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# Experimental Evaluation of Concrete Performance Using Treated Wastewater as a Sustainable Alternative to Potable Water

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**ABSTRACT -** The increasing demand for freshwater resources and the growing concerns over water scarcity have created a need for sustainable alternatives in construction practices. Concrete production, which consumes a significant quantity of potable water, offers potential for conservation through the use of treated wastewater. This study presents an experimental investigation into the suitability of treated municipal wastewater as a replacement for potable water in M40 grade concrete.

Concrete specimens were prepared using identical mix proportions designed in accordance with IS 10262:2009 and IS 456:2000, with the only variable being the type of mixing water. The quality of treated wastewater was evaluated based on key physicochemical parameters to ensure compliance with standard requirements. The performance of concrete was assessed through compressive strength testing at curing ages of 7, 14, and 28 days.

The experimental results indicate that concrete produced with treated wastewater exhibits strength characteristics comparable to conventional concrete made with potable water. At 28 days, the treated wastewater concrete achieved approximately 97% of the compressive strength of the control mix, with only minor variations observed at earlier ages. These variations are attributed to the presence of dissolved constituents in treated wastewater, which may slightly influence hydration behavior without adversely affecting overall performance.

The findings demonstrate that treated wastewater can be effectively utilized in concrete production when it meets permissible quality standards. This approach contributes to the conservation of potable water resources and supports sustainable construction practices. The study highlights the practical feasibility of wastewater reuse in concrete and encourages its adoption in regions facing water scarcity.

***Key Words:*** Treated wastewater, Concrete performance, Compressive strength, Sustainable construction, Alternative mixing water, Water quality, M40 grade concrete, Wastewater reuse, Mechanical properties, Environmental sustainability.

## 1.INTRODUCTION

Concrete remains the most extensively utilized construction material worldwide due to its versatility, durability, and economic feasibility. The production of concrete, however, requires substantial quantities of water for mixing, curing, and finishing processes. Traditionally, potable water has been considered essential to ensure the desired performance and durability of concrete. With the rapid growth of urban populations, industrial expansion, and infrastructure development, the demand for freshwater resources has increased significantly, leading to growing concerns regarding water scarcity and sustainable resource management.

In recent years, the construction industry has been compelled to explore alternative water sources to reduce dependency on potable water. Among these alternatives, treated wastewater has emerged as a promising option due to its availability and potential for reuse. Municipal wastewater treatment plants generate large volumes of treated effluent daily, much of which is discharged into natural water bodies. Utilizing this treated wastewater in concrete production not only conserves freshwater resources but also contributes to efficient wastewater management and environmental protection.

The quality of mixing water plays a critical role in determining the properties of concrete in both fresh and hardened states. Parameters such as pH, dissolved solids, chlorides, sulfates, and organic matter can influence cement hydration, setting time, strength development, and long-term durability. While potable water provides a controlled and predictable medium for concrete production, treated wastewater contains various dissolved constituents that may affect hydration mechanisms either positively or negatively. Certain mineral components present in treated wastewater may act as accelerators or supplementary agents, enhancing early strength development, whereas excessive impurities may lead to adverse effects such as reduced durability or corrosion risks in reinforced concrete.

Previous research has demonstrated that when treated wastewater meets specified quality limits, it can produce concrete with mechanical properties comparable to those made with potable water. However, variations in wastewater composition, treatment processes, and environmental conditions introduce uncertainties regarding its consistent performance in structural applications. This necessitates systematic experimental evaluation to establish its reliability and suitability for practical use.

The present study focuses on assessing the performance of concrete prepared using treated municipal wastewater as a replacement for potable water, specifically targeting M40 grade concrete. The investigation involves the preparation of concrete specimens using identical mix proportions, followed by evaluation of compressive strength at different curing ages. By comparing the results with conventional concrete, the study aims to determine whether treated wastewater can be safely and effectively utilized without compromising structural performance.

In addition to mechanical evaluation, this research highlights the broader implications of adopting treated wastewater in construction. The reuse of wastewater aligns with sustainable development principles by promoting resource efficiency, reducing environmental pollution, and minimizing the strain on freshwater reserves. The findings of this study are expected to contribute to the development of guidelines and encourage the adoption of alternative water sources in concrete production, particularly in regions facing acute water shortages.

