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Experimental research on high-fluidity and super high-early strength concrete for cement pavement repairing

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ABSTRACT: The concrete for pavement repair must have very high-early strength for opening to traffic as soon, good anti-shrinkage and anti-cracking performance, interfacial bond between old and new concrete surface besides the basic pavement performance. High fluidity is also needed for simplifying repairing operation and for guaranteeing the repair quality. In a sense, high fluidity is conflict with super high-early strength. In this paper, focusing on the early flexural strength, interfacial bond, shrinkage and cracking performance, the preparing and testing of high-fluidity and super high-early strength concrete (HFESC) for pavement repair was investigated. The repair concrete material, which prepared with Sulphoaluminate cement, Amino-superplasticizer and RF admixture, has 3.5MPa 5h-flexural strength, 20MPa 5h-compressive strength and 200mm slump value. The laboratory test and field pavement repairing results revealed that the concrete has high fluidity and good mechanics performance and durability, which can be used in rapid repair of concrete pavement.

1 INSTRUCTIONS

Cement concrete pavement (CCP in short) is possessed of traffic safety, stability and durability comparing with asphalt pavement. Besides which, the comprehensive cost especially maintenance expanse of CCP is lower than that of asphalt pavement. While the rehabilitation of pavement surface distress, once it occurs, must be conducted in time for avoiding the serious pavement damage. Along with the increasing of pavement service life, driving speed, especially the road traffic volume and axle load, more and more CCP was destroyed in different degree in China (Li et al. 1998, Xie 2000). The local damage is the main type of pavement failure results form nature disaster and the deficiencies involving pavement design, materials, construction technology, management and quality control. The further deterioration of local damage in pavement will affect the ride comfort even destroy vehicles which may result in traffic accidents. It is very important to investigate feasible rapid repair materials and methods for the use and development of CCP. The rapid repair concrete for pavement must have many performances including very high-early strength for opening to traffic with 3.5MPa flexural strength and 20MPa compressive strength (Wang & Li 2006), good anti-shrinkage and anti-cracking performance (Yang et al. 2000, Morgan. 1996), interfacial bond between old and new concrete surface for long term repair effect besides the basic properties (Morgan 1996). High fluidity is also needed for simplifying repairing operation and for guaranteeing the repair quality (Palacios et al. 2009, Yang et al. 2000). Considering the stress characteristics of CCP and the actual specifications of cement concrete pavement design, flexural strength was used as control index and compressive strength as reference one in experiment test.

In a sense, high fluidity is conflict with super high-early strength (Chen et al. 2006). In this paper, focusing on the early flexural strength, interfacial bond, shrinkage and cracking performance, the preparing and testing of concrete with high-fluidity and super high-early strength for pavement repair was investigated. Based on the all kinds of experiments relevant with compatibility of cement and addictives, strength, interfacial bond and freeze-thaw durability, HFESC was prepared and applied for pavement damage repair. Many kinds of materials, such as Sulphoaluminate cement, magnesia-phosphate cement, early strength agent, fiber and polymers etc (Chung 2004, Yang et al. 2000, Huang et al. 2004), can be used for concrete pavement repairing. In this paper, the concrete repairing material was prepared with Sulphoaluminate cement, Amino-superplasticizer (ASS in short) and RF admixture. The repair materials possessed of 3.5Mpa 5h-flexural strength, 20MPa 5h-compressive strength and 200mm slump value and could meet demand for traffic recovery. The laboratory test and field pavement repairing results revealed that the concrete has high fluidity and good mechanics performance and durability, which can be used in rapid repair of concrete pavement.

2 EXPERIMETN PROGRAM

2.1 *Basic materials*

2.1.1 *Cement*

Industrial blended Portland cement, produced by grinding Portland clinker and mixing with up to 3 mass% gypsum and about 6 mass%~15 mass% of the mixing materials (type PO42.5 according to GB175-1999) in the Tianjin cement Works (PO in short) was used in this study. Rapid hardening Sulphoaluminate cement (SA in short) was also used in experiment. The basic performance indexes of cements were listed in Table 1.

Table 1. Basic performance indexes of cements.

