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EXPERIMENTAL STUDY ON THE EFFECT OF CHEMICAL ADMIXTURES ON THE COMPRESSIVE STRENGTH OF CONCRETE

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Abstract

Concrete is among the most often utilized building materials because to its exceptional compressive strength and longevity. Chemical additives are frequently used into concrete formulations to enhance its mechanical characteristics and building efficacy. This research empirically examined the influence of chemical additives on the compressive strength of concrete. Two concrete formulations, specifically standard concrete and concrete with chemical additives, were evaluated at curing durations of 3, 7, and 28 days following SNI 1974:2011 guidelines. The findings indicated that concrete with chemical admixtures consistently attained superior compressive strength compared to standard concrete. The mean compressive strengths of conventional concrete at 3, 7, and 28 days were 18.45 MPa, 22.30 MPa, and 29.80 MPa, respectively, whereas the corresponding values for admixture concrete were 23.90 MPa, 30.60 MPa, and 41.30 MPa. The application of chemical admixtures enhanced the compressive strength by 29.54%, 37.22%, and 38.59% during the corresponding curing durations. These results demonstrate that chemical additives significantly enhance the compressive strength of concrete and can be utilized to create high-performance concrete for structural applications.

Keywords: Chemical admixtures; compressive strength; concrete; experimental study;

INTRODUCTION

Concrete is among the most extensively utilized materials in civil engineering, attributed to its remarkable compressive strength, longevity, and adaptability [1]. It is often utilized in edifices, overpasses, roadways, reservoirs, and various infrastructure endeavors due to its capacity to endure substantial compressive forces while preserving structural integrity. With the progression of construction technology, there is a growing necessity for concrete that exhibits superior mechanical properties, including elevated compressive strength, enhanced workability, and increased durability. Consequently, numerous techniques have been devised to enhance the quality of concrete while keeping building expenses relatively low.

The integration of chemical admixtures is among the most efficient strategies to improve concrete performance. Chemical admixtures are substances incorporated into concrete prior to or during the mixing process to alter the characteristics of both fresh and cured concrete. Chemical admixtures can enhance workability, diminish water requirements, expedite or delay setting time, and augment the mechanical characteristics of concrete, contingent upon their roles. Superplasticizers are extensively utilized as they considerably diminish the water-to-cement ratio while preserving the necessary workability. A diminished water-cement ratio often yields a more compact cement matrix, leading to enhanced compressive strength and greater durability [3].

The compressive strength of concrete is a critical factor in structural design as it indicates concrete's capacity to withstand compressive forces. The compressive strength is affected by various elements, including as the quality of raw materials, the water-cement ratio, curing conditions, and the incorporation of chemical admixtures. Appropriate application of chemical admixtures can enhance cement hydration, diminish internal porosity, and fortify the interfacial transition zone (ITZ) between cement paste and aggregates, thus improving the overall mechanical properties of concrete. Prior research has shown that the addition of chemical admixtures can markedly enhance the compressive strength of concrete [4]. The extent of enhancement is contingent upon the nature and quantity of admixtures, material properties, and curing circumstances. Consequently, laboratory assessment is essential to confirm the efficacy of chemical admixtures within particular mix ratios and testing parameters. This research seeks to empirically examine the influence of chemical additives on the compressive strength of concrete by contrasting standard concrete with concrete that incorporates chemical admixtures. Compressive strength evaluations were performed at curing durations of 3, 7, and 28 days, adhering to SNI 1974:2011 standards. The results of this research are anticipated to yield valuable insights into the efficacy of chemical admixtures in enhancing concrete strength and to act as a benchmark for the utilization of high-performance concrete in structural engineering.

LITERATURE REVIEW

2.1 Concrete Compressive Strength

Concrete is a composite substance made up of cement, water, fine aggregates, coarse aggregates, and, if necessary, chemical additives. Compressive strength serves as the principal metric for assessing the quality and structural efficacy of concrete among its mechanical attributes. The compressive strength indicates the highest compressive stress that concrete can endure prior to breakdown, making it a crucial factor in the construction of reinforced concrete edifices.

The compressive strength of concrete is affected by various elements, such as the water-to-cement ratio, cement quantity, aggregate quality, curing conditions, and the addition of chemical admixtures. A diminished water-to-cement ratio often yields a more compact cement paste with decreased porosity, leading to enhanced compressive strength. Nonetheless, diminishing the moisture level without preserving workability could result in challenges during the mixing and application processes. Consequently, the application of chemical admixtures has emerged as a potent remedy to enhance both workability and strength. Contemporary evaluations highlight that concrete performance is influenced not solely by the mix ratio but also by the interplay between admixtures and cement hydration.

