VIABILITY OF COMBINING WATER REDUCING ADMIXTURES AND WATERPROOFING ADMIXTURES IN CONCRETE

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ABSTRACT
Purpose
This research aimed to investigate the effect of incorporating two admixtures, Costamix-R200 (a water-reducing admixture) and Hydropruf-WP-300 (a waterproofing admixture), into concrete mixes to optimize performance and mitigate the impact of imbalanced water content on concrete's mechanical properties.

Methodology
A full factorial experimental design was implemented, including tests to determine the concrete's strength, workability, and water absorption properties. Four mix designs were analyzed: a control mix (Mix 1) and three variations with the admixtures (Mix 2, 3, and 4), all using a 1:2:4 mix ratio and a 0.55 water-cement ratio.

Findings
The control mix (Mix 1) met ACI 318 requirements for M15 concrete, achieving a compressive strength of 21.0 N/mm² at 28 days. Mix 2, with Hydropruf-WP-300, showed a strength of 16.0 N/mm², while Mix 3, with Costamix-R200, reached 17.0 N/mm² at 28 days. The highest strength, 23.1 N/mm², was observed in Mix 4, which incorporated both admixtures. Additionally, higher density was correlated with increased compressive strength.

Practical implications
The study offers valuable guidance for the judicious use of water-reducing and waterproofing admixtures in concrete mixes, providing insights into their role in optimizing strength, durability, and workability for various construction applications.

Originality/value
This research contributes novel findings on the synergistic effects of combining water-reducing and waterproofing admixtures to improve concrete properties, offering practical recommendations for enhancing concrete performance in construction.

KEYWORDS: *Admixture, Compressive strength, Concrete, Waterproofing Admixture, Water reducing Admixture.*

INTRODUCTION
Concrete, a composite material made of aggregate bonded with fluid cement, is the world's second most-used substance after water, and the most widely used building material. Its global use is twice that of steel, wood, plastics and aluminum combined (Gagg, 2014). However, the porosity of concrete makes it vulnerable to moisture ingress, leading to

deterioration. This arises due to concretes inherent limitations, such as low tensile strength and water permeability, which compromise structural integrity and lifespan (American Concrete Institute, 2010). Water plays a crucial role in all forms of concrete degradation, necessitating improved durability measures (Shetty, 2010). Recent advancements in concrete technology involve the use of chemical admixtures to enhance concrete properties and overcome these limitations (Patel & Shah, 2013). Various admixtures, including plasticizers, accelerators, retarders, waterproofing agents, air-entraining agents, and shrinkage-reducing agents, serve specific purposes in improving concrete's performance (Albayraka et al., 2015).

The performance of concrete is heavily influenced by its water content, with both excessive and insufficient water compromising concrete strength and durability. Achieving the optimal water-to-cement ratio is crucial for maintaining concrete's mechanical properties. However, variations in water content often lead to inconsistent results, which negatively affect the overall quality of concrete. While water-reducing and waterproofing admixtures are commonly used to address these challenges, their combined impact on concrete's strength, workability, and durability has not been fully explored. This research, therefore, aims to address the gap in understanding how these admixtures can optimize concrete performance, particularly to overcome the adverse effects of imbalanced water content in the mix.

The combination of water-reducing admixtures (WRAs) and waterproofing admixtures (WAs) is particularly promising. WRAs reduce water content, improve workability, and enhance early strength; while WAs minimize water penetration and increase resistance to moisture ingress. The main challenge is ensuring these admixtures do not interfere with each other's chemical reactions, which could negate their benefits. Extensive testing is required to optimize the dosage, composition and interaction of these admixtures in various concrete mixes, considering curing conditions and exposure environments (Neville, 2010). Hence, the study aims at evaluating the viability of combining water reducing admixtures and waterproofing admixtures in concretes, with an objective to evaluate the physical and mechanical properties of concretes. Combining WRAs and WAs may offer a comprehensive solution to enhance concrete strength and durability while reducing permeability, potentially revolutionizing concrete construction practices.

LITERATURE REVIEW

Concrete is one of the most widely used construction materials, but its performance is highly susceptible to variations in water content. The water-to-cement (w/c) ratio is crucial in determining concrete's strength, durability, and workability. However, fluctuations in water content can compromise concrete quality, leading to weakened structures due to excess water or impaired hydration from insufficient water. To mitigate these challenges, researchers have focused on utilizing admixtures such as water-reducing and waterproofing agents to enhance concrete performance. This literature review examines existing studies on the effectiveness of these admixtures in optimizing concrete strength and durability, to provide valuable insights for future applications.

