Hindawi
Advances in Materials Science and Engineering
Volume 2023, Article ID 4994299, 11 pages
https://doi.org/10.1155/2023/4994299

Research Article

Study on the Influence of SAP on Properties of White Fair-Faced Concrete with Limestone Powder

Jun Shi,[1] **Fan Zhang**,[1] **Jinping Zhuang**,[2] **Zhangbao Wu**,[3] **Rong Chen**,[4] **and Huixia Li**[2]

[1]*Fujian Communications Planning & Design Institute Co., Ltd., Fuzhou 350000, China*
[2]*School of Civil Engineering, Fujian University of Technology, Fuzhou 350118, China*
[3]*Fujian Jiuding Construction Group Co., Ltd., Fuzhou 350000, China*
[4]*Hengchao Construction Engineering Group Co., Ltd., Xiamen 361000, China*

Correspondence should be addressed to Jinping Zhuang; 19781208@fjut.edu.cn

Received 8 November 2022; Revised 19 December 2022; Accepted 19 December 2022; Published 3 January 2023

Academic Editor: Yasir Nawab

Introducing SAP internal curing material and limestone powder into white fair-faced concrete in order to greatly improve the durability of white fair-faced concrete, alleviate the influence of mechanical property deterioration caused by SAP, and facilitate the popularization and application of SAP and limestone powder in white fair-faced concrete. Therefore, this paper studies the effect of the content of SAP and limestone powder on the properties of white fair-faced concrete, conducts slump, electric flux, standard cube compressive strength, and splitting tensile strength tests, and examines SAP and limestone powder from a macroscopic perspective. The effect of the dosage on the properties of white, fair-faced concrete was explained by a scanning electron microscope (SEM) from a microscopic point of view. The results show that SAP can increase the slump of white fair-faced concrete, and the slump of SAP white fair-faced concrete increases with the addition of limestone powder content. Adding SAP can greatly reduce the electric flux of white fair-faced concrete. The addition of limestone powder can further reduce the electric flux and improve the durability and adding SAP will deteriorate the mechanical properties of white fair-faced concrete. Adding limestone powder is beneficial to the improvement of the mechanical properties of SAP mixed with white fair-faced concrete. Adding 30% limestone powder can give full play to the optimal performance of SAP white fair-faced concrete. SAP can refine the internal structure of white fair-faced concrete, and the filling and nucleation effects of limestone powder can improve the situation where SAP deteriorates the mechanical properties of white fair-faced concrete, further optimizing concrete internal structure.

1. Introduction

Fair-faced concrete directly uses the concrete surface as the surface, so it has good economic benefits and environmental protection effects in engineering applications. It conforms to the concept of low-carbon, environmentally friendly development and has broad development prospects [1–3]. With the improvement of the architectural aesthetic level, white fair-faced concrete with a smooth surface and bright white has received extensive attention [4, 5]. It can be equipped with white fair-faced concrete with excellent apparent performance. The early hydration reaction rate of white cement is fast, and the hydration heat is high, which easily leads to the cracking of the surface of the white fair-faced concrete [6]. The compounding of ordinary Portland cement and white cement is not conducive to the durability of the white-faced concrete [7], which will affect the surface of the white fair-faced concrete. So, the SAP with super water absorption and water retention capacity is used in white fair-faced concrete in engineering for internal curing technology [8–10]. By preabsorbing and curing water, when the humidity inside the concrete decreases, it is affected by the humidity gradient and releases the preabsorbed water, which maintains the humidity inside the concrete, promotes the secondary hydration reaction, refines the internal structure, and effectively inhibits autogenous shrinkage [11, 12]. It can enhance durability [13, 14], prevent cracking, and improve the durability of fair-faced concrete. However, the addition of SAP will lead to a decrease in the compressive strength and tensile strength of concrete [15, 16]. How to reduce the adverse effect of SAP on the mechanical properties of white fair-faced concrete is an urgent problem to be solved.

Adding limestone powder into concrete can not only save cost effectively but also protect the environment [17]. It mainly has four effects on concrete filling, nucleation, dilution, and chemistry[18]. There have been many research results on the influence of limestone powder on concrete. Chen and Kong [18] showed that the filling effect of limestone powder and its own particle morphology help to improve the workability of concrete. Zhao and Ma [19] found that limestone powder has a certain water-reducing performance and that proper mixing can improve the workability of roller-compacted concrete through experimental research. Limestone powder can improve the workability of concrete [20], and some scholars have shown that limestone powder can increase water consumption and reduce rheological properties, which are mainly affected by the impurity content and fineness of limestone powder [21, 22]. Li and Kwan [23] systematically studied the effect of limestone fine powder on concrete, and concluded that adding limestone fine powder to replace cement can effectively improve the tensile strength and stiffness of concrete. The addition of limestone powder to compact concrete shows that the filling effect of limestone powder can enhance the compressive strength of concrete [24]. Sezer [25] concluded that when the content of limestone powder exceeds 35%, the compressive strength of concrete will be affected by the dilution effect. It can be seen that limestone powder has an optimal dosage in concrete. When the dosage is appropriate, the filling effect dominates and improves the compressive strength. When the dosage is too high, the dilution effect dominates and reduces the compressive strength [26, 27]. Tongaroonsri and Tangtermsirikul [28] studied the effect of limestone powder on the self-shrinkage of concrete and concluded that replacing cement with 10% limestone powder can reduce the self-shrinkage value by 19%, which can effectively prevent concrete from cracking. Courard and Michel [29] studies have shown that the self-shrinkage of the added concrete decreases with the increase of the limestone powder content, which is due to the fact that the addition of limestone powder reduces the cement content, the actual water-cement ratio increases, and the internal humidity increases, thereby reducing the concrete's capacity. The research results of autogenous shrinkage by Li and Kwan [23] and Gesoglu et al. [30] have proved the positive effect of limestone powder on concrete resistance to chloride ion erosion, indicating that adding limestone powder can improve the durability of concrete, and adding limestone powder also contributes to permeability [31], corrosion resistance [32], sulphate resistance [25] improvement. Based on the research results of limestone powder in concrete, adding limestone powder into SAP mixed with white fair-faced concrete can not only solve the mechanical property deterioration caused by SAP but also further improve the durability of SAP mixed with white fair-faced concrete. The effect of powder content on SAP mixed with white fair-faced concrete is significant.

