Rheological Properties of Cement Paste incorporating Domestic HWRA for Ultra-high-fluidity concrete

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ABSTRACT

An understanding of rheological property on cement paste is one of the important factor to design concrete such as High-fluidity Concrete (HFC) for a specific application. The HFC is a specially proportioned hydraulic cement concrete that enables the fresh concrete to flow easily into the forms and around the reinforcement and prestressing steel without vibration and segregation. Use of this type of concrete for the concrete building construction, manufacture of precast, prestressed bridge elements provides the benefits of increased rate of production and safety, reduced labor needs, and lower noise levels. This paper presents the performance of rheological properties of cement paste incorporating domestic high-water-reduced-admixture (HWRA) for an Ultra-high-fluidity concrete (UHFC). Investigation was carried out on cement pastes with combinations of various dosages of HWRA and water/cement ratios.

1. Introduction

Concrete in its fresh state can be thought of as a fluid with a certain degree of flow. Early high-fluidity concrete (so called self-compacting concrete (SCC)) was developed in Japan in the late 1980s, and currently, this concrete has gained wide research in Europe and North America. HFC is defined as a new type of concrete that has high fluidity with 600mm ± 50mm of slump flow approximately and resistance to segregation, and can be easily flowed into the forms and around the reinforcement and prestressing steel without vibration. In spite of its wide benefits and widespread use in Japan and Europe, the use of HFC in the Korea has been limited because of concerns about certain mix design, guidelines and construction issues that are perceived to influence the structural integrity. These issues include workability, strength development, creep and shrinkage properties, durability and other factors that influence constructability and performance. Many different investigations have been conducted to develop this type of concrete.

M. Lachemi et al [1] reported the performance of four new polysaccharide-based viscosity modifying admixtures (VMA) in enhancing the rheological and consistency properties of cement pastes. Investigation was carried out on cement pastes with combinations of various dosages of new VMAs and of a superpasticizer (SP) to study the influence on rheology, consistency and washout mass loss. The combined use of proper dosages of VMA and SP is shown to clearly contribute to securing high-performance cement pastes that is highly fluid yet cohesive enough to

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reduce water dilution and enhance water retention. The present work, however, shows an experimental results for rheplogical properties of cement paste for developing of a new concrete, saying Ultra-high-fludity concrete (UHFC), that has a range of slump flow approximately 700-1000 mm.

2. Experimental Program

To design concrete for a specific application or for a desired fluidity without segregation, there are many different procedures to estimate rheological properties depending on factors such as w/c ratio, chemical and mineral admixture dosages. The experimental investigation was carried out on various cement paste mixes with four different High-water-reducer admixtures (0.25, 0.50, 0.75 and 1.0%). In this investigation, both rheological tests and slump-flow test were conducted for measuring the rheology data such as the viscosity, shear stress, shear rate, slump flow and yield stress. Uniaxial tests were also carried out in the present work.

2.1 Materials

In this experimental program, ordinary type I cement with specific gravity of 3.16 and blain fineness of 3548 cm^2/g was used. A high-water-reducer Admixture of polycarbonate condensates having gravity of 1.04, PH=6.7 and total solid content of 19% was used. Physical and chemical properties of cement are shown in Table 1.

Table 1 Chemical and physical properties of cement

Physical Properties			Chemical Properties	
Blaine (㎠/g)	3548		Loss of Ignation	1.84
Consistency (%)	26.3		SiO_2	20.59
Soundness (%)	0.11		Al_2O_3	4.96
Setting time	Initial	213	Fe_2O_3	3.40
(hr:min.)	Final	5:45	CaO	62.04
Pure paste test	5min.	183	MgO	3.47
(mm)	60min	150	SO_3	2.47
Compressive strength	7D	281	Na_2O	0.34
(kg/㎠)	28D	370	K_2O	1.02

2.2 Mix proportions and Tests on Rheological Properties

A total of 20 cement paste mixes were made to investigate the effect of HWRA on rheological properties. HWRA content by weight of cement were determined. The rheological properties of cement paste were measured using a commercially available digital Brookfield Viscometer (Model RVDV-II) equipped with small sample adapter spindle at normal room temperature. The tests were conducted stepwise a 100, 50, 30, 20, 10 and 5 rpm, respectively. At each rotational speed of spindle, torque, shear rate, shear stress and apparent viscosity data were recorded using an acquisition program (Wingather). A truncated conical shape of slump apparatus, 100 mm of bottom diameter, 50 mm height and 70 mm of top diameter, was used. The slump-flow test was used to examine the effect of HWRA content on the fluidity of the cement pastes. All slump-flow tests were carried out at room temperature. The test required small quantity of cement paste and the results could be obtained immediately. Cement was weighed first in a bowl, water and HWRA were weighed and mixed in a beaker. Then cement was poured to beaker and the mixture was

mixed by hand for 3 minutes. The diameter of the spread paste was measured in two perpendicular axes and the average of the two measurements was obtained as slump-flow value.

