World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Effect of the C-A-S-H based hardening accelerator on the compressive strength of concrete

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World Journal of Advanced Research and Reviews, 2026, 30(02), 1829-1832

Publication history: Received on 10 April 2026; revised on 20 May 2026; accepted on 22 May 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.30.2.1464

Abstract

C-A-S-H($CaO(-Al_2O_3)-SiO_2-H_2O$)) based hardening accelerator is one of the new types of accelerators for improving the 28-day strength of concrete and causes no corrosion to reinforced concrete. In this study, aluminum nitrate, calcium nitrate, water glass and PCEs were used to synthesize the C-A-S-H based hardening accelerator. The efficacy of this hardening accelerator was evaluated by measuring the compressive strength of concrete at different curing periods. The results showed that the hardening accelerator had a significant effect on improving the early-age strength of concrete and particularly enhanced its 28-day strength. The C-A-S-H based accelerator not only exhibited excellent accelerating performance and compressive strength improvement, but also contained no chloride ions, thus holding great potential as a green additive in construction.

Keywords: C-A-S-H; Accelerator; Compressive strength

1. Introduction

With the continuous advancement of construction technologies, various chemical admixtures have been widely adopted to improve concrete performance. Among these admixtures, hardening accelerators play a crucial role in accelerating construction schedules, and their application has steadily expanded over time. In recent years, many accelerators have been applied in construction to improve the early strength of concrete [1,2]. Extensive research has been conducted on numerous types of hardening accelerators, including those based on inorganic salts such as sodium sulfate and aluminum sulfate, as well as mineral-based additives. However, many conventional hardening accelerators contain chloride ions, which significantly accelerate corrosion in reinforced concrete structures, ultimately limiting their long-term durability and resulting in their gradual discontinuation. In addition, sulfate-based accelerators are also known to adversely affect steel reinforcement.

To address these limitations, recent studies have focused on developing chloride-free hardening accelerators, including mineral-based admixtures and C-S-H based micro-particles [2-5]. Nevertheless, research on C-A-S-H based hardening accelerators remains relatively limited. Furthermore, while extensive investigations have been conducted on admixtures for ultra-high-performance concrete in response to the increasing construction of super high-rise buildings, studies aimed at improving the performance of low-strength cement systems for structural applications remain insufficient.

In this study, a high-performance hardening accelerator based on C-A-S-H micro-particles and a polycarboxylate ether-based superplasticizer was developed. The hardening behavior and compressive strength development of concrete incorporating this accelerator were systematically evaluated. The results confirm that the proposed admixture functions as an eco-friendly, chloride-free hardening accelerator with excellent early-age strength development,

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enhanced workability, and stable long-term performance. These characteristics indicate its strong potential as a next-generation hardening accelerator for practical construction applications.

2. Experiments

2.1. Raw Materials and Mix Design

The raw materials used to manufacture the high-performance C-A-S-H hardening accelerator included a polycarboxylate ether-based superplasticizer, aluminum nitrate, calcium nitrate, sodium silicate (water glass), and a defoaming agent.

For concrete production, ordinary Portland cement with a 28-day compressive strength of 25.6 MPa was used. Additional components included quartz sand, gravel, mixing water, and the developed high-performance C-A-S-H hardening accelerator. The admixture dosage was fixed at 2% by weight of cement, and the detailed mix proportions are summarized in Table 1.

2.2. Manufacturing of the High-Performance C-A-S-H Hardening Accelerator

To synthesize the high-performance C-A-S-H hardening accelerator, three precursor solutions were prepared: an aluminum nitrate solution with a concentration of 2.4%, a calcium nitrate solution with a concentration of 35%, and a sodium silicate solution with a concentration of 30% and a modulus of 3.

