Study on Long-Term Performance of C80 Manufactured Sand High Performance Concrete

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Abstract. By testing the resistance to chloride ion penetration and dry shrinkage performance combined with microscopic analysis, the effects of different machine-made sand mud powder content, silica fume and nano-SiO_2 content on the long-term performance of machine-made sand high-performance concrete were studied. The results show that the chloride ion penetration resistance of concrete increases with the increase of stone powder content and mineral admixture content, and decreases with the increase of mud powder content. Stone powder and mineral admixture can reduce the electric flux of concrete by 26.5 % and 50.1 % respectively. Similarly, silica fume and nano-SiO_2 can effectively reduce the drying shrinkage of concrete, while stone powder and mud powder will increase the drying shrinkage of concrete. From the microscopic analysis, it can be seen that stone powder can reduce the porosity of concrete and improve the compactness, while mud powder will increase the porosity of concrete. Silica fume and nano-SiO_2 can promote hydration to produce more products to effectively fill the internal structure and reduce the porosity of concrete, thus affecting the long-term performance of concrete to varying degrees.

Keywords: manufacture sand; high performance concrete; mudstone powder; silica fume; nano-SiO_2; long-term performance; micro-analysis.

1 Introduction

In recent years, with the rapid increase in the demand for sand and gravel aggregates, natural river sand resources have been in short supply [1]. Compared with natural sand, mechanism sand has characteristics such as easy availability of raw materials, and has been proven to be a large-scale alternative to natural sand for concrete preparation [2-3]. The production of mechanism sand will be accompanied by the generation of a large number of mud and stone powder particles, and adversely affect the performance of concrete [4-10], which also puts forward a technical challenge to the high strength and high performance of mechanism sand concrete. Existing studies have shown that the various properties of concrete decrease with the increase of MB value of mechanism sand, and the higher the strength grade of concrete is affected more [11, 12]. Concrete workability does not change significantly with increasing stone dust content, while mechanical strength and durability show a trend of decreasing and then increasing [13].

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The concrete workability decreased and compressive strength and electrical flux increased with increasing stone dust content [14, 15]. Therefore, the preparation of concrete from mechanism sand containing mud and stone dust will have different degrees of impact, in order to prepare high performance concrete from mechanism sand existing studies consider the addition of various active mineral admixtures and nanomaterials [16-18]. Some studies have shown that compounding a variety of mineral admixtures within a certain admixture range is beneficial to improve the mechanical properties of concrete and reduce drying shrinkage [16]. Xiong et al. [19] experimentally concluded that the addition of silica fume to high-performance concrete can improve the resistance of concrete to chloride ion penetration. Zhou et al. [18] showed that nano-silica can effectively improve the mechanical strength and volume stability of mechanism sand concrete. In summary, the composition design of high-strength mechanized sand concrete and its long-term performance still need to be studied in depth.

In this paper, the effects of mudstone powder content in mechanism sand and high-performance mineral admixture on the chlorine ion penetration resistance and drying shrinkage performance of C80 mechanism sand high-performance concrete were investigated, and combined with thermogravimetric and pore structure analyses to explore the role of mudstone powder and admixture on the long-term performance of this type of concrete mechanism sand high-performance concrete.

2 Materials and Test Methods

2.1 Materials

The silicate cement used in the test is Huaxin P-O52.5; the slag powder is S95 grade blast furnace slag; the color of silica fume is light grey and the content of SiO2 is more than 93%; the nano-silica adopts hydrophilic nano-silica powder with the particle size range of 10-30nm; the stone powder adopts limestone powder; the kaolin clay is used as the mud powder; and the polycarboxylic acid high-efficiency water reducer is used as the water reducer with the water reducer rate of 25%. The fine aggregate was made of II area mechanism sand with fineness modulus of 2.6~3.0, and continuous graded gravel within the range of 5~20mm particle size was used as coarse aggregate. Table 1 shows the high-performance concrete mix ratio of C80 mechanism sand with different admixtures.