Water-Reducing Admixtures (WRAs) are specialized chemicals designed to minimize concrete's water content without compromising its workability. By lowering the water-cement ratio, WRAs significantly enhance concrete strength and durability. These admixtures are categorized into three types: normal, mid-range and high-range water reducers (superplasticizers) based on their water reduction capabilities. The benefits of WRAs are multifaceted. They facilitate improved early strength development; better compaction; and increased concrete density, ultimately resulting in structures that are more durable.

Research by Zhang et al. (2014) highlights the direct impact of WRAs on reducing the water-cement ratio, which in turn enhances strength and durability. Additionally, studies by Li et al. (2018) demonstrate WRAs' potential in improving early-age strength, making them ideal for fast-track construction projects. The reduced water content in WRAs-treated concrete also leads to lower permeability, minimizing the infiltration of harmful substances, and improving the overall durability of concrete structures.

Water-Proofing Admixtures (WPAs) are specifically designed to enhance concrete durability by reducing its permeability and preventing water ingress. These admixtures, including hydrophobic pore blockers, crystalline admixtures and water-repellent chemicals, block capillary pores in concrete, minimizing water and corrosive agent movement (Gojević et al., 2021). By reducing permeability, WPAs mitigate concrete deterioration risks caused by freeze-thaw cycles, sulfate attacks and embedded steel corrosion (Patel & Shah, 2013). According to Liu and Zhang (2017), WPAs play a vital role in extending the lifespan of concrete structures, particularly in harsh weather conditions or constant water exposure. WPAs form a water-repellent barrier within the concrete matrix, reducing its permeability. Moreover, WPAs prevent the ingress of harmful ions that could corrode reinforcement, causing structural degradation over time. Research by Xie et al. (2019) showed that incorporating WPAs significantly improved concrete's water resistance, providing enhanced protection for reinforced concrete in coastal or marine environments.

The combination of Water-Reducing Admixtures (WRAs) and Waterproofing Admixtures (WPAs) has gained attention in concrete technology for enhancing mechanical properties and durability. However, their effects vary, depending on climate. In temperate climates, concrete structures face challenges such as freeze-thaw cycles, moisture cycling, and varying humidity levels. WRAs and WPAs improve strength and durability by reducing water-to-cement ratio and preventing water infiltration. Chou et al. (2016) found that their combined use enhances freeze-thaw durability. WPAs also prevent chemical attacks by reducing permeability. In tropical climates, characterized by high temperatures and humidity, the performance requirements for concrete differ significantly from those in temperate regions. WRAs and WPAs increase resistance to moisture infiltration and prevent efflorescence and alkali-silica reaction. They also improve long-term durability and heat resistance.

RESEARCH METHODS

Materials employs were Hydropruf-WP-300 (water-proofing admixture), water-reducing admixture (Costamix-R200), cement, and granite. The experimental methods employed were in accordance with provisions of BS EN 197-1:2011.

Hydropruf-WP-300 (water-proofing admixture), was purchased from Costar Industries Inc. Hydropruf-WP-300 was chosen for its integral waterproofing admixture abilities, and for its abilities to minimize segregation and bleeding.

Costamix-R200 (water-reducing admixture), was purchased from Costar Industries Inc. Costamix-R200 is suitable for improving the performance of polyether superplasticizer, which includes improving the adaptability of polyether superplasticizer to cement in concretes. Costamix-R200 improves the stability of water reducing agent; reduces concrete bleeding; reduces high grade concrete viscosity, and improves the concrete pumping. 20% of water reduction was used based on the technical data provided by costar industries.

Dangote Cement, an Ordinary Portland Cement (OPC) of grade type N42.5 and compliant with the Nigerian Industrial Standard (NIS) 444-1:2014, was used as the binding material. The cement was sourced from a commercial supplier in Bariga, Lagos State. For physical properties, weight analysis, workability tests and water absorption test were conducted, while compressive strength was assessed for mechanical properties.

