Academic Education Publishing House

Industry Science and Engineering Vol. 2 No. 10, 2025

The Influence of Composite Ratio on the Setting Time and Flexural Bond Strength of OPC-SAC Binary Pavement Repair Material

Yuxin Yang[1], Shuang Yao[1,*], Ni Li[2], Nan Li[2], Mingjia Xu[1], Jianan Liang[1]

[1]School of Civil Engineering and Architecture, Yangtze Normal University, Chongqing, China

[2]Yicheng Construction Project Management Co., Ltd., Xi'an, China

**Corresponding Author*

Abstract: To address the demand for cement concrete pavement repair, this paper studies the effect of OPC-SAC composite ratio on the setting time and flexural bond strength of binary pavement repair materials under standard conditions, and determines the standard consistency water requirement. It also analyzes the influence of different ratios on flexural/compressive strength to verify the feasibility of durable pavement repair. Seven composite ratios (10:0 to 0:10) were set to test water requirement, setting time and fluidity; 36 groups of specimens with six ratios were prepared to test flexural bond strength at 1, 3, 7 days. Results show that SAC reduces OPC's standard consistency water consumption, shortens setting time, and increases fluidity by 200%, achieving performance complementarity (SAC dosage must be controlled). The 7-day flexural bond strength is the highest (1.2MPa), peaking at OPC: SAC=6:4 (increase rate 140%), suitable for pavement repair. Appropriate ratios can be selected to optimize performance, providing technical support for cement concrete pavement maintenance.

Keywords: Composite Ratio; OPC-SAC Binary Repair Material; Setting Time; Flexural Bond Strength

1. Introduction

Under the long-term actions of traffic loads, environmental erosion, and other factors, pavements are prone to developing distresses such as cracks and potholes. If not repaired in a timely manner, these issues will accelerate pavement deterioration, compromising both the road's service performance and driving safety. Consequently, the development of high-performance pavement repair materials represents a critical demand in the field of road maintenance. As a conventional cementitious material, Ordinary Portland Cement (OPC) is widely applied in pavement repair; however, it is plagued by limitations including poor controllability of setting time and room for improvement in bonding performance with existing pavements. Sulfoaluminate Cement (SAC), by contrast, boasts the advantages of rapid setting and early strength development, endowing it with considerable potential for rapid repair scenarios. Nevertheless, its standalone application is hindered by constraints such as insufficient long-term performance stability and relatively high costs, making it unable to fully meet the comprehensive requirements of pavement repair.

For decades, scholars worldwide have predominantly focused their research on the properties and functionalities of single cement types. However, exploring how to integrate the advantages of OPC and SAC for the fabrication of high-performance repair materials has emerged as a research hotspot in this field [1]. A multitude of scholars have also adopted diverse approaches to continuously enhance the performance of OPC, with the aim of improving the durability of concrete structures [2]. As a specialized cementitious material, SAC exhibits merits such as rapid hardening, early strength development, dense microstructure, and superior impermeability and corrosion resistance [3-5]. Nevertheless, it is plagued by the issue of insignificant long-term strength growth or even strength retrogression [6]. Furthermore, the limited number of SAC manufacturers and its relatively high production cost have imposed certain constraints on its practical application [7]. Additionally, it encounters problems of poor fluidity and excessively rapid setting in grouting projects [8]. Sun [9] conducted research on Portland-sulfoaluminate cement as the cementitious material, modifying it with mineral admixtures to develop a low-cost repair material with excellent anti-corrosion and anti-permeability properties, which is applicable to concrete and marine construction projects. Janotka and Ray [10] not only carried out individual studies on OPC and SAC but also conducted experiments on their blended systems, achieving phased outcomes. Building on this foundation, the University of California successfully produced expansive cement by mixing OPC with 15%-20% calcium sulfoaluminate and free calcium oxide. Pera and Ambroise [11] prepared self-leveling repair mortars with favorable performance by blending OPC and SAC in specific proportions

Meanwhile, ensuring the continuous and reliable production of cement, while minimizing cement dosage and maximizing its performance, has become a consensus among experts, scholars, relevant institutions, and enterprises both domestically and internationally [12]. In the early stages of pavement construction, manual work was the primary method with machinery as auxiliary support, making it difficult to guarantee construction quality. Furthermore, some contractors engaged in practices such as using inferior materials to replace quality ones and failing to operate in accordance with specifications, which resulted in pavement distresses even before the road was opened to traffic [13]. Calcium sulfoaluminate minerals exhibit high reactivity and rapid hydration, enabling them to accelerate setting and enhance early strength [14]. With the deepening of research, SAC, which uses materials such as alunite as raw materials, has gradually facilitated the development of a series of new cement types featuring high strength, self-stress, and rapid hardening [15].