Performance	SA	PO
Fineness (80μm sieve residue), %	1.5	1
Volume stability	qualify	qualify
Initial setting, min	40	220
Final setting, min	100	380
Cement strength, MPa		
12h flexural strength	6.4	-
12h compressive strength	39.7	-
1d flexural strength	7.2	-
1d compressive strength	49.8	-
3d flexural strength	8.6	5.1
3d compressive strength	62.4	36.6
28d flexural strength	-	9.4
28d compressive strength	-	54.8

2.1.2 *Aggregates*

Crushed limestone aggregate is used as coarse aggregate in concrete. Limestone is a natural stone material composing of more than 97 mass% calcium carbonate. The used coarse aggregate is continuous grading with the size of 5~15mm. The apparent density of the coarse aggregate is 2470kg/m^3.

The river sand (quartz) with the fineness modulus of 2.5 and apparent density of 2610kg/m^3 is used as fine aggregate in the study.

2.1.3 *Water*

Tap water from municipal pipe network was used for production of concrete.

2.2 *Admixtures*

2.2.1 *Water reducing agent*

For insure the high fluidity of concrete, the commercial water reducer agent of Amino-superplasticizer was used after being selected through comparative experiment on the efficiency and compatibility of different water reducers. The experiment result of compatibility between water reducer and binder will be given in section 3.1.

2.2.2 *Early strength admixture*

Early strength admixture is the key to preparing HFESC pavement repair material. Considering the requirement that HFESC must posses both high fluidity and super-high early strength, numerous kinds of early strength admixtures were investigated by comparative test on the early strength. The result showed that the super high-early strength of concrete was impossible to be prepared only relying on some one early strength agent without weakening the fluidity when using Amino-superplasticizer as water reducer. Fortunately we have developed a ternary compound early strength admixture (named RF admixture) composing of active powdered admixture and inorganic salts such as sulfate and nitrite, which obviously improved the early strength of concrete and also guaranteed the high fluidity of fresh concrete.

The improving effect of RF on cement mortar and concrete will be showed in section 3.2.

2.3 *Concrete mixture*

Experiment investigation on 28 groups of concrete specimen with basic different mix proportion was carried out for further research on the reasonable usage of RF admixture, fluidity of fresh concrete, compressive strength and flexural strength based on the optimizing experiments and analysis of the raw materials for concrete preparation. Based on the selected basic mix proportion form 28 groups, four kinds of concrete mixtures were further investigated. Table 2 shows the mix proportions of concrete.

Table 2. Composition of concrete mixtures (kg/m^3).

Mixture	PO	SA	RF	Water	Sand	Gravel	ASS
PO	380	-	-	190	656	1090	42
PO+RF	335	-	45	190	656	1090	37
SA	-	380	-	190	656	1090	42
SA+RF	-	335	45	190	656	1090	37

3 RESULTS AND DISCUSSION

3.1 *Early strength of cement mortar using RF*

The effect of RF admixture on early strength of cement mortar was investigated by early flexural and compressive strength based on the methodology proposed in the GB/T 17671-1999: Method of testing cements−Determination of strength. The experiment results were showed in Figures 1-2.

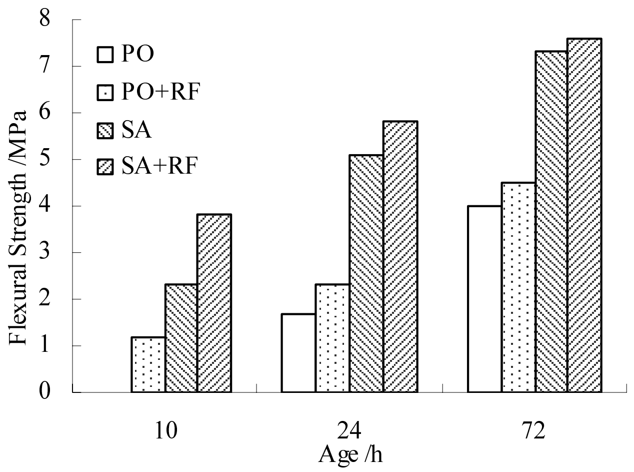

Figure 1. Early flexural strength of cement mortar using RF.

