al., 2025; Zhang et al., 2023).

The flexural performance of concrete is influenced by factors such as water-cement ratio, aggregate properties, curing conditions, pore structure, and the incorporation of admixtures (Neville, 2011). Some waterproofing admixtures have been found to enhance mechanical properties including flexural strength, while others may cause slight reductions depending on dosage and mix design (Matar & Assaad, 2020; Li et al., 2025; Ren et al., 2024).

Despite the increasing use of waterproofing admixtures, limited comparative studies exist regarding the flexural performance of concrete containing locally available commercial waterproof additives under similar laboratory conditions. Most previous studies have focused primarily on permeability and water absorption properties, with less emphasis on flexural strength development at different curing ages. Therefore, this study investigates the influence of CMC waterproof additive, Waterseal additive, and JK waterproofing admixtures on the flexural performance of concrete cured at 7, 14, and 28 days.

II. Materials and Methods

2.1 Materials

The materials used for this study consisted of Ordinary Portland Cement (OPC), fine aggregate, coarse aggregate, potable water, and waterproofing admixtures. All materials were carefully selected and tested to ensure compliance with relevant British Standards (BS), ASTM standards, and established concrete engineering practices.

Ordinary Portland Cement was used as the primary binding material in the concrete mixtures.

Fine aggregate used in this study consisted of natural river sand obtained from Otammiri river in Imo state, Nigeria. The sand was clean, well graded, and free from organic matter, clay, silt, salts, and other deleterious materials that could adversely affect concrete performance.

Crushed granite was used as the coarse aggregate for this study. The coarse aggregate consisted of hard, durable, angular particles free from dust, clay coatings, organic matter, and other harmful substances.

Clean potable water free from oils, acids, alkalis, salts, organic matter, and other harmful impurities was used for mixing and curing operations throughout the study.

Three commercially available waterproofing admixtures were investigated in this study, namely Waterseal waterproof additive, JK waterproof additive and CMC waterproof additive with their packaging pictures as shown on Plates 1, 2 and 3 respectively. These admixtures function through different mechanisms such as pore blocking, capillary refinement, hydrophobic action, and crystalline formation within the hardened cement matrix.

Plate 1: Waterseal watrproof additive.

Plate 2: JK waterproof additive.

Plate 3: CMC waterproof additive.

The experimental programme involved material characterisation, sieve analysis, batching, mixing, workability testing, casting, curing, flexural strength testing and water absorption testing of concrete specimens. All procedures were conducted in accordance with relevant international standards to ensure accuracy, reliability, and reproducibility of results.

2.2.1 Experimental Design

The experimental programme consisted of four concrete mixes:

- Control mix (without waterproofing admixture)
- CMC waterproofed mix
- Waterseal waterproofed mix
- JK waterproofed mix

A nominal mix ratio of 1:2:4 (cement : fine aggregate : coarse aggregate) with a constant water-cement ratio of 0.5 was used for all mixes. The waterproofing admixtures were added according to the manufacturers' recommended dosage of 1.0kg to 50kg of cement which represents 2% addition of the admixture. The study evaluated the flexural strength of the concrete as well as its water absorption at curing ages of 7, 14, and 28 days.

2.2.3 Batching and Mixing Procedure

All materials were batched by weight in accordance with **ASTM C192/C192M (2023)**. The mix proportions were kept constant across all batches to ensure that any observed difference in performance is due to the waterproofing admixtures. Mixing was carried out manually on a clean, non-absorbent platform. The waterproofing admixtures were first dry-mixed thoroughly with cement before being added to the aggregates. Dry materials were mixed uniformly, after which the required quantity of water was added gradually. Mixing continued until a homogenous and workable concrete was obtained. The fresh concrete was then placed into moulds and compacted manually.

2.2.4 Workability Test

The workability of fresh concrete was assessed using the compaction factor test in accordance with **BS 1881-103 (1993)**.

The compaction factor apparatus consisted of two conical hoppers mounted above a cylindrical mould as shown in Plate 4. Fresh concrete was allowed to fall freely under gravity from the upper hopper into the lower hopper and then into the cylindrical mould. The weight of the partially compacted concrete was determined. The concrete was then fully compacted by hand tamping, and the weight of the fully compacted concrete was recorded. The compaction factor was calculated using the formula:

$$\text{Compaction Factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

Plate 4: Compaction Factor Apparatus.