## 2. LITERATURE SURVEY

The growing scarcity of freshwater resources has become a significant concern for the construction industry, which relies heavily on potable water for concrete production. As urbanization and infrastructure development continue to expand, the demand for sustainable alternatives has intensified. One of the most promising approaches is the use of treated wastewater as a substitute for potable water in concrete mixing and curing. Over the past few decades, extensive research has been conducted to evaluate the feasibility, performance, and limitations of this approach.

The fundamental understanding that water used in concrete does not necessarily have to be potable has been emphasized in earlier studies. Neville (2011) stated that the suitability of mixing water should be judged based on its effect on concrete properties rather than its origin or purity level [1]. This concept has paved the way for the exploration of non-potable water sources, including treated wastewater, in concrete production.

One of the earliest experimental investigations by Al-Ghusain and Terro (2003) demonstrated that treated municipal wastewater could be used in concrete without significantly affecting compressive strength or setting time [2]. The study observed only minor reductions in workability, which were still within acceptable limits. Similarly, Tay and Yip (1987) reported that concrete prepared with treated wastewater achieved approximately 95–100% of the strength of conventional concrete, confirming its suitability when chemical parameters are controlled [3].

Further research by Al-Jabri et al. (2011) revealed that treated wastewater did not adversely affect compressive strength at different curing ages [4]. In some cases, a slight improvement in strength was observed, which was attributed to the presence of dissolved minerals that may accelerate cement hydration. Asadollahfardi et al. (2015) also reported comparable workability and strength characteristics, emphasizing the importance of proper mix design and water quality control [5].

Durability aspects of concrete using treated wastewater have also been examined. Mohammed et al. (2018) investigated chloride penetration and sulfate resistance and found that treated wastewater increased chloride content slightly but remained within permissible limits [6]. This suggests that treated wastewater can be safely used in reinforced concrete provided that durability considerations are adequately addressed.

Standards and codes have played a crucial role in supporting the use of alternative water sources. ASTM C1602 (2018) permits the use of non-potable water based on performance criteria rather than strict chemical limits [7]. Similarly, IS 456:2000 allows the use of non-potable water as long as it does not adversely affect strength and setting time [8]. These provisions encourage the adoption of treated wastewater in concrete production, particularly in regions facing water scarcity.

The environmental benefits of using treated wastewater have been widely recognized. Kou and Poon (2009) highlighted that replacing potable water with recycled water significantly reduces environmental impact while maintaining concrete performance [9]. Matar and Al-Khatib (2020) further demonstrated that treated wastewater can produce concrete with mechanical properties comparable to conventional mixes, making it suitable for both normal and high-strength applications [10].

Shetty and Krishnamurthy (2012) supported the use of recycled water in concrete production, stating that treated wastewater can be used safely when chemical parameters are within acceptable limits [11]. Similarly, Al-Harthy et al. (2014) observed that variations in wastewater quality may slightly affect workability but do not significantly influence compressive strength [12].

Additional experimental studies have reinforced these findings. Ghrici et al. (2016) reported that concrete prepared with non-potable water exhibited similar compressive and flexural strength compared to control mixes [13]. Al-Mutairi et al. (2017) found that treated wastewater met strength requirements specified by design codes, although slight increases in dissolved solids were observed [14].

Kadir et al. (2018) conducted a detailed investigation into the short-term and long-term performance of concrete using treated wastewater and concluded that it is a viable alternative for sustainable construction [15]. Singh and Gupta (2019) reported that compressive strength values ranged between 95–100% of conventional concrete, confirming its suitability for structural applications [16].

Recent studies have continued to validate these findings. Saleem et al. (2021) observed consistent strength development and recommended the use of treated wastewater in both structural and non-structural applications [17]. Rao and Prasad (2022) emphasized the environmental advantages of wastewater reuse, demonstrating that it can significantly reduce freshwater consumption without compromising performance [18]. Ahmed et al. (2023) further confirmed that concrete prepared with treated wastewater exhibits comparable mechanical and durability properties [19].