In summary, incorporating SAP into the internal curing method is a preferred method that strengthens the internal structure of the concrete and improves crack resistance. However, it will adversely affect the performance of concrete. The amount of limestone powder in moderation can effectively improve the performance of concrete, but these studies are concentrated on the impact on plain concrete. It is unknown whether the influence of white fair-faced concrete mixed with white cement is consistent; there are no related research reports that mixed limestone powder and SAP at the same time into white fair-faced concrete. It is worth developing research to determine whether limestone powder can further improve the performance of white fair-faced concrete without affecting the SAP effect. The article first analyzes the impact of SAP on the workability, durability, and mechanical performance of white fair-faced concrete and is supplemented by SEM to explain the working mechanism. On this basis, by mixing limestone powder, the effects of limestone powder on SAP white fair-faced concrete's workability, durability, and mechanical properties are examined. At the same time, in conjunction with the SEM to explain the working mechanism, with the amount of limestone powder mixing as the variable, the amount of limestone powder that makes SAP white water concrete performance is the best.

Thus, 6 groups of concrete with different mix ratios were designed, including ordinary fair-faced concrete, white fair-faced concrete, and SAP mixed with white fair-faced concrete, SAP mixed with white fair-faced concrete with different limestone powder contents. The research studied the influence of limestone powder content and SAP on the durability and mechanical properties of white fair-faced concrete. The effect of limestone powder content and SAP on the workability and electric flux of white fair-faced concrete from slump were investigated macroscopically. The effects of limestone powder content and SAP on the durability of white fair-faced concrete were studied. The standard cube compressive and split tensile strength tests were conducted to investigate the influence of limestone powder content and SAP on the mechanical properties of white fair-faced concrete. SEM observation to explain the effect mechanism. The obtained research results can provide theoretical basis and application support for the application of limestone powder and SAP mixed with white fair-faced concrete.

2. Materials and Methods

2.1. Materials. Hailuo Ordinary Portland cement was supplied with a strength grade 42.5 code P·W and a fineness of 325 mesh. White Portland cement was supplied with strength grade 42.5 with a fineness 300 mesh, provided by Alf Portland (Anqing) Co., Ltd. Fly ash II is provided by Henan Yuanyuan Water Co., Ltd. with a fineness 300 mesh limestone powder provided by the Tianjin Guangfu Fine Chemical Research Institute. The chemical composition of cementitious materials is shown in Table 1.

Table 1: Main chemical composition of cementitious materials (%).

Composition	Ordinary Portland cement	White Portland cement	Fly ash
CaO	52.84	62.79	3.32
SiO_2	14.24	20.75	39.80
Al_2O_3	5.41	3.22	28.99
MgO	1.80	2.53	0.52
Fe_2O_3	2.46	0.25	4.28
K_2O	0.89	1.34	1.31
LOI	9.87	1.96	21.28

The fine aggregate is medium sand with a fineness modulus of 2.7. The coarse aggregate is 5–10 mm and 10–25 mm graded crushed stone.

The water-reducing agent is a polycarboxylate superplasticizer provided by Xiamen Lets Group. The super absorbent resin particle size is 30–60 mesh, provided by Yixing's Kexin Chemical Co., Ltd.

2.2. Mix Ratio of Fair-Faced Concrete. On the basis of ordinary fair-faced concrete in reference mix ratio group C, white fair-faced concrete was prepared by adjusting the content of white cement. According to the literature [33, 34], SAP is 0.2% of the total mass of the cementitious material, and the additional maintenance water is 10 times the mass of the SAP. Different dosages of limestone powder were set up to investigate the effect of limestone powder dosage on the performance of SAP mixed with white fair-faced concrete. The mix ratio of the specimens is shown in Table 2. AC stands for white fair-faced concrete specimen. SAC stands for SAP mixed with white fair-faced concrete specimen. LSAC stands for limestone powder SAP mixed with white fair-faced concrete specimen. 10, 20, and 30 represent the limestone powder content, which replaces the quality of the cementitious material, respectively, 10%, 20%, and 30%.

2.3. Fabrication of Fair-Faced Concrete Specimens. Test a sample concrete mixer with a double-bedroom axis test (HJS-60), The mixing process of limestone powder SAP mixed with white fair-faced concrete is different from that of ordinary concrete. The specific steps are as follows: (1) SAP preabsorbs 10 times its mass of curing water. (2) Dry mixing of white cement, ordinary Portland cement, fly ash, limestone powder, and coarse and fine aggregates for 1 min. (3) Pour all the water reducer and half of the mixing water mixing for 30 s. (4) Finally, pour the preabsorbent SAP and the other half of the mixing water and stir for 2 minutes to ensure that the water-reducing agent disperses evenly and prevents SAP from absorbing water reducer. The appearance of the mixed-formedfair-faced concrete is shown in Figure 1, which meets the application requirements for the appearance of white fair-faced concrete.

2.4. Test

2.4.1. Slump Test. The slump test was carried out with reference to Standards for Performance Tests of Ordinary Concrete Mixtures (GB/T50080-2016) [35]. It used to study the effect of limestone powder content and SAP on the workability of white fair-faced concrete.

2.4.2. Electric Flux Test. The electric flux test is carried out with reference to the Standard for Long-term Performance and Durability Test of Ordinary Concrete (GBT50082-2009) [36]. After curing for 28 days, the standard specimen with $100 \times 50\,mm^2$ are put into the Chlorine ionic power flux measurement (DTL-T). The influence of limestone powder and SAP on the durability of white fair-faced concrete was analyzed.

2.4.3. Standard Cube Compressive Strength and Split Tensile Strength Tests. The standard cube compressive strength and splitting tensile strength tests were carried out with reference to the Standards for Test Methods of Mechanical Properties of Ordinary Concrete (GB/T50081-2002) [37]. Six standard pieces of different types of fair-faced concrete were made, and the standard curing periods were 3 d, 7 d, and 28 d. Microcomputer control electronic universal testing machine (HCT306E) perform strength test and split tensile strength test, analyze the impact of limestone powder and SAP on white water concrete performance.

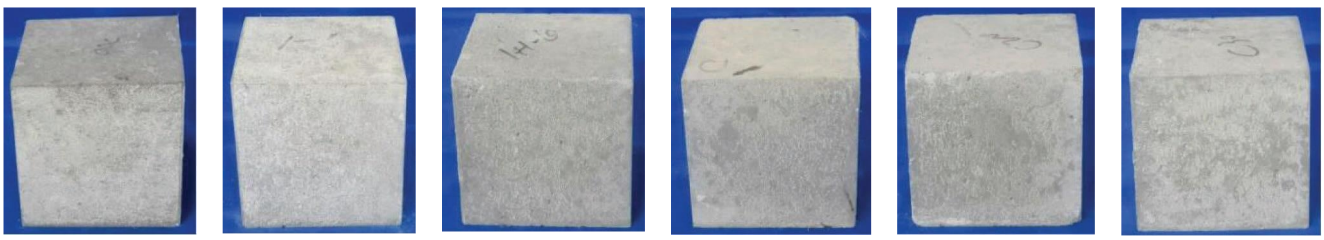
2.4.4. SEM Test. The observation samples of $1\,cm \times 1\,cm \times 3\,mm$ were taken from the specimens AC, SAC, and LSAC-20 of 28 d curing age respectively. The surface was gold-plated. Then the white fair-faced concrete under different magnifications was observed by SEM (TESCAN MIRA LMS). The influence of limestone powder and SAP on the microstructure of white fair-faced concrete was analyzed, and the macroscopic law mechanism was explained.