2.2 Chemical Admixtures in Concrete

Chemical admixtures are substances incorporated into concrete prior to or during the mixing process to alter the characteristics of both fresh and cured concrete. They are frequently utilized to boost workability, diminish water requirements, regulate setting time, augment compressive strength, and bolster durability. As per ASTM C494, chemical admixtures encompass many classifications, including water reducers, high-range water reducers (superplasticizers), retarders, accelerators, and their functional combinations.

Superplasticizers are the most commonly utilized chemical admixtures in high-performance concrete. They markedly diminish the water demand while preserving sufficient workability, facilitating the creation of concrete with a reduced water-to-cement ratio. The decrease in water content fosters the development of a more compact cement matrix, enhances the interfacial transition zone (ITZ) between cement paste and aggregates, and finally elevates the compressive strength of concrete. Recent evaluations indicate that developments in polycarboxylate-based superplasticizers have significantly enhanced the efficacy of both conventional and high-strength concrete. Nanosilica serves as an exceptionally reactive pozzolanic substance that hastens hydration, enhances the generation of supplementary calcium silicate hydrate (C–S–H), and optimizes the concrete microstructure, thereby augmenting compressive strength.

2.3 Previous Studies

A multitude of research endeavors have examined the impact of chemical additives on the mechanical characteristics of concrete. Prior research repeatedly demonstrates that the addition of chemical admixtures improves workability while lowering the water-to-cement ratio, hence increasing compressive strength. The enhancement is chiefly linked to superior particle distribution, enhanced cement hydration, less capillary porosity, and a more compact concrete microstructure. Analyses have indicated that the efficacy of chemical admixtures is contingent upon various elements, such as the admixture type, dose, cement formulation, aggregate properties, and curing circumstances. Thus, laboratory assessment is essential to ascertain the ideal efficacy of admixtures for a particular concrete formulation.

According to prior research, the application of chemical admixtures has emerged as a highly successful technique for enhancing the compressive strength of concrete. Nonetheless, discrepancies in material characteristics and mixture ratios may lead to varying degrees of strength improvement. This research empirically assesses the influence of chemical additives on the compressive strength of concrete by contrasting standard concrete with concrete that includes chemical admixtures in a laboratory setting.

METHOD

3.1 Research Design

This research utilized an experimental laboratory approach to examine the influence of chemical additives on the compressive strength of concrete. The study analyzed two varieties of concrete compositions: standard concrete (NC) and concrete with chemical additives (CAC). The experimental study concentrated on assessing the compressive strength characteristics of both combinations at curing durations of 3, 7, and 28 days. The experimental methodology encompassed material preparation, concrete amalgamation, specimen formation, curing, compressive strength evaluation, and data analysis. The laboratory test results for compressive strength were analyzed to assess the efficacy of chemical admixtures in enhancing concrete performance.

3.2 Materials

The materials used in this study consisted of Ordinary Portland Cement (OPC Type I), clean water, fine aggregate (natural sand), coarse aggregates (split 1–2 and split 2–3), and chemical admixtures. The chemical admixtures consisted of a superplasticizer and a water-reducing/retarding admixture to improve workability and compressive strength. Based on the laboratory mix design, the normal concrete mixture contained 450 kg/m³ of cement, 190 L/m³ of water, 632 kg/m³ of fine aggregate, 341 kg/m³ of split 1–2, and 795 kg/m³ of split 2–3. For the concrete containing chemical admixtures, the cement and coarse aggregate contents remained unchanged, while 6 L of superplasticizer and 1 L of water-reducing/retarding admixture were incorporated. The water content was reduced to 90 L/m³, and the fine aggregate content was adjusted to 734 kg/m³. These mix proportions were adopted from the laboratory experimental data.

3.3 Preparation of Test Specimens

The concrete was blended according to the ratios outlined in the laboratory mix design. Newly mixed concrete was cast into cylindrical forms measuring 150 mm in diameter and 300 mm in height. The samples were compressed to reduce air pockets and guarantee consistency. Following casting, the samples were subjected to curing in a laboratory environment until the specified testing intervals of 3, 7, and 28 days. At every curing interval, the samples were extracted from the curing conditions and readied for compressive strength evaluation.

