Performance of Concrete Mixed with Non-Potable Water Sources : A Compressive Strength Investigation

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Abstract. With growing concern over freshwater scarcity, this study explores the feasibility of using non-conventional water sources rainwater, underground water, mosque wastewater, and agricultural runoff as alternatives to potable water in concrete mixing. Five types of water were sourced locally and used in concrete mixtures designed using the ACI 211.1-91 method with a constant water-to-cement ratio of 0.475. A total of 45 cylindrical specimens were tested for compressive strength at curing ages of 7, 14, and 28 days. The control mix using potable water achieved the highest 28-day strength (16.3 MPa), while concrete made with mosque wastewater and underground water reached 15.2 MPa and 14.7 MPa, respectively, demonstrating strong performance. Agricultural runoff showed acceptable results (14.1 MPa), suitable for non-critical applications. Rainwater, however, resulted in the lowest strength (8.5 MPa at 28 days), indicating potential issues with its chemical composition. The findings suggest that mosque wastewater and underground water are promising substitutes for structural-grade concrete, offering sustainable water reuse options in construction. This study provides practical insights for implementing alternative water strategies in water-scarce regions and underscores the need for further chemical and durability evaluations to support broader application. **Keywords:** Non-potable water, Sustainable concrete, Compressive strength, Alternative water sources, Wastewater

1 Introduction

Concrete remains the cornerstone of modern infrastructure, with water being a fundamental component in its production. Conventionally, potable water is used for mixing and curing to ensure quality and performance [1]. However, the growing concerns over freshwater scarcity and the global push toward sustainable construction practices have necessitated the exploration of alternative water sources for concrete production [2]. In many regions, especially those facing water stress or limited access to clean water, using non-conventional water sources is not only practical but essential [1].

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Recent research has focused on partially or fully replacing potable water with alternative water sources such as rainwater, agricultural runoff, greywater, and treated wastewater [3]. While several of these studies have demonstrated promising results regarding cost savings and environmental impact, the primary concern remains the effect of such substitutions on the mechanical properties of concrete [4–5]. Bochare et al [6] found that using groundwater and sewage water results in lower compressive strengths than tap and river water, and the concrete made with sewage water resulted in only 77.6% of the required strength. However, using 100% treated wastewater increased the compressive strength by 17.7% [7]. Yao et al. [8] found that using 75% wastewater resulted in the highest compressive strength among different proportions tested. Complementing these water-focused studies, Zaki et al. [9] evaluated how adding coconut fiber (0.25–1% by cement weight) influenced the mechanical strength of corroded reinforced concrete beams under accelerated corrosion conditions, demonstrating that natural fiber additives can improve both flexural and compressive properties. In another study, Zaki et al. [10] explored an eco-friendly concrete mix using bottom ash (10–30%) as a partial sand replacement along with *Bacillus subtilis* bacteria to promote self-healing in corroded RC. These investigations affirm that locally available, sustainable alternatives—whether in mixing water, fine aggregates, or bio-agents—can significantly contribute to mechanical performance and environmental resilience when properly integrated and evaluated.

This study presents an experimental investigation into the compressive strength of concrete mixed with five different water sources: rainwater, underground water, agricultural runoff cylindrical specimens), mosque wastewater, and potable water (used as a control). Samples were tested at different curing ages, and the compressive strength was analyzed to determine the suitability of these alternative sources for construction purposes. The outcome of this study aims to contribute to sustainable construction efforts by identifying viable non-conventional water sources that do not significantly compromise concrete performance. The results are particularly relevant to developing regions or areas experiencing water scarcity, where innovative water reuse strategies are crucial for future infrastructure development.

2 Methodology

This experimental study was conducted to assess the influence of various non-conventional water sources on the compressive strength performance of concrete. All water samples were collected within the campus of Universitas Muhammadiyah Yogyakarta, ensuring realistic and sustainable sourcing relevant to local construction practices, as in Table 1. The five types of water used in this research were: rainwater (harvested from rooftop catchments), underground water (obtained from a borewell), mosque water (Collected from the university mosque's ablution facilities), agricultural runoff (sourced from horticulture fields and tested in both cubic and cylindrical samples), and potable water, which served as the control group.