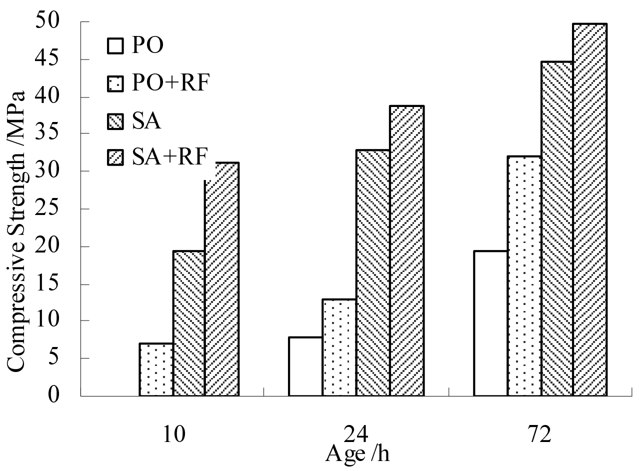

Figure 2. Early compressive strength of cement mortar using RF.

From the figures 1-2, we can see that the early strength of cement mortar is obvious increased when use RF admixture. The flexural strength using RF is nearly 2-3 times of that without RF admixture, and the compressive strength is nearly 3-5 times.

3.2 *Compatibility between admixture and cement*

The compatibility between binder (including cement and RF admixture) and ASS was analyzed through the time-dependent slump extension (Qin 2000). Fluidity of cement paste was measured According to GB 8077-2000: *methods for testing uniformity of concrete admixture*.

The results of time-dependent slump extension of cement paste without RF admixture were showed in Figure 3, the results of cement paste using RF admixture were shown in Figure 4.

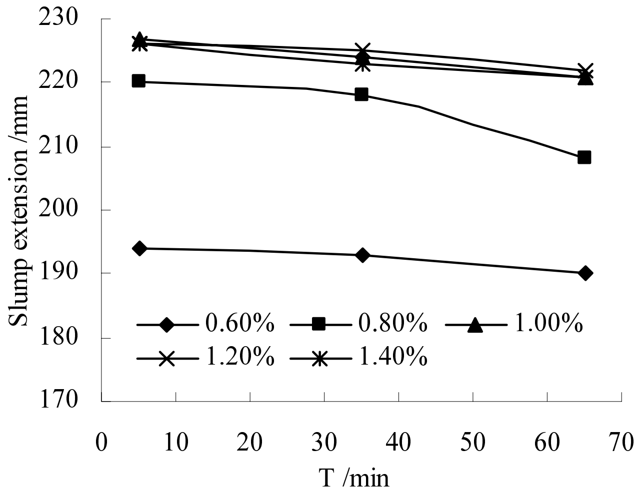

Figure 3. Slump extension of cement mortar using RF admixture.

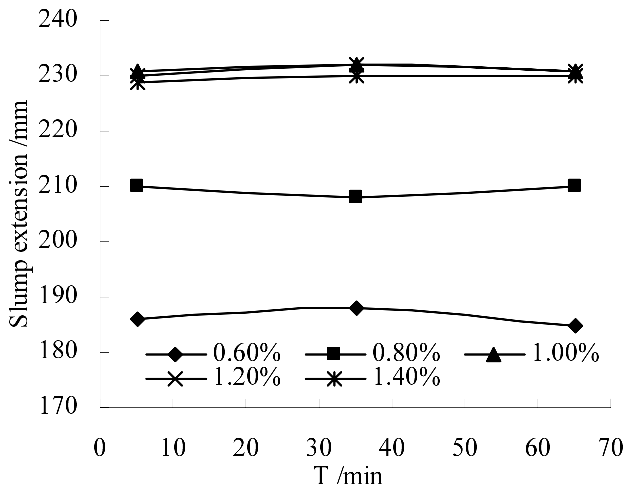

Figure 4. Slump extension of cement mortar without RF admixture.

Figures 3-4 shows good compatibility between ASS, RF admixture and cement. The obvious increasing of fluidity by using ASS also occurs whether using RF admixture or not. The optimum dosage of ASS is 1.0 mass% of cement.

3.3 *Early strength of concrete*

Early strengths of four kinds of concrete mixture (see Table 2) were investigated according to GB-T 50081-2002: Standard for test method of mechanical properties on ordinary concrete. The fluidity of fresh concrete was also measured according to GB-T 50080-2002: Test method for ordinary fresh concrete. And all the slumps of them were over 200mm.

The results of early strength of concrete were showed in Figures 5-6.

