

Research on the Performance of Concrete Anti-Segregation Agent

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Abstract. Through tests on the workability of concrete, setting time and compressive strength of different anti-segregation raw materials, B1 was selected as the anti-segregation raw material. Then, a series of anti-segregation agents were compounded by blending B1 with cement and mineral powder in certain proportions respectively. The effects of the anti-segregation agents on the workability, setting time and compressive strength of concrete were studied. The results show that after adding anti-segregation agents J2, J3 and J4 to the segregated concrete, compared with the blank concrete, the cohesion of the concrete is improved, the workability is enhanced, the effect on the setting time is minimal, and the 28-day compressive strength of the concrete can be increased.

1. Introduction

Concrete is currently the most widely used material by humans. Ensuring the workability of concrete is a key and challenging aspect in the actual production and application process. The various properties of the freshly mixed concrete have deteriorated, with phenomena such as segregation and water seepage occurring. This might be due to fluctuations in the performance of the concrete raw materials, such as changes in the moisture content of sand and gravel, the gradation of aggregates, the compatibility between cement and admixtures, and human errors^[1]. For instance, the cement hydration process has a significant impact on the phenomenon of bleeding. Therefore, the performance indicators of cement-based composite materials form the basis for their wide application in the construction field^[2-3]. On the other hand, the high water-reducing property of polycarboxylate superplasticizer is sensitive to the quality fluctuations of raw materials such as cement, manufactured sand and crushed stones in concrete, causing concrete to seep water and segregate. Therefore, additives to improve the workability of concrete have emerged^[4-6]. Lin Zeyu^[7-8] used acrylamide as the raw material to prepare an anti-segregation agent, which can effectively solve the problems of concrete segregation caused by excessive dosage of water reducer, excessive water consumption, and too low sand ratio. Liu Ke^[9] et al. synthesized two different molecular weight anti-dissolution agents, KLX-1 and KLX-2. Due to their carboxyl and ester-type polyether structures, they can effectively enhance the slurry collection performance and water retention performance, and significantly improve the workability of concrete. Xie Dali^[10] et al. developed a new type of concrete anti-segregation agent by compounding polyvinyl alcohol, anhydrous sodium

sulfate, maltodextrin and defoamer. This agent can effectively solve the problems of segregation, bleeding, poor workability and reduced strength of concrete.

This paper develops a new anti-segregation agent by combining polyacrylate sodium with cement or fly ash. This agent can effectively alleviate the segregation and bleeding problems of concrete, without affecting the workability, setting time and compressive strength of the concrete.

2. Test

2.1. Test raw materials

The raw materials used in the experiment were all of industrial grade, and the specific information is shown in Table 1.

Cement: Guangdong Jinyang Building Materials Co., Ltd., P•42.5 grade cement; Fly ash: Foshan Guixiang Building Materials Co., Ltd., Grade II; Mineral powder: Rizhao Huabao Mining Co., Ltd., S95. Fine aggregate: Mechanized sand, specific gravity of 3.0, stone powder content of 5.0%, bulk density of 1530 kg/m³, washed sand: specific gravity of 3.1, clay content of 0.2%, bulk density of 1590 kg/m³; Crushed stone: 10-25mm, apparent density of 2680 kg/m³, bulk density of 1510 kg/m³. Water: Tap water. Polycarboxylate superplasticizer: Point-421HS, Kozhijie New Materials Group (Guangdong) Co., Ltd.

2.2. Preparation Method of Anti-Segregation Agent

Through concrete tests, the raw materials prone to segregation were screened. The most effective anti-

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segregation agent raw materials were selected and mixed with cement or fly ash in a certain proportion to prepare

the concrete anti-segregation agent.

Table 1. Test raw materials

Name of raw material	Specification and model	Manufacturer
Polyvinyl alcohol 2488(A1)	120 mesh	Zhengzhou Yufan Biotechnology Co., Ltd.
Polyvinyl alcohol 2088(A2)	160 mesh	Zhengzhou Yufan Biotechnology Co., Ltd.
Polyvinyl alcohol 1788(A3)	120 mesh	Zhengzhou Yufan Biotechnology Co., Ltd.
Polyvinyl alcohol 2488(A4)	160 mesh	Zhengzhou Yufan Biotechnology Co., Ltd.
Sodium polyacrylate (B1)	10,000 molecular weight	Shandong Qingmu Biotechnology Co., Ltd.
Sodium polyacrylate (B2)	100,000 molecular weight	Shandong Qingmu Biotechnology Co., Ltd.
Sodium polyacrylate (B3)	1,000,000 molecular weight	Henan Jiachuang Chemical Technology Co., Ltd.
Sodium polyacrylate (B4)	3,000,000 molecular weight	Wujiang Jinjin Light Industry Co., Ltd.
Sodium polyacrylate (B5)	5,000,000 molecular weight	Wujiang Jinjin Light Industry Co., Ltd.
Jinyu anti-segregation agent(L1)	0.315 mm screening the residue ≤12%	Shandong Jinyu Building Materials Technology Co., Ltd.
Shuangke anti-segregation agent(L2)	0.315 mm screening the residue ≤12%	Guangdong Shuangke Building Materials Co., Ltd.
KZJ-RIA(L3)	10% solid content	Kozhijie New Materials Group Co., Ltd.
Napthalene powder(L4)	Brownish-brown powder	Shandong Wenhe New Materials Co., Ltd.

