

Test of Desert Sand PVA Fiber Engineered Cementitious Composites

Quanwei LI, Jialing CHE*, Caixia MA, Guansheng HAN, Lijun LIU, Ning AN

School of Civil Engineering and Hydraulic Engineering

Ningxia University

Yinchuan, China

e-mail: *che_jialing@126.com

Abstract—In order to replace the natural sand with Fiber Engineered Cementitious Composites (PVA-ECC) in desert sand, the PVA-ECC of desert sand was put forward. Four factors, namely, water-cement ratio, fly ash content, PVA fiber content and desert sand substitution, The four-level orthogonal test was used to analyze the compressive properties, and flexural properties of desert sand PVA-ECC of 7d aged. The effects of each dosage on the PVA-ECC strength and ductility of desert sand were analyzed. Impact. The results show that the substitution rate of desert sand has little effect on the compressive strength, splitting tensile strength and flexural strength of desert sand PVA-ECC, and the water-cement ratio and fly ash content are the most important factor of compressive strength.

Keywords—component; desert sand, PVA, ECC, orthogonal test

I. INTRODUCTION

In recent years, as China's environmental problems become more and more serious, all walks of life are advocating sustainable development, the direction of the development of fiber-reinforced cement-based composite materials (ECC) must be environmentally friendly energy saving, high mechanical performance. Various scholars have studied the fly ash content fiber type and so on [1-6]. The preparation of ECC is in need of large amounts of sieved river sand, and it is not conducive to the protection of the ecological environment [7].

In this paper, desert sand is used as the natural river sand in PVA-ECC. The mechanical properties of desert sand PVA-ECC is analyzed, and the optimum ratio of PVA-ECC is obtained.

II. TEST OVERVIEW

A. Materials

P · O 42.5R ordinary portland cement produced by Ningxia Saima, the performance indicators as shown in Table I. Grade I fly ash produced by Ningxia Lingwu Thermal Power Plant, water content is 0.4%, the water demand ratio is 90%, fineness is 8.4%, loss on ignition is 3%.

High-strength and high-modulus PVA fiber produced by Japan Kuraray, the diameter is 31mm. The apparent density of river sand is 2624 kg / m³, the mud content is 0.14%, and the fineness modulus is 0.194, and the maximum diameter is Dmax = 1.18mm. The desert sand is taken from the southern part of the Mu Us Desert, The average diameter of 0.238mm. Test water is tap water. Addition agent is polycarboxylate high performance water reducing agent, with a water reduction rate of 30%.

B. Mix Design

Four-factor and four-level orthogonal test was designed by four factors: water-binder ratio, fly ash content, PVA fiber content and desert sand substitution amount, as shown in Table II. Among them, the water-binder ratio were 0.29,0.32,0.35,0.38; fly ash instead The amount of cement is 30%, 40%, 50% and 60% respectively, and the sand-binder ratio is 0.36. The sand content of desert sand is 0, 10%, 20% and 30% respectively. PVA fiber content is 1.00%, 1.50%, 1.75%, 2%.

C. Preparation of test pieces

In the preparation of the specimens, PVA fiber must be evenly dispersed in the material, so as to play the toughness of PVA fiber. Therefore, in the mixing process, the use of fiber after dosing method is adopted. All the material mixing process is completed in the mortar mixer, first cement, fly ash, desert sand, and fine sand poured into the mortar mixer for 2 minutes, and then water and PVA fiber. PVA fibers add to the mixer after the water, so PVA fiber can be fully mixed with the mortar, the last stirring 3 minutes. After the completion of mixing pouring the specimen, and vibrating compaction.

Each group of test production of 6 70.7mm × 70.7mm × 70.7mm cubes test block; 6 40mm × 40mm × 160mm cubes. The test pieces were removed after 24 hours after the completion of the production in the laboratory. The mechanical properties of the test pieces were measured after the test pieces were placed in a standard curing room for a temperature of (20 ± 3) °C and a humidity of 95% or more. Test piece of compressive strength and flexural strength with reference to GB / T 50081-2002 "ordinary concrete mechanical properties test method standards" for testing.

