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Impact of Water Reducing Agent on Concrete Strength

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In this paper, the effect of the type and amount of water reducing agent on the rheological parameters of concrete was determined by a high-precision rheological meter, and the Bingham equation was fitted. Based on the influence of the three kinds of water reducing agents on the rheological parameters, the effects of the dosage of water reducing agent on the rheological parameters of concrete were summarized. And the law of how the rheological parameters change with time was concluded, which provides some reference and guidance for the reasonable selection of water reducing agent in concrete preparation.

1. Introduction

The development of modern concrete admixtures dates back to the beginning of the 1930s, when an American, E.W. Sikely found that sulfite pulp waste could improve the fluidity of concrete and enhance its strength and durability. Modern concrete admixtures then embraced the first period of development, the main additive chemical ingredients being calcium chloride, sodium chloride, sodium rosin, lignin sulfonate, stearic acid soap and other chemicals. By the early 1960s, the Federal Republic of Germany has also successfully developed a highly effective water reducing agent, its main component being melamine sulfonate formaldehyde condensate (“MSF”). In the 1970s, the Japanese water scavenger researchers discovered the reason why naphthalene super-plasticizer was not ideal in terms of conservation was due to its molecular structure constraints, (Zhang and Xie, 2006) and only the development of new multi-functional water reducing agents could fundamentally solve the problem of collateralization**.**

2. Water Reducing Agent

2.1 Role of water reducing agent

Water reducing agent is a kind of admixture, its role can be summarized as the following (Wachi et al., 2005). Firstly, the water reducing agent can reduce the unit amount of water used in concrete mixing without affecting the workability of the concrete so as to reduce the water-cement ratio and effectively improve the strength of concrete; Secondly, the water reducing agent does not reduce the concrete mix performance other than the unit water consumption, and you can significantly change the concrete mix compound workability, reduce construction energy consumption, and facilitate easy construction; Thirdly (Kinoshita et al., 1995), the water reducing agent can reduce the strength of the concrete mixture, the hardening time of the concrete, and the amount of cement used per unit of concrete, thereby saving cement and reducing the cost.
According to water reduction capacity, water reducing agent is divided into several types, including ordinary water reducing agent (Lange and Schlotthauer, 1980), super-plasticizer, high-performance water reducing agent (Zhang et al., 2008) and others.

2.2 Mechanism of Action

2.2.1 Electrostatic repulsion theory

The DLOV theory is a classic theory of electrostatic repulsion. It thinks that between the colloidal particles, there is not only a repulsive potential energy, but also the existence of gravitational potential energy (Cepa and Lepingle, 1997).

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The DLOV theory can successfully explain the mechanism of the super-plasticizer (naphthalene super-plasticizer and melamine super-plasticizer). But it can’t explain the mechanism in poly-carboxylate super-plasticizer and sulfamic acid super-plasticizer (Minton and Edelhoch, 1982). Poly-carboxylate super-plasticizer has a very good dispersion effect on cement particles, but the zeta potential of the particles is very low, which contradicts with the DLOV theory. In order to better explain the mechanism of action, the theory of steric hindrance has been introduced by the researchers.

2.2.2Water reducing agent blending technology

The addition of water reducing agent is not the same, with the overall consideration being when the water reducing agent is added to water. There are three main methods of adding water reducing agents. The first method is the pre-mixed method, although the first ingredient being mixed with the argument is not the same, but in general, the concrete is prepared by adding water to the water reducing agent, sand, stone, cement and other uniform mixing. Generally, the powder-like water reducing agent application is prepared using this method.

3. Rheological Properties of Concrete

3.1 Test Materials

3.1.1 Cement and water

Tap water meets the JGJ63-2006 concrete water standard.
The cement used in this test is the cement produced by Harbin Cement Ordinary Portland Cement, labeled as 425.

3.1.2 Fine aggregate

Fine aggregate of the river sand, in line with “JGJ52-2006 Ordinary Concrete Sand, Stone Quality and Test Methods" on sand requirements, is prepared. In the experiment, the rheometer was used to determine the particle size of the slurry. Before the preparation of the sample, the sieve was screened with a sieve with a mesh size of 0.16mm.

3.1.3 Water reducing agent

Three kinds of water reducing agent were used in this paper.
(1) Product Description:
The main component of this product is β naphthalene sulfonic acid formaldehyde condensate. The cement particles have a strong scattering ability, and the product is a naphthalene super-plasticizer. By adding other components (air, early strength, retardation, frost, plastic, impermeable, waterproof agent, etc.) to the product, it can produce a variety of composite concrete admixture;
(2) Main technical performance:
The product is a powder product of the appearance of brown powder; the PH value is between 7 and 9, neutral to weak alkaline; the recommended dosage is 0.35% to 1.5%, when the content ratio of water reducing agent is greater than 0.75%, it reduces use of water by up to 20%. The product is non-toxic, non-corrosive, non-flammable, soluble in water, and the concrete in the steel does not result in corrosion.

