

Enhancing water resistance of plaster mortar with cement additives

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Abstract. Global research on waterproofing admixtures has progressed significantly over decades, driven by the need to enhance structural durability against water-induced degradation. In Vietnam, such investigations are particularly relevant due to the challenges posed by tropical monsoon climates on building integrity. This study evaluates the effect of cement-based waterproofing additive dosage (0–20% by weight) on cement–sand mortar performance. Experimental testing of compressive strength and water permeability revealed that additive incorporation up to 10% improves both mechanical properties and water resistance. Beyond this threshold, waterproofing efficiency declines, with some mixtures exhibiting inferior performance to additive-free controls. The findings emphasize the necessity of optimal additive dosage to maintain equilibrium between mechanical strength and water resistance in construction applications.

1 Introduction

In Vietnam, the issue of waterproofing in construction is particularly critical due to the country's tropical monsoon climate, which subjects buildings to prolonged humidity, high rainfall, and repeated thermal stress. A study conducted by the Ho Chi Minh City University of Technology reported that approximately 84.35% of urban buildings exhibited leakage problems, with over 50% being under five years of age—figures that surpass leakage rates in countries such as the United States (60%) and Singapore (53%) [1]. According to specialists at Sika Vietnam, water penetration into building materials typically occurs through two dominant mechanisms: capillary suction via micro-pores, and cracking induced by thermal expansion and contraction in hot and humid environments [2].

To mitigate these durability issues, recent domestic research has prioritized the development of effective waterproofing materials and chemical admixtures. Cement-sand mortar, although widely used for plastering and rendering, inherently suffers from high porosity due to its low binder and water content, which limits its ability to compact and fill voids between sand particles. The integration of waterproofing additives, such as Sika Grout 214-11—a cement-based admixture—has been shown to significantly improve mortar density, reduce water absorption, and enhance compressive strength [2].

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Vietnamese researchers have examined various approaches to enhancing impermeability. In 2013, Ngo Van Toan demonstrated that the incorporation of rice husk ash combined with superplasticizers yielded notable improvements in both strength and water resistance [3]. Nguyen Quang Binh, in 2014, investigated multifunctional superplasticizers for roller-compacted concrete, achieving high impermeability and structural integrity [4]. Furthermore, Phan Van Chuong et al. emphasized the necessity of using low-permeability concrete layers in marine construction to withstand aggressive environments [5].

2 Research Methods

The research team prepared cement–sand mortar specimens in two shapes: prismatic samples with dimensions of 160×40×40 mm and cylindrical samples with a diameter and height of 150 mm. The mixes will incorporate waterproofing admixtures as partial replacements for cement at varying proportions of 0%, 5%, 10%, 15% and 20%. All mortar samples were produced according to the mix design presented in Table 1, corresponding to a concrete grade of 100. Following casting, the specimens will be cured in water for 28 days prior to testing to ensure consistent hydration and material properties.

2.1 Compressive strength of the mortar sample

The compressive strength of each individual specimen was evaluated in accordance with the Vietnamese standard TCVN 6355-2:2009, which specifies procedures for testing hardened concrete. The compressive strength f_c was calculated based on the applied maximum load divided by the cross-sectional area of the specimen, as defined by the following equation [6]

$$f_c = \frac{P}{A} \quad (1)$$

where:

f_c is the compressive strength (MPa),

P is the maximum load at failure (N),

A is the loaded surface area of the specimen (mm²).

The compressive strength of each concrete batch was determined as the average compressive strength f_{avg} of three individual specimens. This average is considered valid if the variation among samples does not exceed 15%, in accordance with the acceptance criteria specified in TCVN 6355-2:2009 [6]. The average compressive strength is calculated using the following expression:

$$f_{avg} = \frac{f_1 + f_2 + f_3}{3} \quad (2)$$

where:

f_{avg} is the average compressive strength (MPa),

f_1, f_2, f_3 are the compressive strengths of the three tested specimens (MPa).

