Experimental Study on Preparation of High-strength Mortar with Abandoned Super Fine Sand

Bo Xu[1, a], Tianhui Chen[1, b], Yiji Zhang[1, c], Linfeng Jiang[1, d], Zhitian Liu[1, e], Xiaoyu Li[2, f*]

[1]College of Dayu, Hohai University, Nanjing 210098, China

[2]College of Harbour, Coastal and Offshore Engineering, Hohai University, Nanjing 210098, China

[a]okynrroxwx@qq.com,[b]931818577@qq.com,[c]2595773823@qq.com,[d]1151252203@qq.com,

[e]1435322899@ qq.com,[f] xiaoyuli@hhu.edu.cn

Corresponding author:Xiaoyu Li

Keywords: Mineral admixture, High-strength mortar, Waterway Engineering, Super fine sand

Abstract. The preparation of high-strength mortar with super fine sand from waterway engineering and the improvement of its mechanical properties by mineral admixtures were studied in this paper. The effect of fly ash, silica fume and both of them on compressive strength and flexural strength of super fine sand mortar were tested. The result shows that fly ash can reduce the early compressive strength and flexural strength of mortar, but improve the rate of gain in strength. Silica fume can improve the early strength of mortar, but reduce the rate of gain in strength. Fly ash and silica fume admixture can play a complementary role between admixtures. The maximum compressive strength of 28d sample reached 45.6MPa, with the help of fly ash and silica fume together.

Introduction:

Super fine sand is widely distributed in China, such as the Yangtze River, the Yellow River, the Pearl River, and the northwest of China [1]. The process of channel improvement will produce lots of abandoned super fine sands, which can be seen in Fig.1. In-field use of the abandoned sands to produce high-strength mortar can reduce the transport of sand, adverse effects on the environment, and further reduce the project cost to reach sustainable utilization of waste resources.

Fig.1 Abandoned super fine sand produced by channel improvement

At present, there are few researches on the preparation of mortar with special fine sand, B.C. Sun [2] preliminary study the preparation process and molding process of coarse aggregate concrete without coarse aggregate, and forecasted its wide application prospect. In addition to the use of high quality cement and aggregate, adding appropriate amount of admixture and high efficiency

plasticizer can effectively improve the mechanical properties and working performance of concrete [3], and ensure the rationality of the economy.

At home and abroad, the most widely used mineral admixtures are slag, fly ash and silica fume. There were few researches on the single or double mineral admixtures in the special fine sand mortar.

In this paper, the special fine sand from waterway engineering is used as raw material to prepare high-strength mortar by vibration molding, with adding fly ash, silica fume and other admixtures. The effect of fly ash, silica fume and both of them on compressive strength and flexural strength of super fine sand mortar were studied, in order to provide the basis for the use of waste superfine sand to prepare facing bricks and other hydraulic materials used in port and waterway engineering.

Mixture Ratio Design

The different samples groups use the same water to binder, sand, plaster and plasticizer ratio, which can be seen in the Table 1. Table 1 also shows the mix ratio of super fine sand mortar. In consideration of the use in actual engineering, the experiment only consider fly ash, silica fume or both of them of super fine sand mortar, which were named Group MF, MG and MFG.

Table 1 Mix ratio of super fine sand mortar

Number	W/B	Mineral admixtures content /%		Cement /[kg/m^3]	Super fine sand /[kg/m^3]	Plaster /[kg/m^3]	Water /[kg/m^3]	Plasticizer /%
		Fly ash	Silica fume					
NM	0.43	—	—	562.5	1406.3	40.2	241	0.6
MF1	0.43	2	—	522.3	1406.3	40.2	241	0.6
MF2	0.43	6	—	442.0	1406.3	40.2	241	0.6
MF3	0.43	8	—	401.8	1406.3	40.2	241	0.6
MF4	0.43	10	—	361.6	1406.3	40.2	241	0.6
MG1	0.43	—	2	522.3	1406.3	40.2	241	0.6
MG2	0.43	—	4	482.1	1406.3	40.2	241	0.6
MG3	0.43	—	6	442.0	1406.3	40.2	241	0.6
MFG1	0.43	6	2	401.8	1406.3	40.2	241	0.6
MFG2	0.43	8	2	361.6	1406.3	40.2	241	0.6

Experimentation

Raw Materials. The super fine sand comes from the waterway engineering, whose water content is 5% and pH is 7.8. Its chemical composition and particle gradation can be seen in Table 2 and Table 3. The particles are mainly distribute in 0.3-0.15mm. By computation, its fineness modulu is 0.82.

The cement is ordinary portland cement of P`O 42.5, whose composition can be seen in Table 2.

