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Research on mechanical performances of composite cementitious material system in new bridge expansion joint UHPC material

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Abstract—In the bridge expansion joint repair project, in order to ensure the efficiency of the project, the repair material needs to have better flow properties and higher early strength. The introduction of sulfoaluminate cement will significantly change the properties of UHPC. Compared with ordinary Portland cement, the composition of its cement clinker mineral belongs to another physical and chemical system, which has excellent properties such as early strength, high strength, impermeability and corrosion resistance. Therefore, different groups of UHPC were prepared by changing the content of sulfoaluminate cement, and the fluidity test of each group of slurry and the compressive strength and flexural strength test of 1d, 3d, 7d, 28d were carried out to study the sulfur. The influence of aluminate cement content on slurry fluidity and early mechanical properties in order to obtain the optimal mix ratio of UHPC materials for new bridge expansion joints.

1. Introduction

With the intensification of domestic expressway traffic and the increase in the number of years of operation, many serious diseases have appeared on bridges and pavements, and there is an urgent need for fast and effective maintenance programs. The traditional repair plan for fast hardening concrete has poor repair effects and a high repair rate due to complex pavement forces, limited curing time, insufficient concrete tensile strength, and poor durability. And because UHPC has the advantages of high strength, high toughness, good wear resistance, good impermeability and good durability, and the adjustment of the components can well meet the construction performance and operating time during the pouring construction process. It is required to quickly condense and harden and increase the strength after the construction is completed, and the traffic can be quickly restored. UHPC is considered to be a new type of cement-based material with ultra-high strength, ultra-high toughness and excellent durability^[1] in terms of ultra-high performance concrete. It is used in highway bridge structures, building structures, prefabricated decorative structures, and building repair and reinforcement projects. There are more and more applications in the field, and it has become a research hotspot of cement-based materials at home and abroad^[2, 3]. It is promising in the application of structural materials and has great development potential. Now in various engineering applications, many experts and their teams are tapping the potential and availability of UHPC^[4]. SHAFIEIFAR et



al.^[5] found that the compressive strength of UHPC is three to four times higher than that of ordinary strength concrete, and the modulus of elasticity is twice that of ordinary concrete; therefore, UHPC is considered by the engineering community to be a better repair material for engineering structures. In summary, starting from the material point of view, preparing repair materials with high performance and greater social and economic benefits according to the requirements of different repair projects undoubtedly has important theoretical value and engineering application value.

Under normal circumstances, different systems of cement should not be mixed, but in view of the different advantages and disadvantages of the two kinds of cement, many scholars have developed a strong research interest in the mixed system. Yu Jin et al. analyzed the specific effect of adding sulfoaluminate cement on the hydration process of Portland cement, and studied the effects of sulfoaluminate cement with different particle sizes and content as admixtures on various properties of Portland cement^[6,7]. Yang Qing et al. research on ordinary silicate aluminate composite cementing system found that sulfoaluminate cement can significantly shorten the setting time of composite cementing system at a certain amount, and obtain a substantial increase in early strength^[8]. Bizzozero et al. studied the development and changes of the microstructure during the hydration process of the composite gelling system, and analyzed the hydration products^[9]. Research by Pellie et al. believes that the two cements can improve the performance of the composite cementing system at a certain ratio^[10]. This experiment mainly studied the mechanical properties of ordinary silicate-sulfoaluminate cement composite cementing system in concrete.

Ordinary Portland cement is currently the most widely used building cementing material in the world. It is widely used because of its low cost and stable performance^[11]. Since the 21st century, with the introduction of the concept of green development and the continuous changes in the use of cement, sulfoaluminate cement has shown certain advantages. As a low-energy cement, it not only consumes less energy in the production process, but also it has the characteristics of high early strength, rapid strength development, and corrosion resistance in the process of use, which has attracted wide attention from the industry^[12]. This experiment mainly studies the effect of ordinary silicate-aluminate cement composite cementing system in concrete on the fluidity and mechanical properties of concrete, and further optimizes the mix ratio of ordinary silicate-aluminate cement composite system.

2. Test

2.1. Materials

The cement used in the experiment is P.O 52.5 grade ordinary Portland cement and 42.5 fast hardening high-strength sulfoaluminate cement. Its basic composition and related performance are shown in the following Table 1 and Table 2 respectively.

Table 1 Chemical composition of P.O 52.5 ordinary Portland cement cement (%)

composition	Fe ₂ O ₃	Al ₂ O ₃	CaO	SiO ₂	MgO
content	4.52	5.75	64.5	23.2	1.3

Table 2 Chemical composition of R.SAC 42.5 fast-hardening high-strength sulfoaluminate cement (%)

composition	CaO	Al ₂ O ₃	SiO ₂	SO ₃	MgO ₃	Fe ₂ O ₃	TiO ₂
content	48.9	5.85	5.85	1.78	1.78	1.43	0.50

2.2. Test ratio design

This experiment mainly studies the influence of the content of sulfoaluminate cement on the performance of UHPC. A unified matrix mix ratio is adopted. The matrix mix ratio is obtained through a large number of previous mix ratio tests and has the best mechanical properties. The specific coordination of the test is shown in Table 3; The concrete test block produced in the experiment is a standard cubic test block with a side length of 100mm, and is cured to a specified age under normal temperature curing.