Recent domestic studies have shown that the combined application of OPC and SAC yields favorable results:

An increase in OPC content accelerates the hydration rate of SAC and standard consistency water requirement, shortens the initial and final setting times, reduces the early strength of mortar, and enhances its long-term strength[16]; In tap water, artificial seawater, and various salt environments, OPC can improve the compressive strength and chloride ion binding capacity of SAC, with similar trends in index changes across different systems; Within a reasonable blending ratio range, the setting time, strength, and original pull-off strength of the two cements all meet the performance criteria for general-purpose rapid repair mortars[17]; The incorporation of admixtures (e.g., mineral admixtures, retarders, and latex) into mortars based on these two cements can enhance the material's long-term strength, fluidity, and flexural/compressive strength (with a more pronounced impact on early-stage performance), reduce the tensile bond strength, improve construction workability, shorten the setting time, and increase the impermeability pressure[18-22].

In addition, Li [23] et al. investigated the effect of nano-silica on binary blends, and found that it can significantly shorten the setting time, remarkably enhance early strength while maintaining stable long-term strength, and improve hydrate bonding. Wang [24] et al. studied rapid-strength reactive powder concrete with SAC and OPC as basic components, and demonstrated that an increase in steel fiber volume leads to reduced fluidity and slower setting rate. The electrical resistance of 28-day specimens is higher than that of 1-day specimens, and there exists a functional relationship between flexural/compressive strength and both steel fiber volume and electrical resistance. Steel fibers can improve flexural toughness and reduce shrinkage: with the addition of 3% steel fibers, the flexural toughness increases by 3.9 times, and the shrinkage rate decreases to 88.3% of that of specimens without steel fibers, which confirms that rapid-hardening cement can be applied to the rapid repair of concrete structures. Zhu [25] et al. explored the influence of polycarboxylate superplasticizers on the rheological properties of Portland-sulfoaluminate cement composite slurries, and noted that these superplasticizers can alter the flow pattern of the slurry, exhibiting a positive correlation with rheological indices and a negative correlation with consistency coefficient. Owing to electrostatic repulsion, lubrication, and steric hindrance effects, the shear stress decreases gradually with their addition, which macroscopically reduces the shear resistance and viscosity of the system.

It should be noted that this study focuses on the impact of the blending ratio (as a single variable) on the core properties of the material, and has not yet incorporated admixtures such as nano-silica or polycarboxylate superplasticizers. Future research may further explore the synergistic effects between admixtures and blending ratios. The combination of OPC and SAC to form a binary cementitious system is expected to integrate the performance advantages of both: leveraging the rapid setting and early strength characteristics of SAC to shorten repair duration, and utilizing the hydration properties of OPC to optimize the long-term performance and bonding effect of the system. However, the blending ratio of OPC and SAC directly affects the hydration process and microstructural evolution of the system, thereby exerting a crucial influence on the material's setting time (which relates to the efficiency of rapid opening of pavement to traffic) and flexural bond strength (which determines the cooperative working ability and durability between the repair layer and the existing pavement). Currently, systematic research on the effect of blending ratio on setting time and flexural bond strength of the OPC-SAC binary system in pavement repair materials remains relatively scarce.

In view of this, this study systematically investigates the regulatory mechanism of different OPC-SAC blending ratios on the setting time and flexural bond strength of pavement repair materials by designing varied blending proportion schemes. Compared with existing studies that only analyze setting time or strength in isolation, this research for the first time clarifies the differences in optimal ratios for these two core properties and their underlying mechanisms, thereby providing more precise theoretical and technical support for the mix ratio optimization and engineering application of OPC-SAC binary pavement repair materials.

2. Experimental Materials and Methods

2.1 Experimental Materials

The Ordinary Portland Cement (OPC) employed in this experiment was of Grade 42.5R, which complied with the requirements specified in the standard GB 175-2007 Common Portland Cement and was manufactured by Fuling District Wuwan Cement Products Processing Plant. The rapid-hardening Sulfoaluminate Cement (SAC) used was of Grade 42.5, conforming to the criteria outlined in GB 20472-2006 Sulfoaluminate Cement and produced by Wuxi Jinying Building Materials Co., Ltd.The machine-made sand utilized in the experiment had a fineness modulus of 2.7 (medium sand), meeting the relevant requirements of GB/T 17671-2021 Method for the Determination of Strength of Cement Mortar (ISO Method). Tap water was adopted as the experimental water, which adhered to the specifications of JGJ 63-2006 Standard for Water Used in Concrete.

2.2 Experimental Methods

All procedures in this experiment were strictly conducted in accordance with national standards: standard consistency water requirement and setting time were determined with reference to GB/T 1346-2024 Methods for Determination of Standard Consistency Water Requirement, Setting Time and Soundness of Cement; the fluidity of cement paste was measured in compliance with GB/T 8077-2023 Test Methods for Homogeneity of Concrete Admixtures; the flexural bond strength were tested following GB/T 17671-2021 Method for the Determination of Strength of Cement Mortar (ISO Method).