2.3. Anti-segregation Agent Concrete Test

Using a C30 concrete mix ratio, the anti-segregation materials were tested. Nine types of anti-segregation raw materials (A1, A2, A3, A4, B1, B2, B3, B4, B5) were respectively tested for their effects on the workability, strength and setting time of the concrete. They were compared with four commercial anti-segregation samples (L1, L2, L3 and L4). The C30 concrete mix ratio used for the tests was m(Cement): m(Fly ash): m(Grade): m(Washed sand): m(Mechanized sand): m(Crushed stone): m(Water) = 170: 90: 70: 600: 200: 1040: 160.

2.4. Concrete Performance Testing Methods

The performance tests of concrete mixtures are strictly carried out in accordance with the standard GB/T 50080-2016 "Test Methods for Properties of Normal Concrete Mixtures". During the tests, the environmental conditions are maintained at a temperature of 20±2°C and a relative humidity of ≥50%. The standard forced concrete mixer SJD60 type is used for mixing. The tests for slump and setting time are all conducted under the specified temperature and humidity conditions. The mechanical property tests of concrete are conducted in accordance with the standard GB/T 50081-2019 "Test Methods for Physical and Mechanical Properties of Concrete". After the specimens are formed, they are cured in a standard curing room at a temperature of 20±2°C and a relative humidity of ≥95% until the specified age. The compressive strength test was conducted using a TYE-2000B digital pressure testing machine with a range of 3000kN and a measurement accuracy of ±1%.

3. Experimental results and discussion

3.1. Selection of Anti-Segregation Raw Materials

3.1.1. Concrete workability test

The anti-segregation raw material screening concrete test was conducted using a single horizontal shaft mixer. The concrete was mixed in one batch of 20 L, with 2% of polycarboxylate superplasticizer added. Taking this group of concrete samples as the reference sample, the slump was controlled at (220 ± 10) mm and the spread was (580 ± 20) mm. Then, the amount of the superplasticizer was increased to 2.5%, and the concrete was mixed until it reached the segregation state, with the spread ≥ 630 mm. This group of concrete samples was used as the blank sample. On the basis of the blank sample, different anti-segregation raw materials were added (the addition amount was based on the total mass of the cementitious materials and was the same for all). The performance of the concrete with different anti-segregation raw materials is shown in Table 2.

As shown in Table 2, compared with the blank sample, when the anti-segregation raw materials B1 and B2 were added, the workability of the concrete was comparable to the Reference sample, and the initial slump/extension of the concrete was not much different from the Reference sample. After 2 hours of aging, the slump/extension of the concrete with B1 was similar to that of the Reference sample concrete. Compared with the amount of anti-segregation raw materials added, the amount of B2 was 2.1% higher than that of B1. The workability of the concrete mixed with A1, A2, A3, A4, B3, B4 and B5 was average or poor. When these anti-

segregation raw materials were added, there was no absorption of the slurry by the concrete particles, which was similar to the blank sample without anti-segregation materials. Therefore, these materials cannot be used as anti-segregation raw materials for concrete. The above test results indicate that for disordered concrete, when B1 was added, the state of the concrete was the same as the

Reference sample. Further comparison of setting time and compressive strength of the concrete is needed; when B1 was added, the state of the concrete was the same as the Reference sample sample, but its addition amount was higher, so it is not studied; while the other raw materials cannot be used as anti-segregation raw materials for concrete.