Research has also explored the influence of different wastewater sources and treatment levels. Al-Otaibi et al. (2009) concluded that treated sewage effluent can be safely used in concrete production with proper quality control [20]. These findings highlight that the effectiveness of treated wastewater largely depends on its chemical composition and treatment level.

Overall, the literature consistently indicates that treated wastewater can be used in concrete production without significant loss of strength or performance, provided it meets standard quality requirements. Most studies report compressive strength values close to or slightly lower than those of conventional concrete, with differences generally within acceptable limits. In some cases, the presence of dissolved minerals has been found to enhance hydration and improve early strength development.

However, despite the encouraging results, certain challenges remain. Variability in wastewater composition, differences in treatment processes, and the lack of long-term durability studies continue to raise concerns regarding its widespread adoption. While most research has focused on compressive strength, there is a need for more comprehensive studies addressing durability aspects such as permeability, reinforcement corrosion, and performance under aggressive environmental conditions.

Another limitation identified in the literature is the lack of standardized guidelines for the use of treated wastewater in concrete production. Although existing codes provide general provisions, there is a need for more specific recommendations regarding acceptable limits of chemical constituents and their effects on concrete properties. This gap highlights the importance of conducting further experimental investigations to establish reliable and consistent performance criteria.

In summary, the reviewed literature demonstrates that treated wastewater is a promising alternative to potable water in concrete production, offering both technical and environmental benefits. The majority of studies confirm that concrete prepared with treated wastewater can achieve comparable compressive strength and acceptable durability performance.

## 3.RESEARCH GAP & PROBLEM STATEMENT

### 3.1 Research Gap

The increasing demand for sustainable construction practices has led to extensive research on the use of treated wastewater as an alternative to potable water in concrete production. Existing studies widely report that treated wastewater can produce concrete with compressive strength comparable to conventional mixes, typically achieving 95–100% of the strength of potable water concrete under controlled conditions. These findings indicate strong potential for reducing freshwater consumption in the construction industry.

However, a closer examination of the literature reveals several critical gaps that limit the practical adoption and standardization of treated wastewater in concrete applications.

Firstly, a significant portion of previous studies focuses on general performance evaluation without targeting specific concrete grades. The behavior of higher-grade concrete, such as

M40, which is commonly used in structural applications, has not been sufficiently investigated under controlled experimental conditions. Since higher-grade concrete is more sensitive to variations in mix constituents and water quality, the direct applicability of earlier findings remains uncertain.

Secondly, although many studies report comparable compressive strength results, there is limited emphasis on systematic comparative analysis using identical mix proportions while isolating water type as the only variable. Variations in mix design, materials, and testing conditions across studies create inconsistencies, making it difficult to establish reliable conclusions regarding the true influence of treated wastewater on concrete performance.

Another important gap lies in the insufficient characterization of treated wastewater in relation to standard permissible limits. While several researchers acknowledge the presence of dissolved solids, chlorides, sulfates, and organic matter, detailed correlation between these parameters and their direct impact on strength development is not consistently addressed. This lack of clarity raises concerns regarding the reproducibility of results across different wastewater sources and treatment facilities.

Furthermore, most existing research primarily focuses on short-term strength properties, particularly compressive strength at early curing ages. There is limited discussion on the progression of strength development over time and the consistency of performance across multiple curing stages. Understanding this progression is essential for validating the reliability of treated wastewater in structural applications.

In addition, despite the availability of general guidelines in standards such as IS 456 and ASTM C1602, there is a lack of clear, performance-based validation specifically tailored to treated wastewater use in concrete. The absence of standardized experimental frameworks and practical evaluation methods contributes to hesitation among engineers and construction practitioners in adopting this alternative on a wider scale.

Therefore, there exists a need for a structured experimental investigation that focuses on a specific concrete grade, utilizes controlled mix design conditions, ensures compliance with standard water quality parameters, and provides a clear comparative evaluation of strength development using treated wastewater and potable water.

### 3.2 Problem Statement

Concrete production is highly dependent on the availability of potable water, which is increasingly becoming a scarce resource due to rapid urbanization, industrial growth, and environmental challenges. At the same time, large volumes of treated wastewater are generated daily from municipal treatment plants, yet a significant portion of this resource remains underutilized and is often discharged into the environment.