Table 1. Test mix ratio (kg/m^3)

No.	Cement	Slag	Silica Fume	Nano SiO_2	stone powder	kaolin clay	Mechanized Sand	Coarse Aggregate	Water	Water Reducer
SP0MP0	425.0	82.8	44.2	0	0	0	659.9			
SP6MP0	425.0	82.8	44.2	0	39.6	0	620.3			
SP9MP0	425.0	82.8	44.2	0	59.4	0	600.5	1095.7	147.2	9.8
SP9MP15	425.0	82.8	44.2	0	50.5	8.9	600.5			
SP9MP60	425.0	82.8	8	0	23.8	35.6	600.5			

SF0NS0	469.2	82.8	0	0	0	0	659.9
SF4NS0	447.1	82.8	22.1	0	0	0	659.9
SF8NS0	425.0	82.8	44.2	0	0	0	659.9
SF8NS1	419.5	82.8	44.2	5.5	0	0	659.9
SF8NS2	414.0	82.8	44.2	11.0	0	0	659.9

Note: SP stands for stone powder, MP stands for mud powder, SF stands for silica fume, NS stands for nano-SiO_2, the first digit stands for stone powder or silica fume mixing amount, the second digit stands for mud powder equal mass replacement of stone powder substitution rate or nano-SiO_2 mixing amount.

2.2 Test Methods

Mechanical properties test was conducted according to the Standard Test Methods for Physical and Mechanical Properties of Ordinary Concrete (GB/T50081-2019), the long-term performance test was conducted with reference to the standard Test Methods for Long-term and Durability Properties of Ordinary Concrete (GB/T50082-2009), and the test of resistance to chlorine penetration was conducted by the electric flux method. The thermogravimetric analysis (DTG) and pore structure analysis (MIP) were determined by thermal analyzer and fully automatic mercuric pressure meter, respectively.

3 Test results and discussion

3.1 Mechanical property

Figure 1 demonstrates the effect of different mud and stone powder contents on the compressive strength of C80 mechanism sand high-performance concrete. As can be seen from the figure, the cubic compressive strength of mechanism sand high-performance concrete at 7d and 28d both increased and then decreased with the increase of stone powder mixing, and showed a gradual decrease with the increase of mud powder content. The compressive strength of the mechanism sand high-performance concrete cube with 6% stone dust content increased by 8.21% and 10.70% at 7d and 28d, respectively, compared with that of the concrete cube with 0 stone dust content, and the compressive strength of the mechanism sand high-performance concrete cube with 9% stone dust content decreased by 6.57% and 7.13% at 7d and 28d, respectively, compared with that of the concrete cube with 6% stone dust content. 7.13%. 7d, mud powder substitution rate of 15% and 60% of the concrete cubic compressive strength than mud powder content of 0 concrete cubic compressive strength reduced by 3.52% and 9.58%. 28d, mud powder substitution rate of 15% and 60% of the concrete cubic compressive strength than mud powder content of 0 concrete cubic compressive strength reduced by 2.94% and 8.83%. The Figure 2 demonstrates the effect of single admixture of silica fume and compound admixture of silica fume and nano-silica on the compressive strength of mechanism sand concrete. The cubic compressive strength of concrete at both 7d and 28d increased gradually with the increase in silica fume admixture, but its growth rate gradually became slower. With the increase of nano-silica dosage first increased and then decreased, the dosage of 1.0% of the concrete 7d and 28d cubic compressive strength reached the maximum value.

