CHEMICAL ENGINEERING TRANSACTIONS
VOL. 55, 2016
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Tichun Wang, Hongyang Zhang, Lei Tian

ISBN 978-88-95608-46-4; **ISSN** 2283-9216
DOI: 10.3303/CET1655074

Effect of Chemical Admixture on Durability of Concrete

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In this paper, the effect of the polynaphthaene sulphonate type water reducer (PSWR) and new type polycarboxylate water reducer (PAWR) on the internal pore structure, internal defects and forces of resistance to external environmental of concrete are fully compared and analyzed. The effect of PAWR on improving the durability of concrete was revealed. The test result showed that compared with PSWR, PAWR can improve the pore structure and pore size distribution of concrete grout, improve the density of concrete, reduce the adiabatic temperature rise of concrete, optimize the hydration heat curve of cement, reduce the shrinkage and deformation of concrete, improve concrete anti-cracking performance and volume stability, to reduce the internal defects of concrete; at the same time, but also to improve the ability of the concrete, including anti-carbonation, frost resistance, chloride ion erosion resistance and steel protection in different degree, as well as to enhance the resistance of concrete to the external environment, thereby greatly improving the durability of concrete.

1. Introduction

With the implementation of the national sustainable development strategy, people pay more and more attention to the durability of concrete. Concrete durability involves two aspects: First is the acting force caused damage or destructive force; Second is the resistance of material itself to destructive. The confrontation result of two kinds of force determines the durability of the material (Tang et al., 2015; Cui and Ni, 2016; Geng et al., 2016; Yang et al., 2016; Zhou et al., 2016; Zhang et al., 2016; Zhang, 2015). To improve the durability of concrete, its essence is to improve the resistance of the material itself to destructive. As the old man Mr. Wu Zhongwei said, the destruction factors of concrete materials contain internal and external factors. External factors often through the internal factors or into the internal part of concrete to react; external factors are often affect each other and a number of factors successively or at the same time to cause destructive effect. These all increased the complexity of the concrete durability problem (AïTcin, 2003).
External factors are objective, and only by improving the ability of concrete to resist the destructive effect to achieve the durability of concrete. The internal pore structure, the interface state between the cement aggregate, the internal defects (including internal microcracks, etc.) all have a direct impact on the durability of the concrete.

2. Effect of admixture on internal defects of concrete

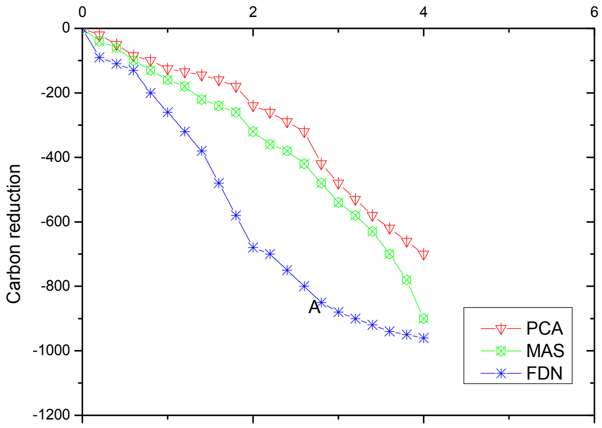
The results showed that the volume stability of concrete had a great influence on the internal defects of concrete. Microcracks in concrete are mainly caused by the shrinkage of cement, due to the surface humidity and temperature is differ with the internal humidity and temperature, so that to caused internal stress and cracks.

2.1 Effect of admixtures on the concrete shrinkage

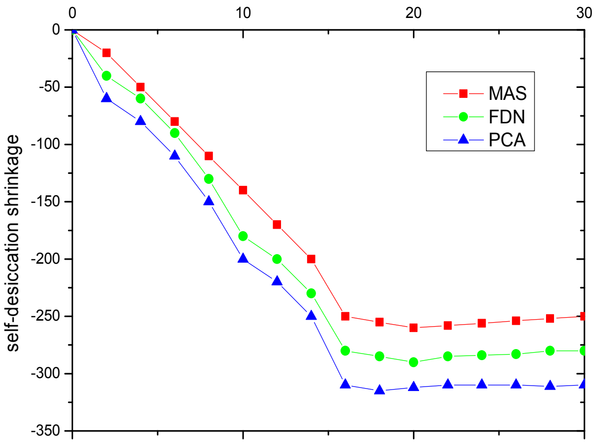
Figure 1 showed the various types of concrete deformation test results by different types of admixture, through the use of self-developed in stages-the whole process of concrete deformation measurement system. From the test results it can be seen that different admixtures had greater impact on the shrinkage of concrete (Li (1994)). For naphthalene series water reducer (FDN) and aminosulfonic acid based water reducer (MAS), condensation, spontaneous shrinkage and self-desiccation shrinkage were all larger. For polycarboxylate