It is important to emphasize that the chemical and physical characteristics of the water samples were not analyzed before use. This decision reflects real-world constraints in many developing regions, where such alternative water sources are often used without prior treatment or testing, especially in small-scale or rural construction projects. Table 2 summarizes the key physical properties of the materials used in the mix design, all of which were determined through laboratory testing following applicable ASTM and SNI standards.

Table 1. Water Types and Their Collection Sources.

Water Type	Source Description
Rainwater	Collected from the rooftop catchment within the university campus
Underground Water	Collected from the nearest underground water station located at the university student residence.
Agricultural Water	Sourced from the Agriculture Department's irrigation runoff collection system
Mosque Wastewater	Collected from the university mosque's
Potable Water	Campus municipal supply network

The concrete was designed using the ACI 211.1-91 method for normal-weight concrete [11]. The mix composition included Ordinary Portland Cement (OPC) as the primary binder, natural river sand as fine aggregate, and crushed gravel as coarse aggregate. A constant water-to-cement (w/c) was maintained for all mixes to ensure a uniform basis for comparing the effects of different water types on concrete strength. The target compressive strength for the control mix was set at 20 MPa. The materials were batched by weight using the following mix ratio: cement: sand: gravel: water is 1.4: 2.4: 3.6: 1.0, which was consistent across all mixes. Mixing was performed mechanically to ensure homogeneity, and slump values were monitored to confirm consistency across batches. A total of 45 concrete specimens were prepared, 9 samples for each of the five water types and tested at 7, 14, and 28 days to evaluate compressive strength development across curing ages.

Table 2. Physical Properties of Concrete Materials.

Property	Value
Specific gravity of sand	2.17857
Specific gravity of gravel	2.67206
Specific gravity of cement (OPC)	3.15
Fineness modulus of sand	2.289
Maximum size of gravel (mm)	19
Dry bulk density of aggregates (kg/m^3)	1.60
Water absorption of gravel (%)	0.75
Water absorption of sand (%)	0.22
Water-to-cement ratio (w/c)	0.475
Target compressive strength (MPa)	20.0

Concrete was mixed manuallyusing a clean mixing tray and standard hand tools to ensure consistency across all batches as in Fig. 1. The dry components cement, sand, and gravel were first thoroughly blended, after which the designated water from each source was gradually added and mixed until a uniform consistency was achieved. The freshly mixed concrete was then cast exclusively into cylindrical moulds measuring 150 mm in diameter and 300 mm in height, following standard testing requirements.

After 24 hours of initial setting, the specimens were demolded and transferred into a water curing pool maintained under laboratory conditions until the designated testing age, as shown in Fig. 2. The compressive strength tests were carried out at 7, 14, and 28 days using a calibrated digital compression testing machine. Three specimens were tested at each curing age for each water type, and the average compressive strength value was calculated to ensure reliable and representative results.

Fig. 1. Manual Preparation of Concrete Mix Components.