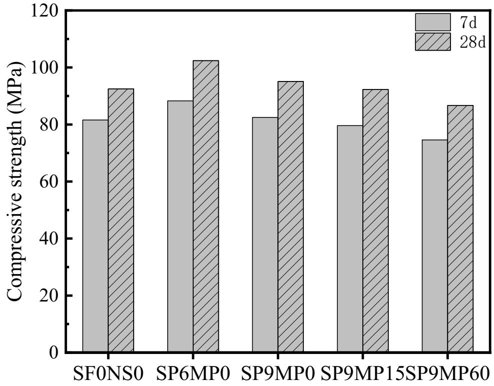

Fig. 1. Effect of mud and stone powder content on compressive strength of concrete

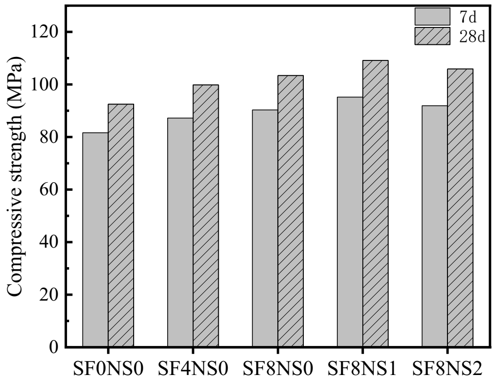

Fig. 2. Effect of mineral admixture on compressive strength of concrete

3.2 Chloride permeation resistance

Figure 3 shows the effect of stone mud powder content on the resistance of mechanism sand concrete to chloride ion penetration. When the content of stone mud powder is 0%, the electrical flux of concrete of SP0NS0 at 56d is lower than 1000C, which meets the design criterion of 100 years. Compared to SP0NS0, the electric flux of SP6MP0 decreased by 18.1% and 20.1% at 28d and 56d, respectively, and the electric flux of SP9MP0 decreased by 23.6% and 26.5% at 28d and 56d, respectively. It is shown that when mechanism sand concrete contains a certain content of stone powder, it can improve its resistance to chloride ion penetration, and it improves with the increase of stone powder content within a certain range. Compared to SP9MP0, the fluxes of SP9MP15 increased by 21.95% and 26.27% at 28d and 56d, respectively, and those of

SP9MP60 increased by 41.55% and 51.27% at 28d and 56d, respectively, indicating that mud powder has a deteriorating effect on the chloride ion permeation resistance of the concrete, and decreases with the increase of the content of mud powder within a certain range. Figure 4 demonstrates the effect of mineral admixtures on the chloride ion permeation resistance of mechanism sand concrete. When the content of silica fume and nano-silica is 0%, the electric flux at 56 d is lower than 1000 C. Compared with SF0NS0, SF4NS0 shows a decrease of 10.2% and 10.6% at 28 d and 56 d, respectively, and SF8NS0 shows a decrease of 12.7% and 18.1% at 28 d and 56 d, respectively, so there is a deterioration of the chloride ion permeation resistance of concrete in a certain range. chloride ion permeability improves with increasing silica fume admixture. Compared with SF8NS0, the electric flux of SF8NS1 decreased by 48.8% and 49.1% at 28d and 56d, respectively, and that of SF8NS2 decreased by 49.4% and 50.1% at 28d and 56d, respectively, which can be proved that the anti-chlorine permeability of the mechanism sand is better than that of the single silica fume doping with silica fume and the anti-chlorine permeability of the mechanism sand is better than that of the single silica fume doping with silica fume and the anti-chlorine permeation performance of the mechanism sand is better than the mechanism sand with silica fume doping with silica fume doping with silica fume doping with silica fume doping with nanometer. silica doping increases, but when the nano-silica doping exceeds 1%, the enhancement effect is not significant.