Table 2. Anti-segregation agent raw material selection and concrete work performance test results

Test specimen number	Anti-segregation raw material	Water-reducing agent dosage/%	Anti-segregation raw material dosage/%	TL0h /mm	TL2h /mm	TK0h /mm	TK2h /mm	Concrete condition
D0	-(Reference sample)	2.0	0	230	210	580	440	good workability
D1	-(Blank sample)	2.5	0	220	220	640	550	Poor workability
D2	A1	2.5	1.1	210	215	650	540	Poor workability
D3	A2	2.5	1.2	210	220	640	545	Poor workability
D4	A3	2.5	1.6	215	210	630	540	Poor workability
D5	A4	2.5	1.5	220	210	620	550	Generally workability
D6	B1	2.5	0.31	230	220	570	485	good workability
D7	B2	2.5	0.51	215	215	600	500	good workability
D8	B3	2.5	1.1	220	210	635	540	Poor workability
D9	B4	2.5	0.97	220	215	630	550	Poor workability
D10	B5	2.5	1.1	220	215	635	550	Poor workability

3.1.2. Concrete compressive strength test

The results of the compressive strength of the concrete using the selected anti-segregation raw materials are shown in Table 3.

As shown in Table 3, the 3d, 7d and 28d compressive strengths of the separated concrete (blank sample) were lower than those of the reference sample. The reason was that the concrete was separated, the cohesion of the slurry decreased, and the aggregates and the slurry separated, thereby affecting the strength of the concrete. The concrete with B1 admixture differed slightly from the reference sample, indicating that B1 can be used as a raw material for preventing concrete from separating.

Table 3. Anti-segregation raw material screening and concrete compressive strength results

Test specimen number	Anti-segregation raw material	Compressive strength/MPa		
		3d	7d	28d
D0	-(Reference sample)	16.9	22.8	37.6
D1	-(Blank sample)	12.3	18.6	34.7
D6	B1	16.5	21.9	38.2

3.2. Preparation of Concrete Anti-segregation Agent and Performance Comparison Test

3.2.1. The influence of different anti-segregation agents on the workability of concrete

The anti-segregation raw materials B1 selected from the above experiments were respectively compounded with cement (C) and fly ash (K) in certain proportions to form different concrete anti-segregation agents. They were denoted as J1, J2, J3, J4, J5, J6, J7 and J8. The different concrete anti-segregation agents developed were compared with the four commercial anti-segregation agents (L1, L2, L3 and L4) in concrete tests. Different anti-segregation agents were added to the dispersed concrete, and the test results are shown in Table 4.

From Table 4, it can be seen that: (1) After adding anti-segregation agents J2, J3, J4, J6, J7, J8, L1 and L3 to the blank sample, the initial state and expansion degree of the concrete are basically similar to the reference sample, but the initial expansion degree and concrete state of the concrete samples with added anti-segregation agents J1, J5, L2 and L4 are quite different from the reference sample, and the concrete paste does not contract, while the paste and coarse aggregates separate and disperse, resulting in poor initial and workability of the concrete, and affecting the workability

of the concrete. (2) The expansion degree of the concrete after 2 hours of aging is larger than that of the reference sample. The reason is that the retarder and water retention components in the super-dosed admixture are higher than those of the Reference sample, so the 2-hour fluidity of the concrete is better than that of the reference sample. (3) With the increase of B1 dosage, the dosage of anti-segregation agents J2, J3, J4, J6, J7 and J8

decreases when added to the disperse concrete, and the shrinkage of the disperse concrete becomes more obvious. For the separated concrete, the anti-dispersion effects of adding anti-dispersion agents J2, J3, J4, J6, J7 and J8 are comparable to those of the commercially available similar products L1 and L3, and are significantly better than those of L2 and L4.

Table 4. The influence of different anti-segregation agents on the workability of concrete

Test specimen number	anti-segregation agent	Recom -binant ratio	Water-reducing agent dosage/%	Anti-segregation agent dosage/%	TL0h /mm	TL2h /mm	TK0h /mm	TK2h /mm	Concrete condition
D11	-(Reference sample)	-	2.0	0	230	210	580	440	good workability
D12	-(Blank sample)	-	2.5	0	220	220	640	550	Poor workability
D13	J1	B1:C=2:8	2.5	0.34	230	220	620	540	Generally good workability
D14	J2	B1:C=4:6	2.5	0.30	225	220	500	490	good workability
D15	J3	B1:C=6:4	2.5	0.29	230	220	585	495	good workability
D16	J4	B1:C=8:2	2.5	0.27	220	220	590	500	good workability
D17	J5	B1:K=2:8	2.5	0.34	220	210	620	535	Generally good workability
D18	J6	B1:K=4:6	2.5	0.30	220	215	590	490	good workability
D19	J7	B1:K=6:4	2.5	0.29	230	220	580	500	good workability
D20	J8	B1:K=8:2	2.5	0.27	220	205	580	480	good workability
D21	L1	-	2.5	0.33	220	220	590	490	good workability
D22	L2	-	2.5	0.35	220	210	620	535	Generally good workability
D23	L3	-	2.5	0.33	220	220	585	500	good workability
D24	L4	-	2.5	0.33	220	210	620	470	Generally good workability

3.2.2. The influence of different anti-segregation agents on the setting time of concrete

The influence of different concrete anti-segregation agents on the setting time of concrete is shown in Table 5.