3. Results and Discussion

3.1. Influence on Slump. The effect of white cement and SAP on the slump of fair-faced concrete is shown in Figure 2(a). It can be seen that the slump of fair-faced concrete will be affected by adding white cement. This is because, compared with ordinary Portland cement, the hydration reaction rate of white cement is faster and more C_3A is generated, which easily leads to the occurrence of flash setting, resulting a loss of slump performance [38], and the addition of white cement is not conducive to the slump of fair-faced concrete. After adding SAP to white fair-faced concrete, its slump improved. The reason is that SAP becomes spherical after

Table 2: Mixing ratio of fair-faced concrete (kg/m^3).

Specimen number	White cement	Portland cement	Limestone powder	Fly ash	Gravel	Sand	Water	Water reducer	Super absorbent resin	Internal maintenance water
C	0	317	0	133	1083	752	150	4.6	0	0
AC	158.5	158.5	0	133	1083	752	150	4.6	0	0
SAC	158.5	158.5	0	133	1083	752	150	4.6	0.9	9
LSAC-10	136	136	45	133	1083	752	150	4.6	0.9	9
LSAC-20	113.5	113.5	90	133	1083	752	150	4.6	0.9	9
LSAC-30	91	91	135	133	1083	752	150	4.6	0.9	9



(a) (b) (c) (d) (e) (f)

Figure 1: Appearance of fair-faced concrete. (a) C. (b) AC. (c) SAC. (d) LSAC-10. (e) LSAC-20. (f) LSAC-30.

absorbing water, which plays a lubricating role between the slurry and the aggregate and increases the fluidity and slump of white fair-faced concrete. So, the workability of white fair-faced concrete can be improved by adding SAP.

It can be seen from Figure 2(b) that the slump of SAP white fair-faced concrete increases with the increase in limestone powder content. Because the main chemical component of limestone powder is $CaCO_3$, which is an inert material with effect of water reduce, the actual water-cement ratio of SAP mixed with white fair-faced concrete is improved. On the other hand, the morphology effect of limestone powder, that is, the approximate spherical particle morphology after grinding has a "ball effect," which improves the rheological properties and increases the slump of concrete. The addition of limestone powder is beneficial to the workability and the slump of white fair-faced concrete.

3.2. Influence on Electric Flux. The electric flux of different types of fair-faced concrete is shown in Figure 3. The effect of limestone powder content of SAP white fair-faced concrete is shown in Figure 3(a). The electric flux of LSAC-10, LSAC-20, and LSAC-30 decreased by 7.4%, 10.2% and 17.6% respectively. The addition of limestone powder helps to improve the durability of SAP mixed with white fair-faced concrete. As the limestone powder content is higher, the durability of fair-faced concrete is better. The reason is that limestone powder has a microaggregate filling effect, which is finer than cement and fly ash, making the slurry denser and optimizing the internal structure. In addition, limestone powder has a nucleation effect and can act as a nucleation matrix for C-S-H, reducing the nucleation barrier and facilitating the formation of C-S-H crystals. The durability of fair-faced concrete can be further enhanced by adding limestone powder to SAP fair-faced concrete.

The influence of SAP on white fair-faced concrete can be analyzed from Figure 3(b). The electric flux of the AC group of compound white cement is higher than that of the C group of ordinary fair-faced concrete, which is consistent with the results of the literature [7]. The addition of white cement leads to the deterioration of the durability of fair-faced concrete. Because the early hydration rate of white cement is higher than that of ordinary Portland cement and the hydration heat is larger, it is easier to form a coarse-porous slurry structure, resulting in an increase in porosity and affecting the durability of fair-faced concrete. Compared with the AC group, the electric flux of the SAC group decreased by 26.4%, obviously. The reason is that with the internal humidity of the fair-faced concrete, the decrease of SAP releases preabsorbed water, supplements the water required for the reaction of $Ca(OH)_2$ and SiO_2, produces a structurally stable C-S-H crystal, cuts off the capillary connection inside the white fair-faced concrete, and refines the pore structure, thereby limiting the through passage of electric current. The curing effect of SAP in white fair-faced concrete is obvious, and the durability performance is significantly improved.

3.3. Influence on Mechanical Properties

3.3.1. Fracture Form. The failure forms of the fair-faced concrete specimen in the compressive strength test and the splitting tensile strength test are basically the same. In the early cube compressive strength test, cracks in the concrete test specimen were not obvious. As the load increases, vertical cracks begin to appear on both sides of the test specimen, and then continue to extend to the upper and lower ends, and finally destroy as the concrete on both sides of the test specimen falls off. The failure form is shown in

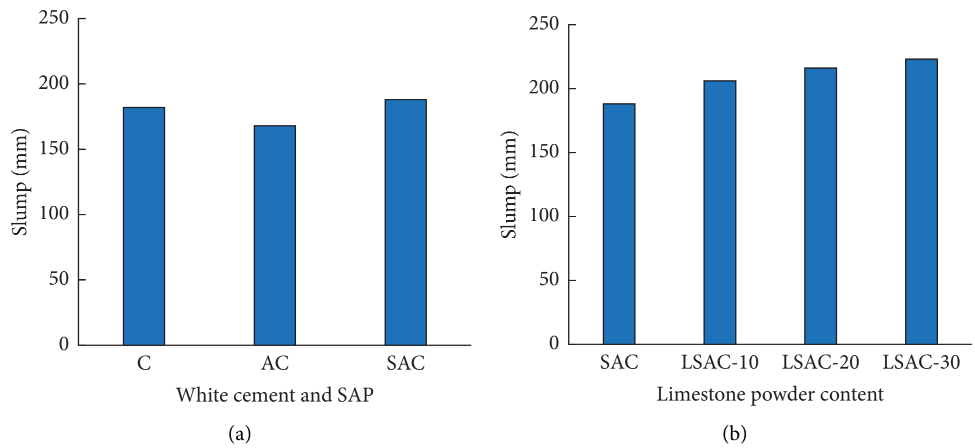


Figure 2: Slump of different types of fair-faced concrete. (a) Effects of white cement and superabsorbent resin. (b) Effect of limestone powder content.