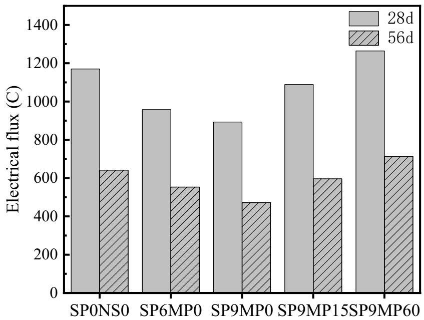

Fig. 3. Effect of mudstone powder content on the electrical flux of concrete

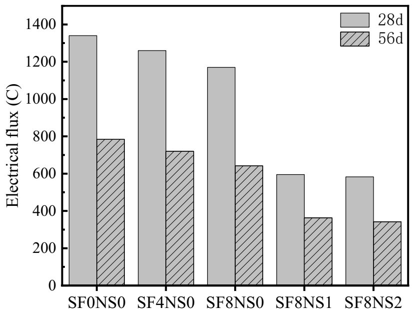

Fig. 4. Effect of mineral admixtures on the electrical flux of concrete

3.3 Drying Shrinkage Properties

Figure 5 shows the drying shrinkage change rule of mechanism sand high-performance concrete with age under different mudstone powder content. Figure 5 shows that the drying shrinkage of mechanism sand high-performance concrete under different silt and stone powder content increases with the increase of age, and its drying shrinkage mainly occurs before 28d, the concrete drying shrinkage growth rate is faster before 28d, and the drying shrinkage growth rate gradually slows down after 28d. The dry shrinkage of concrete under the same age increases with the increase of mud and stone powder content. SP6MP0 and SP9MP0 dry shrinkage than SP0MP0 dry shrinkage increased by a maximum of 29.17% and 48.33%. SP9MP15 and SP9MP60 dry shrinkage than SP9MP0 dry shrinkage can be increased by a maximum of 19.66% and 36.52% respectively.

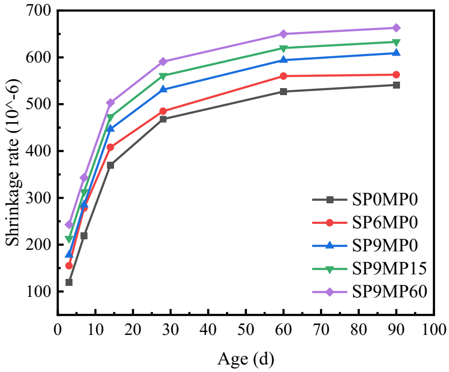

Fig. 5. Effect of mud and stone powder content on drying and shrinking properties of concrete

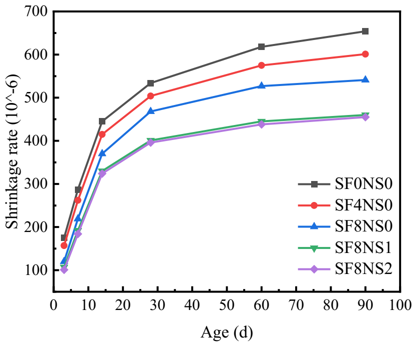

Fig. 6. Effect of mineral admixtures on the drying and shrinking properties of concrete

Figure 6 shows the drying shrinkage rule of mechanism sand high-performance concrete with age under different mineral admixture mixing amount. For mechanism sand high-performance concrete mixed with silica fume and nano-silica, different age under the law of change and mud and stone powder consistent, the same age, mixed with silica fume and nano-silica will make the mechanism sand high-performance concrete dry shrinkage rate is reduced, but mixed with 2.0% of the nano-silica when the mechanism sand high-performance concrete dry shrinkage rate is not significantly reduced compared to the amount of mixing for 1%. SF4NS0 and SF8NS0 SF4NS0 and SF8NS0 dry shrinkage rate than SF0NS0 dry shrinkage rate of the maximum reduction of 10.29% and 31.43%, SF8NS1 and SF8NS2 dry shrinkage rate than SF8NS0 dry shrinkage rate of the maximum reduction of 15.56% and 16.89%, SF8NS2 dry shrinkage rate than SF0NS0 dry shrinkage rate in the 3d, 7d, 14d, 28d, 60d and 90d, respectively, reduced 42.29%, 35.89%, 27.19%, 25.84%, 29.13% and 30.43% respectively.