TABLE I. PERFORMANCE INDICATORS OF ORDINARY PORTLAND CEMENT

Performance	Fineness /%	Consistency water consumption /%	Initial setting time /min	Final setting time /min	Flexural strength /MPa	Compressive strength /MPa
Indicators	4.4	26	130	180	9.0	55.6

TABLE II. THE FOUR FACTORS AND FOUR LEVELS OF ORTHOGONAL EXPERIMENTS

	Water-cement ratio	Replacement of fly ash/%	Desert sand replacement/%	PVA fiber content/%
1	0.29	30	0	1.00
2	0.32	40	10	1.50
3	0.35	50	20	1.75
4	0.38	60	30	2.00

TABLE III. SCHEME AND RESULTS OF ORTHOGONAL TEST

Serial number	Factors in A Water-binder ratio	Factor B Replaceme nt amount of fly ash	Factor C desert sand Replacement rate /%	Factor D PVA fiber dosage/%	Compressive strength/MPa	Flexural strength/MPa
					7d	7d
1	0.29	0.3	0	1.00%	46.78	9.67
2	0.29	0.4	10%	1.50%	29.05	10.93
3	0.29	0.5	20%	1.75%	30.76	11.44
4	0.29	0.6	30%	2%	25.02	8.75
5	0.32	0.4	20%	1.00%	30.26	8.30
6	0.32	0.3	30%	1.50%	42.58	11.73
7	0.32	0.6	0	1.75%	20.83	9.53
8	0.32	0.5	10%	2%	29.03	10.43
9	0.35	0.5	30%	1.00%	24.47	8.75
10	0.35	0.6	20%	1.50%	18.88	7.30
11	0.35	0.3	10%	1.75%	33.78	9.05
12	0.35	0.4	0	2%	29.94	8.15
13	0.38	0.6	10%	1.00%	11.93	6.05
14	0.38	0.5	0	1.50%	15.58	7.08
15	0.38	0.4	30%	1.75%	21.70	9.43
16	0.38	0.3	20%	2%	24.59	10.88

TABLE IV. RANGE ANALYSIS OF ORTHOGONAL TEST

Performance nature	Level and poor	Factors			
		Water-binder ratio(A)	Replacment amount of fly ash(B)	The desert sand Replacement rate(C)	PVA fiber dosage(D)
7d Compressive strength	K_1	131.61	147.73	113.13	113.44
	K_2	122.70	110.95	103.79	106.09
	K_3	107.07	99.84	104.49	107.07
	K_4	73.80	76.66	113.77	108.58
	R	14.45	17.59	2.50	1.88
7d Flexural strength	K_1	40.79	41.33	34.43	32.77
	K_2	39.99	36.81	36.46	37.04
	K_3	33.25	37.70	37.92	39.45
	K_4	33.44	31.63	38.66	38.21
	R	1.89	2.43	1.06	1.67

III. TEST RESULTS AND ANALYSIS

A. Strength and Deviation Materials

The compressive and flexural strength tests of 16 groups of desert sand PVA-ECC was carried out using the four-factor and four-level orthogonal test. The results are shown in Table III, and the difference is shown in Table IV. As can be seen from Table III and Table IV:

- Fly ash content is the most important factor affecting the PVA-ECC intensity of desert sand.

With the increase of fly ash content, the PVA-ECC intensity of desert sand will decrease.

- The effect of water-cement ratio on the compressive strength of desert sand PVA-ECC is relatively large. With the increase of water-cement ratio, the intensity of desert sand PVA-ECC is reduced, so it is necessary to prepare PVA-ECC with high strength. Toughness and consistency should be used under the premise of a lower water-cement ratio.