As shown in Table 5, when the anti-segregation agents were added to the stratified concrete, both the initial setting time and the final setting time of the concrete were prolonged compared to the reference sample. The initial and final setting times of the concrete with the anti-segregation agents J1, J2, J3, and J4, which were made with the compound cement, shortened as the proportion of the anti-segregation raw materials increased, and were all shorter than the blank sample. The initial and final setting times of the concrete with J1 were prolonged by 1.2 hours and 1.3 hours respectively compared to the reference sample, while the other concrete's initial and final setting times were prolonged by less than 1 hour compared to the reference sample,

basically not affecting the concrete construction. The concrete with the anti-segregation agent J5, J6, J7, and J8, which was made with the compound mineral powder, shortened the initial and final setting times as the proportion of the anti-segregation raw materials increased, and were all shorter than the blank sample. However, the final setting time of these concrete samples was more than 1 hour longer than the reference sample. The concrete with L2 had the most significant increase in setting time, with the initial and final setting times prolonged by 2 hours and 2.5 hours respectively. The reason was that the admixture was over-added, resulting in more retardant and stabilizing components in the concrete compared to the reference sample. For the separated concrete, anti-segregation agents J2, J3 and J4 can be used to adjust the concrete to a workable state. These agents have a relatively small impact on the setting time of the concrete and do not significantly affect the construction of the concrete.

Table 5. The influence of different anti-segregation agents on the setting time of concrete

anti-segregation agent	Reference sample	Blank sample	J1	J2	J3	J4	J5	J6	J7	J8	L1	L2	L3	L4
initial setting time/h	6.5	8.5	7.7	7.0	7.5	7.2	7.9	7.9	7.4	7.2	7.4	8.5	7.5	6.9
Final setting time/h	8.5	10.8	9.8	9.3	9.3	9.2	10.2	9.8	9.8	9.6	9.8	11.0	9.5	9.8

3.2.3. The influence of different anti-segregation agents on the compressive strength of concrete

The results of compressive strength of concrete with different anti-segregation agents are shown in Table 6.

Table 6. The influence of different anti-segregation agents on the setting time of concrete

Test specimen number	Compressive strength/MPa		
	3d	7d	28d
D11	14.9	20.8	33.6
D12	12.3	18.6	31.7
D13	15.9	24.3	35.4
D14	15.8	23.4	36.9
D15	14.7	20.7	35.1
D16	14.6	18.9	35.6
D17	13.4	19.7	36.1
D18	14.2	20.8	35.0
D19	13.2	20.0	35.6
D21	13.2	20.3	36.8
D22	14.4	21.5	38.0
D23	14.2	21.2	38.8
D24	14.1	20.8	34.8
D21	13.7	20.3	37.5

As shown in Table 6, after adding anti-segregation agents to the stratified concrete, the 3d and 7d compressive strengths of the concrete were not significantly different from the reference sample, while the 28d compressive strength was slightly higher than that of the control sample. Among them, the 28d compressive strengths of J2, J3, and J4 were 1.5 to 3.3 MPa higher than that of the reference sample. Therefore, it can be concluded that the anti-segregation agent restored the homogeneity of the components in the concrete system, ensuring the effective realization of the mix ratio. The results of the concrete performance tests and the setting time tests indicate that the addition of anti-segregation agents J2, J2 and J3 can guarantee the workability and compressive strength of the concrete.

4. Conclusion

(1) By conducting tests on the work performance, setting time and compressive strength of concrete using different anti-segregation raw materials, suitable anti-segregation raw materials were selected. These materials were then combined with cement and fly ash in specific proportions to prepare a series of anti-segregation agents for concrete.

(2) Based on the test results, the ratios of anti-segregation raw materials to cement for the combinations of 4:6, 6:4, and 8:2 (i.e., J2, J3, and J4) can be used to obtain effective anti-segregation agents.

(3) Based on the test results, when disintegrated concrete is mixed with J2, J3 and J4, it can be adjusted to have better workability, with little impact on the setting time, without affecting the concrete construction, and can slightly increase the compressive strength. This can avoid the waste of resources and environmental pollution caused by concrete segregation, and is in line with the national energy conservation and emission reduction policy.

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