The main instruments and equipment used in the experiment are as follows: electronic balance (Model YP3001N, measuring range: 3000g, accuracy: 0.1g), employed for weighing materials; cement paste mixer (Model NJ-160B), utilized for preparing experimental cement paste and determining indices such as setting time and standard consistency water requirement; standard curing box (Model YH-40B, compliant with JC/T 959-2018), applied to accelerate the hardening and solidification processes of materials like cement concrete; standard vicat apparatus, used for testing the water requirement for cement paste and setting time; cement mortar mixer (Model JJ-5, conforming to JC/T 681-2022), adopted for mixing cement mortar; cement mortar molding mold (40mm×40mm×160mm, in line with JC/T 683-2005), used for specimen molding and casting; vibration table (Model ZS-15, meeting JC/T 682-2022 requirements), employed for vibrating specimens; lever-type flexural testing machine (Model DKZ-5000, compliant with JC/T 724, maximum test force: 11.7MPa), applied to test the flexural/compressive strength and the flexural bond strength.

3. Experimental Results and Analysis

3.1 The Influence of Composite Proportion on the Setting Time and Flexural Bond

Strength of OPC-SAC Binary Pavement Repair Materials under Standard Conditions

The core of this experiment is to study the influence of composite ratios on the setting time and flexural bond strength of OPC-SAC binary pavement repair materials under standard conditions, with the aim of exploring the influence regularity of different cement mix ratios. Specifically, the data regarding changes in standard consistency water requirement, initial setting time, final setting time, cement paste fluidity, and flexural /compressive strength of OPC-SAC blends with varying proportions under standard curing conditions were converted into line charts corresponding to different curing ages. Targeted analysis was then carried out by integrating the regularity reflected in these line charts.

The variation in water demand for normal consistency when SAC and OPC were mixed at different ratios is illustrated in Figure 1. As shown in Figure 1, the standard consistency water requirement of OPC without SAC addition (OPC: SAC = 10:0) was 27.20%. With an increase in the proportion of SAC, the standard consistency water requirement decreased gradually, dropping to 18.40% when the ratio of OPC to SAC reached 0:10. The primary reason for this phenomenon is that SAC exhibits a fast hydration rate and low water requirement. The rational incorporation of SAC can improve the performance of cement-based products such as concrete to meet the requirements of different engineering scenarios. Notably, an appropriate water dosage is crucial for the strength and quality of concrete; reducing the water demand can further enhance the quality and performance of both concrete and cement.

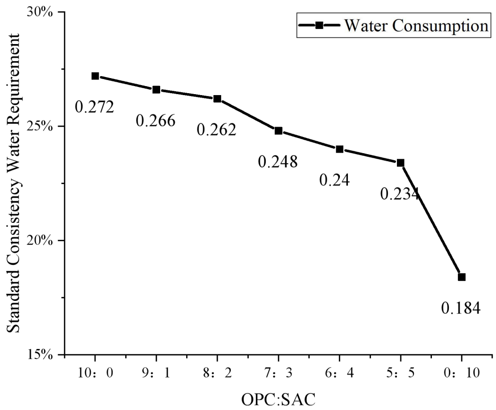

Figure 1. Standard Consistency Water Requirement

The variation in the initial setting time of cement when SAC and OPC were mixed at different ratios is presented in Figure 2. As indicated in Figure 2, the initial setting time of OPC without SAC addition (OPC: SAC = 10:0) was 220 minutes and 26 seconds. With an increase in the proportion of SAC, the initial setting time shortened gradually:

When the OPC:SAC ratio reached 0:10, it decreased to 24 minutes and 55 seconds, representing a reduction of 195 minutes and 31 seconds. The initial setting time exerts a significant impact on concrete engineering. An excessively short initial setting time will result in insufficient construction duration, making it difficult to complete pouring operations; conversely, an excessively long initial setting time will slow down the construction progress, increase project costs, and even predispose concrete to quality issues such as cracking.

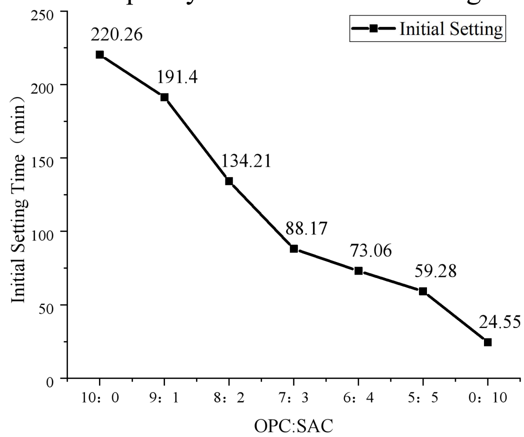

Figure 2. Initial Setting Time

The variation in the final setting time of cement with different SAC-OPC mixing ratios is depicted in Figure 3. As shown in Figure 3, the final setting time of OPC without SAC (OPC: SAC = 10:0) was 287 minutes and 36 seconds. With the increase in SAC proportion, the final setting time shortened progressively:

When the OPC:SAC ratio reached 0:10, it dropped to 32 minutes and 25 seconds, corresponding to a reduction of 255 minutes and 11 seconds. The final setting time is equally critical to concrete engineering. An excessively short final setting time will cause concrete to lose workability, preventing it from being constructed as designed and achieving plastic deformation; in contrast, an excessively long final setting time will prolong waiting periods and increase costs, while also rendering concrete prone to cracking and fragmentation—ultimately compromising material performance and engineering quality.

