Optimization of concrete design mixing artificial pozzolan based on orthogonal test

JIANG Baoshi [1, a], ZHANG Yang [2,b*]

[1,2]College of Civil Engineering and Architecture, Hainan University, Haikou 570228, China

[a]lanbaoshi-hit@qq.com, [b] 506870816@qq.com

Keywords: SAC; Early strength; Pozzolan; Concrete

Abstract. In this paper, 42.5 sulfate aluminate cement mixing pozzolan was used to prepare fast early strength concrete to reduce the application costs by the equivalent of cement, Pozzolan content, sand ratio, water-cement ratio investigated by orthogonal experiment method to seek meet with the strength requirements C30 concrete. Then the relationship between the concrete aggregate / cement-slurry ratio, dosage of water reducer and the slump, the strength were studied under the optimal concrete design.

Introduction

The cost of Sulfate aluminate cement is higher than Portland cement. Adding ash and other admixtures to the concrete has important practical significance to reduce their application costs.Many domestic scholars based carried out the research of the sulfur aluminate cement concrete. Y. Huang et al [1] studied the effect of setting time, hydration process, hydration product types by adding concrete retarder and hardening accelerator to the fast hard sulfur cement. X.Q. Wang et al [2] studied the effect of the addition of the admixtures [m (slag): m (ash) = 2:1] to the Sulphoaluminate cement concrete's compressive strength and impermeability impact. Results showed admixtures led the early and late strength of concrete are significantly reduced permeability decreases, and the higher the content, compressive strength, impermeability to reduce the more obvious.X.H. Jiang et al [3] studied the chloride ion penetration of sulfur cement concrete with mixed material content (the mixed material is 1:1 slag and fly ash), studies show that with the increase of admixtures, anti-chlorine ion permeability decreases.Zhang Decheng et al [4] studied the sulfur cement concrete rheology and microstructure analysis, that the polycarboxylate superplasticizer, amino and naphthalene superplasticizer for cement, have a good slurry rheological properties.Zhao et al.

Based on the above document content, it shows that commonly used cement admixtures has volcanic ash, slag, fly ash, silica fumes, etc. They can be used alone or in combination added to the cement in order to improve properties of the respective concrete. Currently admixtures research on ordinary Portland cement has been more comprehensive and mature, basically figure out their chemistry and microstructure of hydration products.

But for Sulphoaluminate cement, admixtures of the current study was mainly to slag, fly ash and their mixes, the research how the volcanic ash, slag, fly ash and their admixtures affects their hydration properties is extremely rare. The reason is the territorial distribution of volcanic ash, volcanic areas may distribute lava or ash, and the high cost of its acquisition is detrimental to their large-scale application. The artificial pozzolan confected by ash fly ash, slag, basalt and others is an excellent choice, its chemical composition as shown in Table 1, and its chemical composition is similar to natural pozzolan.

Table 1 Artificial chemical composition of volcanic ash

ingredient name	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	SiO_2	SO_3	TiO_2
content（%）	14.95	9.1	10.74	1.51	4.05	0.145	4.43	52.21	0.0759	2.08

In this paper, 42.5 sulfate aluminate cement mixing pozzolan was used to prepare fast early strength concrete to reduce the application costs by the equivalent of cement, Pozzolan content, sand ratio, water-cement ratio investigated by orthogonal experiment method to seek meet with the strength requirements C30 concrete. Then the relationship between the concrete aggregate / slurry ratio, dosage of water reducer and the slump, the strength were studied under the optimal concrete design.

© 2015. The authors - Published by Atlantis Press

The orthogonal design

Compressive strength and water-cement ratio. The strength of concrete has an inverse relationship with water-cement ratio [5], water-cement ratio is the most direct factors that determine the strength of concrete. Modern concrete, especially high-strength concrete, mostly incorporates silica fume, ground slag, fly ash and other mineral admixtures and super plasticizer. So the relationship formula of water-cement ratio and strength is not the same for different concrete. Design strength of ordinary concrete is designed in accordance with its 28-day strength. The relationship between concrete strength and water-cement ratio refers to the relationships of 28 days. As for the early-strength concrete, the smaller water-cement ratio leads to the higher the strength. Taking into account the construction design of convenience, the main reference concrete design with "ordinary concrete design procedures" (JGJ 55-2011). Thus, the initial water-cement ratio of early strength concrete is about 0.4.