Please cite this article as: Cui J., 2016, Effect of chemical admixture on durability of concrete, Chemical Engineering Transactions, 55, 439-444 DOI:10.3303/CET1655074

water reducer, not only the plastic shrinkage (condensation) before hardened was small, but also values of spontaneous shrinkage and self-desiccation shrinkage were small (Schutter, 2002).



(a) Condensation



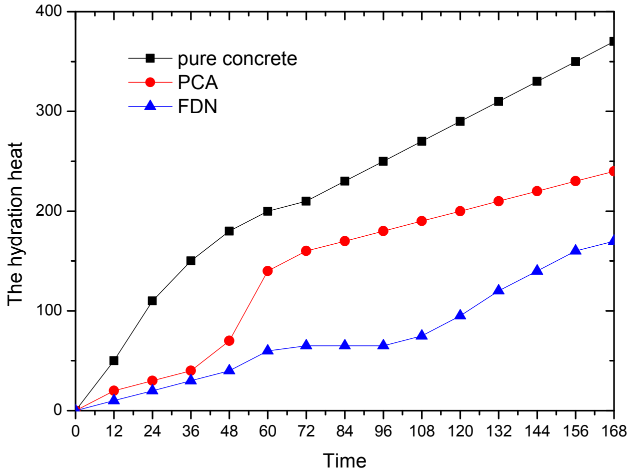
(b) Self-desiccation shrinkage

Figure 1: Effect of admixtures on the concrete shrinkage

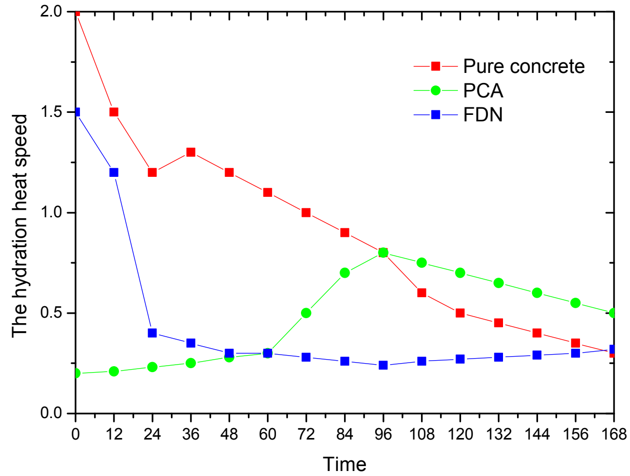
2.2 Effect of admixtures on concrete hydration heat

In many projects, especially in the mass concrete projects, it is commonly seen that because the concentration of hydration heat of cement in concrete, leading to the phenomenon of concrete cracking. In order to reduce the temperature rise of concrete, many projects using large amounts of fly ash, grinding slag and other mixed materials to replace the same amount or excess cement, for the purpose of reducing the total amount of hydration heat in concrete, there are projects by using middle-heat, low-heat cement to control cement hydration heat (Pacheco-Torgal and Labrincha, 2013). Practice had proved that a reasonable distribution of concrete hydration heat was also very important to temperature rise control of concrete. Figure 2 showed the effect of admixtures on hydration heat of cement. The hydration heat values of the cement paste mixed with polycarboxylate water reducer were 28.0, 43.0 and 186.1 J/g, for 1 d, 3d and 7 d, respectively. The hydration heat values of the cement paste mixed with naphthalene series water reducer were 13.8, 158.3 and 224.0 J/g, for 1 d, 3d and 7d, respectively (Li and Li, 2006). Compared with the hydration heat of pure cement paste, although the hydration heat of cement paste with retarding water reducer decreased in 1-7d, but hydration heat of the paste mixed with polycarboxylate water reducer decreased more in early age. In the case of the rate of hydration heat release, there was almost no obvious peak of rate of hydration heat release and the distribution of hydration heat was more reasonable (Aït-Mokhtar et al., 2013).