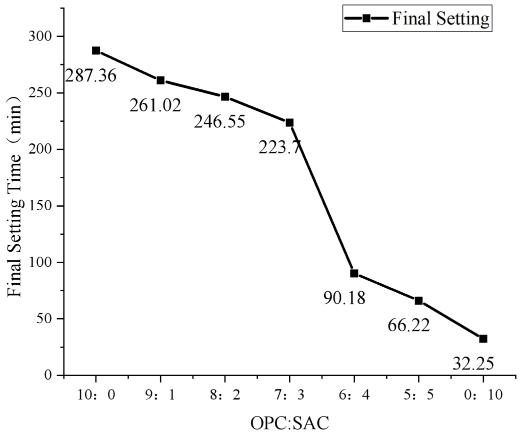

Figure 3. Final Setting Time

The variations in the fluidity of cement paste with different SAC-OPC mixing ratios at 30s, 5min, and 15min are illustrated in Figure 4, Figure 5, and Figure 6, respectively. As shown in Figure 4, the average 30s fluidity of OPC paste without SAC addition (OPC: SAC = 10:0) was 7 cm. With an increase in the SAC proportion, the average fluidity increased gradually:

When the OPC:SAC ratio reached 0:10, it rose to 21 cm, representing a growth of 14 cm. According to Figure 5, the average 5min fluidity of OPC paste without SAC was 7.2 cm; as the SAC proportion increased, the average fluidity also increased progressively, reaching 21.1 cm (with a growth of 13.9 cm) at the OPC:SAC ratio of 0:10. Figure 6 indicates that the average 15min fluidity of OPC paste without SAC was 7.5 cm. With the increase in SAC content, the average fluidity continued to increase, reaching 21.2 cm (a growth of 13.7 cm) when the OPC:SAC ratio was 0:10. Cement paste with favorable fluidity is conducive to ensuring the molding quality of concrete. However, in practical engineering, the application effect should be comprehensively considered in conjunction with construction requirements.

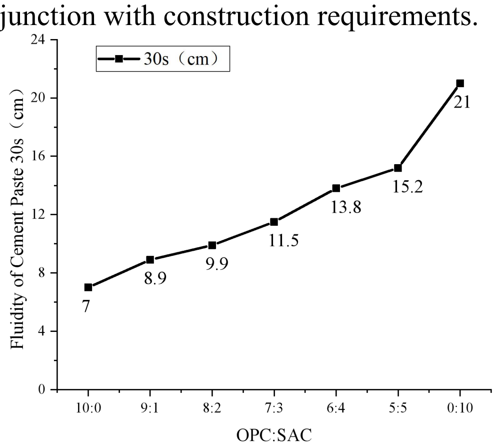

Figure 4. Fluidity of Cement Paste (30s)

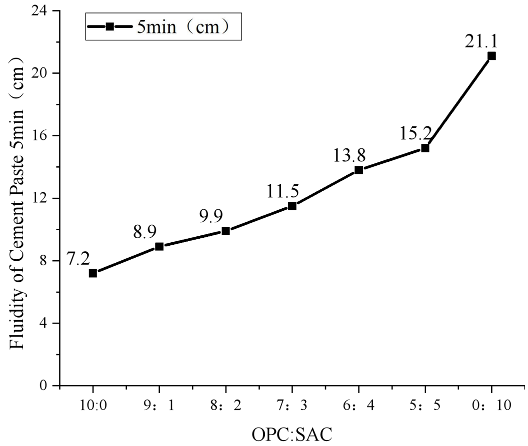

Figure 5. Fluidity of Cement Paste (5min)

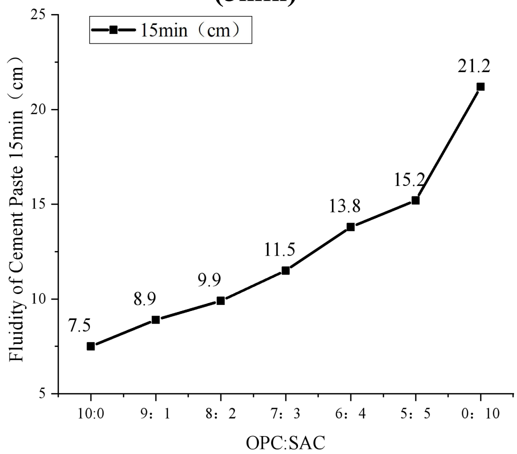

Figure 6. Fluidity of Cement Paste (15min)