3.4 Compressive Strength Test

The compressive strength test was performed in accordance with SNI 1974:2011, which specifies the testing procedure for cylindrical concrete specimens. Each specimen was placed in a compression testing machine, and the load was applied continuously until failure occurred.
The compressive strength of each specimen was calculated using the following equation:

$$f'c = \frac{P}{A}$$

dengan:

f'c= kuat tekan beton (MPa)
P = beban maksimum (N)
A = luas penampang benda uji (mm²)

RESULTS AND DISCUSSION

4.1 Compressive Strength Test Results

The compressive strength of normal concrete (NC) and concrete incorporating chemical admixtures (CAC) was evaluated at curing ages of 3, 7, and 28 days. The average compressive strength values obtained from the laboratory tests are presented in **Table 1**.

Table 1. Average Compressive Strength of Concrete

Curing Age (Days)	Normal Concrete (MPa)	Concrete with Chemical Admixtures (MPa)	Increase (%)
3	18.45	23.90	29.54
7	22.30	30.60	37.22
28	29.80	41.30	38.59

As shown in Table 1, the compressive strength of both concrete mixtures increased with curing age. However, the concrete incorporating chemical admixtures consistently exhibited higher compressive strength than the normal concrete throughout the testing period.

At the age of 3 days, the average compressive strength increased from 18.45 MPa for normal concrete to 23.90 MPa for concrete containing chemical admixtures, corresponding to an increase of 29.54%. At 7 days, the compressive strength increased from 22.30 MPa to 30.60 MPa, representing an increase of 37.22%. At 28 days, the average compressive strength reached 41.30 MPa, compared with 29.80 MPa for normal concrete, indicating the highest improvement of 38.59%. These results confirm that the incorporation of chemical admixtures significantly enhanced the compressive strength of concrete

4.2 Discussion

The enhancement in compressive strength noted in concrete containing chemical admixtures can be ascribed to the alteration of the concrete's microstructure throughout the hydration phase. Chemical additives enhance the distribution of cement particles, facilitating a more uniform and efficient formation of hydration products. As a result, the cement paste attains greater density and demonstrates enhanced adhesion to the aggregates, leading to superior compressive strength. A significant element that bolsters strength is the diminished water-to-cement ratio attained via chemical admixtures. Diminished water content lessens the development of capillary voids in the solidified concrete, resulting in a denser microstructure. The more compact internal composition enhances concrete's capacity to withstand compressive forces and postpones the onset of microcracks.

The experimental findings further suggest that the impact of chemical additives become more pronounced with an extended curing duration. Both concrete combinations demonstrated ongoing strength enhancement; however, the concrete with chemical admixtures showed a superior rate of strength increase. This conduct indicates that the hydration process was more efficient with the use of chemical admixtures, resulting in the formation of extra calcium silicate hydrate (C–S–H) gel that enhances concrete strength. At 28 days, the concrete with chemical admixtures attained an average compressive strength of 41.30 MPa, surpassing the specified design strength of 36 MPa, whereas the standard concrete only achieved 29.80 MPa. This discovery indicates that the addition of chemical admixtures is a successful method for generating higher-strength concrete without augmenting the cement content [7]. Consequently, the incorporation of chemical admixtures is advisable for structural concrete applications that necessitate enhanced mechanical properties and construction efficacy.

CONCLUSION

This research empirically assessed the influence of chemical additives on the compressive strength of concrete via laboratory experiments. According to the experimental findings, the compressive strength of both standard concrete and concrete with chemical admixtures improved with the age of curing. Nonetheless, the concrete with chemical admixtures continuously demonstrated superior compressive strength compared to the standard concrete at every testing age. The mean compressive strengths of concrete with chemical admixtures were 23.90 MPa, 30.60 MPa, and 41.30 MPa for curing durations of 3, 7, and 28 days, respectively, while the equivalent figures for standard concrete were 18.45 MPa, 22.30 MPa, and 29.80 MPa. The application of chemical admixtures enhanced the compressive strength by 29.54%, 37.22%, and 38.59% during the corresponding curing durations.

The findings indicate that the use of chemical admixtures significantly improves the compressive strength of concrete by augmenting the quality of the cement matrix and diminishing internal porosity. Consequently, the use of chemical admixtures is seen as a viable method for generating high-strength concrete appropriate for structural uses that demand enhanced mechanical properties and construction efficacy. Future research is advised to explore various types and dosages of chemical admixtures, along with their impacts on additional concrete parameters like durability, water absorption, permeability, and microstructural attributes.

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