Effect of the two kinds of admixtures on the adiabatic temperature rise of concrete was shown in Figure 2, the test used in the mix proportion as shown in Table 1. The results showed that the adiabatic temperature rise of concrete mixed with polycarboxylate water reducer was obviously lower than that of concrete mixed with naphthalene series water reducer (Lima et al., 2008).



(a) Effect on the hydration heat



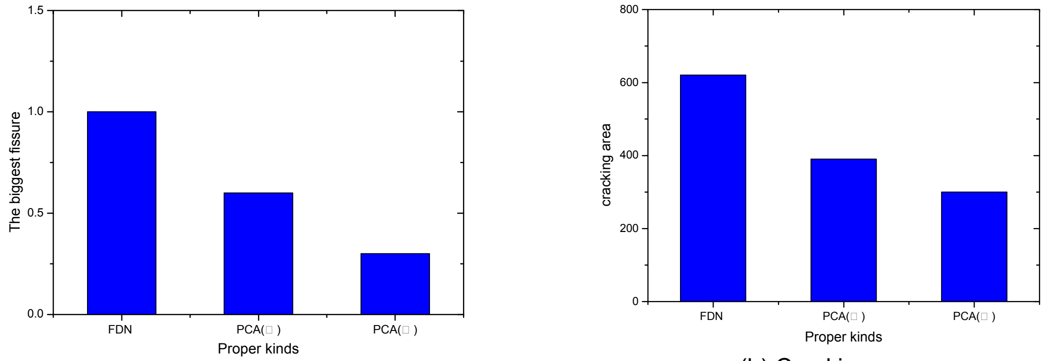
(b) Influence of hydration heat rate

Figure 2: The influence of admixture on cement hydration

Table 1: Mix proportion of concrete in adiabatic temperature rise test

	Mix proportion					Compressive strength	
	C	FA	S	G	W	7d	28d
FDN	255	185	700	1195	150	27.5	46.3
PCA						29.3	46.3

Effect of admixture on cracking performance of concrete was shown in Figure 3. The results showed that the new generation of polycarboxylate water reducer which had the function of reduction. After mixed with concrete, the cracking area of the concrete was the smallest and the width of the crack was also the smallest. This test result further proved the improvement effect of the new generation of polycarboxylate water reducer on the concrete performance. As the polycarboxylate water reducer had excellent hydration heat properties, the volume of concrete with good stability, less internal defects, good crack resistance.



(a) Maximum crack width (b) Cracking area

Figure 3: Effect of admixtures on early plastic cracking

3. Effect of admixture on concrete's resistance to external environment

3.1 Effect of admixture on the chloride ion permeability resistance of concrete

Table 2: Mix proportion and its basic performance of Test concrete

admixtures	slump	water content	compressive strength			
			7d	28d	56d	84d
FDN	18.5	2.0	48.2	70.2	76.9	79.6
PCA	20.0	2.2	49.6	70.5	77.5	80.5
FDC+air entraining agent	19.5	7.5	52.3	68.1	65.8	77.5
PCA+air entraining agent	21.5	7.6	50.2	66.5	72.1	75.6