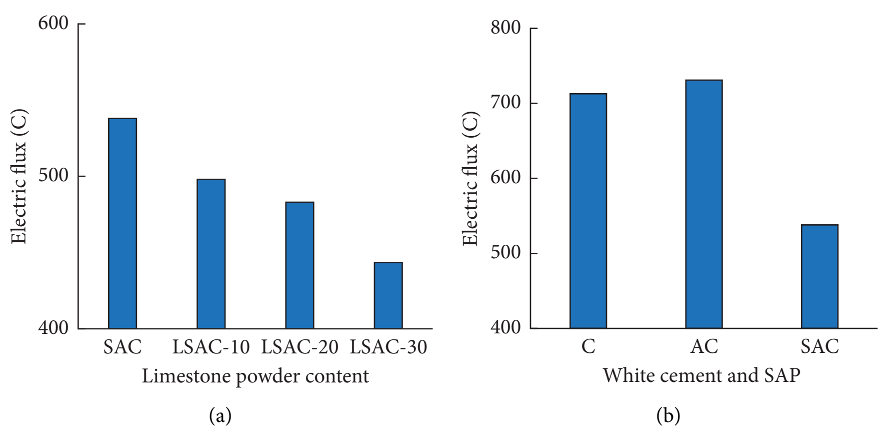


Figure 3: Electric flux of different types of fair-faced concrete. (a) Effect of limestone powder content. (b) Effects of white cement and SAP.

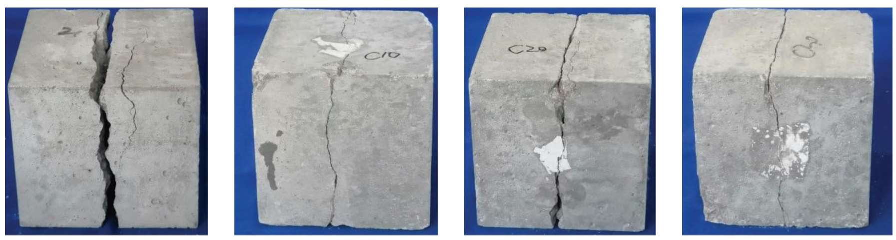
Figure 4. As the limestone content increases, the shedding on both sides of the test specimen gradually decreases, indicating that the integrity of the test specimen is better and the strength is higher. Figure 5 shows that the test specimen begins to crack at the center of the cross line on the surface in the split tensile strength test. As the load increases, cracks develop along the center line to the upper and lower edges, the width of the crack gradually widens, and it finally forms a penetrating crack and splits. Limestone powder can promote the tensile strength of fair-faced concrete.

It can be seen from Figure 6 that aggregate splitting occurs in the damaged cross section of the concrete test specimen, and the failure form is not only the bonding failure of the interface between the aggregate and the cement but also the fracture failure of the coarse aggregate. The splitting test specimen of fair-faced concrete with four limestone contents in Figure 6 shows that aggregate destruction in Figure 6(a) is relatively higher, and in Figures 6(b)–6(d) with the increase of limestone content, the number of coarse aggregates damaged by fracture decreased gradually, and most of the fractured aggregates were small-sized aggregates, which indicated that the increase in limestone powder content improved the bonding of the interface between the aggregate and the cement and increased the self-resistance strength of the concrete specimen.

3.3.2. Influence of Compressive Strength. It can be seen from Figure 7(a) that the 7 d strength of white fair-faced concrete is slightly higher than that of ordinary fair-faced concrete. The reason is that the hydration of white cement produces more C_3A, which has the characteristics of early strength. But on the whole, compound white cement has little effect on the compressive strength. Mixing SAP can cause the degradation of white fair-faced concrete's compressive strength [34]. The compressive strength of white fair-faced concrete at 7 d and 28 d curing age decreased by 10.6% and 11.8%, respectively, after adding SAP. This is similar to the research results of Zheng et al. [33], Pierard et al. [39], and the two observed that the strength of the concrete was reduced by 13.6% and 13.0%. This is because the water-swellable SAP will form more pores after water release

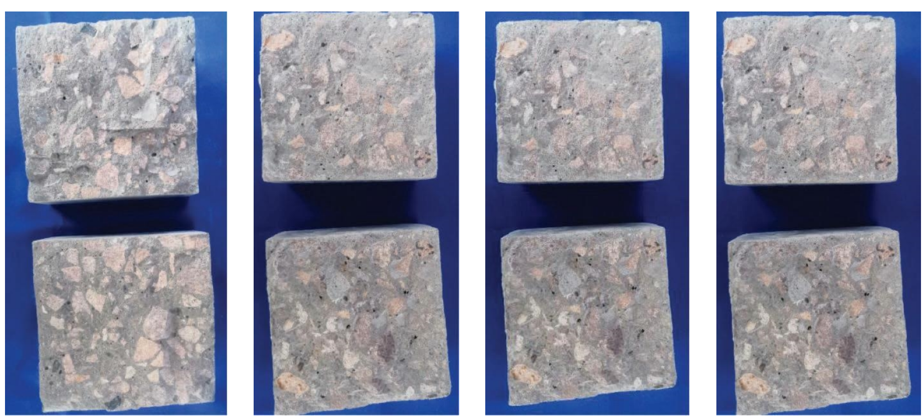
(a) (b) (c) (d)

Figure 4: Compressive test destructive form. (a) SAC. (b) LSAC-10. (c) LSAC-20. (d) LSAC-30.



(a) (b) (c) (d)

Figure 5: Splitting tensile test destructive form. (a) SAC. (b) LSAC-10. (c) LSAC-20. (d) LSAC-30.



(a) (b) (c) (d)

Figure 6: Splitting tensile test destruction interface. (a) SAC. (b) LSAC-10. (c) LSAC-20. (d) LSAC-30.

and shrinkage [15]. At the same time, due to the addition of additional curing water, the actual water-cement ratio of the white fair-faced concrete is increased, resulting in a decrease in the compressive strength of the white fair-faced concrete.

It can be seen from Figure 7(b)that when the limestone powder content is 20%, the 3 d, 7 d, and 28 d compressive strengths of SAP mixed with white fair-faced concrete are improved by 9.8%, 16.7%, and 13.6%. This is similar to the research results of Li et al. [40], Huo et al. [41], and Ghafoori et al. [42]. The reason is that limestone powder has a filling effect, which can optimize the pore size of concrete and reduce the influence of the increase in porosity caused by the incorporation of SAP on the mechanical properties of white fair-faced concrete. It is conducive to the densification of the internal structure and the improvement of compressive strength. When the limestone powder content is 30%, the compressive strength of SAP white fair-faced concrete 3 d and 7 d decreases slightly. The reason is that with an increase in limestone powder content, its dilution effect is enhanced, and the hydration products generated by white fair-faced concrete in the early stage are higher than those of white fair-faced concrete. However, with the increase in curing age, the compressive strength of SAP mixed with white fair-faced concrete increased by 11.6% at 28 d. Based on the results of the 28 d standard curing age, adding limestone powder is beneficial to SAP. When the compressive strength of white fair-faced concrete is improved when the limestone powder content is 20%, the overall strength is improved most significantly.