The fly ash is Level II, whose chemical composition can be seen in Table 2. Its density is 923kg/m^3, and its water requirement ratio is 104%.

The silica fume is produced in Nanjing, China whose composition can be seen in Table 2.

The plasticizer is kind of polycarboxylic acid superplasticizer (HLC), whose water-reducing rate is 20%~42%. Its content should be 0.3~1.0%.

Table 2 Chemical composition

Content (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	SO_3	Na_2O	K_2O
Sand	68.73	11.33	3.82	8.54	3.02	0.648	0.05	1.46	2.00
Cement	20.58	5.64	3.95	62.25	2.48	0.32	3.18	0.36	-
Fly ash	54.82	32.20	3.66	2.34	1.08	-	-	0.12	0.37
Silica fume	93.42	0.41	0.56	0.47	0.48	-	-	-	-

Table 3 Particle gradation of super fine sand

Granularity (mm)	1.18	0.6	0.3	0.15	0.075	<0.075
Content (%)	0.02	0.02	3.21	75.34	20.16	1.29

Experiment Method. The experiment mainly studied the effect of fly ash and silica fume on compressive strength and flexural strength of super fine sand mortar. The mortar samples were prepared by vibration molding. After the super fine sand being naturally dried, according to the mix ratio, weigh sand, cement, fly ash and silica fume into the JJ-5 cement mixer to dry mix. When the dry mixing evenly, add HLC water reducer after adding water and wet mixing 3mins.

Weigh the stir mixture and add into the moulds of 40×40×160mm. Put the moulds on the HZJ-A concrete vibrating table to vibrate and form. Then cover film on the moulds and stand for 24 hours. After that, the samples were put into the standard curing room. According to the discipline of GB/T 17671-1999, test the compressive strength and flexural strength on the EHDC300-03 compression-testing machine and DKZ-5000 bending test machine when curing 3d, 14d and 28d.

Results and Discussion

Experiment data. The experimental data is shown in the Table 4.

Table 4 Result of the compressive strength and flexural strength experiment

Number	W/B	Mineral admixtures content /%		Compressive strength/MPa			Flexural strength experiment/MPa		
		Fly ash	Silica fume	3d	14d	28d	3d	14d	28d
NM	0.43	—	—	30.8	39.7	45.6	7.2	9.6	11.0
MF1	0.43	2	—	29.8	38.8	44.5	7.1	9.5	10.9
MF2	0.43	6	—	28.2	38.4	44.2	6.9	9.0	10.7
MF3	0.43	8	—	27.6	37.9	43.8	6.8	8.9	10.6
MF4	0.43	10	—	26.9	37.2	43.2	6.6	8.8	10.5
MG1	0.43	—	2	31.7	40.1	45.9	7.4	9.7	11.2
MG2	0.43	—	4	32.4	41.2	46.2	7.6	9.8	11.4
MG3	0.43	—	6	32.7	41.8	46.6	7.7	9.9	11.6
MFG1	0.43	6	2	28.1	39.2	45.6	7.0	9.3	10.8
MFG2	0.43	8	2	27.8	37.7	44.1	7.1	9.1	10.8

Single admixture of fly ash. The samples were numbered MF1, MF2, MF3 and MF4. The content of fly ash was from 2% to 10%, replacing equal amounts of cement to study the effect of fly ash on mechanical properties of super fine sand mortar. The results are shown in the Fig.2 and Fig.3.