2.2 Water Penetration Resistance of Cylindrical Specimens

The water resistance of concrete was assessed using the penetration method specified in TCVN 3116:2022, issued by the Ministry of Science and Technology of Vietnam [7-9]. This standard outlines a procedure for evaluating the permeability of concrete by measuring the depth of water penetration under hydrostatic pressure over a fixed testing period.

The procedure consists of the following steps:

Specimen preparation: Concrete specimens are fabricated and cured according to the requirements of the standard.

Testing procedure: Each sample is placed into a testing apparatus and subjected to increasing levels of water pressure in stages.

Test duration: The test continues until visible signs of water penetration, such as damp spots or droplets, appear on the exposed surface of the specimen. At this point, the valve is closed and the specimen is removed.

Evaluation: The water penetration resistance of the specimen group is determined based on the highest pressure stage at which no leakage is observed.

Table 1. Waterproofing Grade Specification.

| Water Penetration Resistance of the Specimen Group | Waterproofing Grade |
|---|----------------------------|
| 0,2 | W02 |
| 0,4 | W04 |
| 0,6 | W06 |
| 0,8 | W08 |
| 1,0 | W10 |
| 1,4 | W14 |
| 1,8 | W18 |
| 2,0 | W20 |

2.3 Material Composition

The cement–sand mortar used in this study was produced from conventional concrete materials, including sand, cement, and water, in accordance with the requirements of TCVN 7570:2006 issued by the Ministry of Science and Technology [7]. The mix design was developed to achieve a concrete grade of M100, as illustrated in Figure 1 and detailed in Table 2.

Five mortar mix variations were prepared by partially replacing cement with a cement-based waterproofing additive (Sika Grout 214-11, hereinafter referred to as PGSK) at different substitution rates: 0%, 5%, 10%, 15%, and 20%. These mixes were labeled M00, M05, M10, M15, and M20, respectively, corresponding to the percentage of PGSK used in each formulation.



(a) Vicem Ha Tien PCB40 Cement (b) Sand (c) Sika Grout

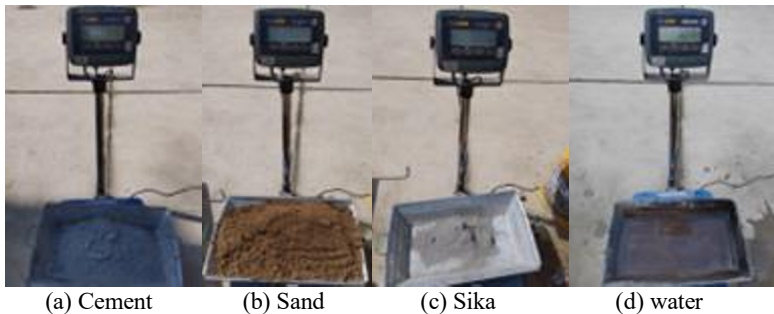
Fig. 1. Constituent Materials Used for Specimen Casting

Table 2. Mix Proportions per 1 m³ of Concrete.

| Material | Quantity (kg) |
|----------|---------------|
| Water | 150 |
| Cement | 260 |
| Sand | 1050 |

The amount of PGSK used to replace part of cement with the ratio from 0% to 20% in 1m³ of concrete is as follows: M00 0% (0kg) - M05 5% (13kg) - M10 10% (26kg) - M15 15% (39kg) - M20 20% (52kg)

During the experiment, the material samples were fabricated by specialized casting equipment and the raw material composition was accurately quantified. The process of weighing the raw materials is shown in Figure 2.



(a) Cement (b) Sand (c) Sika (d) water

Fig. 2. Weighing of the constituent materials.



(a) Specimen Molds (b) Mixing Machine

Fig. 3. Equipment used for specimen casting.

3 Results and Discussion

3.1 Research Findings

The mixing process plays a critical role in determining the physical and mechanical properties of concrete, as well as the overall durability of the final product. Ensuring homogeneity of the concrete mixture and the accurate measurement of input materials is essential for maintaining construction quality and facilitating subsequent handling. Given that PGSK is used in relatively small dosages, precise proportioning is particularly important to guarantee both the effectiveness of the admixture and the uniformity of the mix.