Despite the potential advantages of using treated wastewater in concrete production, its practical adoption remains limited due to uncertainties regarding its effect on concrete performance. Variations in chemical composition, including the presence of dissolved solids, chlorides, sulfates, and organic matter, raise concerns about their influence on cement hydration, strength development, and overall structural integrity.

Moreover, the lack of consistent experimental evidence under controlled conditions, particularly for higher-grade concrete such as M40, has created a gap between theoretical feasibility and practical implementation. Engineers and industry stakeholders require reliable, performance-based validation to ensure that treated wastewater can be safely used without compromising the strength and quality of concrete.

Therefore, the central problem addressed in this study is to determine whether treated municipal wastewater, when meeting permissible quality limits, can effectively replace potable water in the production of M40 grade concrete without adversely affecting its compressive strength. The study aims to provide a systematic experimental comparison between concrete prepared with treated wastewater and conventional concrete, thereby establishing the feasibility, reliability, and practical applicability of treated wastewater as a sustainable alternative in construction.

## 4.METHODOLOGY

### 4.1 General Approach

The present investigation is based on an experimental framework developed to evaluate the performance of concrete prepared using treated wastewater as a substitute for potable water. The methodology is formulated to ensure scientific rigor, repeatability, and direct comparability of results. All experimental variables influencing concrete behavior, including material characteristics, mix proportions, curing conditions, and testing procedures, were maintained constant throughout the study, with the exception of the type of mixing water. The entire experimental process was conducted in accordance with the provisions of IS 10262:2009 and IS 456:2000 to ensure compliance with standard engineering practices.

### 4.2 Material Characterization

Concrete was prepared using Ordinary Portland Cement (OPC), fine aggregate conforming to Zone II grading, and crushed coarse aggregate of nominal maximum size 20 mm. The physical properties of materials were selected within standard ranges to ensure consistency in performance. The specific gravity of cement, fine aggregate, and coarse aggregate were considered as 3.15, 2.65, and 2.70 respectively, which are typical values used in mix design calculations.

Two categories of water were utilized, namely potable water and treated wastewater. The treated wastewater was characterized through laboratory testing for parameters such as hydrogen ion concentration (pH), chloride content, sulfate concentration, total dissolved solids (TDS), and organic content. The measured values were found to lie within the permissible limits specified by IS 456:2000, ensuring that the water quality was suitable for concrete production. The presence of dissolved minerals in treated wastewater was considered as a factor influencing hydration kinetics and microstructural development.

### 4.3 Mix Design Principles

The concrete mix was designed for M40 grade based on the guidelines of IS 10262:2009. The target mean compressive strength was calculated to account for variability in material properties and workmanship using the relationship:

$$f_{cm} = f_{ck} + 1.65S$$

For M40 grade concrete, the characteristic strength $f_{ck}$was taken as 40 MPa, and the standard deviation $S$was assumed based on standard recommendations. The water–cement ratio was selected as 0.50 to satisfy durability requirements under severe exposure conditions.

The water–cement ratio is defined as:

$$w/c = \frac{W}{C}$$

where $W$is the mass of water and $C$is the mass of cement.

The water content was adjusted based on workability requirements. For a nominal slump range, the base water content was increased by a percentage factor to achieve adequate consistency. The cement content was then calculated using:

$$C = \frac{W}{(w/c)}$$

ensuring that it satisfied the minimum and maximum limits specified in IS 456:2000.

The proportioning of aggregates was carried out using volumetric analysis. The absolute volume of concrete was determined using:

$$V = \frac{W}{1000} + \frac{C}{S_c \times 1000} + \frac{F.A}{S_{fa} \times 1000} + \frac{C.A}{S_{ca} \times 1000}$$

where $S_c$, $S_{fa}$, and $S_{ca}$represent the specific gravities of cement, fine aggregate, and coarse aggregate respectively.

The final mix proportions were established to maintain consistency across all specimens, ensuring that any variation in results could be attributed solely to the type of water used.

### 4.4 Concrete Production and Casting

Concrete mixing was carried out using a uniform procedure to ensure homogeneity. The dry materials were first blended thoroughly, followed by the gradual addition of water to achieve a cohesive mix. Care was taken to maintain uniform distribution of water throughout the mixture.