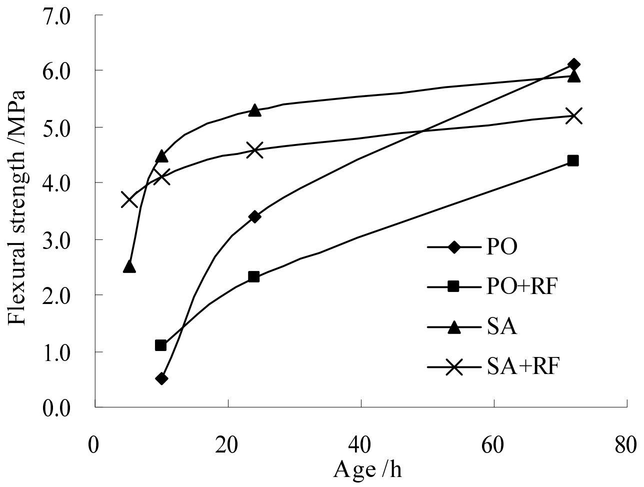

Figure 5. Early flexural strength of concrete.

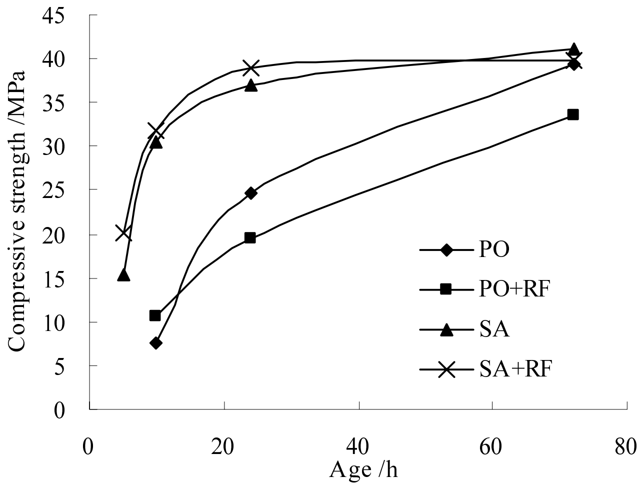

Figure 6. Early compressive strength of concrete.

It is difficult to get super-early high strength (with in 10 hours) using Ordinary Portland Cement even the RF admixture is added, the flexural strength of it is not enough to open traffic as early as 10 hours. While using rapid hardened cement such as ASS, it is easy to open traffic in 10 hours. As to HFESC prepared with ASS and RF admixture, its 5-hour flexural strength is as high as 3.7MPa and enough to open traffic.

3.4 *Interfacial bond strength*

Splitting strength of concrete was used for representing the interfacial bond strength based on the methodology proposed in reference (Zhao et al. 1999). Half of the specimen after split test was placed in specimen mould and then cast HFESC in mould as the other half of specimen using for splitting test. The specimen, with the size of 150×150×150mm, was placed with the old-new concrete interface vertical after 28d's curing for testing. Figure 7 gives the experimental result.

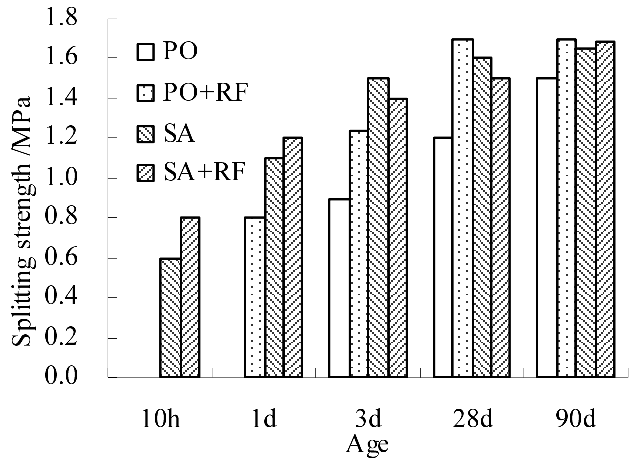

Figure 7. Interfacial bond strength of concrete.

Figure 7 shows that the using of RF admixture increases the interfacial bond strength between old concrete and new repair HFESC especially in early age. The enhancement of RF admixture on concrete early strength may result form the active effect of early strength compound in RF.

3.5 *Freeze-thaw durability*

The frost resistance of concrete is essential for concrete durability, especially in the area existing freeze-thaw circle. The freeze-thaw durability was evaluated according to GB/T 50082 200×: Standard for test method of long-term performance and durability of ordinary concrete (opinion soliciting draft).

Figure 8 gives the freeze-thaw circle experiment results.