3.3.3. Effect on Splitting Tensile Strength. The effect of white cement and SAP on fair-faced concrete is shown in Figure 8(a). It shows that the addition of white cement

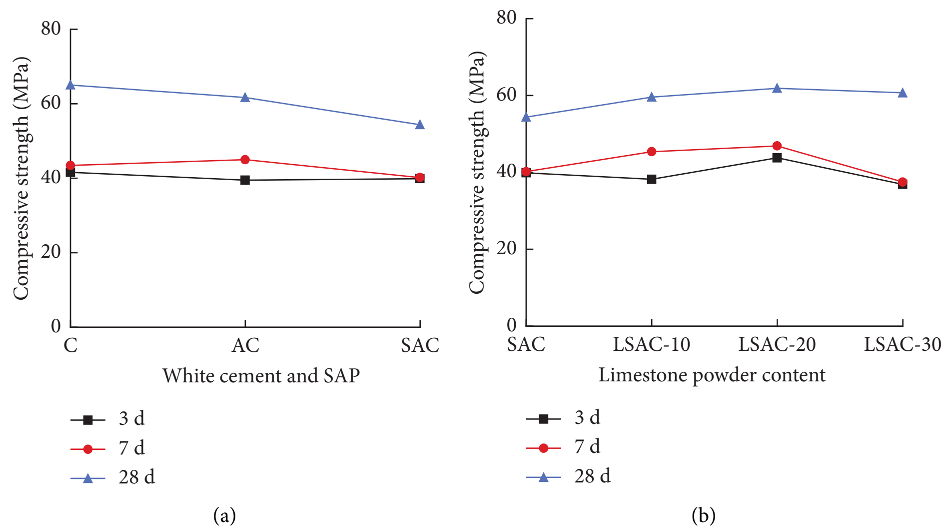


Figure 7: Compressive strength curves of different types of fair-faced concrete. (a) Effects of white cement and SAP. (b) Effect of limestone powder content.

slightly reduces the tensile strength of fair-faced concrete, and the 3 d, 7 d, and 28 d splitting tensile strength decrease by 2.5%, 6.2%, 0.8%, and it is not obviously. The 3 d and 7 d splitting tensile strength of SAP mixed with white fair-faced concrete are basically the same as those of white fair-faced concrete. However, the 28 d tensile strength decreased by 39.0%, obviously. Because the water inside the SAP was sucked away by the surrounding medium to leave pores [16, 33] and additional internal curing water, the actual water-cement ratio is increased. The addition of SAP has a significant effect on the tensile strength of white fair-faced concrete.

The effect of limestone powder content on SAP mixed with white fair-faced concrete is shown in Figure 8(b). When the limestone powder content is 30%, the tensile strength of SAP mixed with fair-faced concrete increases by 17.6%, 10.5%, and 12.1%, respectively. Obviously, it can be seen that the filling effect and nucleation effect of limestone powder are also beneficial to the tensile strength improvement of SAP mixed with white fair-faced concrete [23].

3.3.4. Influence on the Tension-Compression Ratio. The high tensile-compression ratio can increase the tensile strength of concrete on the premise that it meets the design requirements for compressive strength. Higher tensile strength can effectively prevent the occurrence of concrete cracks [43]. It can be seen from Figure 9(a) that the effect of cement and SAP mixed with fair-faced concrete, at the age of 3 d, 7 d, and 28 d, the increase of the tension-compression ratio of the fair-faced concrete by adding white cement was 3.4%, −9.0%, and 5.1%, respectively. The addition of SAP slightly increased the tension-compression ratio of white fair-faced concrete at 3 d and 7 d age by 4.9% and 8.2%, respectively, but at 28 d curing age, the tension-compression ratio decreased by 19.3%, and the tension-compression ratio decreased significantly. It is not beneficial to the application of white fair-faced concrete.

Figure 9(b) shows that the tensile-compression ratio of 3 d, 7 d, and 28 d curing periods decreased by 6.3%, 4.6%, and 2% slightly. When the limestone powder content was 20%, the tensile-compression ratio of SAP mixed with white fair-faced concrete decreased significantly, and the tension-compression ratio of 3 d, 7 d, and 28 d curing period decreased by 32.8%, 21.2%, and 10%, respectively, which was not conducive to the application of SAP mixed with fair-faced concrete. When the limestone powder content was 30%, the tensile-compression ratio of SAP mixed with white fair-faced concrete was greatly improved. At the curing age of 3 d, 7 d, and 28 d, the tension-compression ratio increased by 28.1%, 18.2%, and 2.0%, respectively. The tensile-compression ratio of SAP mixed with white fair-faced concrete with limestone powder content of 30% is the best, which is beneficial to the application of SAP mixed with fair-faced concrete in engineering.

3.4. Microscopic Mechanism Analysis. Three groups of tests of AC, SAC, and LSAC-20 at the curing age of 28 days were selected, and observation pieces were made for microscopic observation. Figures 10(a)–10(c) are the morphologies of the samples magnified 16 times. It can be observed that the surface pores of the SAC group specimens mixed with SAP are significantly more than those of the AC group. The pores caused by SAP's release of water in white fair-faced concrete are the main reasons for the decrease in the compressive and tensile strengths of white fair-faced concrete.

Compared with the SAC group, the surface pores of the LSAC-20 group have been reduced, and the filling effect of limestone powder can effectively solve the problem of increased pores caused by the incorporation of SAP. This alleviates the effect of SAP on the mechanical properties of white fair-faced concrete and improves the compressive and tensile strengths. Figures 10(d)–10(f) are the morphologies of the samples magnified 3000 times. It can be seen from the comparison of the pictures of the AC group and the SAC

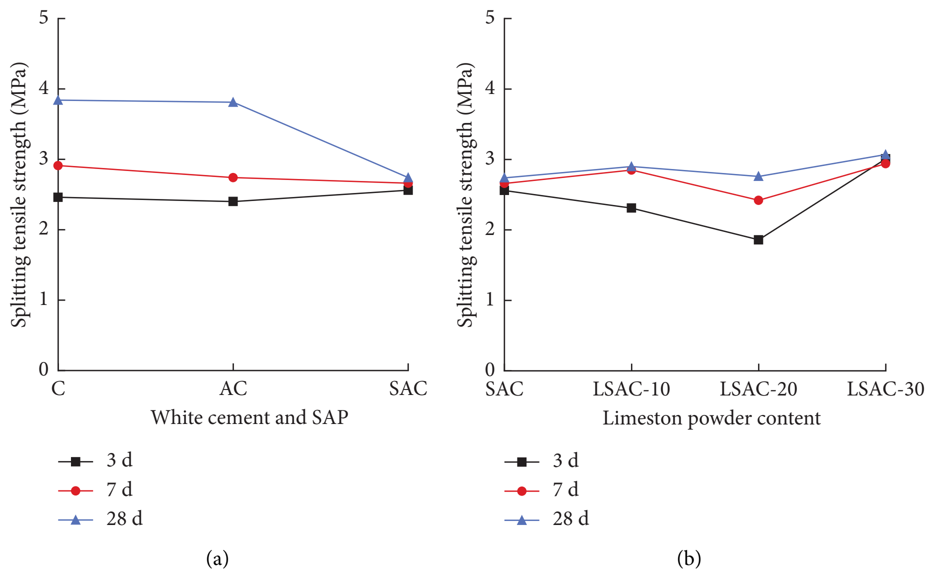


Figure 8: Splitting tensile strength curves of different types of fair-faced concrete. (a) Effects of white cement and SAP. (b) Effect of limestone powder content.