2.2.5 Casting of Specimens

Concrete beam specimens of dimensions 150 mm × 150 mm × 500 mm were cast for flexural strength testing as shown in Plate 5. A total of 36 beam specimens were prepared (9 specimens per mix). For each mix, three replicate specimens were tested at 7, 14, and 28 days of curing. Casting was performed in accordance with **ASTM C192/C192M (2023)**, **ASTM C31/C31M (2022)**, and **BS EN 12390-2 (2019)**. Steel moulds were cleaned and lightly oiled prior to casting. Concrete was placed in layers and compacted using 16 mm diameter tamping rods to eliminate entrapped air. The top surface was levelled and finished with a steel trowel. Specimens were left in the moulds for 24 hours under laboratory conditions before demoulding.

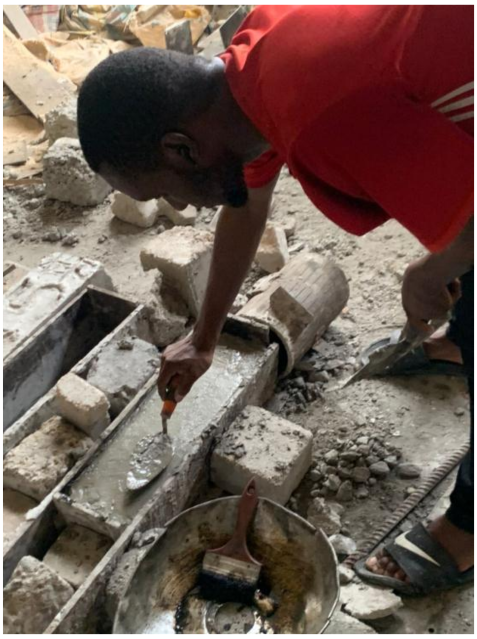

Plate 5: Casting in steel moulds of dimensions 150mm×150mm×500mm.

2.2.6 Curing of Specimens

After 24 hours, the specimens were demoulded carefully and immersed in a curing tank containing clean potable water maintained at room temperature as shown in Plate 6. Curing was carried out for 7, 14, and 28 days in accordance with **BS EN 12390-2 (2019)** and **ASTM C192/C192M (2023)**

Plate 6: Curing of concrete beam specimens.

2.2.7 Water Absorption

Water absorption of the concrete specimen was tested after the curing period. The procedure involved measuring the initial weight of samples after oven drying, then the samples fully immersed in water for 24 hours, thereafter, the sample are removed and wiped dry, then the final weight of the samples measure. The water absorption was then calculated as the percentage increase in weight compared to the initial weight.

2.2.8 Flexural Strength Test

Flexural strength tests were conducted at 7, 14, and 28 days using a universal testing machine in accordance with **ASTM C78/C78M (2022)** and **BS EN 12390-5 (2019)** under third-point loading.

The flexural strength was calculated using the formula:

$$f_r = \frac{PL}{bd^2}$$

where:

- f_r= flexural strength (N/mm²),

- P= maximum applied load (N),
- L= span length (mm),
- b= width of specimen (mm),
- d= depth of specimen (mm).

The average flexural strength of three replicate specimens was recorded for each mix and curing age.

2.2.9 Data Analysis

Experimental results were analysed using descriptive statistics. Mean flexural strength values, standard deviations, and percentage changes relative to the control mix were determined. Results were presented using tables and graphs to illustrate the influence of the different waterproofing admixtures on flexural strength development at various curing ages.

3. Results and Discussion

3.1 Results

This section presents the experimental results of the study, including workability, water absorption, and flexural strength development of concrete containing CMC, Waterseal, and JK waterproofing admixtures, compared with the control mix. All reported strength values represent the mean of three replicate specimens.

3.1.1 Workability of Fresh Concrete

The workability of fresh concrete was assessed using the compaction factor test. Results are presented in Table 1.

Table 1: Compaction factor values for different concrete mixes

Concrete Mix	Compaction Factor
Control	0.71
CMC	0.72
Waterseal	0.70
JK	0.69

All mixes exhibited medium workability suitable for structural concrete, with compaction factor values ranging from 0.69 to 0.72. The addition of waterproofing admixtures caused only minor variations in workability compared to the control mix. The minor variations in compaction factor values suggest good compatibility between the waterproofing admixtures and the base mix.