3.4 Thermogravimetric analysis

Figure 7 shows the DTG curves of the specimens with 0% stone powder doping and 0% mud powder substitution, 9% stone powder doping and 0% mud powder substitution, and 9% stone powder doping and 60% mud powder substitution, respectively, after the age of 28d maintenance. All groups showed three heat absorption peaks around 90°C, 420°C and 660°C. The first heat absorption peak was mainly caused by the volatilization of free water in the system by heat C-(A)-S-H gel removing water molecules and the decomposition of calomel AFt caused by the second was due to the decomposition of calcium hydroxide by heat, and the last was due to the decomposition of calcite. With the addition of stone powder, the heat absorption peak of the gel was significantly enhanced, but after adding a certain proportion of mud powder to replace stone powder, the heat absorption peak of the gel slightly decreased again, which further verified that mud powder was not favorable to the development of high-performance concrete with mechanism sand. Figure 8 shows the DTG curves of the baseline group and the specimens with 8% silica fume admixture and 2% nano-silica admixture, respectively, after 28d curing. After the addition of silica fume and nano-silica, the specimens showed weight loss peaks near 420°C and 620°C, which corresponded to the heat-absorbing decomposition of $Ca(OH)_2$ and $CaCO_3$, respectively, and a certain degree of reduction of the weight loss peak of $Ca(OH)_2$ after the addition of admixtures, indicating that the secondary hydration reaction promotes the generation of hydration products, which in turn is conducive to the enhancement of the degree of matrix densification.

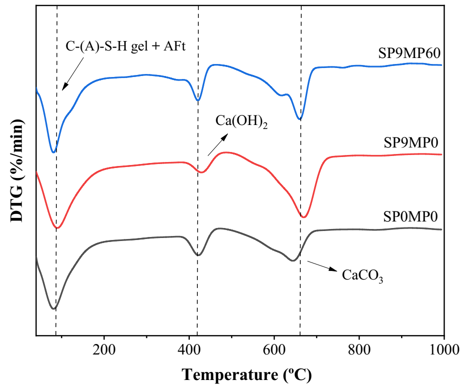

Fig. 7. Effect of discharge powder content on the product

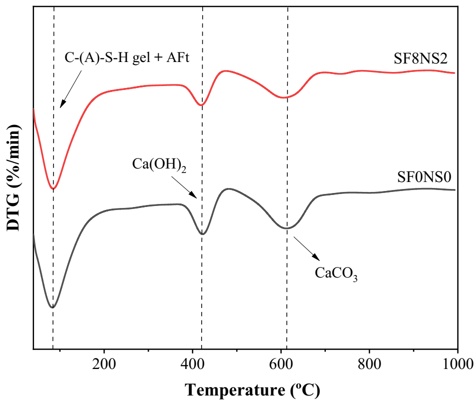

Fig. 8. Effect of mineral admixture on product

3.5 Hole structure analysis

The pore structure of each group of specimens was determined by mercuric pressure method, and the pore structure parameters of each group of specimens after 28 days of curing are shown in Table 2. The porosity of mechanism sand high-performance concrete with 0% mud and stone powder substitution was 10.68% after 28d of curing, and the porosity was 9.67% with 9% stone powder substitution, indicating that due to the stone powder particles played the role of filling the pores. When the mud powder substitution rate was 60%, the porosity increased to 12.51%, indicating that the mud powder increased the internal structural pores of the concrete, and therefore there was a certain deterioration of the concrete properties.

Table 2. Pore structure parameters of each group of specimens after 28d of curing

NO.	Porosity (%)	Average pore size (nm)	Maximum pore size (nm)	Median pore size (nm)
SP0MP0	10.68	16.46	21.92	8.04
SP9MP0	9.67	14.36	15.32	7.13
SP9MP60	12.51	15.55	20.19	7.40
SF0NS0	23.98	23.56	30.84	18.78
SF8NS2	9.79	22.77	84.28	9.06

From Table 2, Figure 9 and Figure 10 it can be seen that the porosity of SF0NS0 is 23.98% and SF8NS2 is 9.79%, the porosity is reduced by 59.17%, which indicates that the addition of silica fume and nano-silica makes the structure of high-performance concrete with machine-made sand denser and fills up the internal structure of the material, so that there is a better performance with the incorporation of the mineral admixtures. Due to the small size of nano-silica particles, the incorporation resulted in a decrease in the mean pore size and median pore size by 0.79 nm and 9.72 nm, respectively. Silica fume, as a mineral additive, reacts to generate more hydration products thereby altering the internal microstructure, which in turn affects the long-term performance.