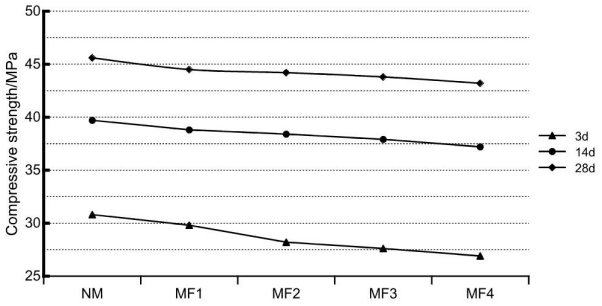

Fig.2 Effect of fly ash on the compressive strength of super fine sand mortar

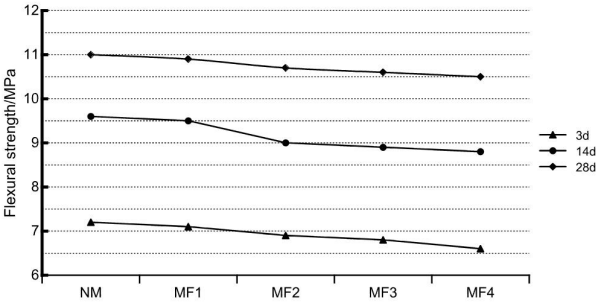

Fig.3 Effect of fly ash on the flexural strength of super fine sand mortar

As can be seen from Fig.3 and Fig.4, when the fly ash content is from 2% to 10%, the compressive and flexural strength were lower than those of NM group, and with the increase of the dosage, the strength decreases gradually, especially the samples of 3d.According to the strength growth rate, the maximum growth rate of compressive strength and flexural strength of MF group were 59.8% and 53%. The growth rate of flexural strength is slightly higher than that of the baseline group 50.7%. The results show that the admixture of fly ash can improve the growth rate of compressive strength of super fine sand mortar before 28d, but less effect on flexural strength.

As the help of fly ash, the proportion of cement in the paste decreased. Reduction of the quality of early hydration products in cement paste delay the hydration rate of the whole system. At the same time, the structure of fly ash is stable vitreous body with very compact surface, which is not easy to hydrate. Therefore, the mortar mixed with fly ash has lower strength than the baseline mortar in the earlier stage of curing. However, fly ash has pozzolanic effect. The SiO_2 and Al_2O_3 on the surface of vitreous body occur secondary hydration reaction with $Ca(OH)_2$ produced by the hydration, which further accelerate the hydration. Fly ash also has micro aggregate effect [4]. The fine particles are uniformly distributed in the cement paste filling and refining the pores in the paste. Therefore, the growth rate of mortar mixed with fly ash is higher than that of baseline mortar.

Single admixture of silica fume. The samples were numbered MG1, MG2, and MG3. The content of silica fume was 2%, 6% and 8%, replacing equal cement to study the effect of silica fume on mechanical properties of super fine sand mortar. The results are shown in the Fig.4 and Fig.5.

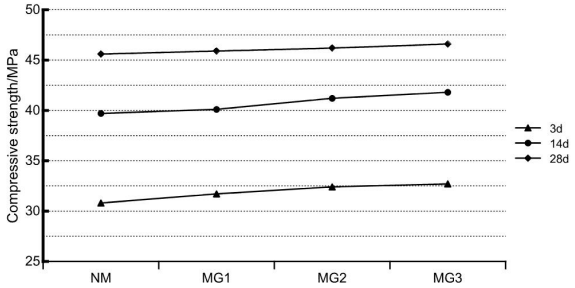

Fig.4 Effect of silica fume on the compressive strength of super fine sand mortar

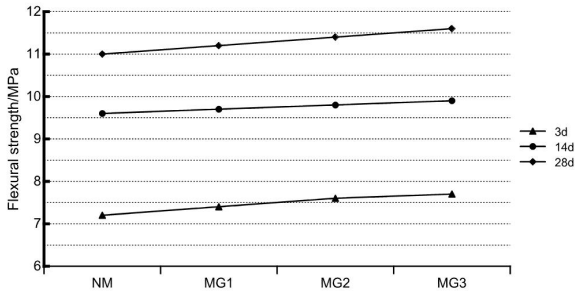

Fig.5 Effect of silica fume on the flexural strength of super fine sand mortar

As can be seen from Fig.4 and Fig.5, when the silica fume content is from 2% to 8%, the compressive strength and flexural strength of 3d, 14d and 28d were higher than those of NM baseline group, and with the increase of the dosage, the strength increased gradually. According to the strength growth rate, the growth rates of compressive and flexural strength are lower than that of the baseline group 50.7%. The results show that silica fume can improve the compressive strength and flexural strength of super fine sand mortar, but the strength growth rate slows down later.

Silica fume has chemical unstability, is a highly active pozzolanic materials. When silica fume and water contact, some particles dissolve rapidly. The gel forms film on the surface of silica fume, then the film occur the hydration reaction with Ca(OH)2 generating calcium silicate hydrate gel [5], which gives the mortar higher strength. At the same time, silica fume has micro aggregate effect too. The fine particles are uniformly distributed in the cement paste filling and refining the pores in the paste to improve mechanical properties [6]. With the extension of curing age, the cement hydration heat cannot meet the needs of the pozzolanic reaction. Strength growth rate gradually slows down.

Double admixtures of silica fume and fly ash. The samples were numbered MFG1 and MFG2. The content of silica fume was 2%, and the content of fly ash was 6% and 8%, replacing equal amounts of cement to study the effect of double admixture of fly ash and silica fume on mechanical properties of super fine sand mortar. The results are shown in the Fig.6 and Fig.7.