RESULTS AND DISCUSSION

The investigation involved four concrete mixes, each with varying combinations of admixtures. The mix proportion and compressive strength of the various samples are presented below:

Compressive strength

Mix 1, the control sample, consists of 12.2 kg water, 41.9 kg fine aggregate, 78.5 kg coarse aggregate, and 19 kg cement. As shown in Table 1, its compressive strength increased from 18.3 N/mm² at 7 days to 21.0 N/mm² at 28 days, meeting the ACI 318 Building Code standards for structural concrete. Serving as a baseline, Mix 1's compressive strength trends over time.

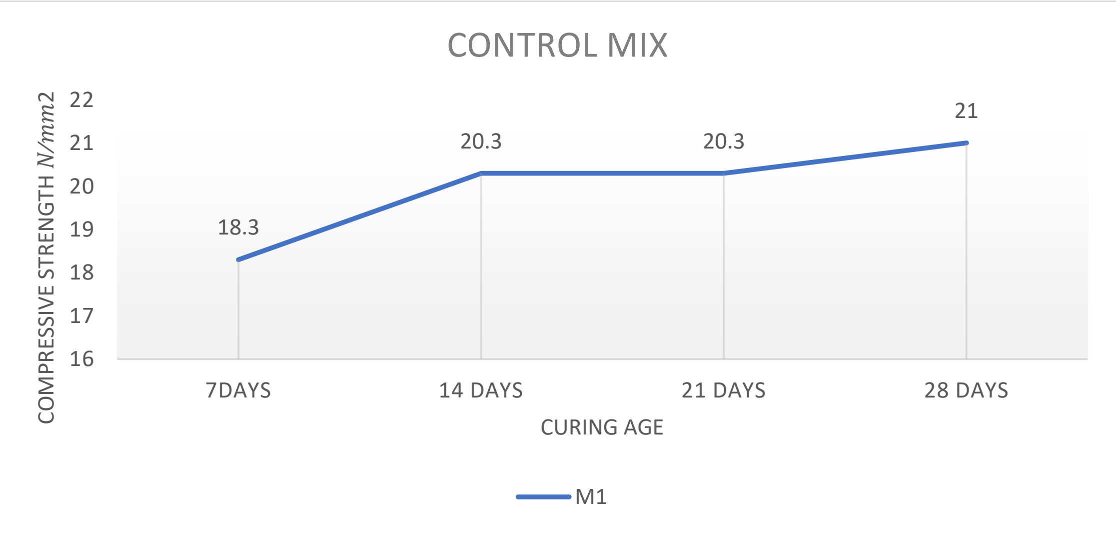

Figure 1: Compressive Strength of Control Sample

Mix 2 comprises 10.37 kg water, 41.9 kg fine aggregate, 78.5 kg coarse aggregate, 19 kg cement, and 76 ml Hydropruf-WP-300. As indicated in Figure 2, the compressive strength of Mix 2 increases from 13.3 N/mm² at 7 days to 16.0 N/mm² at 28 days. Despite an initial strength decrease, the mix achieves stability at 16.0 N/mm² from 14 days onward, meeting the required strength for M15 concrete.