The variations in the 3-day flexural bond strength and compressive strength of cement mortar with different SAC-OPC mixing ratios are presented in Figure 7 and Figure 8, respectively. As shown in Figure 7, the flexural bond strength was 2.72 MPa when the OPC:SAC ratio was 8:2, 2.85 MPa at a ratio of 7:3, and 2.75 MPa at 6:4. The overall range of increase and decrease was relatively small; among these, the intermediate ratio of OPC:SAC = 7:3 exhibited stable flexural bond strength performance. According to Figure 8, the compressive strength measured 18.57 MPa at an OPC:SAC ratio of 8:2, 17.76 MPa at 7:3, and 17.65 MPa at 6:4, showing a slight downward trend. Similarly, the intermediate ratio of OPC:SAC = 7:3 maintained stable compressive strength.

Among the seven composite ratios, the OPC: SAC = 7:3 ratio exhibited key characteristic performance:

The water demand for normal consistency was 24.8%, representing a turning point where the water demand shifted from a sharp decline to a stable trend; the initial setting time was 88 minutes and 17 seconds, serving as a turning point where the setting time transitioned from a rapid reduction to a slowdown; the final setting time was 224 minutes and 10 seconds, marking a turning point where the setting time changed from a stable state to a sudden drop; meanwhile, the fluidity values at 30s, 5min, and 15min were consistently 11.5 cm, indicating stable fluidity performance.

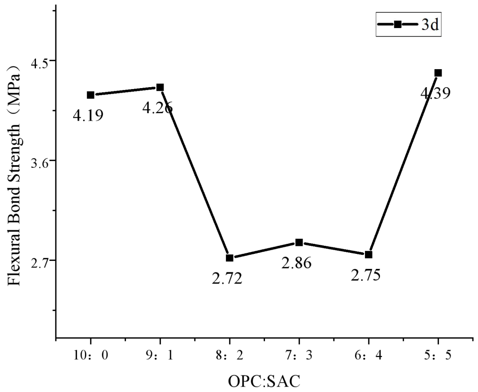

Figure 7. Flexural Bond strength (3d)

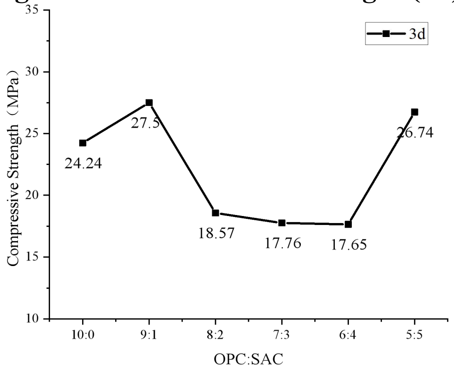

Figure 8. Compressive Strength (3d)

The incorporation of SAC at an appropriate proportion can effectively improve the performance of cement-based products such as concrete, thereby meeting the requirements of diverse engineering scenarios. The addition of SAC accelerates the early hydration process of Portland cement, and an increase in SAC content reduces the water demand for normal consistency of the system. Moreover, blending OPC and SAC at different ratios enables fundamental control and adjustment of the initial setting time of concrete, further enhancing construction efficiency. SAC has a relatively simple composition, mainly consisting of anhydrous calcium sulfoaluminate and dicalcium silicate, which endows it with short setting time and high strength. For the composite system, the initial setting time of the material shortens with the increase in SAC proportion; correspondingly, the average fluidity of the cement paste rises as the SAC content increases. Considering the concrete setting time requirements and the influence of composite ratios on the mechanical properties of OPC-SAC binary pavement repair materials, the optimal blending ratio for the setting time of this material is determined to be OPC: SAC = 7:3.

It is important to note that this ratio (OPC: SAC = 7:3) differs from the optimal ratio for the flexural bond strength (OPC: SAC = 6:4) determined in subsequent tests. The primary reason lies in the distinct influence mechanisms of the two properties: For the setting rate, the accelerating effect of increased SAC content reaches an "efficiency threshold" at the OPC: SAC = 7:3 ratio. Beyond this ratio, the effect of further increasing SAC content on shortening the setting time weakens significantly. In contrast, for the interfacial bonding performance, the optimizing effect of SAC content peaks when the SAC proportion reaches 40% (i.e., OPC: SAC = 6:4). If the SAC proportion exceeds this threshold, the inherent characteristic of SAC—long-term strength retrogression—will impair the stability of interfacial bonding, ultimately leading to a decline in the flexural bond strength.

3.2 Flexural Bond Strength of OPC-SAC Binary Pavement Repair Materials

After completing the flexural/compressive strength tests, further analysis was conducted on the measured data to explore the influence regularity of different cement mix ratios. Specifically, the flexural bond strength data of OPC-SAC blends with varying proportions under 1-day, 3-day, and 7-day curing conditions were converted into line charts corresponding to each curing age. Targeted analysis was then carried out by integrating the variation patterns reflected in these line charts.