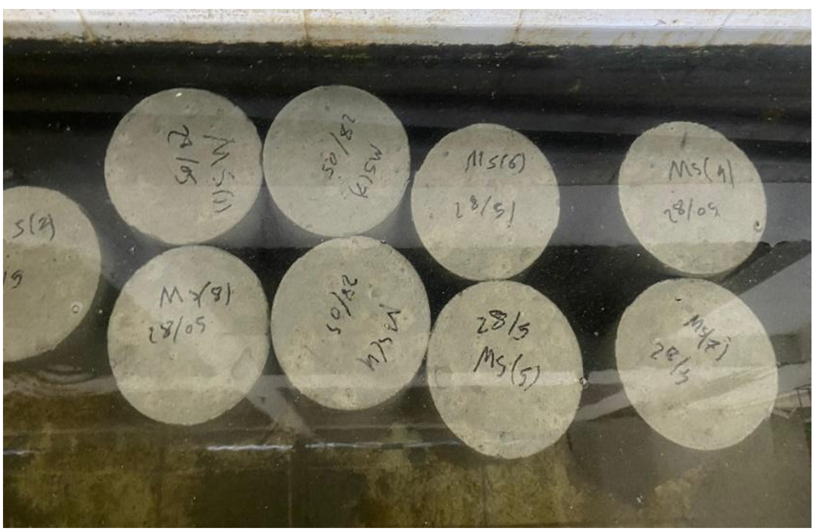

Fig. 2. Concrete Specimen Curing Setup Under Laboratory Conditions.

All experimental procedures complied with ASTM C39/C39M for compressive strength testing of cylindrical concrete specimens [12]. As shown in Fig. 3, each sample was placed vertically in a calibrated digital compression machine to ensure accurate load application and failure measurement. The strength results were then analyzed to determine the relative performance of each water type and to evaluate the feasibility of replacing potable water with alternative sources in sustainable concrete production. The outcomes of this study are expected to provide valuable insights into water reuse practices in concrete, particularly in water-scarce or resource-limited settings.

Fig. 3. Compressive Strength Testing of Cylindrical Concrete Specimen Using Digital Compression Machine.

3 Result and Discussion

The experimental results, summarized in Table 3, highlight the compressive strength development of concrete mixed with five different water sources at curing ages of 7, 14, and 28 days. A clear strength gain trend was observed over time across all mixtures, consistent with standard cement hydration processes. As expected, the control group (LAB water) demonstrated the highest compressive strength at 28 days (16.3 MPa), serving as the benchmark for performance comparison. As illustrated in Fig. 4, concrete samples mixed with mosque water and agriculture water also exhibited strong performance, closely approaching the control's. Meanwhile, rainwater resulted in the lowest compressive strength values throughout all curing periods, suggesting potential issues related to impurities or inadequate alkalinity that may have inhibited cement hydration.

Mosque wastewater exhibited surprisingly strong results among the non-conventional water sources, achieving 15.2 MPa at 28 days, closely trailing the control. Its early strength at 7 days (12.1 MPa) was also significantly higher than the rest, indicating adequate chemical compatibility for effective hydration. This suggests the viability of mosque wastewater as a sustainable and high-performing alternative, especially for non-critical applications where potable water is unavailable.

Underground water showed moderate performance, recording 14.7 MPa at 28 days. While its initial strength at 7 days was the lowest among the top three (8.2 MPa), This steady increase suggests that underground water supports continued hydration, albeit at a slightly reduced rate compared to other water sources. The long-term strength development is crucial for the stability and durability of concrete structures, and the consistent quality of underground water can make it a viable substitute in regions where its quality is uncontaminated [13].

Table 3. Compressive Strength of Concrete Using Different Water Sources at Various Curing Ages.

Water Type	7 Days	14 Days	28 Days
Underground Water	8.2	12.1	14.7
Rainwater	4.2	5.8	8.5
Mosque Wastewater	12.1	13.8	15.2
Agriculture Water	10.2	13.6	14.1
LAB (Control Sample/normal water)	12.1	13.7	16.3

Agricultural runoff performed slightly below underground water, with compressive strengths of 10.2 MPa, 13.6 MPa, and 14.1 MPa at 7, 14, and 28 days, respectively. Although it displayed a robust early strength profile, its lower 28-day performance suggests the possible presence of mild contaminants or organic materials that may hinder long-term hydration. Nevertheless, the values remained within acceptable margins for general-purpose construction in low-load conditions.

Conversely, rainwater produced the weakest results, particularly at 7 days (4.2 MPa), less than half of the control mix. Even after 28 days, the strength peaked at only 8.5 MPa. This underperformance could be attributed to the soft nature of rainwater, which typically lacks dissolved minerals or ions that facilitate cement hydration. Additionally, the possibility of airborne contaminants accumulating during rooftop collection may have introduced impurities that affected the setting and strength development. Rainwater can contain various impurities, especially during the initial stages of rainfall, known as the "first flush. These impurities can negatively affect the concrete's strength and durability [14].