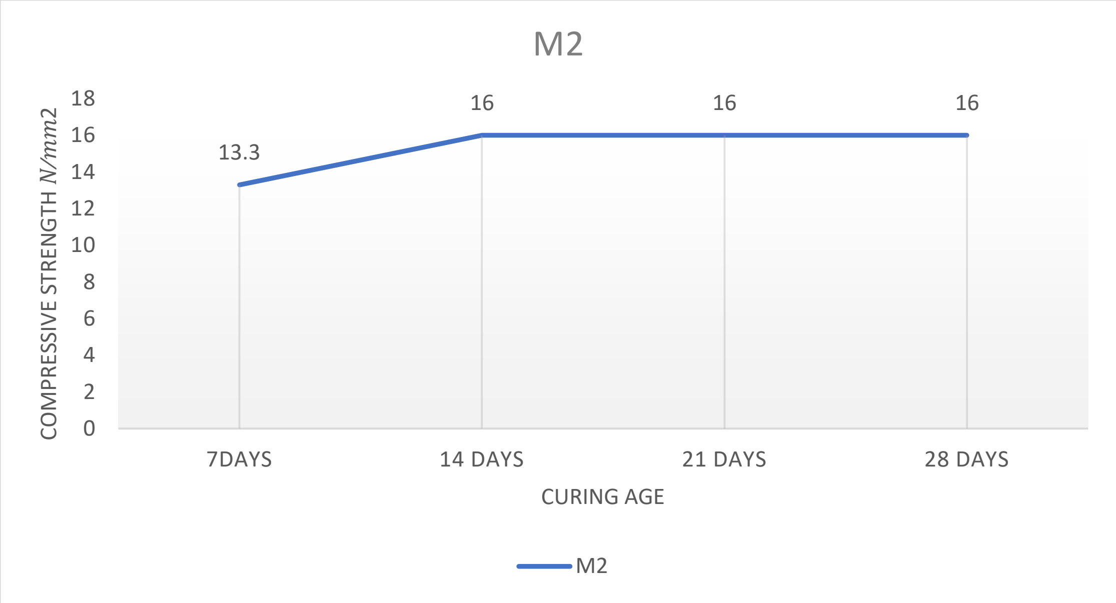

Figure 2: Compressive Strength of Water-Proofing Admixture

Mix 3 is composed of 12.02 kg of water, 41.9 kg of fine aggregate, 78.5 kg of coarse aggregate, 19 kg of cement, and 0.18 kg of Costamix-R200. Figure 3 reveals that the compressive strength of Mix 3 increases from 15.2 N/mm² at 7 days to 17.0 N/mm² at 28 days. The results highlights that there is no significant increase in strength from day 21 to day 28, indicating a plateau in strength development.

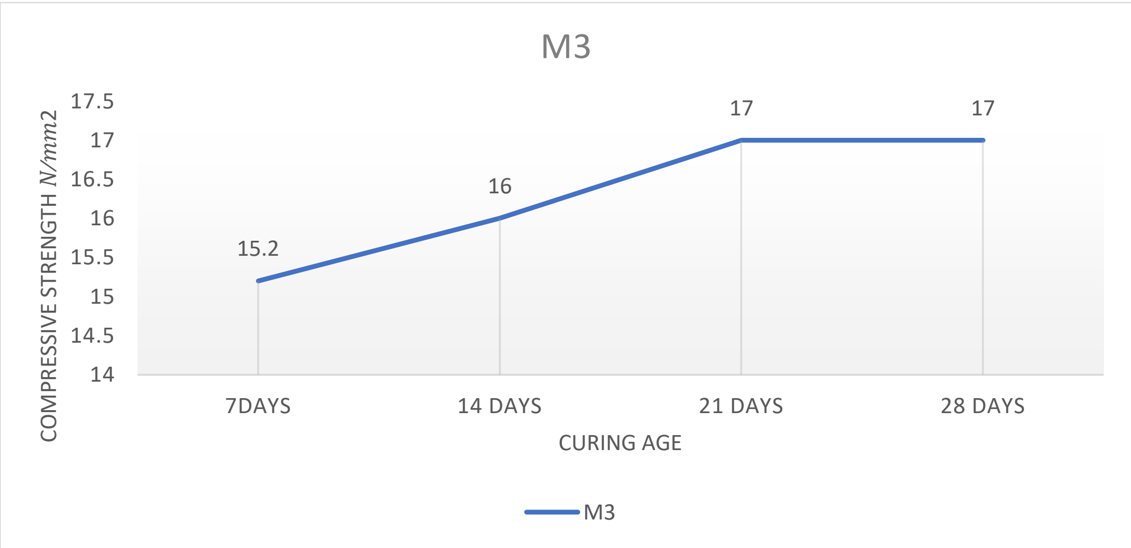

Figure 3: Compressive Strength of Water-Reducing Admixture

Mix 4, containing 11.20 kg of water, 41.9 kg of fine aggregate, 78.5 kg of coarse aggregate, 19 kg of cement, 76 ml of Hydropruf-WP-300, and 0.18 kg of Costamix-R200, shows an increase in compressive strength from 16.3 N/mm² at 7 days to 23.1 N/mm² at 28 days as shown in Figure 4, indicating a strength retention period from day 7 to day 14, with no significant gain during this time frame, followed by a notable increase in strength thereafter.