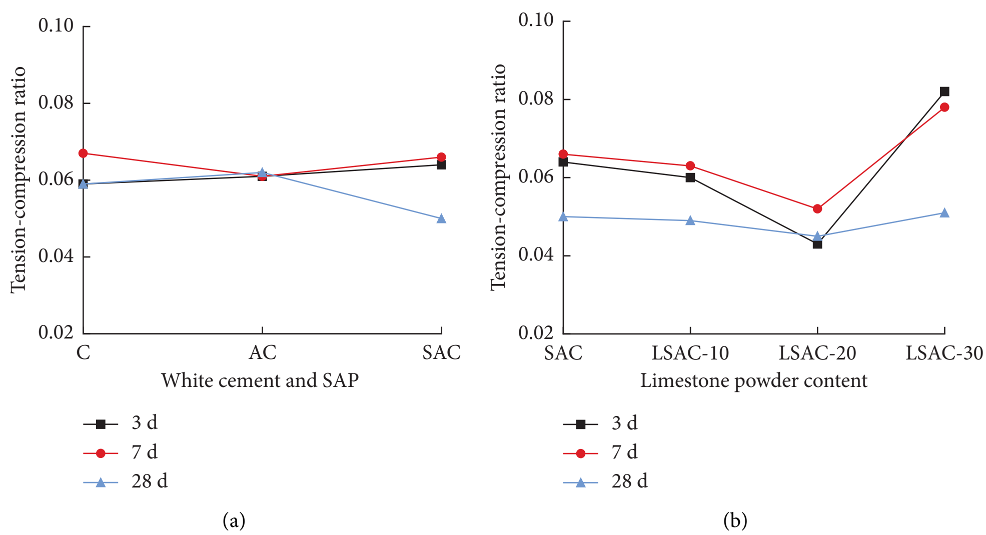


Figure 9: Tensile-compression ratio curves of different types of fair-faced concrete. (a) Effects of white cement and superabsorbent resin. (b) Effect of limestone powder content.

group that the internal structure of the concrete in the AC group is loose, with more $Ca(OH)_2$plate-like particles, so the fly ash cannot effectively exert its activation effect and there is no gel surrounding it. The internal structure of the concrete in the SAC group is relatively dense; the fly ash is wrapped by the C-S-H gel, and there is no large amount of Ca $(OH)_2$ tabular particles. The water release of SAP is conducive to the activation of fly ash and promotes the reaction of SiO_2 and Ca $(OH)_2$ to generate a stable C-S-H gel. This further reveals the reason why SAP improves the durability of white fair-faced concrete. Similarly, the LSAC-20 concrete has a dense internal structure, and the nucleation effect of limestone powder is effectively exerted, which is beneficial to the formation of C-S-H gel. In the SEM, it can be seen that a large amount of C-S-H gel is formed around the limestone powder. Therefore, adding limestone powder

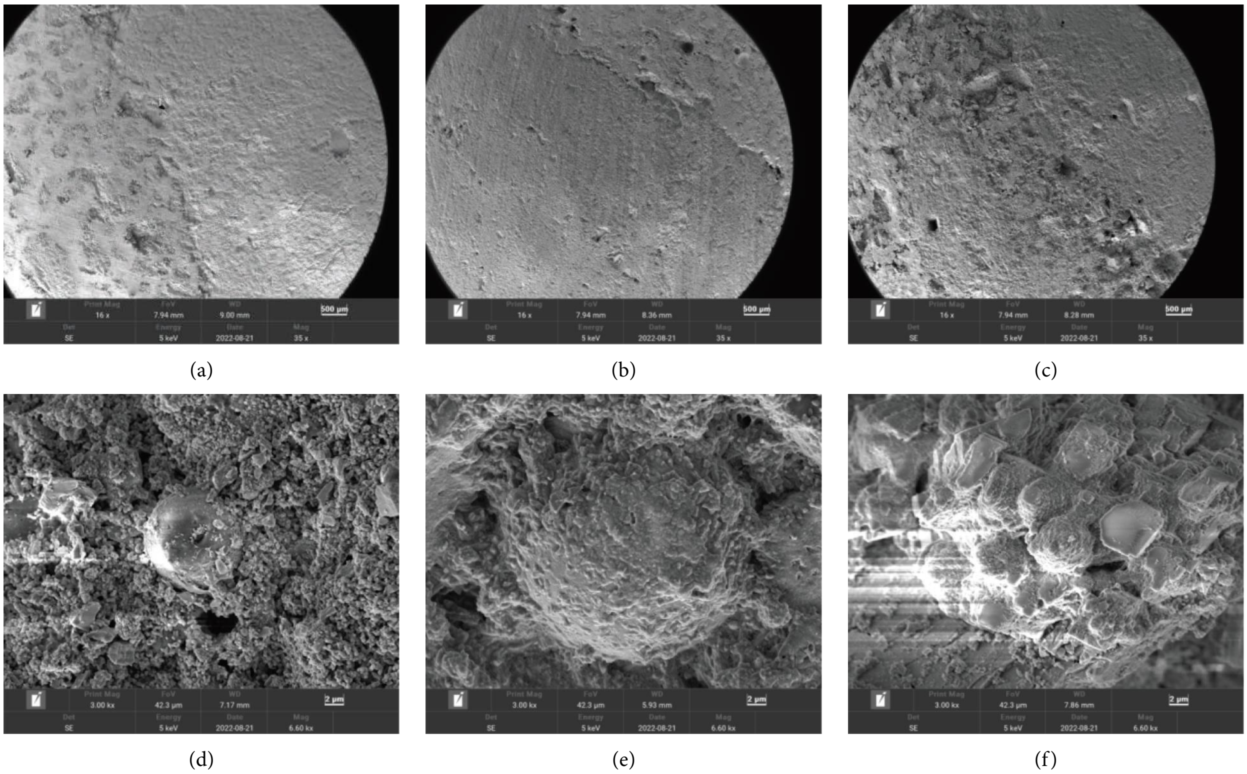


Figure 10: SEM image of 28 d fair-faced concrete. (a) 16x SEM image of group AC. (b) 16x SEM image of group SAC. (c) 16x SEM image of group LSAC-20. (d) 3000x SEM image of group AC. (e) 3000x SEM image of group SAC. (f) 3000x SEM image of group LSAC.

into SAP mixed with white fair-faced concrete can further improve the durability of SAP mixed with white fair-faced concrete.