Table 3 The mixing ratio of the research experiment on the preparation method of New Bridge Expansion Joint UHPC Material

Test group	Portland cement	Sulphoaluminate cement	Silica fume	Fly ash	Steel fiber	Quartz sand	Water reducing agent
A1	0.682	/	0.154	0.164	0.110	0.900	0.032
A2	0.614	0.068	0.154	0.164	0.110	0.900	0.032
A3	0.545	0.137	0.154	0.164	0.110	0.900	0.032
A4	/	0.682	0.154	0.164	0.110	0.900	0.032

3. Results and analysis

3.1. Flow performance

As can be seen in Fig.1, when the sulphoaluminate cement content gradually increases, the fluidity of the fresh UHPC slurry shows a trend of first rising and then falling. Observing the changes in the graph, it can be seen that when the content of sulphoaluminate cement is below 0.137, the increase in fluidity is more obvious; when the content of sulphoaluminate cement is above 0.137, the decrease in fluidity is relatively slow; When the acid salt cement content is 20%, the fluidity of the slurry is 163mm, and the fluidity of the slurry is better at this time.

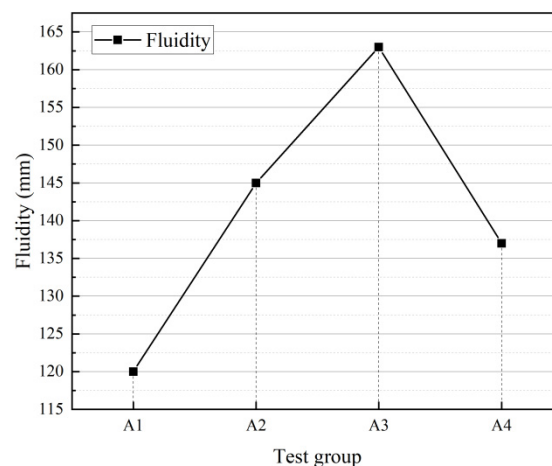


Fig.1 The influence on the fluidity of New Bridge Expansion Joint UHPC Material

3.2. Compressive strength

Fig.2 show the following results: The compressive strength of UHPC at 1d, 3d, 7d, 28d ages all show a trend of first increasing and then decreasing with the increase of the sulphoaluminate cement content. When the sulphoaluminate cement content reaches 0.068, it reaches the maximum. The maximum compressive strength of 1d is 26.97MPa; the maximum compressive strength of 3d is 78.12MPa; when the age is 7d, the maximum compressive strength is 96.27MPa; when the age is 28d, the maximum is 122.13MPa. When the aluminate cement content is 10%, the early compressive strength of UHPC concrete has the fastest growth rate, and the 3d growth percentage of A2 group reaches 220%. After more than 0.068, the UHPC compressive strength shows an overall downward trend.

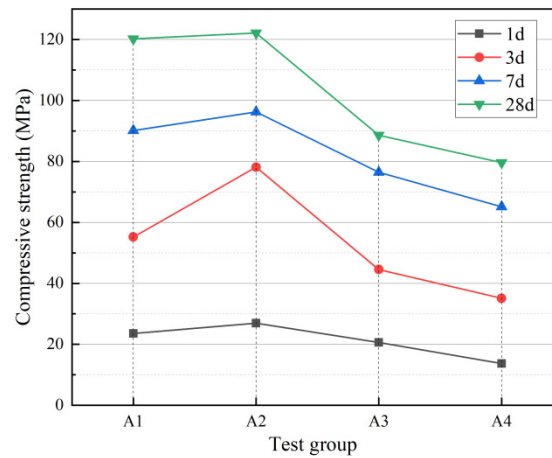


Fig.2 The influence on the compressive strength of New Bridge Expansion Joint UHPC Material

3.3. Flexural strength

Fig.3 show that the content of sulfoaluminate cement can enhance the early flexural strength of UHPC, and the overall situation is relatively complicated. When the age is 1d, the UHPC flexural strength first increases and then decreases with the sulfoaluminate cement content, and reaches the maximum value of 6.55MPa when the sulfoaluminate cement content is 0.137. The flexural strengths of ages 3d, 7d and 28d all reach the maximum when the sulfoaluminate cement content is 0.068, which are respectively 13.55Pa, 14.3MPa and 18.13MPa. When the sulfoaluminate cement content is greater than 0.068. Shows a downward trend, and the flexural strength shows a shrinking phenomenon.