3.2 Test Instrument

The main instrument used in this paper is the AR series rheometer produced by a US company. The rheometer, using the CMT Technology, is currently the world's best stress-controlled rheometer. It uses the latest Mobius drive, equipped with more Hole carbon air bearings, so that it can accurately carry out stress control and strain control test. In this way, it improves both the accuracy and breadth of the study, which is applicable to the test of cement slurry. Table 4 includes the main parameters of the instrument used in the test. Figure 4 and Figure 5 show the rheometer air source, pressure gauge, air bearing lock, fixture and host.

3.3 Test Method

3.3.1 Match the proportion

In order to prepare for cement slurry for the test and in preparing concrete for the future study, the mixing ratio of cement paste and mortar in this test is consistent with that of the concrete, and the specific ratio is consistent with Table 1.

Table 1: Mixing ratio of concrete and cement

	Water(kg)	Cement(kg)	Sand (kg)	Stone(kg)	Water-cement ratio	Sand rate
Concrete	165	458	686	1037	0.36	0.4
Cement paste	165	458			0.36	
Cement-sand	165	458	686		0.36	

3.3.2 Calculation and correction of water absorption of fine sand

The conversion is calculated based on the water absorption of the sand proportional to its surface area and is based on two basic assumptions: the average particle size of each graded sand is the arithmetic mean of the upper and lower sieves; and the sand is the ideal sphere.

3.4 Test Results and Analysis

3.4.1 Effect of FDN on rheological parameters of cement

The content ratios of water reducing agent FDN were 0.45%, 0.55%, 0.65%, 0.75%, 0.85% and 0.95%. The rheological parameters of each group of cement paste samples were tested at 5 minutes. The test results are shown in Figure 1-3.

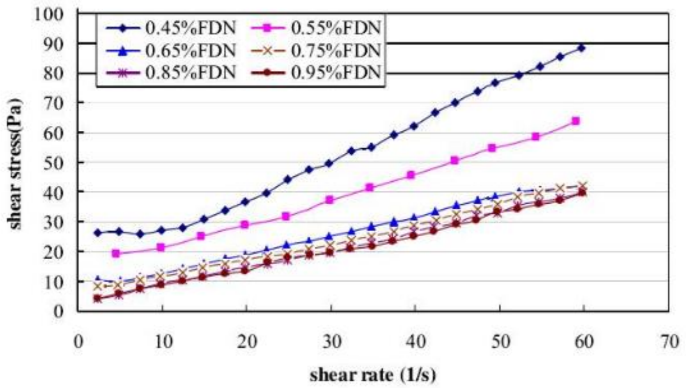

Figure 1: Shear Rate - Shear stress curve of FDN cement paste at 5 minutes

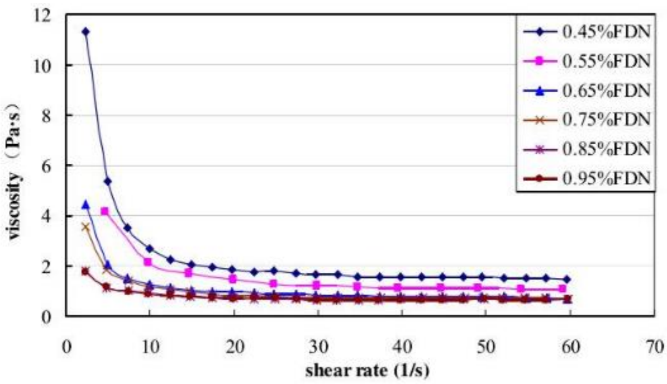

Figure 2: Shear rate - Plastic viscosity curve at 5 minutes with FDN cement paste