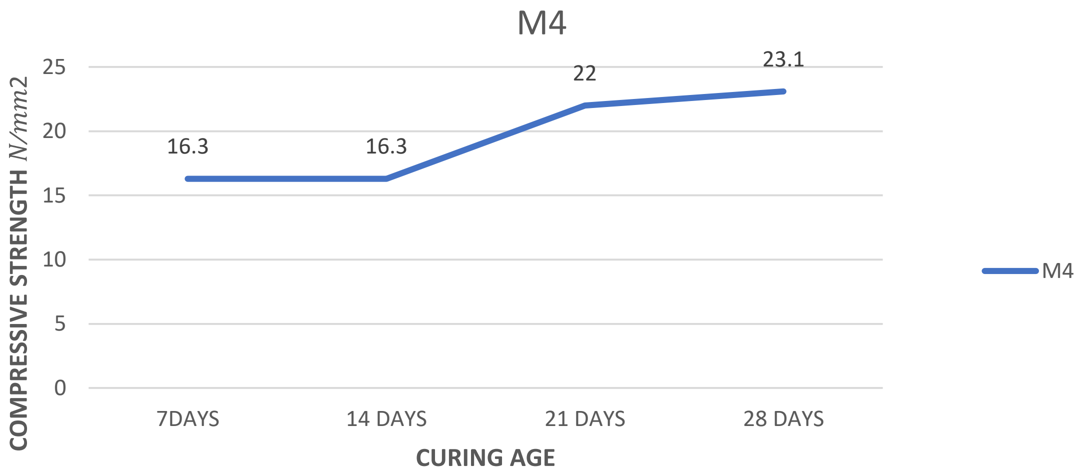

Figure 4: Compressive Strength of WPAs & WRAs

Workability of Concrete Mixes

Table 1: Workability Test

SAMPLES	SLUMP(MM)	WORKABILITY RATE
M1	70	Medium
M2	100	High
M3	125	High
M4	170	High

Table 1 provides the slump test values, reflecting the workability of different mixes incorporating Costamix-R200 and Hydropruf-WP-300 and the workability rates based on ASTM C143 / C143M categorization.

The workability of the concrete mixes was evaluated based on their slump values. Mix M1, with a slump of 70 mm, falls into the "Medium" workability category, indicating a balance between stiffness and fluidity, making it suitable for applications requiring moderate workability. In contrast, Mixes M2, M3, and M4 exhibit higher workability, with slump values of 100 mm, 125 mm, and 170 mm, respectively, all classified as "High" workability. These mixes are increasingly fluid and easy to work with, making them suitable for complex shapes, easy placement, and compaction. The progressive increase in workability from M1 to M4 can be attributed to the inclusion of admixtures, while maintaining a constant water-cement ratio. This suggests that the admixtures play a significant role in enhancing the workability of the concrete mixes.

Water Absorption Rate

Table 2: Water Absorption Rate

SAMPLES	DRY WEIGTH W1	WET WEIGTH W2	% WATER ABSORPTION	ABSORTION RATING	CONCRETE QUALITY
M1	8.95	9.00	0.56	Low	Good
M2	8.93	9.00	0.78	Low	Good
M3	8.88	8.95	0.79	Low	Good
M4	8.93	9.10	1.90	Low	Good

Table 2 shows the water absorption rate for various concrete mixes, which is an indicator of the material's permeability and porosity, crucial for determining strength and durability. The results indicate that all mixes have a low rate of water absorption, which is beneficial for compressive strength and durability.

Weight of Concrete Samples

The weights of the concrete samples over different curing periods are presented in Figure 5, showing a correlation between the density and compressive strength of the mixes. The control sample (Mix 1) shows a weight increase from 8.65 kg to 9.25 kg from 7days to 28 days. The weight fluctuates among the other mixes, which may be influenced by changes in the mix design. Higher density typically correlates with higher compressive strength, as shown in Figure 5.