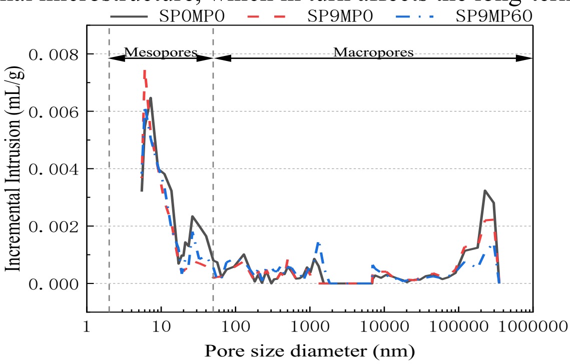

Fig. 9. Effect of discharge powder content on pore structure

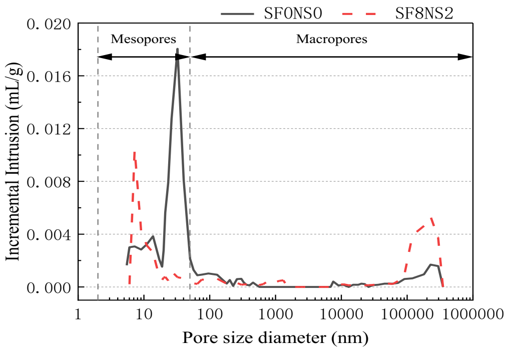

Fig. 10. Effect of mineral admixtures on pore structure

4 Conclusions

Based on the test results, the following conclusions were mainly obtained:

(1) Both stone powder and mineral admixture have an enhancing effect on the anti-chlorine ion permeation performance of concrete within a certain range, while mud powder is unfavorable to the anti-chlorine ion permeation performance. When the content of stone powder is 9%, the maximum reduction of electric flux is 26.5% compared with the content of 0, and the maximum reduction of electric flux is 50.1% compared with the group without any admixture when double mixing silica fume and nano-silica.

(2) Mud and stone powder are not conducive to the dry shrinkage performance of concrete, when the content of stone powder is 9% compared to the content of 0 when the dry shrinkage rate increased by 48.33%, mud powder substitution rate of 60% when the dry shrinkage rate increased by 36.52%; silica fume and nano-silica can effectively reduce the drying shrinkage, nano-mixed with 1% of the time to make the concrete dry shrinkage performance to reach the optimum.

(3) A small amount of stone powder can reduce the porosity of concrete to make the concrete system denser, while the addition of mud powder increases the porosity of concrete, which in turn affects the dry shrinkage performance. The incorporation of mineral admixtures facilitates the generation of hydration products and effectively fills the internal structure of concrete, and the silica fume admixture of 8% and nano-silica admixture of 2% can reduce the porosity by 59.17%, thus improving the long-term performance of concrete.