4. Conclusion

(1) Adding white cement will reduce the slump of fair-faced concrete. Adding SAP can increase the slump of white fair-faced concrete. Limestone powder is beneficial to the slump of SAP mixed with white fair-faced concrete, and it increases with the increase of limestone powder content.

(2) Mixed with white cement will deteriorate the durability of fair-faced concrete. Adding SAP to white fair-faced concrete can effectively reduce the electrical flux. The electrical flux of SAP mixed with white fair-faced concrete decreases with the increase of limestone powder content. Limestone powder is beneficial to improving the durability of SAP mixed with white fair-faced concrete.

(3) Adding white cement has little effect on the mechanical properties of fair-faced concrete. Adding SAP will deteriorate the mechanical properties of white fair-faced concrete. Adding limestone powder is beneficial to the improvement of the mechanical properties of SAP mixed with white fair-faced concrete. Adding 30% limestone powder, the tensile-compression ratio of SAP white fair-faced concrete is significantly improved, which is conducive to improving the tensile strength and preventing cracking of SAP mixed with white fair-faced concrete under the premise of meeting the design requirements for compressive strength.

(4) The incorporation of SAP can effectively improve the internal structure of white fair-faced concrete, promote the secondary hydration of fly ash, and facilitate the densification of the internal structure of white fair-faced concrete. The limestone powder mixed in the SAP white fair-faced concrete can effectively exert its filling effect and crystal nucleation effect, which is beneficial to the improvement of the comprehensive performance of the SAP mixed with white fair-faced concrete. The limestone powder has strong applicability in the SAP mixed with white fair-faced concrete.

(5) According to comprehensive workability of durability performance and mechanical performance, SAP mixed with white fair-faced concrete has the best performance when the limestone powder content is 30%.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Jun Shi and Jinping Zhuang conducted the conceptualization. Jinping Zhuang performed the methodology. Zhangbao Wu and Fan Zhang contributed to software. Rong Chen contributed to validation and formal analysis., Huixia Li and Zhangbao Wu performed the investigation. Zhangbao Wu and Huixia Li curated the data. Jun Shi and Huixia Li contributed to writing-original draft preparation. Jinping Zhuang contributed to writing-review and editing. Jun Shi supervised the project. Jinping Zhuang contributed to project administration. Jun Shi contributed to funding acquisition.

Acknowledgments

This work was financially supported by the National Natural Science Foundation of China (51678152), the Fujian Province Residential Construction Industry Construction Technology Research and Development Project (2022-K-29), the Natural Science Foundation Project of Fujian Province (2021J011060) and College Student Innovation and Entrepreneurship Training Program Project (3200601422).

References

[1] Z. Wang, Q Guan, and L Li, "Influence of construction technology on appearance quality of fair faced concrete and its evaluation method," *Concrete*, vol. 44, no. 04, pp. 120–123+128, 2022.

[2] Y. Chen, C. Qian, and J. Zhang, "Effect of material parameters on the control of the apparent porosity of fair-faced concrete," *Materials Reports*, vol. 36, no. S1, pp. 225–233, 2022.

[3] X. Han, Yi Pan, and Y. Xie, "Research on appraisal of fair-faced concrete appearance quality by UAV image acquisition method," *Materials Reports*, vol. 35, no. 02, pp. 205–212, 2021.

[4] D. Yang, C. Cao, and J. Xia, "Research on the application of white Portland cement in mass concrete," *Construction Technology*, vol. 51, no. 10, pp. 107–111, 2022.

[5] C. Dow and F. P. Glasser, "Calcium carbonate efflorescence on Portland cement and building materials," *Cement and Concrete Research*, vol. 33, no. 1, pp. 147–154, 2003.

[6] Yeping, K. Gu, and S. Zhong, "The effect of fly ash on the durability of fair-faced concrete under seawater erosion environment," *New Building Materials*, vol. 45, no. 05, pp. 14–17+40, 2018.

[7] Y. Wu, W. Liu, and S. Liu, "Research on optimum preparation of white fair-faced concrete for main structure of Taihu tunnel," *New Building Materials*, vol. 48, no. 06, pp. 46–50+11, 20210.

[8] R. Henkensiefken, T. E. Nantung, and W. J. Weiss, "Reducing Restrained Shrinkage Cracking in concrete: Examining the Behavior of Self-Curing concrete Made Using Different Volumes of Saturated Lightweight Aggregate," in *Proceedings of the 2008 Concrete Bridge Conference Federal Highway Administration National Concrete Bridge Council Missouri Department of Transportation American Concrete Institute (ACI)*, Washington, DC, USA, 2008.

[9] A. Radlinska, F. Rajabipour, B. Bucher, R. Henkensiefken, G. Sant, and J. Weiss, "Shrinkage mitigation strategies in cementitious systems: a closer look at differences in sealed and unsealed behavior," *Transportation Research Record*, vol. 2070, no. 1, pp. 59–67, Article ID 2070-08, 2008.

[10] K. Kovler and O. M. Jensen, "Internal curing of concrete, state-of-the-art report of RILEM technical committee 196-ICC," *RILEM Report*, vol. 41, 2007.

[11] D. Shen, T. Wang, Y. Chen, M. Wang, and G. Jiang, "Effect of internal curing with super absorbent polymers on the relative humidity of early-age concrete," *Construction and Building Materials*, vol. 99, no. 30, pp. 246–253, 2015.

[12] M. T. Hasholt, O. M. Jensen, K. Kovler, and S. Zhutovsky, "Can superabsorbent polymers mitigate autogenous shrinkage of internally cured concrete without compromising the strength?" *Construction and Building Materials*, vol. 31, pp. 226–230, 2012.

[13] Q. Sun, Y. Wei, and Y. Meng, "Study on impermeability of super absorption polymer concrete," *New Building Materials*, vol. 36, no. 6, pp. 68–71, 2009.

[14] C. Ouattara Coumoin, F. Wang, J. Yang, and Z. Liu, "Effect of SAP on properties of high-performance concrete under marine wetting and drying cycles," *Journal of Wuhan University of Technology-Materials Science Edition*, vol. 34, no. 5, pp. 1136–1142, 2019.