First, 30 g of the polycarboxylate ether-based superplasticizer was added to 180 g of water, followed by a small amount of defoaming agent. The mixture was stirred until complete dissolution of the superplasticizer was achieved. Subsequently, the three precursor solutions were gradually introduced into the mixture under continuous stirring at 1800 rpm in a water bath. The aluminum nitrate solution was added at a rate of 0.1–0.2 mL/min, the calcium nitrate solution at 0.2–0.25 mL/min, and the sodium silicate solution at 0.3–0.4 mL/min. The total addition process lasted approximately 3–5 hours.

After completion of the solution addition, the mixture was further stirred for an additional 2–3 hours to ensure homogeneity and stabilization of the product. The resulting high-performance C-A-S-H hardening accelerator exhibited a solid content of approximately 15–20%.

2.3. Preparation of Samples and Testing Methods

The water-reducing performance of the hardening accelerator was initially evaluated using the mortar test method, yielding a water-reducing rate of approximately 14–15%. Based on these results, concrete mixtures were prepared, and slump tests were conducted to determine the water-reducing rate under equivalent workability conditions.

For each concrete mixture, twelve cubic specimens with dimensions of 100 × 100 × 100 mm^3 were prepared at identical slump levels. Compressive strength tests were conducted after curing periods of 1, 3, 7, and 28 days.

3. Results and Analysis

3.1. Water-Reducing Performance of the High-Performance C-A-S-H Hardening Accelerator

The slump values of the concrete mixtures are presented in Table 1. The results indicate that the high-performance C-A-S-H hardening accelerator achieved a water-reducing rate of 12.88% when applied at a dosage of 2% by weight of cement. This reveals that the incorporated C-A-S-H based hardening accelerator increase the fluidity of concrete and dispersion of the cement particles.

Table 1 The slump of concrete mixtures

No	Cem(kg)	QS(kg)	Gravel(kg)	Water(kg)	SP(kg)	CASH-HA(kg)	Slump(cm)
Ref	300	564	1316	180			6
SP	300	570	1330	150	1		6
CASH	300	570	1330	152		6	6

3.2. Effect of the High-Performance C-A-S-H Hardening Accelerator on Compressive Strength Development

The compressive strength results of the concrete specimens are summarized in Table 2.

Table 2 The effect of C-A-S-H hardening accelerator to enhance the compressive strength of concrete

No	1d strength (MPa)	3d strength (MPa)	7d strength (MPa)	28d strength (MPa)
Ref	1.9	8.1	12.1	20.1
SP	4.2	12.1	16.5	22.8
CASH	5.1	14.1	18.2	25.2

Figures 1 and 2 illustrate the compressive strength development and the corresponding strength enhancement rates as a function of curing time.