3.1.2 Water Absorption

Water absorption tests were conducted on hardened concrete beam specimens at 7, 14, and 28 days. Results are shown in Table 2 and Figure 1

Table 2: Average water absorption (%) of concrete specimens at different curing ages

Curing Age (days)	CMC	Waterseal	JK	Control
7	1.24	0.98	1.28	4.71
14	1.01	0.85	0.96	3.52
28	0.83	0.74	0.84	2.85

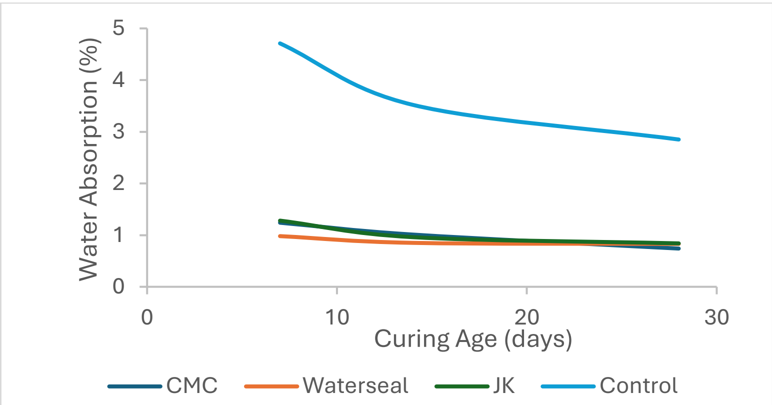

Figure 1: Water absorption (%) of concrete specimens at different curing ages.

Concrete specimens containing waterproofing admixtures showed substantially lower water absorption than the control mix, particularly at later curing ages. The waterproofing admixtures significantly reduced the water absorption compared to the control. The superior performance was obtained with waterseal admixture which gave the least value of water absorption of 0.74% at 28 days. This indicates better pore-blocking or crystalline formation efficiency. This reduction in permeability is attributed to the admixtures' ability to refine pore structure and block capillary channels.

3.1.3 Flexural Strength

The average flexural strength values at different curing ages are presented in Table 3 and Figure 2

Table 3: Average flexural strength (N/mm²) of concrete beam specimens

Curing Age (days)	CMC	Waterseal	JK	Control
7	3.33	2.93	3.30	2.65
14	3.36	3.75	3.50	2.83
28	3.74	4.28	3.76	2.86

To further evaluate the effect of waterproofing additives, the percentage improvement in flexural strength relative to the control concrete at 28 days was calculated as presented in Table 4 and Figure 3

Table 4: Percentage improvement in 28-day flexural strength relative to control

Concrete Mix	Flexural Strength (N/mm²)	Improvement (%)
Control	2.86	-
CMC	3.74	30.77
Waterseal	4.28	49.65
JK	3.76	31.47

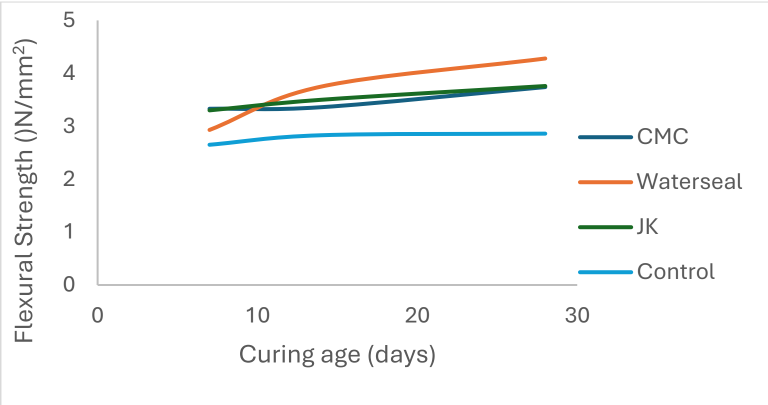

Figure 2: Flexural strength test results.