The fresh concrete was placed into standard cube moulds of dimensions 150 mm × 150 mm × 150 mm. The moulds were filled in layers, and each layer was compacted adequately to eliminate entrapped air and ensure proper density. Surface finishing was carried out to achieve a smooth and level top surface.

After casting, the specimens were kept undisturbed for a period of 24 hours under controlled environmental conditions to allow initial setting. This stage is critical to prevent premature moisture loss and ensure proper formation of the cement matrix.

### 4.5 Curing Regime

After demoulding, the specimens were subjected to curing for durations of 7, 14, and 28 days. Curing was carried out in a controlled environment to maintain adequate moisture conditions required for hydration. The curing process ensures the continuation of hydration reactions, leading to progressive strength development.

The degree of hydration and strength gain is influenced by curing time and environmental conditions. The relationship between strength and curing age is often represented as:

$$f_c(t) = f_{28}\left(\frac{t}{a + bt}\right)$$

where $f_c(t)$is the compressive strength at time $t$, and $a$and $b$are empirical constants.

### 4.6 Compressive Strength Testing

The compressive strength of concrete specimens was determined using a Compression Testing Machine in accordance with IS 516:1959. The load was applied uniformly at a controlled rate until failure occurred.

The compressive strength was calculated using the expression:

$$f_c = \frac{P}{A}$$

For a standard cube specimen, the cross-sectional area was:

$$A = 150 \times 150 = 22500 \text{ mm}^2$$

The failure load recorded during testing was used to compute the compressive strength. Multiple specimens were tested at each curing age, and the average value was considered to reduce experimental error and improve reliability.

### 4.7 Analytical Evaluation

The performance of concrete prepared using treated wastewater was evaluated by comparing it with conventional concrete. The variation in compressive strength was quantified using the percentage difference:

$$\%\ \text{Difference} = \frac{f_{control} - f_{treated}}{f_{control}} \times 100$$

This evaluation provides a quantitative measure of deviation and helps in assessing the feasibility of treated wastewater as an alternative mixing water.

In addition, strength efficiency can be expressed as:

$$\text{Efficiency} = \frac{f_{treated}}{f_{control}} \times 100$$

which indicates the relative performance of treated wastewater concrete with respect to conventional concrete

### 4.8 Methodological Significance

The methodology adopted in this study ensures a comprehensive and unbiased evaluation of treated wastewater in concrete production. By maintaining strict control over all variables except the type of water, the study isolates the effect of treated wastewater on concrete performance. The integration of standard codes, quantitative analysis, and systematic testing enhances the reliability and applicability of the findings.

## 5.RESULTS AND DISCUSSION

### 5.1 Compressive Strength Development

The compressive strength results obtained at 7, 14, and 28 days demonstrate a consistent and progressive increase in strength for both conventional concrete and treated wastewater concrete. At 7 days, the treated wastewater concrete achieved a compressive strength of approximately 28.66 MPa, while the conventional concrete exhibited a slightly higher strength of about 30.00 MPa. This initial difference indicates a marginal reduction in early-age strength when treated wastewater is used. The reduction can be attributed to the presence of dissolved solids and minor impurities that may slightly influence the initial hydration rate of cement.

At 14 days, the compressive strength of treated wastewater concrete increased to approximately 33.37 MPa, compared to 35.00 MPa for potable water concrete. The reduction in strength difference at this stage suggests that the hydration process continues effectively, and the influence of initial impurities becomes less significant as hydration progresses. The observed strength values indicate that

treated wastewater does not hinder intermediate strength development.

At 28 days, the treated wastewater concrete achieved a compressive strength of approximately 41.75 MPa, while the control mix reached about 43.00 MPa. The difference between the two mixes further reduced to a minimal level, with treated wastewater concrete achieving nearly 97% of the strength of conventional concrete. This convergence in strength values demonstrates that long-term hydration and microstructural development are not adversely affected by the use of treated wastewater.

The variation of compressive strength with curing age follows the typical trend of concrete behavior, where strength increases rapidly at early stages and gradually stabilizes at later ages. The strength development pattern can be represented by the empirical relationship:

$$f_c(t) = f_{28}\left(\frac{t}{a + bt}\right)$$

where $f_c(t)$is the compressive strength at time $t$, and $a$and $b$are constants related to hydration characteristics. The similarity in strength development trends for both mixes indicates comparable hydration mechanisms.