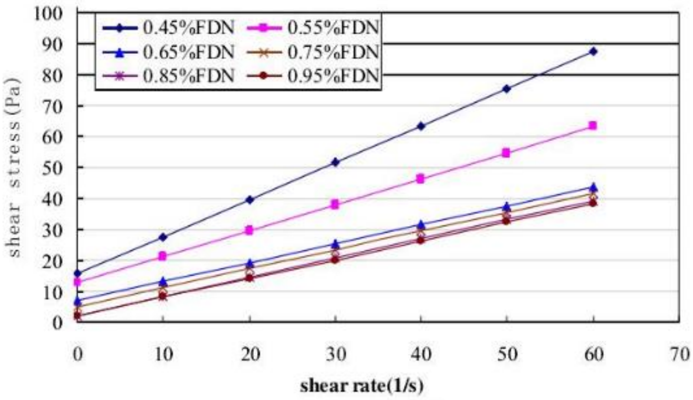

Figure 3: The Bingham curve of FDN cement paste at 5 minutes

Figure 1 and Figure 2 show the curves of shear stress and plastic viscosity and shear rate of FDN cement paste. From Figure 1, it indicates that the shear stress of FDN superplasticizer at each content ratio increases with the increase of shear rate and shows a good linear relationship (Figure 3), which proves that cement paste conforms to the Bingham model. As from Figure 2, the plastic viscosity of each content decreases as the shear rate increases, and the rate of decrease is declining before stabilizing at the final stage. This is because, with the increase of shear rate, cement hydration after the flocculation structure is destroyed, the plastic viscosity is rapidly reduced, when most of the flocculation structure is destroyed, the plastic viscosity tends to stabilize.

4. Test results and analysis

4.1 Slump and strength study of concrete mixed with FDN

The FDN content ratios were at 0.25%, 0.35%, 0.45% and 0.50%, and the laboratory temperature was 18 ° C. The slump of concrete with different content ratio of concrete at 5 minutes was prepared and the compressive strength was measured over 28 days. Table 8 shows the test results. Figure 10 shows the relation between the slump and compressive strength of concrete with the amount of water reducing agent.

Table 2: FDN concrete slump and 28-day compressive strength test results

FDNContent	0	025	0.35	0.45	05
Slump degree (mm)	40	45	105	180	200
28d compressive strength (Mpa)	44.7	38.6	40.6	41.1	36.8