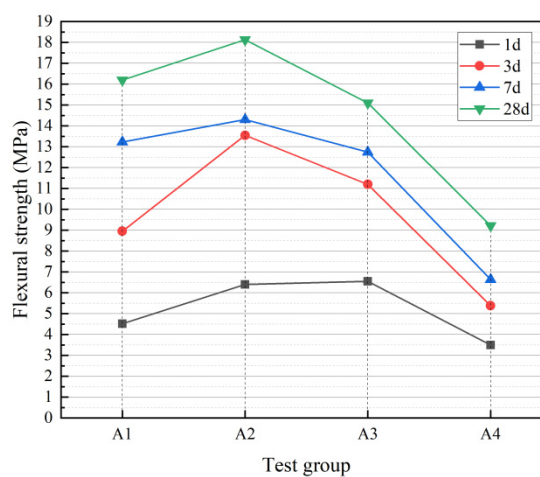


Fig.3 The influence on of New Bridge Expansion Joint UHPC Material

4. Conclusion

Based on the results and discussions presented above, the conclusions are obtained as below:

- (1) When the content of sulfoaluminate cement reaches 0.137, the fluidity of composite cementing system concrete is the largest.
- (2) Combined with the development of compressive and flexural strength, the optimal content of sulfoaluminate cement should be controlled at 0.068~0.137. The blending amount can be formulated into a salt cement-sulfoaluminate cement composite cementing material that is easy to shape, has good fluidity and high early strength.

(3) The early compressive and flexural strength of composite cementing system concrete increases first and then gradually decreases with the increase of sulphoaluminate cement content. The composite cementation system with sulphoaluminate cement content of 10%. The compressive and flexural strength of concrete is better than other admixtures, and it has good mechanical properties. In the later stage of strength, the composite cementing system concrete with a cement content of 20% showed a greater decline overall.

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References

- [1] SHI C, WU Z, XIAO J, et al. (2015) A review on ultra high performance concrete: Part I. Raw materials and mixture design. *Construction & Building Materials*, 101: 741-751.
- [2] Zhao Du, Lian Huizhen, Jin Jianlu. (2014) A new mode of steel-concrete composite—UHPC/UHPFRC (4): Engineering and product application, value, potential and sustainable development. *Concrete World*, 1: 48-64.
- [3] Zhao Du, Lian Huizhen, Jin Jianlu. (2013) The new mode of steel-concrete composite—UHPC/UHPFRC: the status quo, problems and countermeasures of steel-concrete composite model and the development history of UHPC. *Concrete World*, 10: 56-69.
- [4] China concrete & cement-based products association-UHPC. (2020) 2019 China Ultra High Performance Concrete (UHPC) Technology and Application Development Report. *Concrete World*, 02: 30-43.
- [5] SHAFIEIFAR M, FARZAD M, AZIZINAMINI A. (2017) Experimental and numerical study on mechanical properties of ultra high performance concrete (UHPC) . *Construction & Building Materials*, 156: 402-411.
- [6] Zizeng Lin, Hai Yang, Huiming Chen. (2019) Influence of Fillerson the Removal of Rainwater Runoff Pollutantsby aPermeable Brick System With a Frame Structure Base. *Water Sci Technol*, 80(11): 2131-2140.
- [7] Jiake Li, Ya Li, Yajiao Li. (2016) SWMM based Evaluation of the Effect of Rain Gardens on Urbanized Areas. *Environ Earth Sci*, 75: 17-31.
- [8] Yang Qing, Zhang Xiuzhi, Liu Di, et al. (2018) Study on the hydration performance and mechanism of ordinary silicate-sulfoaluminate composite gelling system. *Materials Review*, , 32(S2); 517-521,534.
- [9] Julien Bizzozero, Christophe Gosselin, Karen L Scrivener. (2014) Expansion Mechanisms in Calcium Aluminate and Sulfoaluminate Systems with Calcium Sulfate. *Cement and Concrete Research*, 56:190-202.
- [10] Laure Pelletier, Frank Winnefeld, Barbara Lothenhach. (2010) The Ternary System Portland Cement-calcium Sulphoaluminate Clinker-anhydrite:Hydration Mechanism and Mottar Properties. *Cement and Concrete Composites*, 32(7):497-507.
- [11] Wang Laiguo, Lu Lingchao, Cheng Xin. (2004) Research progress of silicate and sulfoaluminate mineral composite cement materials J Xi. *Journal of Jinan University (Natural Science Edition)*, 18(1): 21-27.
- [12] Zhang Zhentao. (2020) Research on the performance of ordinary Portland cement-sulphoaluminate cement composite system with polycarboxylic acid water reducing agent. *Concrete*, (1): 115-118.