The preparation of concrete specimens—including mixing, casting, curing, compressive strength testing, and water penetration resistance evaluation—was carried out following the procedures illustrated in Figures 3, 4, and 5. The application of bitumen coating was conducted in accordance with TCVN 9065:2012, issued by the Ministry of Science and Technology [8]. Strict adherence to each stage of the experimental process is fundamental to ensuring the accuracy and reliability of the research outcomes.



(a) Curing

(b) Bitumen Coating

Fig. 4. Curing and Bitumen Coating Process

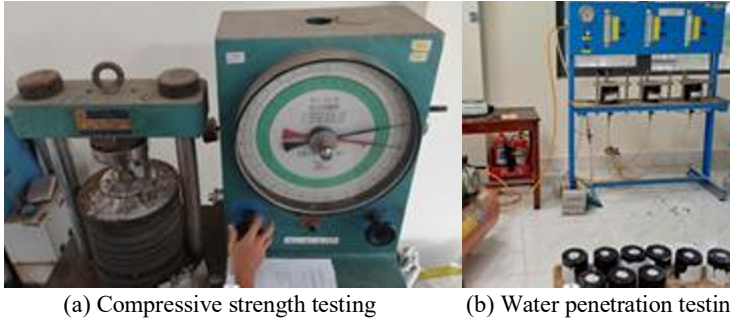


Fig. 5. Laboratory equipment

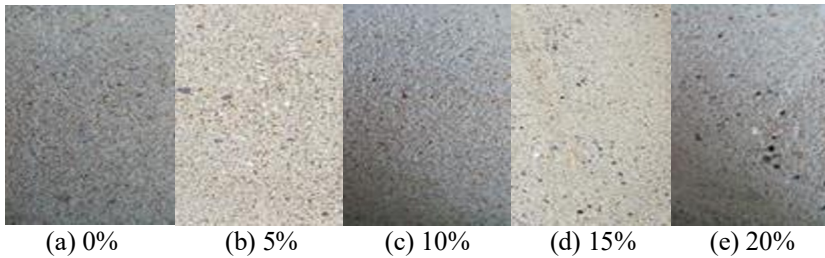


Fig. 6. Cross-section of specimens with Sika content ranging from 0% to 20%.

Observations and Results:

Specimens containing 5–10% PGSK exhibited noticeably smoother surfaces compared to the 0% control sample. However, as the PGSK content increased to 15–20%, visible pores began to form within the matrix. At the 20% replacement level, pores became prominent and were observable with the naked eye, indicating potential issues with mix homogeneity and compaction.

After 28 days of curing in water environment, the samples were tested for compressive strength and water resistance. The test results of cement-sand mortar samples are summarized in Figures 7 and 8. These results reflect the influence of PGSK content on the mechanical performance and permeability of the mortar mixture, according to TCVN 3116:2022 and TCVN 6355-2:2009 [6, 9].

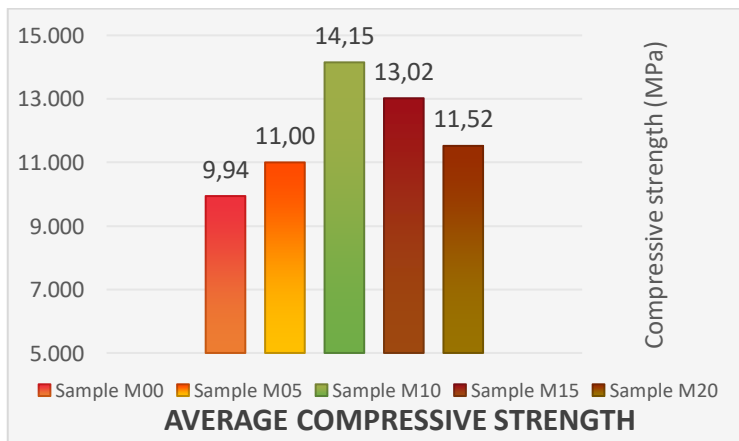


Fig. 7. Compressive Strength Results

Observation: The results indicate that the compressive strength of the cement–sand mortar improved with the inclusion of PGSK. However, when the admixture content exceeded 10%, the strength began to decline, though it remained approximately 15% higher than that of the control sample (M00).