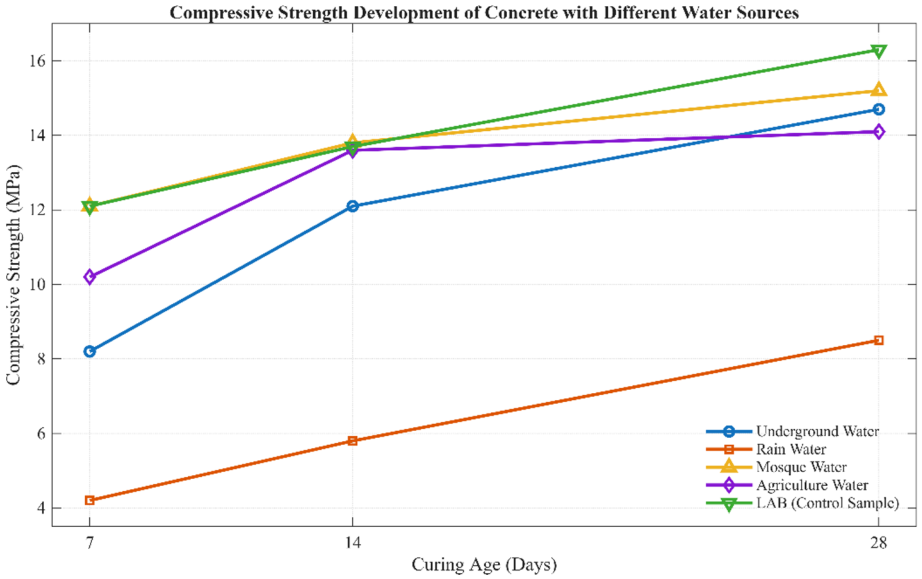

Fig. 4. Compressive strength development of concrete at 7, 14, and 28 days using different water sources.

Finally, the findings support mosque wastewater and underground water as promising non-potable sources in concrete mixing, especially in regions facing freshwater scarcity. The performance of agricultural water is also notable, though further chemical assessment is recommended for broader implementation. Rainwater, while environmentally favourable, may require pre-treatment or blending with stronger water sources to meet structural strength requirements. These results underscore the potential for reusing non-conventional water sources in concrete production without significantly compromising compressive strength. The study also emphasizes the importance of localized testing and context-driven water quality evaluation before adopting alternative water strategies at scale.

4 Conclusion

This study investigated the feasibility of using non-conventional water sources—rainwater, underground water, mosque wastewater, and agricultural runoff—as partial or full replacements for potable water in concrete mixing. Through systematic compressive strength testing at 7, 14, and 28 days, the findings reveal significant variation in performance depending on the water source. Among the tested alternatives, mosque wastewater and underground water demonstrated compressive strengths comparable to the control mix, particularly at later curing stages. Mosque wastewater emerged as a high-performing candidate, achieving 15.2 MPa at 28 days, while underground water followed closely with 14.7 MPa. These results suggest that treated greywater and clean underground water can be confidently used in structural or semi-structural concrete applications under proper quality control.

While slightly lower in final strength (14.1 MPa), agricultural runoff still showed potential for use in non-critical construction, especially in rural areas with limited water infrastructure. On the other hand, rainwater exhibited the lowest strength values throughout all curing stages, indicating the need for further investigation or blending strategies before it can be recommended for widespread use in concrete applications. The study confirms that, when locally available and contextually appropriate, non-conventional water sources can serve as viable substitutes for potable water in concrete production. This has significant implications for sustainable construction practices, especially in water-scarce regions. Future work should include detailed chemical characterization of these water sources and explore their long-term effects on durability, permeability, and reinforcement corrosion to ensure safe and sustainable implementation in broader construction sectors.

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