### 5.2 Strength Comparison and Efficiency Analysis

To quantify the influence of treated wastewater, the percentage difference in compressive strength between the two mixes was evaluated. The percentage reduction at 7 days was approximately 4.47%, which slightly increased to around 4.66% at 14 days and reduced significantly to about 2.91% at 28 days. This decreasing trend in percentage difference with curing age highlights the diminishing impact of treated wastewater on strength development over time.

The relative performance of treated wastewater concrete can be expressed in terms of strength efficiency:

$$\text{Efficiency} = \frac{f_{treated}}{f_{control}} \times 100$$

At 28 days, the efficiency was observed to be approximately 97%, indicating that treated wastewater concrete performs nearly equivalent to conventional concrete. Such a high efficiency value confirms that the substitution of potable water does not lead to significant loss in mechanical performance.

### 5.3 Influence of Water Quality on Concrete Behavior

The behavior of concrete prepared with treated wastewater is influenced by its chemical composition, including the presence of chlorides, sulfates, and total dissolved solids. Although these constituents were higher in treated wastewater compared to potable water, they remained within permissible limits specified by IS standards. The presence of certain dissolved minerals may contribute to the acceleration of hydration reactions, particularly at later stages, thereby compensating for the initial reduction in strength.

The slightly lower early-age strength observed in treated wastewater concrete can be attributed to the interaction of organic and inorganic compounds with cement hydration products. However, as curing progresses, these effects become negligible due to the continued formation of calcium silicate hydrate (C–S–H) gel, which is primarily responsible for strength development. The densification of the microstructure at later ages results in improved strength and reduced differences between the two mixes.

### 5.4 Consistency and Reliability of Results

The experimental results exhibited minimal variation among specimens at each curing age, indicating uniform mixing, proper compaction, and consistent curing conditions. The close agreement between individual specimen values suggests that the methodology adopted in the study ensured high reliability and repeatability of results. The absence of abnormal failure patterns further confirms that the use of treated wastewater does not introduce structural irregularities in concrete.

### 5.5 Discussion in Context of Structural Performance

From a structural perspective, the compressive strength values achieved by treated wastewater concrete satisfy the requirements of M40 grade concrete as specified by relevant standards. The slight reduction in strength at early ages does not pose a significant concern, as the 28-day strength, which is critical for design considerations, remains within acceptable limits. The ability of treated wastewater concrete to achieve more than 95% of the target strength demonstrates its suitability for structural applications.

The findings indicate that the use of treated wastewater does not adversely affect the fundamental properties of concrete when its quality is maintained within permissible limits. The comparable strength performance suggests that treated wastewater can be considered a viable alternative to potable water in concrete production, particularly in regions facing water scarcity.

### 5.6 Overall Interpretation

The overall analysis of results confirms that the use of treated wastewater leads to only marginal differences in compressive strength, which diminish with curing time. The strength development pattern, efficiency values, and consistency of results collectively indicate that treated wastewater does not significantly alter the hydration process or structural integrity of concrete. The minor variations observed can be attributed to the chemical composition of treated wastewater, which, when controlled within acceptable limits, does not hinder concrete performance.

The study establishes that treated wastewater can effectively replace potable water in concrete production without compromising strength characteristics. This finding supports the adoption of sustainable practices in the construction industry by promoting the reuse of wastewater and reducing dependency on freshwater resources.

## 6.CONCLUSION

This study investigated the feasibility of using treated wastewater as a replacement for potable water in the production of M40 grade concrete, with emphasis on compressive strength performance. The experimental results demonstrate that concrete prepared with treated wastewater exhibits strength characteristics closely comparable to those of conventional concrete. A minor reduction in early-age strength was observed; however, this difference decreased with curing time, and the 28-day compressive strength reached approximately 97% of the control mix.

The results indicate that treated wastewater does not significantly affect the hydration process or long-term strength development when its chemical composition remains within permissible limits. The concrete produced using treated wastewater satisfied the strength requirements specified for M40 grade, confirming its suitability for structural applications. The consistency of results further reflects that the use of treated wastewater does not introduce any adverse effects on concrete performance.