TABLE V. DATA ANALYSIS OF VARIANCE

Indicators for performance appraisal	Source of variation	Sum of squares	Degree of freedom	Mean square	F	Critical value	Significance
7d Compressive strength	A	$S_A=485.375$	3	161.792	1235.053	$F_{0.01}(3,3)=29.5$	**
	B	$S_B=658.357$	3	219.452	1675.206	$F_{0.05}(3,3)=9.3$	***
	C	$S_C=37.328$	3	12.443	94.985	$F_{0.1}(3,3)=5.4$	*
	D	$S_D=7.979$	3	2.660	20.305	—	—
	Deviation	$S_E=1.180$	9	0.131	—	—	—
	Sum	$S_T=1190.219$	15	—	—	—	—
7d Flexural strength	A	$S_A=12.493$	3	4.164	64.062	$F_{0.01}(3,3)=29.5$	***
	B	$S_B=12.010$	3	4.000	61.538	$F_{0.05}(3,3)=9.3$	***
	C	$S_C=2.597$	3	0.866	13.323	$F_{0.1}(3,3)=5.4$	*
	D	$S_D=6.323$	3	2.108	32.431	—	**
	Deviation	$S_E=0.587$	9	0.065	—	—	—
	Sum	$S_T=34.010$	15	—	—	—	—

- The effect of desert sand on the compressive strength and flexural strength of desert sand PVA-ECC is small, and the higher desert sand content should be used in meeting the PVA-ECC strength requirement of desert sand. Figure 3 shows the effect of desert sand content on PVA-ECC intensity. The effect of desert sand content on the compressive strength and flexural strength of PVA-ECC is small.
- The effect of PVA fiber on the flexural strength of the PVA fiber is higher than that of the compressive strength. With the increase of the PVA fiber volume, the flexural strength of PVA-ECC will increase, and the PVA fiber will improve the toughness.
- If the compressive strength is the index, the fly ash content is the main factor, and the influence degree of each factor is: $B > A > D > C$, the influence of desert sand on PVA-ECC intensity is small. The ratio of PVA fiber is the main factor. The influence degree of each factor is: $D > B > A > C$, and the proposed ratio is A1B2C4D3.

B. Analysis Selecting

The variance analysis was performed for 16 sets of desert sand PVA-ECC data. The results are shown in Table V. The results show that the water-binder ratio and the fly ash content have a significant effect on the 7-day compressive strength of the desert sand PVA-ECC. The water-cement ratio and the fly ash content have a particularly significant impact on the 7 d Strength of desert sand PVA-ECC.

C. Determination of optimal ratio of PVA - ECC for desert sand

The best combination of compressive strength is A1B1C4D2, and the best combination of flexural strength is A1B2C4D3. The variance analysis of the data shows that the factor A has a significant effect on the 7d flexural strength of the desert sand PVA-ECC and has a certain effect on the compressive strength of 7d. The B factor has a significant effect on the 7d flexural strength of the desert sand PVA-ECC. The effect of factor C on the strength of desert sand PVA-ECC is less. The D factor has a certain influence on the 7th flexural strength of desert sand PVA-ECC, which has a certain influence on the 7d compressive

strength. In this paper, the optimum equilibrium ratio is A1B2C4D3, that is, A1: water-cement ratio of 0.29; B2: fly ash content is 0.4; C4: desert sand content accounts for 30% of natural river sand quality; D3 : PVA fiber volume content of 1.75%.

IV. CONCLUSION

PVA-ECC performance is a new type of high-performance building materials, but with the development of China's economy, PVA-ECC material resources in the fine sand can no longer meet the needs of construction projects. In this paper, desert sand is used to replace some fine river sand, the four-factor and four-level orthogonal test is designed with four factors: water-cement ratio, fly ash content, PVA fiber content and desert sand substitution. Through 7d compression and flexural performance of the desert sand PVA-ECC analysis, the conclusions are as follows:

- The water-binder ratio and fly ash is the most important and the most significant factor affecting the compressive strength of desert sand PVA-ECC. The compressive strength of the test piece is improved with the decrease of water-cement ratio. The bulk compressive strength decreases with the increase of the fly ash content. And fly ash can effectively improve the workability of the matrix.
- The replacement rate of desert sand has little effect on the compressive strength and flexural strength of desert sand PVA-ECC.
- PVA fibers have great influence on the PVA-ECC flexural strength of desert sand.
- The optimum mixing ratio was determined by the comprehensive equilibrium method: water-cement ratio: 0.29; fly ash content: 0.4; desert sand content accounted for 30% of natural river sand; sand ratio: 0.36; PVA fiber volume Ingredients: 1.75%.

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