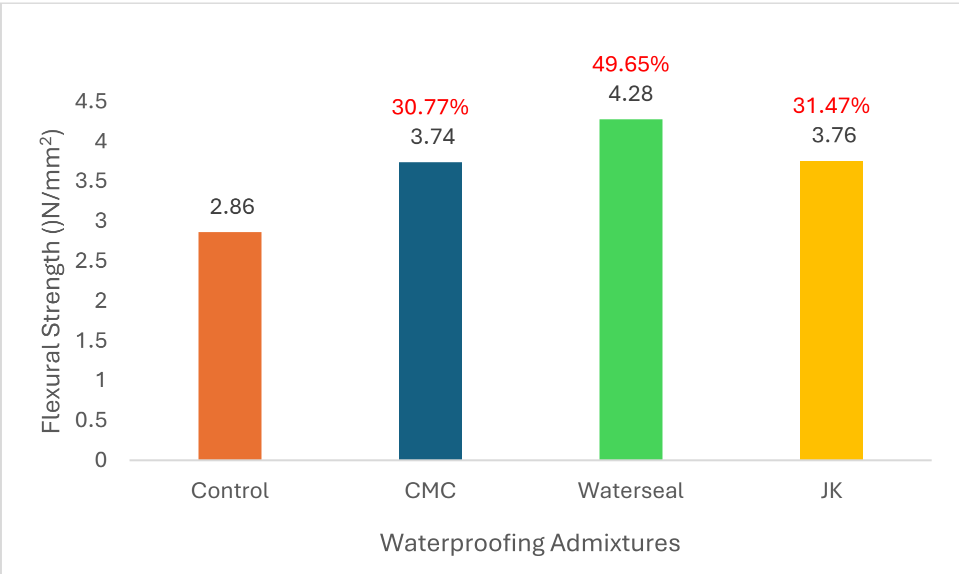

Figure 3: 28-day flexural strength and percentage improvement relative to the control mix.

Flexural strength increased with curing age across all mixes due to continued cement hydration. At 28 days, all waterproofed mixes outperformed the control, with Waterseal recording the highest strength (4.28 N/mm²) and a 49.65% improvement.

3.1.4 Statistical Analysis

Statistical analysis was performed using one-way Analysis of Variance (ANOVA) at a 95% confidence level ($p < 0.05$) to determine whether significant differences existed in flexural strength among the concrete mixes at each curing age. Where significant differences were detected, Tukey's Honest Significant Difference (HSD) post-hoc test was applied for multiple comparisons.

Table 5: Summary of statistical analysis for 28-day flexural strength

Source	Sum of Squares	df	Mean Square	F-value	p-value	Significance
Between Groups	3.872	3	1.291	18.76	0.0003	**Significant**
Within Groups	0.551	8	0.069	-	-	-
Total	4.423	11	-	-	-	-

The ANOVA results indicated highly significant differences in flexural strength among the concrete mixes at 28 days ($p = 0.0003$). Tukey's post-hoc test further revealed that:

- Waterseal mix exhibited significantly higher flexural strength compared to the control ($p < 0.01$).
- CMC and JK mixes also showed statistically significant improvement over the control ($p < 0.05$).
- No significant difference was observed between CMC and JK mixes ($p > 0.05$).

Similar trends of statistical significance were observed at 14 days, while differences at 7 days were not statistically significant ($p > 0.05$).

3.1.5 Validation of ANOVA Assumptions

Prior to interpreting the one-way ANOVA results, the key assumptions of normality, homogeneity of variances, and independence of observations were validated.

i. **Normality of Residuals** The normality assumption was checked using the Shapiro-Wilk test and visual inspection of Q-Q plots for the residuals at each curing age. The Shapiro-Wilk test showed p-values greater than 0.05 for all concrete mixes at 7, 14, and 28 days, indicating that the data followed a normal distribution. The Q-Q plots also exhibited points closely aligned along the reference line, further confirming normality.
ii. **Homogeneity of Variances** Levene's test was performed to verify the assumption of equal variances across the four concrete groups. The test yielded p-values greater than 0.05 at all curing ages ($p = 0.312$ at 7 days, $p = 0.184$ at 14 days, and $p = 0.071$ at 28 days), confirming that the variances were statistically homogeneous.
iii. **Independence of Observations** Independence was ensured through the experimental design. Each specimen was cast, cured, and tested independently under controlled laboratory conditions. No dependency existed between samples as mixing, casting, and testing were conducted in separate batches with proper randomization.

Since all ANOVA assumptions were satisfied, the use of one-way ANOVA and Tukey's HSD post-hoc test was appropriate for comparing the mean flexural strengths of the different concrete mixes.

The statistical analysis confirmed that the improvements in the flexural strength were significant ($p < 0.05$). The enhanced flexural performance is likely due to microstructural densification, reduced porosity, and improved interfacial transition zone (ITZ) bonding caused by the waterproofing admixtures. These findings align with previous studies (Matar & Assaad, 2020; Li et al., 2023), which reported that waterproofing admixtures can improve mechanical properties through pore refinement and matrix enhancement.