From a sustainability perspective, the utilization of treated wastewater offers a practical solution for reducing dependence on potable water in construction activities. It supports resource conservation and promotes environmentally responsible practices without compromising structural performance.

## 7. REFERENCES

[1] Neville, A. M., *Properties of Concrete*, 5th ed., Pearson Education Limited, 2011.

[2] Al-Ghusain, I., and Terro, M. J., "Use of treated wastewater for concrete mixing," *Cement and Concrete Research*, vol. 33, no. 6, pp. 867–872, 2003.

[3] Tay, J. H., and Yip, W. K., "Use of reclaimed wastewater for concrete production," *Journal of Environmental Engineering*, vol. 113, no. 6, pp. 1156–1169, 1987.

[4] Al-Jabri, K. S., Al-Saidy, A. H., and Taha, R., "Effect of using wastewater on the properties of high-strength concrete," *Construction and Building Materials*, vol. 25, no. 2, pp. 600–606, 2011.

[5] Asadollahfardi, G., Delnavaz, M., and Rashnoiee, V., "Use of treated domestic wastewater before and after advanced treatment in concrete," *Construction and Building Materials*, vol. 88, pp. 77–82, 2015.

[6] Mohammed, A., Al-Hadithi, A., and Al-Zubaidi, A., "Durability properties of concrete made with treated wastewater," *Journal of Materials in Civil Engineering*, vol. 30, no. 5, 04018074, 2018.

[7] ASTM C1602/C1602M-18, *Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete*, ASTM International, 2018.

[8] IS 456:2000, *Plain and Reinforced Concrete – Code of Practice*, Bureau of Indian Standards, New Delhi, India, 2000.

[9] Kou, S. C., and Poon, C. S., "Properties of concrete prepared with recycled water," *Cement and Concrete Composites*, vol. 31, no. 8, pp. 577–583, 2009.

[10] Matar, P., and Al-Khatib, J., "Mechanical performance of concrete using recycled water," *Journal of Cleaner Production*, vol. 276, 123234, 2020.

[11] Shetty, M. S., and Krishnamurthy, K. T., *Concrete Technology: Theory and Practice*, S. Chand Publications, 2012.

[12] Al-Harthy, A. S., Taha, R., and Al-Maamari, R. S., "Effect of treated wastewater on concrete properties," *International Journal of Sustainable Construction Engineering*, vol. 5, no. 2, pp. 15–24, 2014.

[13] Ghrici, M., Kenai, S., and Said-Mansour, M., "Mechanical properties of concrete using non-potable water," *Construction and Building Materials*, vol. 47, pp. 117–124, 2016.

[14] Al-Mutairi, N., Terro, M., and Al-Khaleefi, A., "Effect of recycled water on concrete properties," *International Journal of Civil Engineering*, vol. 15, no. 3, pp. 345–352, 2017.

[15] Kadir, M. A., Mohd Sam, A. R., and Mohd Nasir, N., "Performance of concrete using recycled wastewater," *Materials Science Forum*, vol. 917, pp. 45–50, 2018.

[16] Singh, P., and Gupta, R., "Experimental study on concrete using treated wastewater," *International Journal of Civil Engineering and Technology*, vol. 10, no. 2, pp. 112–120, 2019.

[17] Saleem, M., Ahmad, S., and Khan, R., "Effect of treated municipal wastewater on concrete properties," *Journal of Sustainable Construction Materials*, vol. 6, no. 1, pp. 25–32, 2021.

[18] Rao, P. S., and Prasad, K., "Sustainable concrete using treated wastewater," *Materials Today: Proceedings*, vol. 60, pp. 1015–1020, 2022.

[19] Ahmed, S., Zhou, Y., and Rahman, M., “Mechanical properties of concrete using recycled water,” *Journal of Materials in Civil Engineering*, vol. 35, no. 4, 04023012, 2023.

[20] Al-Otaibi, M., Al-Harthy, A., and Taha, R., “Use of treated sewage effluent in concrete production,” *Construction and Building Materials*, vol. 23, no. 1, pp. 110–116, 2009.