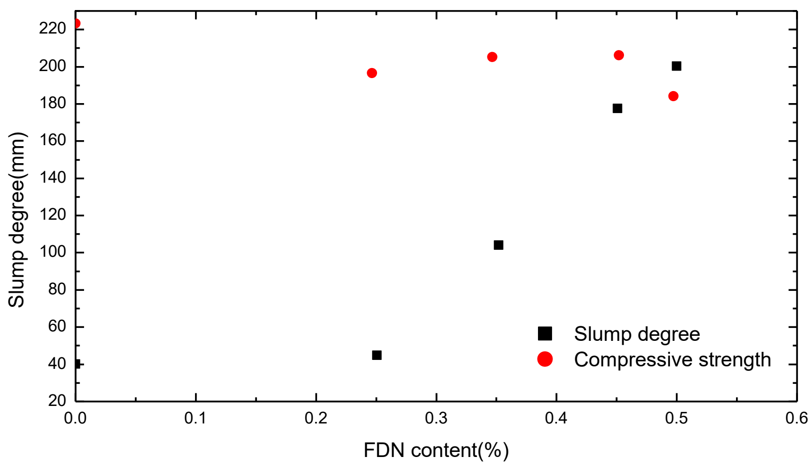

Figure 4: Slump and strength were correlated with FDN content

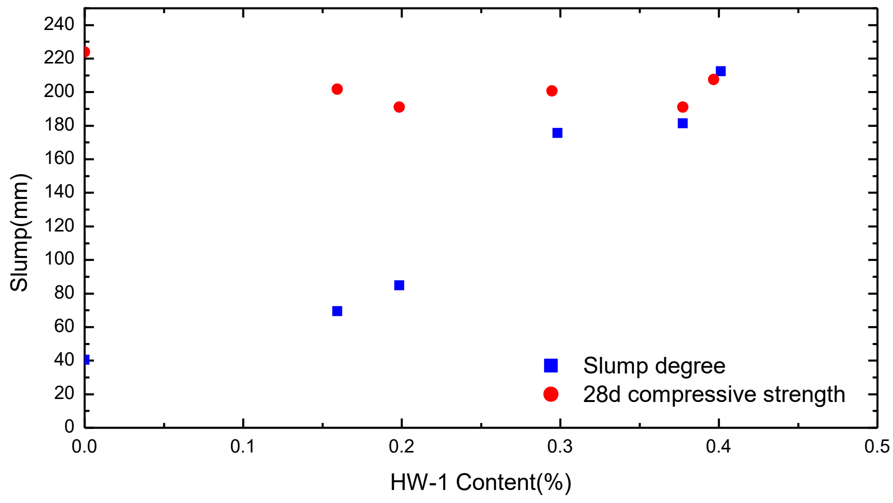

Figure 5: Slump and strength were correlated with the amount of HW-1

It can be seen from Table 2 and Figure 5 that the addition of the FDN improves the slump of the concrete. When the FDN content ratio is lower than 0.25%, the improvement of concrete slump is less noticeable. When the FDN content ratio is between 0.25% and 0.45%, slump of concrete increases rapidly. When the FDN content ratio is between 0.45% and 0.50%, the growth rate of concrete slump decreases. It can be seen, when the FDN content at a ratio between 0.25% to 0.45%, it has the best enhancement to concrete slump. As seen from Table 8 and Figure 10, the FDN content is at 0.45% when the intensity is slightly higher. With the addition of FDN, the concrete strength decreases slightly, and the concrete strength with the FDN content of the basic changes remain unchanged, the average strength at 39.3MPa. Water reducing agent can be used to improve the strength of concrete, because the addition of water reducing agent can reduce the water-cement ratio of concrete, from the water-cement ratio, we see that the concrete strength will increase as the water-cement ratio increases. Adding water reducing agent increases the fluidity of concrete, while the water-cement ratio remains unchanged. So after adding FDN, the concrete strength will decline, as it does not change with the FDN content, and it basically remains stable.

4.2 Slump and strength study of concrete with HW–1

The content ratios of HW-1 were 0.16%, 0.20%, 0.30%, 0.36%, 0.38% and 0.40%. The laboratory temperature is 18° C. The slumps of different concrete mixes at 5 minutes were measured and the test pieces were prepared to test compressive strength over 28 days. Table 9 shows the results of the test, and Figure 11 shows the slump and intensity versus volume.

Table 3: Results of the test of slump and 28-day compressive strength of HW-1 concrete

HW-1Content	0	0.16	02	03	0.38	0.4
Slump degree(mm)	40	70	85	175	180	210
28d compressive strength (Mpa)	44.7	40	38	40	38.2	41.2

As indicated by Table 9 and Figure 11, the addition of water reducing agent HW-1 significantly improves the slump of concrete. When HW-1 dosage is less than 0.20%, the improvement of concrete slump is less noticeable. When the HW-1 content is between 0.20% and 0.30%, between 0.30% and 0.38%, the slump of concrete increases rapidly from 0.38% to 0.38% when the amount of HW-1 is between 0.30% and 0.38%, between 0.38% and 0.40%, the concrete slump increases rapidly. It can be seen that when HW-1 water reducing agent content ration is between 0.20% and 0.30%, and between 0.38% to 0.40%, it has the best effect on the concrete slump. It can be seen from Table 9 and Figure 11 that when HW-1 content is at 0.36%, with the addition of HW-1, the strength of concrete decreases slightly, and the strength of HW-1 is basically unchanged, with an average strength at 39.5MPa. The test results are consistent with those in Section 4.1, and the underlying reasons are the same.

5. Conclusion

The results show that the rheological curves of cement paste and mortar mixed with three kinds of water reducing agents (FDN, HW-1 and HS-1) using the Bingham model anastomosis. With the addition of water reducing agents, the working properties of cement paste and mortar are significantly improved, and with the increase of the dosage of the water reducing agent applied, the rheological parameters of the cement paste and the mortar are reduced and then kept stable. This shows that with the increase in the amount of water reducing agent, cement paste and mortar workability is improving, but to a certain limit, when the work to maintain stability, the amount of water reducing agent is saturated content. And in the three kinds of water reducing agent, HS-1 has the best effect on the dispersion of cement particles. The results show that the dispersion effect of HS-1on cement particles is not weakened with time, but increasing.

References

Cepa E., Lepingle D., 1997, Diffusing particles with electrostatic repulsion, Probability Theory & Related Fields, 107(4), 429-449, DOI: 10.1007/s004400050092

Kinoshita M., Yuki Y., Saitou K., Takahashi T., 1995, Methacrylic Type Water Soluble Polymer as High-Range Water Reducing Agent for Ultra High-Strength Concrete, Kobunshi Kagaku, 52(6), 357-363, DOI: 10.1295/koron.52.357

Lange R.G., Schlotthauer H.L., 1980, Plaster composition containing water-reducing agent, DOI: 106/38.35, 106/110, 106/111

Minton A.P., Edelhoch H., 1982, Light scattering of bovine serum albumin solutions: Extension of the hard particle model to allow for electrostatic repulsion, Biopolymers, 21(2), 451-458,

Wachi M., Iijima M., Kojima M., Okada K., Mitsui K., 2005, 1256 Properties of high strength concrete using low viscousity type high-range water reducing agent, Summaries of technical papers of Annual Meeting Architectural Institute of Japan A, 511-512.

Zhang D.F., Ju B.Z., Zhang S.F., Yang J.Z., 2008, The study on the synthesis and action mechanism of starch succinate half ester as water-reducing agent with super retarding performance, Carbohydrate Polymers, 71(1): 80-84, DOI: 10.1016/j.carbpol.2007.05.020

Zhang Q.F., Xie C.Z., 2006, Influence of Fly Ash, Slag and Water-reducing Agent on the Compression Strength of Concrete, Journal of Xiaogan University.