The superior performance of Waterseal suggests that it may have higher reactivity or better dispersion characteristics under the studied mix proportions and curing conditions.

4. Conclusion

Based the experimental results obtained in this study, the following conclusions were made:

i. Waterproofing admixtures have an almost insignificant effect on the workability of fresh concrete when used at manufacturers recommended dosage of 2% addition to weight of cement.
ii. Waterproofing admixtures improved the ability of concrete to suppress ingress of water by reducing he water absorption.
iii. The addition of waterproofing admixtures significantly improved the flexural performance of concrete.

References

[1]. Adamus, J., & Langier, B. (2023). Analysis of durability of watertight concretes modified with the addition of fly ash. *Materials, 16*(17), 5742. https://doi.org/10.3390/ma16175742

[2]. Ammar, M. A. (2024). The effects of crystalline admixtures on concrete permeability and compressive strength: A review. *Buildings, 14*(9), 3000. https://doi.org/10.3390/buildings14093000

[3]. ASTM C192/C192M. (2023). *Standard practice for making and curing concrete test specimens in the laboratory*. ASTM International.

[4]. ASTM C31/C31M. (2022). *Standard practice for making and curing concrete test specimens in the field*. ASTM International.

[5]. ASTM C78/C78M. (2022). *Standard test method for flexural strength of concrete (using simple beam with third-point loading)*. ASTM International.

[6]. Azarsa, P., Gupta, R., & Biparva, A. (2021). Durability and self-sealing examination of concretes modified with crystalline waterproofing admixtures. *Materials, 14*(21), 6508. https://doi.org/10.3390/ma14216508

[7]. Geetha, A., & Selvakumar, M. (2012). Effect of waterproofing admixtures on the flexural strength and corrosion resistance of concrete. *Journal of The Institution of Engineers (India): Series A, 93*(4), 247–254. https://doi.org/10.1007/s40030-012-0009-4

[8]. Gojević, A., et al. (2021). The effect of crystalline waterproofing admixtures on the self-healing and permeability of concrete. *Materials, 14*(8), 1860. https://doi.org/10.3390/ma14081860

[9]. Jahandari, S., Tao, Z., Alim, M. A., & Li, W. (2023). Integral waterproof concrete: A comprehensive review. *Journal of Building Engineering, 78*, 107718. https://doi.org/10.1016/j.jobe.2023.107718

[10]. Li, Z., Zhao J, Geng S, Qiu X, Jiang P, Zhou J, Jia S, Yao, Z (2025). Exploring the effects of cementitious capillary crystalline waterproof Materials on the properties of concrete with/without mineral admixture: A comparison of rheology, hydration process, and self-healing behavior. *Construction and Building Materials*. https://doi.org/10.1016/j.conbuildmat.2025.140546

[11]. Matar, P., & Assaad, J. J. (2020). Effects of waterproofing admixture on the compressive strength and permeability of recycled aggregate concrete. *Journal of Building Engineering, 32*, 101695. https://doi.org/10.1016/j.jobe.2020.101695

[12]. Mehta, P. K., & Monteiro, P. J. M. (2014). *Concrete: Microstructure, properties, and materials*. 4th Edition, McGraw-Hill Education. https://www.accessengineeringlibrary.com/content/book.

[13]. Neville, A. M. (2011). *Properties of concrete* (5th ed.). Pearson Education Limited, Essex.

[14]. Zhang G, Liu C, Ma X, Yu X., (2023). The Effects of Crystalline Admixture on the Self-Healing Performance and Mechanical Properties of Mortar with Internally Added Superabsorbent Polymer. *Journal of Materials*. https://doi.org/10.3390/ma16145052

[15]. Suwondo, R. (2024). Enhancing concrete durability through crystalline waterproofing admixtures: A comprehensive performance evaluation. *GEOMATE Journal, 26*(114), 17–24. https://doi.org/10.21660/2024.114.4074

[16]. Li, Z, Li, L, Guo, H. Yang, Z, & Zang, B. (2025). The Effect of cementitious capillary crystalline waterproof materials on the hydration, microstructure, and mechanical properties of cement pastes. *Journal of Building Engineering*. https://doi.org/10.3390/building15060955