[15] X. Ma, J. Liu, Z. Wu, and C. Shi, "Effects of SAP on the properties and pore structure of high-performancecement-based materials," *Construction and Building Materials*, vol. 131, pp. 476–484, 2017.

[16] V. Mechtcherine, M. Gorges, C. Schroefl et al., "Effect of internal curing by using superabsorbent polymers (SAP) on autogenous shrinkage and other properties of a high-performancefine-grained concrete: results of a RILEM round-robin test," *Materials and Structures*, vol. 47, no. 3, pp. 541–562, 2014.

[17] Y. Dhandapani, M. Santhanam, G. Kaladharan, and S. Ramanathan, "Towards ternary binders involving limestone additions—a review," *Cement and Concrete Research*, vol. 143, Article ID 106396, 2021.

[18] G. Chen and X. Kong, "Limestone power a new type of RCC admixture," *China Water Resources*, vol. 21, pp. 16–18, 2007.

[19] Z. Zhao and Z. Ma, "Discussion on influence of limestone powder on mechanics performance and durability performance of roller compacted concrete," *Water Resources Development & Management*, vol. 35, no. 05, pp. 30–33, 2015.

[20] S. Yu, N. Lin, and Y. Deng, "Experimental study on the effects of limestone powder for concrete workability and compressive strength," *Industrial Construction*, vol. 42, no. S1, pp. 522–526, 2012.

[21] H. Xie, Y. Zhang, and J. Luan, "Influence of limestone powder on properties of concrete prepared from cement and fly ash," *Bulletin Of The Chinese Ceramic Society*, vol. 31, no. 2, pp. 371–376, 2012.

[22] D. Wang, C. Shi, N. Farzadnia, Z. Shi, and H Jia, "A review on effects of limestone powder on the properties of concrete," *Construction and Building Materials*, vol. 192, no. 20, pp. 153–166, 2018.

[23] L. G. Li and A. K. Kwan, "Adding limestone fines as cementitious paste replacement to improve tensile strength, stiffness and durability of concrete," *Cement and Concrete Composites*, vol. 60, pp. 17–24, 2015.

[24] V. B. Bosiljkov, "SCC mixes with poorly graded aggregate and high volume of limestone filler," *Cement and Concrete Research*, vol. 33, no. 9, pp. 1279–1286, 20036.

[25] G. I. Sezer, "Compressive strength and sulfate resistance of limestone and/or silica fume mortars[J]," *Construction and Building Materials*, vol. 26, no. 1, pp. 613–661, 20128.

[26] P. Pliya and D. Cree, "Limestone derived eggshell powder as a replacement in Portland cement mortar," *Construction and Building Materials*, vol. 95, pp. 1–9, 2015.

[27] A Schöler, B. Lothenbach, F. Winnefeld, and M. Zajac, "Hydration of quaternary Portland cement blends containing blast-furnace slag, siliceous fly ash and limestone powder," *Cement and Concrete Composites*, vol. 55, pp. 374–382, 2015.

[28] S. Tongaroonsri and S. Tangtermsirikul, "Effect of mineral admixtures and curing periods on shrinkage and cracking age under restrained condition," *Construction and Building Materials*, vol. 23, no. 2, pp. 1050–1056, 2009.

[29] L. Courard and F. Michel, "Limestone fillers cement-based composites: effects of blast furnace slags on fresh and hardened properties," *Construction and Building Materials*, vol. 51, no. 1, pp. 439–445, 2014.

[30] M. Gesoglu, E. Güneyisi, M. E. Kocabag, V. Bayram, and K. Mermerdas, "Fresh and hardened characteristics of self-compacting concretes made with combined use of marble powder, limestone filler, and fly ash," *Construction and Building Materials*, vol. 37, pp. 160–170, 2012.

[31] J. Chen, A. Kwan, and Y. Jiang, "Adding limestone fines as cement paste replacement to reduce water permeability and sorptivity of concrete," *Construction and Building Materials*, vol. 56, no. 4, pp. 87–93, 2014.

[32] S. Ahmad, S. K. Adekunle, M. Maslehuddin, and A. K. Azad, "Properties of self-consolidating concrete made utilizing alternative mineral fillers," *Construction and Building Materials*, vol. 68, no. 15, pp. 268–276, 2014.

[33] X. Zheng, M. Han, and L. Liu, "Effect of superabsorbent polymer on the mechanical performance and microstructure of concrete," *Materials*, vol. 14, no. 12, p. 3232, 2021.

[34] J. Dang, J. Zhao, and Z. Du, "Effect of superabsorbent polymer on the properties of concrete," *Polymers*, vol. 9, no. 12, p. 672, 2017.

[35] National standard of the people's Republic of China, *Standard for Performance Test Methods of Ordinary concrete Mixtures: GB/T50080-2016[S]*, China Construction Industry Press, Beijing China, 2016.

[36] National standard of the people's Republic of China, *Standard for Test Methods for Long-Term Performance and Durability of Ordinary concrete: GBT50082-2009[S]*, China Construction Industry Press, Beijing China, 2009.

[37] National standard of the people's Republic of China, *Standard for Test Methods of Mechanical Properties of Ordinary concrete: GB/T50081-2002[S]*, China Construction Industry Press, Beijing China, 2002.

[38] Y. Yu, J. Liu, and Q. Ran, "Effect of polycarboxylate-type superplasticizer on hydration behavior of C3A-gypsum suspension," *Journal of the Chinese Ceramic Society*, vol. 40, no. 5, pp. 685–690, 2012.

[39] J. Piérard, V. Pollet, and N. Cauberg, "Mitigating autogenous shrinkage in HPC by internal curing using superabsorbent polymers," in *Proceedings of the International RILEM Conference on Volume Changes of Hardening concrete: Testing and Mitigation*, pp. 97–106, RILEM Publications SARL, Paris, France, 2006.

[40] W. Li, Z. Huang, F. Cao, Z. Sun, and S. P. Shah, "Effects of nano-silica and nano-limestone on flowability and mechanical properties of ultra-high-performance concrete matrix," *Construction and Building Materials*, vol. 95, pp. 366–374, 2015.

[41] J. Huo, M. Song, and Z. Tong, "Effect of limestone admixture on performance of concrete," *Concrete*, vol. 5, pp. 70–72, 2015.

[42] N. Ghafoori, R. Spitek, and M. Najimi, "Influence of limestone size and content on transport properties of self-consolidating concrete," *Construction and Building Materials*, vol. 127, pp. 588–595, 2016.

[43] Y.-nian Zhang, H. Dong, and L. I. U. Xiao-yang, "Experiment on tension-compression ratio of polypropylene fiber reinforced concrete," *Journal of Shenyang University of Technology*, vol. 39, no. 1, pp. 104–108, 2017.