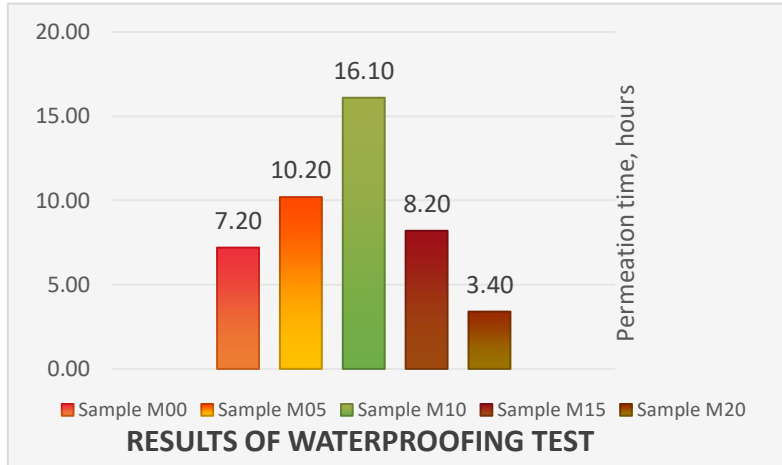


Fig. 8. Waterproofing Test Results

Observation: Similar to the trend observed in compressive strength, water resistance improved significantly with the addition of PGSK. However, when the PGSK content increased to 15–20%, a sharp decline in impermeability was recorded, with performance falling below that of the control specimen without PGSK.

3.2 Discussion

The water resistance of cement–sand mortar showed a marked improvement as PGSK content increased from 0% to 10%, with the M10 specimen demonstrating the highest resistance to water pressure without signs of leakage. This result supports the effectiveness of PGSK in enhancing impermeability by filling capillary pores and reducing overall porosity [10]. However, a significant decline in water resistance was observed in the M20 mix, even lower than that of the control sample (M00), as evident from the visible voids on the cross-sectional surface shown in Figure 6. This deterioration is likely due to excess additive accumulation, which may lead to the formation of microvoids and disrupt the continuity of the mortar structure. These findings align with Picandet’s observations on how internal damage can negatively impact impermeability under compressive loading [10].

Based on experimental results, the optimal PGSK replacement level was identified at 10%, at which both compressive strength and water resistance reached their highest values among the five mixes. Beyond this level, both properties began to decline, particularly at 20%, indicating a threshold beyond which additional PGSK substitution may negatively affect mortar performance.

Despite these findings, the study has certain limitations. It examined only one type of additive (Sika Grout 214-11), focused solely on B7.5-grade cement–sand mortar, and lacked real-world testing to validate laboratory outcomes. As a next step, the research team intends to conduct practical trials to more comprehensively assess the impact of PGSK on mortar behavior under real construction conditions.

4 Conclusion

This study investigated the effect of varying PGSK content on the compressive strength and water resistance of cement–sand mortar. Based on the experimental findings, the following conclusions can be drawn:

Partially replacing cement with PGSK has a positive impact on the compressive strength of cement–sand mortar. The highest strength was recorded at a 10% replacement level, showing an increase of up to 40% compared to the control mix. Although the compressive strength decreased beyond the 10% replacement level, the strength of the M20 mix was still approximately 15% higher than the control sample.

Water impermeability was significantly enhanced when PGSK content remained below 10%. Conversely, at dosages exceeding 10%, water resistance began to decline, with a sharp reduction observed at 20%, even lower than the control sample without any additive.

The decline in impermeability at higher PGSK levels may be attributed to the formation of surface voids resulting from excessive cement replacement. These voids reduce the density and structural continuity of the mortar, thereby weakening its waterproofing performance.

Overall, PGSK demonstrates considerable potential in enhancing both the compressive strength and water resistance of cement–sand mortar. The optimal performance was achieved at a 10% PGSK replacement level, balancing both structural integrity and durability.

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