The variations in the flexural bond strength of cement mortar specimens with different OPC-SAC composite ratios under 1-day, 3-day, and 7-day curing ages are presented in Figure 9, Figure 10, and Figure 11, respectively. Each experiment was repeated three times, and the average value was adopted for analysis; to verify data reliability, standard deviations and coefficient of variations were supplemented for key data points.

As illustrated in Figure 9, the flexural bond strength of OPC-SAC blends with different proportions is as follows: for the OPC:SAC = 5:5 ratio, the strength was 0.5 MPa (with a standard deviation of 0.04 MPa and a coefficient of variation of 8.0%); for ratios of OPC:SAC = 6:4, 7:3, and 8:2, the flexural bond strength was 0 MPa in all cases; for OPC:SAC = 9:1 and 10:0, the strength was consistently 0.7 MPa (with a standard deviation of 0.06 MPa and a coefficient of variation of 8.6%).Notably, three of the proportion formulations resulted in cement mortar specimens with zero flexural bond strength, and the overall strength level of the specimens at the 1-day curing age was relatively low.

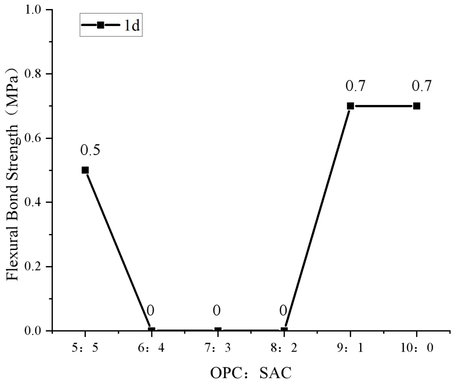

Figure 9. Flexural Bond Strength at 1-Day Curing Age

The low flexural bond strength at the 1-day curing age can be attributed to two aspects: curing age and the bonding interface between new and old cement mortar, as detailed below:

First, the short curing age restricted the development of bond strength. The OPC-SAC cement mortar failed to fully set and harden within 1 day, with local areas inside the specimens possibly remaining in an unhardened state. Although SAC is rapid-setting, its hydration reaction was incomplete within 1 day, resulting in insufficient production of hydration products (e.g., ettringite) that could not effectively fill the interfacial gaps. Meanwhile, OPC exhibits slow early hydration, which prevented it from synergizing with SAC to form a stable interfacial bonding structure—ultimately causing the specimens to break under external forces before the test. Second, the roughness of the bonding interface exerted a significant influence. In the experiment, half-specimens made of ordinary Portland cement were first prepared to simulate old pavement, and then molded with OPC-SAC cement mortar of different composite ratios. The transition zone between these two parts was structurally fragile: a rougher surface of the half-specimen allowed the fresh cement mortar to form stronger mechanical interlocking with it. Higher interlocking force led to a denser overall structure, thereby improving the flexural bond strength; conversely, insufficient roughness weakened this interlocking effect, contributing to lower strength.

As shown in Figure 10, the flexural bond strength of OPC-SAC blends with different proportions under 3-day curing conditions exhibits the following variations:

It measured 0.5 MPa at an OPC:SAC ratio of 5:5; increased to 1 MPa at 6:4, reaching the highest peak strength at this curing age; decreased to 0.5 MPa when the ratio was 7:3, and remained at 0.5 MPa at 8:2; further dropped to 0.4 MPa at 9:1, then rose slightly to 0.5 MPa at 10:0.Notably, with the increase in OPC content, the flexural bond strength shows a characteristic trend of "high strength in the early stage (OPC content < 40%), low strength in the middle stage (40% < OPC content < 80%), and strength recovery in the later stage (OPC content > 80%)" under 3-day curing. Additionally, for the ratios of OPC: SAC = 7:3 and 8:2, the flexural bond strength at 3-day curing is higher than that at 7-day curing.

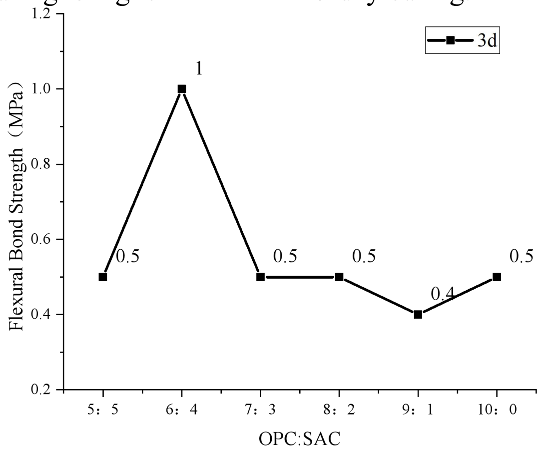

Figure 10. Flexural Bond Strength at 3-Day Curing Age

As indicated in Figure 11, the flexural bond strength of OPC-SAC blends with different proportions under 7-day curing conditions varies as follows:

It was 0.5 MPa at an OPC:SAC ratio of 5:5; increased to 1.2 MPa at 6:4, achieving the highest peak strength at this curing age; decreased to 0.4 MPa at 7:3 and further dropped to 0.3 MPa at 8:2; rose to 0.7 MPa when the ratio reached 9:1, and climbed to 1.2 MPa again at 10:0.Under 7-day curing conditions, with the decrease in SAC content, the flexural bond strength presents a characteristic trend of "high strength in the early stage, low strength in the middle stage, and high strength in the later stage". Specifically, the strength reached its maximum when the SAC content was 40% (i.e., OPC: SAC = 6:4) in the early stage, while the flexural bond strength hit its lowest point when the SAC content was 20% (i.e., OPC: SAC = 8:2) in the middle stage.

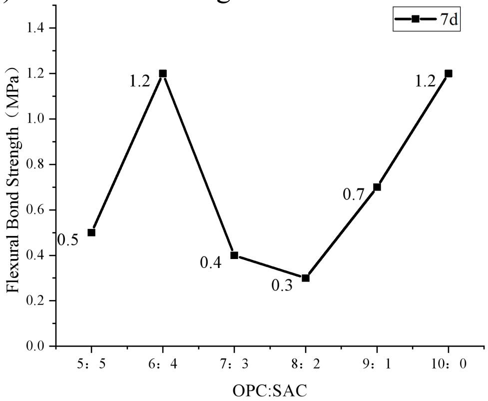

Figure 11. Flexural Bond Strength at 7-Day Curing Age

The OPC-SAC composite cement mortar can be used as a pavement repair mortar material, and the flexural bond strength reaches its maximum when OPC and SAC are blended at a ratio of 6:4. This conclusion is supported by two key observations:

On one hand, after 1-day, 3-day, and 7-day curing, the measured flexural bond strengths of the specimens were 0 MPa, 1.0 MPa, and 1.2 MPa, respectively. The 7-day strength was higher than the strengths at the previous two curing ages, which is consistent with the general rule that the strength of cement-based materials increases with extended curing age. On the other hand, incorporating 40% SAC into OPC significantly promotes the early strength development of the composite cementitious material. When the SAC content decreases from 50% to 40% (i.e., the ratio shifts from OPC: SAC = 5:5 to 6:4), the flexural bond strength increases from 0.5 MPa to 1.2 MPa, representing a growth rate of 140% and reaching the highest peak strength in the entire test.

4. Conclusion

1) The incorporation of SAC can significantly enhance the performance of OPC, with specific improvements as follows: the water demand for OPC's normal consistency decreased from 27.20% to 18.40%; the initial and final setting times were drastically shortened, showing a substantial reduction; the fluidity of cement paste was significantly improved—at 30s, it increased from 7 cm to 21 cm, representing a 200% growth rate. The composite of OPC and SAC enables complementary advantages in performance; however, the dosage of SAC must be controlled (it is recommended not to exceed 50%) to prevent the decline in concrete workability and load-bearing capacity. Considering both the setting time and early mechanical properties, the optimal composite ratio for setting time is determined as OPC: SAC = 7:3.

2) The OPC-SAC composite cementitious material is well-suited for pavement repair projects, and the appropriate mixing ratio can be selected based on different repair requirements: if it is necessary to quickly shorten the setting time to realize the rapid opening of the pavement, the OPC: SAC = 7:3 ratio should be preferred, as it balances fast setting and basic workability. If more emphasis is placed on the long-term bonding strength between the repair layer and the old pavement, the OPC: SAC = 6:4 ratio is recommended, given its optimal flexural strength and stable long-age performance. In summary, the OPC-SAC composite cementitious material is applicable to pavement repair.

3) The flexural bond strength of OPC-SAC composite specimens generally shows an upward trend with the extension of curing age: the 7-day strength (1.2 MPa) is higher than both the 1-day strength (0 MPa) and 3-day strength (1.0 MPa), which conforms to the strength development law of cement-based materials. This is due to the failure to form an effective bond at the interface, rather than the material itself lacking a developmental regularity. When 40% SAC is incorporated into OPC (i.e., OPC: SAC = 6:4), the flexural bond strength increases significantly from 0.5 MPa to 1.2 MPa, with a growth rate of 140% and reaching the maximum value in all tested ratios. By selecting the appropriate ratio according to different repair demands, the performance of the repair material can be optimized. Meanwhile, in practical engineering, the curing method should be determined based on specific environmental conditions (e.g., temperature, humidity) to ensure the repair quality.

Acknowledgements

The present work was funded by the Chongqing University Student Innovation and Entrepreneurship Project (S202310647030).

And the Yangtze Normal University Industry-University-Research Cooperation Project (No. C2025-010725736).