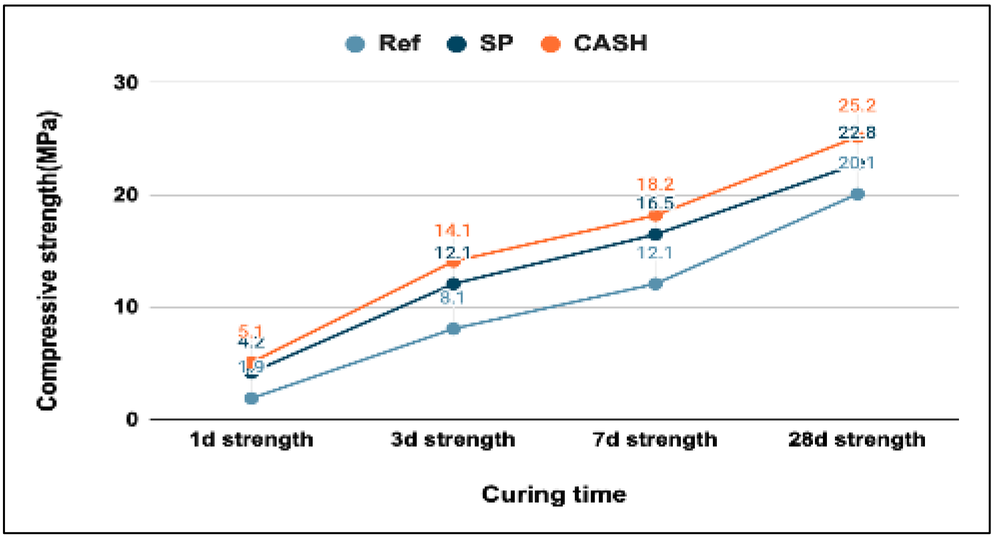

Figure 1 The compressive strength of samples according to curing time

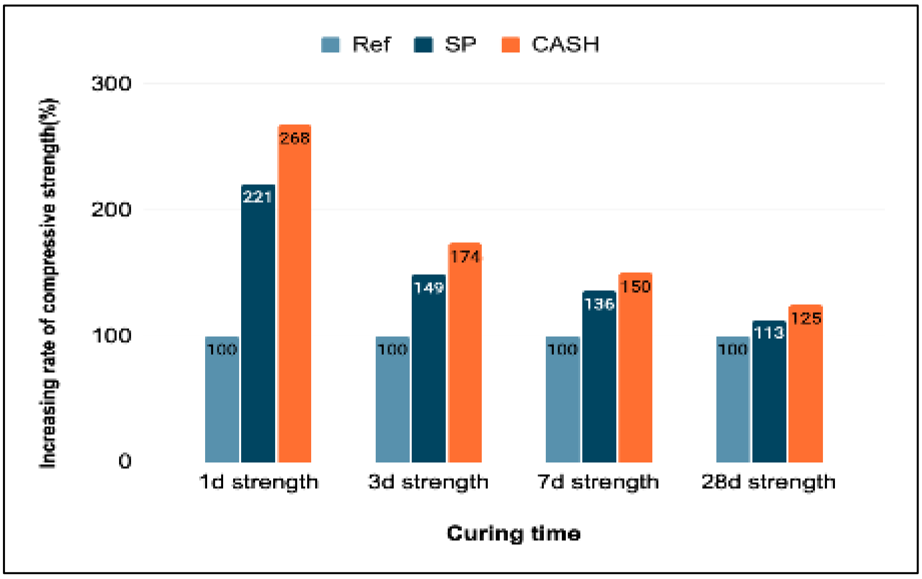

Figure 2 The increasing rate of compressive strength of samples according to curing time

The high-performance C-A-S-H hardening accelerator demonstrated outstanding strength enhancement at all curing ages. Compared to the reference mixture, the strength development rates reached 268%, 174%, 150%, and 125% at curing ages of 1, 3, 7, and 28 days, respectively. These values significantly exceed those observed in the mixture containing only the superplasticizer. This is attributed to the acceleration effect of C-A-S-H particles.

Notably, the strength enhancement at early ages (1 and 3 days) exceeded 25% compared to the superplasticizer-only mixture, indicating that C-A-S-H micro-particles play a decisive role in accelerating the initial hydration process of cement. Furthermore, the 12% increase in 28-day compressive strength suggests that the accelerator contributes to long-term structural integrity, likely through micro-pore refinement and densification of the cement matrix during hydration.

4. Conclusion

The developed high-performance C-A-S-H hardening accelerator exhibited a water-reducing rate of 12.88%, resulting from the combined effects of the polycarboxylate ether-based superplasticizer and the C-A-S-H micro-particles. The dual-action mechanism not only reduces water demand but also significantly accelerates cement hydration. Consequently, strength development rates of 268%, 174%, 150%, and 125% were achieved at curing ages of 1, 3, 7, and 28 days, respectively.

The observed performance confirms that hydrated calcium aluminum silicate micro-particles act as effective crystallization nuclei during early hydration, while synergistic interactions among calcium, aluminum, and silicate ions further accelerate hydration reactions. The chloride-free nature of the accelerator ensures excellent durability and safe application in reinforced concrete structures. Importantly, the accelerator demonstrated effective performance even in low-strength cement systems, enabling accelerated construction schedules while enhancing structural integrity. These findings indicate that the proposed C-A-S-H hardening accelerator is a highly promising admixture with substantial potential for future construction applications.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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