Exploratory experiments. In order to reduce blindness test, before the formal experiment, first in accordance with the above principles selected parameters, an exploratory experiments was conducted. using the assumed apparent density method and considering the right amount of water reducer for the water-reducing efficiency of artificial volcanic ash, the experiment Select one water 168kg/m3, water-cement ratio 0.4, 30% sand, concrete slump in the 10 ~ 30mm, and the superplasticizer dosage 0.8%., an apparent density of 2460kg / m3. Orthogonal test was designed basis on this design to find the optimal mixture ratio.

The content of the orthogonal test program. On the basis of a tentative trial design and its results, water-cement ratio, ash content and sand ratio and artificial pozzolan is the three factors and each factor takes four levels in the orthogonal design. The concrete strength was the assessment indicator to find the optimum mix early-strength concrete. Orthogonal design factors and levels were shown in Table 1, and the orthogonal table L16 (45) was selected. The test program and range analysis process and the 3d concrete compressive strength test results are shown in Table 2.

Table 2 factors and levels of the concrete orthogonal experimental design

Factors	A artificial pozzolan （%）	B water-cement ratio	C sand ratio （%）
Level 1	10	0.4	30
Level 2	20	0.45	35
Level 3	30	0.5	40
Level 4	40	0.55	45

The table 2 shows the range B > the range A >the range C. namely, B affects most, A affected second, C is minimal.

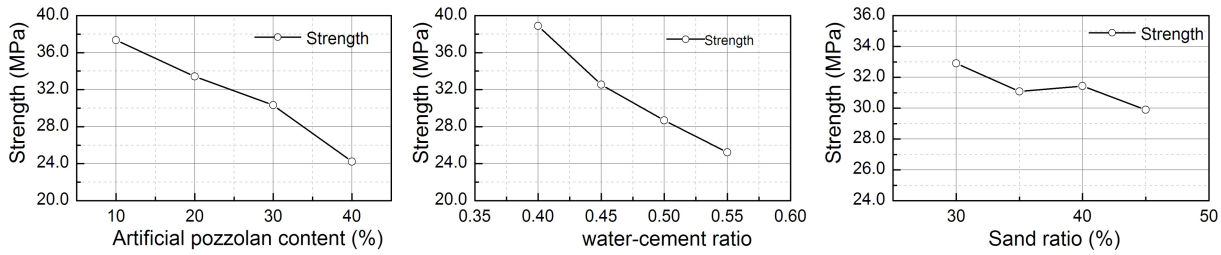
First the direct analysis of single indicator got the primary and secondary factors and gifted programs (results shown in Table 2), and draw the various factors and trends in the various indicators (see Fig. 1).

Factors A - artificial pozzolan. Artificial pozzolan content and 3d strength substantially have a linear relationship. Every 10% increase in dosage, strength decreased by 10%, when the content exceeds 20%, the strength decrease slightly increased. To the optimum dosage of pozzolan content evaluated from 3d strength should be 10%. But the strength with 20% dosage remains meet the requirements. Considering the economy, the best dosage of artificial pozzolan is 20%.

Factors B - water-cement ratio: there is a linear relationship water-cement ratio between strength. The larger water-cement ratio, the lower the strength. From this assessment indicator of 3d compressive strength the water-cement ratio of 0.4 was determined. From the strength point of view, the lower the water-cement ratio, the higher the concrete strength, so the water-cement ratio of 0.4 was finalized appropriately.

Table 3: Test program and results

Column	1	2	3	3d compressive strength (MPa)
factor	A	B	C	
Test1	1	1	1	47.818
Test 2	1	2	2	38.086
Test 3	1	3	3	32.984
Test 4	1	4	4	30.542
Test 5	2	1	2	39.556
Test 6	2	2	1	36.273
Test 7	2	3	4	29.410
Test 8	2	4	3	28.419
Test 9	3	1	3	38.407
Test 10	3	2	4	29.919
Test 11	3	3	1	29.324
Test 12	3	4	2	23.695
Test 13	4	1	4	29.719
Test 14	4	2	3	25.910
Test 15	4	3	2	23.006
Test 16	4	4	1	18.191
mean value1	37.36	38.87	32.90	
mean value 2	33.41	32.55	31.09	
mean value 3	30.34	28.68	31.43	
mean value 4	24.21	25.21	29.90	
range	13.15	13.66	3.00	



(a) (b) (c)

Fig.1 the relationship between artificial pozzolan, water-cement ratio, sand ratio and strength

Factors C- sand ratio: strength firstly decline after the rises with sand ratio increasing, but overall little impact. Its role is to ensure enough lubrication between coarse aggregate filled with cement mortar, greater friction between the coarse aggregate particles, mixing was less mobile and low slump; lastly, sand ratio of 0.35 was selected.