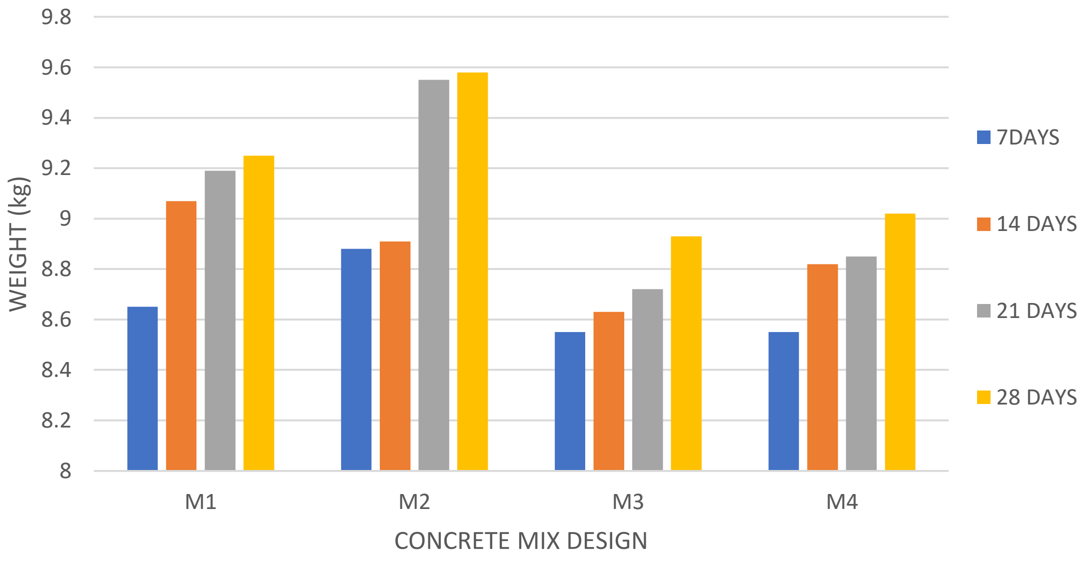

Figure 5: Weight of Concrete Samples

Discussion of findings:

In this research, the compressive strength, weight, workability, and water absorption rate of concrete samples with various mix designs containing Hydropruf-WP-300, Costamix-R200 and a mixture of both were investigated. The results of this study indicate that the incorporation of water-reducing and waterproofing admixtures can significantly impact on the compressive strength and durability of concrete. At day 28, the control mix (Mix 1) achieved a compressive strength of 21.0 N/mm², meeting the M15 concrete specifications outlined by ACI 318.

In contrast, Mix 2, which included a waterproofing admixture, exhibited a lower compressive strength of 16.0 N/mm² at day 28. However, this result is consistent with previous studies, which have shown that waterproofing admixtures can sometimes reduce early-age strength (Neville, 2010). Mix 3, which included a water-reducing admixture, achieved a compressive strength of 17.0 N/mm² at day 28. This result is in line with extant research, which has demonstrated that water-reducing admixtures can improve compressive strength by reducing the water-cement ratio (Rixom & Mailvaganam, 1999). Notably, Mix 4, which included both water-reducing and waterproofing admixtures, achieved the highest compressive strength of 23.1 N/mm² at day 28. This result suggests that the combination of these admixtures can lead to synergistic benefits, resulting in improved compressive strength. This finding is consistent with previous studies, which have demonstrated that the combined use of water-reducing and waterproofing admixtures can enhance concrete performance (Chindaprasirt et al., 2017). The results also indicate that all mix types exhibited low rates of water absorption, suggesting low porosity rates and improved durability. This finding is consistent with extant research, which has shown that waterproofing admixtures can reduce water absorption and improve durability (Liu & Zhang, 2017). Finally, the results show that Mix 2, 3, and 4 exhibited variations in weight, while Mix 1 consistently increased in weight. This finding suggests that the inclusion of admixtures can affect the density of the concrete, with higher density typically corresponding to improved compressive strength.

Overall, the results of this study contribute to the existing body of knowledge on the use of water-reducing and waterproofing admixtures in concrete. The findings suggest that the combination of these admixtures can lead to improved compressive strength and durability, and highlight the importance of careful mix design and testing to optimize concrete performance.

CONCLUSION

This study investigated the effect of incorporating water-reducing and waterproofing admixtures on the compressive strength and durability of concrete. The results show that the combination of these admixtures can lead to synergistic benefits, resulting in improved compressive strength and durability. Specifically, Mix 4, which included both water-reducing and waterproofing admixtures, achieved the highest compressive strength of 23.1 N/mm² at day 28.

The findings of this study are consistent with previous research, which has demonstrated the benefits of using water-reducing and waterproofing admixtures in concrete. The results also highlight the importance of careful mix design and testing to optimize concrete performance.

In conclusion, this study provides evidence that the combination of water-reducing and waterproofing admixtures can improve the compressive strength and durability of concrete. The findings of this study can be used to inform the development of high-performance concrete mixes that meet the demands of modern construction projects, particularly for applications requiring improved strength and durability.

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