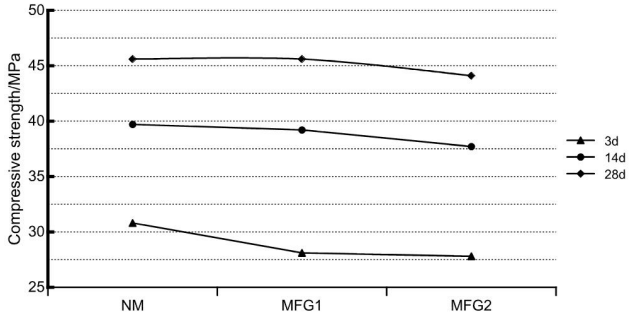

Fig.6 Effect of double admixtures on the compressive strength of super fine sand mortar

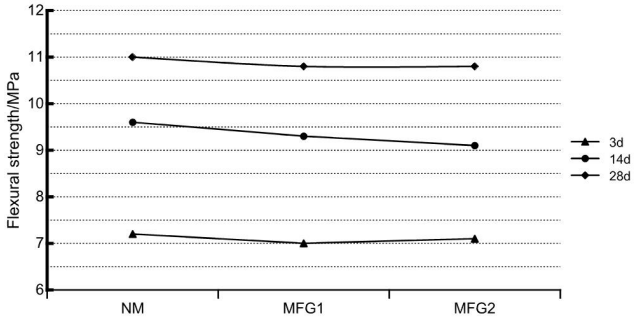

Fig.7 Effect of double admixtures on the flexural strength of super fine sand mortar

As can be seen from Fig. 6 and Fig. 7, the compressive and flexural strength of super fine sand mortar mixed with fly ash and silica fume before the curing age of 14d were lower than those of

group NM. With the increase of fly ash and unchanged silica content, the compressive strength at different ages showed a downward trend, which was the same as that of single admixture.

Contrasting the test results of single and double admixture, it can be found that the strength of double admixture super fine sand mortar is higher than that of single admixture. It proves that admixtures of fly ash and silica fume can form a system of cement, silica fume and fly ash, which optimizes the gradation and reduces the porosity of the cement paste. In addition, the pozzolanic effect and micro aggregate effect of the admixture can further improve the mechanical properties.

The strength growth rate of mortar in MFG group was also higher than that of NM. Because fly ash improves the compressive strength growth rate making up the shortage of silica fume mortar.

Conclusion

In this paper, the special fine sand from waterway engineering is used as raw material to prepare high-strength mortar of C40~C50, with adding fly ash, silica fume and other admixtures, which can replace common concrete to prepare hydraulic materials such as the ballast block.

(1)Fly ash can reduce the early compressive and flexural strength of mortar, but improve the rate of gain in strength. Silica fume can improve the early compressive strength and flexural strength of mortar, but reduce the rate of gain in strength.

(2)Double admixtures of fly ash and silica fume reduces each age compressive strength and flexural strength of super fine sand mortar. When the silica content remained unchanged, with the increase of fly ash content, the compressive strength decreased gradually.

(3)Super fine sand mortar mixed with fly ash and silica fume has higher compressive strength and flexural strength than those of single admixture mortar. And the strength growth rate after curing age of 3d was higher than that of single admixture mortar with equal silica fume content.

(4)Fly ash and silica fume admixture can play a complementary role between admixtures. It is possible to further improve the mechanical properties of superfine sand mortar by taking advantage of the complementary effect between the admixtures.

Acknowledgements

This work was financially supported by the Jiangsu Natural Science Foundation (BK20151496).

References

[1] C.M. Ya. Study on the application of special fine sand fly ash concrete in lock engineering in Jialing river basin [D]. Southwest Jiao Tong University, 2009. (In Chinese)

[2] B.C. Sun. Super fine sand concrete without coarse aggregate and its engineering application [J]. *Water Resources & Hydropower of Northeast China*, 1991, (5): p.2-5. (In Chinese)

[3] S.L. Zhang. Effect of coarse aggregate on performance of concrete [J]. *Shanxi Architecture*, 2004, 30(13): p.106-107. (In Chinese)

[4] J.T. Han, X.D.Shen. Experimental study on early mechanical properties of natural lightweight aggregate concrete with external mixing fly ash [J]. *Bulletin of the Chinese Ceramic Society*, 2012, 31(4): p.847-851. (In Chinese)

[5] P.Yang, Z.B. Peng. Application of silica fume on concrete and its research [J]. *Concrete*, 2002, (1): p.11-13. (In Chinese)

[6] C.L. Chen, Q.M. Tu, Y.Z. Ling. The basic properties and engineering applications of silica fume concrete [J]. *New Building Materials*, 2008, 35(4): p.43-47. (In Chinese)