Derived from the above analysis, the best combination is A2B1C1, namely optimal water-cement ratio of 0.4, and most artificial pozzolan content of 20%, the best sand rate is 0.3.

The relationship between Aggregate/cement slurry ratio, the amount of water reducer and concrete slump, strength

Under the optimal concrete design, the ratio between aggregate and cement slurry is adjusted to explore the relationship between the quality ratio of aggregate/cement slurry and strength and slump, wherein the water-cement ratio was 0.4, sand was 0.35, artificial pozzolan content of 20%, water reducing agent content of 0.8%. The results were shown in Table 3. The results showed that water-cement ratio unchanged, with the increase in cement consumption, water consumption increases, the strength of concrete block is gradually decreasing, after calculation every 10% increase in water consumption the strength declined by about 7 % and the slump increased, more and more, and is a non-linear relationship. In the Table, the concrete with the slump in the case of less than 50mm has

good work performance. JJ4 group showed very watery, highly mobile, have some bleeding phenomenon.

Table 4 The relationship of mass ratio of aggregate/cement slurry and slump, 3 days Strength

Test No.	Mass ratio of Aggregate/cement slurry	Slump（mm）	3 day strength（MPa）
JJ1	3.178	5.000	44.384
JJ2	2.900	25.000	41.264
JJ3	2.600	50.000	39.007
JJ4	2.300	195.000	36.858

The article also discusses the impact of the amount of water reducer on slump and strength. Also in the case of the aforementioned optimum mixture ratio, the water-reducing agent is 0.8%, 1.2%, 1.4%, as shown in Table 4. The test results are shown in the table, the slump and the strength increased with the increased use of water reducer. So there is no need to increase by adding the content of the cement slurry to raise the concrete work performance, and it is enough to add the right amount of water-reducing agent to solve the problem. Superplasticizer dosage should not be excessive to avoid bleeding and reducing the strength.

Table 5 The relationship of Water reducer content and Slump, 3 day strength

Test No.	Water reducer (%)	Slump（mm）	3 day strength（MPa）
JS1	0.8	15.000	44.384
JS2	1.2	45.000	41.264
JS3	1.4	170.000	39.007

Conclusion

Through adding mineral admixtures and superplasticizer, it can greatly improve the performance of concrete; the content of each component has an important impact on the performance of the Sulfate aluminate cement. In this paper, the best mixture ratio is found for the fast hard early strength concrete by orthogonal experiment in order to reduce the cost of their application.

Acknowledgements

The authors wish to express their gratitude to the Scientific Research Starting Foundation of Hainan University (NO.kyqd1402) and the Hainan Natural Science Foundation (20155214) for the financial support. Thanks for the help provided by Professor Wang Junfeng in Materials Research Center of Hainan University.

Reference

[1] S.Y. Huang, C.S. Wu, R. Yang. The impacts of concrete admixtures on sulfur aluminate cement hydration process. China concrete and cement products, , 1(2011):7-12 (In Chinese).

[2] WangXi-quan, Zhang Yu-fei, Luan Jia-chun, Li Jun-chao. Influence on the compressive strength and the impermeability of concrete of sulphoaluminate cement with composite admixture. Shandong chemical industry, ,40(2011):57-60(In Chinese).

[3] X.H. Jiang,Z.X. Guo, Q.Z. Liu, K.F. Sun. Effect of mixed material content on chloride ion penetration of sulfur cement concrete. 21st century building materials, 2(2): 23-27(In Chinese).

[4] Zhang De-cheng, Wang Mingke, Ding Zhu, Bai Xue-mei, Zhang Ming. Rheology and micro-structure analysis of sulphoaluminate cement concrete. China Powder Industry,2010，4(13) (In Chinese).