References

[1] Wang, B., and Yan, T. C. (2021). Preparation and performance study of ordinary portland-sulphoaluminate cement composite gel system. Journal of Functional Materials, 52(07), 7079-7084.

[2] Wu, Y. F. (2022). Study on seawater erosion resistance of sulphoaluminate cement-ordinary portland cement binary repair material. Unpublished master's thesis, Xi'an University of Architecture and Technology, Xi'an.

[3] Zhao, J., Cai, G. C., and Gao, D. Y. (2011). Mechanism analysis on chloride ion erosion resistance of sulphoaluminate cement concrete. Journal of Building Materials, 14(3), 357.

[4] Soltesz SM. Cementitious materials for thin patches. Cement Mortars,2001:1-8.

[5] Wang, J. J., Zhang, Z. L., Wan, S. K., et al. (2011). Development status and prospect of sulphoaluminate cement. New Century Cement Guide, 17(6), 51-53.

[6] Ding, J., and Wang, C. F. (2014). Study on performance of Portland-sulphoaluminate cement composite system. Brick and Tile, 321(09), 20-22.

[7] Zhang, P. (2017). Study on performance improvement and application of sulphoaluminate cement. Published master's thesis, Hunan University, Changsha.

[8] Yuan, J. K., and Chen, L. Y. (2011). Study on performance of grouting material modified by compounding ordinary Portland cement and sulphoaluminate cement. Concrete, 255(01), 128-130.

[9] Sun, K. K. (2017). Study on Portland cement-sulphoaluminate cement based repair material and its anti-corrosion and impermeability performance. Published master's thesis, University of Jinan, Jinan.

[10] Janotka, L., and Ray, A. (2003). The hydration phase and pore structure formation in the blends of sulfoaluminate-belite cement with Portland cement. Cement and Concrete Research, 33(3), 489-497.

[11] Pera, J., and Ambroise, J. (2004). New applications of calcium sulphoaluminate cement. Cement and Concrete Research, 34, 671-676.

[12] Pei, T. (2020). Study on the performance of concrete with ordinary Portland cement-sulphoaluminate cement composite cementitious system. Published master's thesis, Anhui University of Science and Technology, Huainan.

[13] Chen, Z. Y. (2020). Review on research of rapid repair materials for cement concrete pavement. Fujian Transportation Science and Technology, 174(03), 8-10.

[14] Meng, Y. (2020). Study on the hydration, hardening and durability of sulphoaluminate cement-slag-gypsum cementitious system. Published master's thesis, Zhengzhou University, Zhengzhou.

[15] Shi, Y. R. (2022). Study on non - destructive testing of strength and volume stability of sulphoaluminate cement mortar. Published master's thesis, Ningxia University, Yinchuan.

[16] Gai, K. Y., Chen, L. Y., Long, Y., et al. (2023). Study on the performance of multi - component composite ultra - early strength cement - based materials. New Building Materials, 50(01), 128 - 132.

[17] Gou, H. S. (2020). Study on the bonding interface properties of Portland - sulphoaluminate cement - based repair mortar. Published master's thesis, Harbin Institute of Technology, Harbin.

[18] Zhang, G. F., Wang, J. F., Wang, X. H., et al. (2023). Effects of retarder on properties of PC-CSA-FDG ternary cementitious system repair mortar. Journal of Building Materials, 1-11.

[19] Guo, W. Y., Zheng, X. H., Hou, Y. D., et al. (2022). Study on rapid repair materials for cement concrete pavement. Transportation Science and Technology, 313(04), 79-83.

[20] Wang, Y. F., Chen, Q. B., Mei, X. J., et al. (2022). Preparation and performance study of sulphoaluminate-portland composite anti-corrosion mortar doped with EVA rubber powder. Chinese Journal of Colloid and Polymer, 40(01), 3-7.

[21] Chang, Y. (2021). Study on performance and hydration mechanism of multi-component cementitious material system. Published master's thesis, Beijing University of Civil Engineering and Architecture, Beijing.

[22] Ding, X. Q., Zhao, X. Y., Xu, X. W., et al. (2020). Effects of mineral admixtures on

properties of sulphoaluminate cement-ordinary Portland cement composite system. New Building Materials, 47(03), 40-44.
[23] Li, G. X., Liu, Q. F., Li, C., et al. (2020). Characteristic of silica nanoparticles on mechanical performance and microstructure of sulphoaluminate cement/ordinary Portland cement binary blends. Construction and Building Materials, 242(C), 1-8.
[24] Wang, H., Cai, X., Rao, C. M., et al. (2022). Mechanical and Electrical Properties of Rapid-Strength Reactive Powder Concrete with Assembly Unit of Sulphoaluminate Cement and Ordinary Portland Cement. Materials, 15(9), 1-12.
[25] Zhu, Z. J., Liu, R. T., Yan, J., et al. (2022). Effects of a polycarboxylate superplasticiser on the rheological properties of a Portland-sulphoaluminate cement composite slurry. Materials Letters, 317, 1-3.