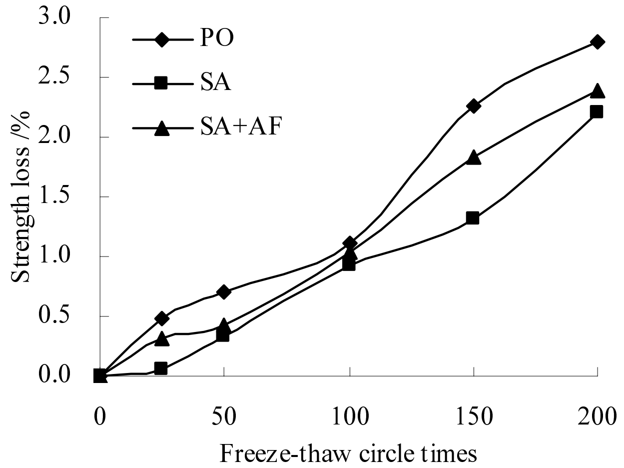

Figure 8. Freeze-thaw durability of concrete.

The experiment results reveal that Group SA posses the best frost resistance performance and the strength loss of Group PO is the highest. All the strength loss of concrete after 200 times freeze-thaw circle is lower than 30%. The 12 mass% substitute of cement with RF admixture lower the freeze-thaw durability of concrete, which may result form the resoluble salt in RF admixture.

4 CONCLUSIONS

Based on the experimental research on RF admixture, water reducing agent, mechanical performance and freeze-thaw durability of HFESC, we can draw some conclusions as follows:

(1) Good compatibility between sulphate aluminium cement, Amino-superplasticizer and RF admixture makes the preparing of HFESC possible.

(2) The 5h flexural strength of HFESC is over 3.5MPa and 5h compressive strength over 2MPa. HFESC, possessing both high fluidity and super high-early strength, is qualified as an efficient rapid pavement repair material. The application of HFESC in actual pavement repair also verifies the high performance of HFESC.

(3) The facts such as easy gain of materials for preparing HFESC, convenient construction and open to traffic as early as 5 hours make HFESC a suitable pavement repair material. HFESC is worth popularizing.

REFERENCES

Chen D, Liu C, Zhao F (2006). A Study on Preparing High-Fluidity and Super High-Early Strength Repairing Concrete. Highway. (11):129-144.

Chung D. D. L (2004). Use of polymers for cement-based structural materials. Journal of Materials Science 39(9): 2973-2978.

GB175-1999: Portland Cement and Ordinary Portland Cement.

GB/T17671-1999: Method of Testing Cements-Determination of Strength.

GB 8077-2000: Methods for Testing Uniformity of Concrete Admixture.

GB/T 50080-2002: Test Method for Ordinary Fresh Concrete.

GB/T50081-2002: Standard for Test Method of Mechanical Properties on Ordinary Concrete.

GB/T 50082 200×: Standard for Test Method of Long-term Performance and Durability of Ordinary Concrete (opinion soliciting draft).

Huang S, Chang J, Liu F, Lu L, Ye Z, Xin C (2004). Poling process and piezoelectric properties of lead zirconate titanate/sulphoaluminate cement composites. Journal of Materials Science 39(23):6975-6979.

Li H, Miao C, Jin Z (1998). Repair technology for cement concrete pavement. Beijing: China Communications Press.

Morgan D.R (1996). Compatibility of concrete repair materials and systems. Construction and Building Materials 10(1):57-67.

Palacios M, Puertas F, Bowen P, Houst Y. F (2009). Effect of PCs superplasticizers on the rheological properties and hydration process of slag-blended cement pastes. Journal of Materials Science 44(10): 2714-2723.

Qin W (2000). Construction engineering materials. Beijing: Tsinghua University Press.

Wang S, Li V.C (2006). High-early-strength engineered cementitious composites. ACI Materials Journal. 103 (2): 97-105.

Xie, Y (2000). Rapid repair technology of thin layer cement concrete pavement. Highway. (7): 62-65.

Yang Q, Zhu B (2000). Properties and applications of magnesia-phosphate cement mortar for rapid repair of concrete. Cement and Concrete Research 30(11):1807-1813.

Zhao Z, Zhao G, Huang C (1999). Research on adhesive splitting tensile behavior of young on old concrete. Industrial Construction. 29 (11): 56-59, 50.