Reference

1. Cui Jun, Xu Xun, You Panli, et al. Shortage of sand and gravel resources for construction and countermeasures[J]. Concrete and cement products, 2023(2): 94-97.
2. Qu Fulai, Yang Yabin, Song Wanwan, et al. Experimental study on the application of mechanism sand concrete in PCCP[J]. Journal of North China University of Water Resources and Hydropower (Natural Science Edition), 2022, 43(5): 19-23.
3. Arulmoly B, Konthesingha C, Nanayakkara A. Performance evaluation of cement mortar produced with manufactured sand and offshore sand as alternatives for river sand[J]. Construction and Building Materials, 2021, 297: 123784.
4. Dilek U, Leming M. Deicer Salt Scaling Resistance of Concrete Containing Manufactured Sands[J]. Journal of Testing and Evaluation, 2007, 35(2): 134-142.
5. Liu Cijun, Chen Fangdong, Zhan Wen, et al. Influence of stone powder and mud powder content of mechanism sand on the performance of C50 box girder concrete[J]. Railway Construction, 2013(10): 132-135.
6. Zhu Rongjun, Ji Tao, Liu Chunping, et al. Effect of mudstone powder on workability and mechanical properties of artificial sand concrete[J]. Journal of Fuzhou University (Natural Science Edition), 2012, 40(3): 388-392.
7. Dong R, Shen Weiguo. Study on the dynamic relationship between stone powder and mud powder on MB value[J]. Concrete, 2017(12): 67-70+74.
8. Huang W, Chen X, Luan J, et al. Deep Insight into Mechanical Behaviour and Microstructure Mechanism of Dredged Sand in The Lower Reaches of The Yangtze River and Manufactured Sand Concrete[J]. Journal of Building Engineering, 2023, 68: 106105.

9. Lu L, Yang Z, Lin Y, et al. Partial Replacement of Manufactured Sand with Homologous Granite Powder in Mortar: The Effect on Porosity and Capillary Water Absorption[J]. Construction and Building Materials, 2023, 376: 131031.
10. Zou Xianjie, Liu Daobin, Lu Zili, et al. Study on the performance of mechanism sand-copper tailings composite sand commercial concrete[J]. Journal of Wuhan University of Technology, 2014, 36(12): 27-31.
11. Li Jiazheng, Gong Dexin, Lin Yuqiang, Li Yang. Analysis of the adverse effect of artificial sand mud powder on concrete properties[J]. People's Changjiang,2023,54(02):177-183+199. DOI: 10.16232/j.cnki.1001-4179.2023.02.027.
12. Xia Jingliang, Gao Yanpeng, Zhang Pengxiang, Guan Qingfeng, Wang Jing, Zhou Yongxiang. Effect of MB value of mechanism sand on electrical flux and chloride diffusion coefficient of concrete[J]. Building Science,2021,37(03): 78-84. DOI: 10.13614/j.cnki.11-1962/tu.2021.03.013.
13. Chunping Gu, Xiaorong Nie, Yang Yang, Zeze Yu, Jian Shen, Guangui Qiu. Effect of calcium stone powder mass fraction on the performance of mechanism sand concrete[J]. Journal of Zhejiang University of Technology,2023,51(01):14-19.
14. Liu Xiaofan, Lu Kai, Fan Qiang, He Yang, Guan Qingfeng, Len Guangming. Influence of stone powder content in granite mechanism sand with tunnel slag on concrete properties[J]. Concrete,2022(12):106-109.
15. Huang Weirong, He Yuechu, Cui Jindong, Chen Xing, Yan Maohao, Wang Jiao. Study on long-term performance of C50 self-compacting concrete with mechanism sand[J]. Concrete,2022(11):106-109+114.
16. Duan Chenggang, Sun Yongtao. Effect of compounding high-performance mineral admixture on the properties of high-strength mechanized sand concrete[J]. Silicate Bulletin, 2021, 40(7): 2296-2305.
17. Liang Yuanbo, Gu Kunpeng, Wang Chengqi. Effect of silica fume on concrete prepared from mechanism sand with high stone powder content[J]. Water Transportation Engineering, 2017(7): 53-57.
18. Zhou Shengbo, Zhou Zhimi, Ma Cong, et al. Research on the effect of nanosilica on the performance of mechanism sand concrete[J]. Concrete, 2020(11): 57-61.
19. Xiong Huixia, Zhang Qian, Li Yan, et al. Effects of fly ash and silica fume admixtures on chloride ion diffusion in high-performance concrete[J]. Concrete, 2021(7): 95-97+102.