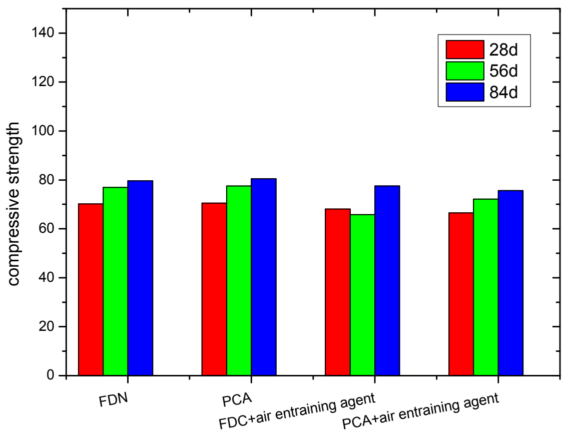


Figure 4 Effect of admixture on permeability of concrete

The Concrete mix proportion of the text was shown in Table 2. The test results of chloride ion permeability resistance of concrete was shown in Figure 4, under the following 4 conditions: Concrete mixed with Naphthalene series water reducer (FDN) and polycarboxylate water reducer (CPA), as well as two kinds of water reducers mixed together with air entraining agent. In the case of the same gas content (2.0% and 2.2%), the electric flux of the concrete mixed with polycarboxylate water reducer was lower than that of the concrete mixed with Naphthalene series water reducer at different stages. Similarly, on the basis of concrete mixed with two kinds of water-reducing admixtures, the air entraining agent was added to make the air content of the concrete reached the same level (7.5% and 7.8%), the electric flux the concrete mixed with polycarboxylate water reducer + air entraining agent was also less than that of mixed with Naphthalene series water reducer and concrete + air entraining agent. The results indicated that polycarboxylate water reducer was more suitable for the improvement of concrete density and pore structure and pore size distribution of concrete, and the chloride ion permeability resistance of concrete was improved.

3.2 Effect of admixture on the frost resistance of concrete

Adopted the mix proportion of test, compared the frost resistance of concrete under the following 4 conditions: Concrete mixed with Naphthalene series water reducer (FDN) and polycarboxylate water reducer (CPA), as well as two kinds of water reducers mixed together with air entraining agent (DFN + air entraining agent and CPA + air entraining agent). It indicated that in the case of same gas content of concrete, the frost resistance of concrete mixed with polycarboxylate water reducer was superior to that of concrete mixed with Naphthalene series water reducer, The relative dynamic elastic modulus of the latter decreased to less than 60% after 75 cycles of freezing and thawing cycles, while the relative elastic modulus of the former decreased to less than 60% after 125 cycles of freezing and thawing cycles; For concrete mixed with CPA + air entraining agent and DFN + air entraining agent, after 300 cycles of freezing and thawing cycles, the damage of the concrete was small. The relative dynamic elastic modulus of the former kept at 98.6%, and the weight loss rate was 0.8%, while the relative dynamic elastic modulus of latter decreased to 95.2% and the weight loss rate was 1.0%. The surface flaking and internal damage of the concrete mixed with CPA + air entraining agent were less than those of the concrete mixed with DFN + air entraining agent.

3.3 Effect of admixture on the carbonation of concrete and steel corrosion resistance

Table 3 showed the carbonation performance comparison test results of concrete mixed with naphthalene series water reducer (FDN) and polycarboxylate water reducer (CPA). Polycarboxylate water reducer was better than naphthalene series water reducer on improving the ability of anti-carbonation of concrete. The effect of CPA on the morphology of cement hydration products made the concrete structure more compact and the mechanical properties, especially the compressive strength was greatly improved, the permeability of CO2 was decreased and the depth of carbonation was reduced accordingly.

Table 3: Comparison of effect of water reducer on the carbonation of concrete

admixtures	Carbonation depth			
	3d	7 d	14 d	28 d
PCA	0.26	0.56	0.66	1.25
FDN	0.85	0.95	2.12	2.36

Because of the higher compactness, stronger chloride ion resistance and anti-CO2 permeation, therefore the concrete mixed with polycarboxylate water reducer had stronger steel protection ability, better to reduce or avoid steel corrosion, improve the safety of concrete structures.

4. Conclusion

The third generation of high-performance polycarboxylate water reduce CPA represents the development direction of concrete admixture, is multi-functional concrete admixture combined large water reduction, high slump loss resistant, high strength, high resistance to cracking and high durability, with the performance that naphthalene series water reducer can't go beyond. Compared with the naphthalene series water reducer, the new concrete admixture of polycarboxylate can improve the pore structure and pore size distribution of concrete grout, improve the density of concrete, reduce the adiabatic temperature rise of concrete, optimize the hydration heat curve of cement, and reduce the shrinkage and deformation of concrete, improve the anti-cracking performance and volume stability of concrete, reduce the internal defects of concrete; at the same time, can also improve the ability of concrete carbonation resistance, frost resistance, chloride ion erosion resistance and steel protective in different degree, as well as to enhance the resistance of concrete to the external environment, thereby greatly improving the durability of concrete.

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