3. Results and Discussions

3.1 Rheological Properties of Cement Pastes

A typical variations of apparent viscosity with shear rate for cement paste with constant water/cement ratios (w/c=45) and four different HWRA contents is shown Figs. 1. Apparent viscosity decreases with the increase of shear rate. The apparent viscosity is also decreased with the increase of HWRA content within maximum of 1.0%. The apparent viscosity of higher water/cement ratio is less affect by the amount of HWRA than the lower water/cement ratio. This result means that the apparent viscosity of cement paste is more affect by the water/cement ratio than HWRA content. A typical variations of shear stress with shear rate for cement paste with constant water/cement ratio (w/c=45%) is shown in Fig. 2. Shear stress increases with the increase of shear rate. Shear stress decreases with the increase of water/cement ratio. The shear stress is also decreased with the increase of HWRA content. However, the higher the water/cement ratio, the lower the variation of shear stress was observed. Fig 3 shows the yield stress of cement paste with different dosages of HWRA and water/cement ratios. The yield stress is decreased with the increase of dosages of HWRA and water/cement ratio. The rate of decreasing of yield stress about increasing of HWRA content and W/C ratio, However, is getting narrowed. The most commonly-used model is the Bingham equation that requires two parameters, i.e., yield stress and the plastic viscosity for estimating rheological properties. Fig. 4 shows that shear stresses determined by Bingham equation are compared with empirical results. Based on the comparison, it would be concluded that the rheoligical test results well can be represented by the Bingham equation.

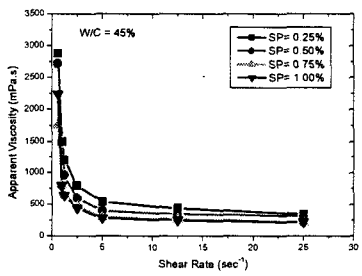

Fig. 1 A typical variation of Apparent viscosity

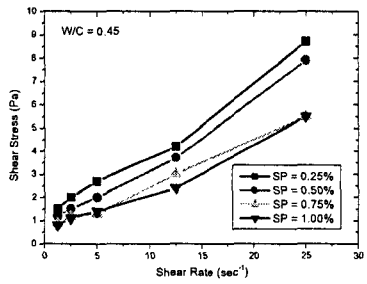

Fig. 2 A typical variation of shear stress

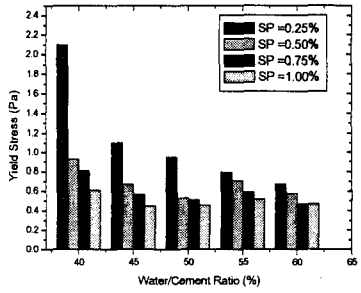

Fig. 3 Variation of yield stress with w/c ratio

3.2 Fluidity of Cement Pastes

Fig 5 shows the variations of slump-flow value with different dosages of HWRA and water/cement ratios. The fluidity of the higher water/cement ratio is much better than the lower water/cement ratio. The slump-flow values having more than 0.5% of HWRA content are not significantly affect by the dosage of HWRA content, and showed almost same values with the water/cement ratio over 50%. Fig. 6 shows a plot of yield stress versus slump-flow value

(diameter). This plot shows that the yield stress is increased with the decrease of slump-flow value under constant water/cement ratio.

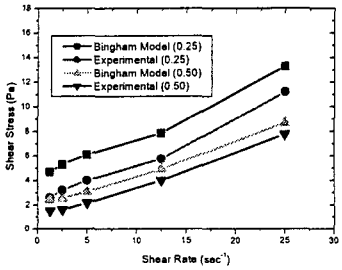

Fig. 4 Comparison of shear stress with Bingham equation

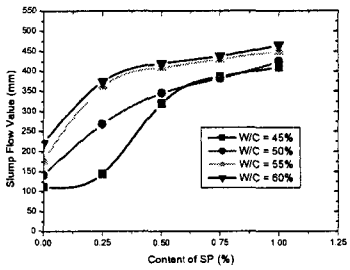

Fig. 5 Variation of slump-flow value with HWRA content

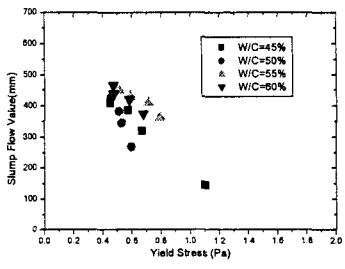

Fig. 6 Correlation between yield stress and viscosity

4. Conclusions

This paper has presented a comprehensive experimental study on rheological properties of cement paste with different dosages of HWRA content and water/cement ratio. Based on the experimental results and data analysis, the following conclusions are drawn:

1. Apparent viscosity decreases with the increase of shear rate. The apparent viscosity is also decreased with the increase of HWRA content within maximum of 1.0%. The apparent viscosity of higher water/cement ratio is less affect by the amount of HWRA than the lower water/cement ratio. This result means that the apparent viscosity of cement paste is more affect by the water/cement ratio than HWRA content.
2. Shear stress increases with the increase of shear rate. Shear stress decreases with the increase of water/cement ratio. The shear stress is also decreased with the increase of HWRA content. However, the higher the water/cement ratio, the lower the variation of shear stress was observed.

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References

1. M.Lachemi, K.M.A Hossain, V. Lambros, P-C. Nkinamubanzi, and N. Bouzoubaa, Seif-consolidating concrete incorporating new viscosity modifying admixtures, Cement and Concrete Research, 34 (2004), 917-926
2. P. Mitschka, Simple conversion of Brookfield R.V.T readings into viscosity functions, Rheol. Acta 21 (1982), 207-209
3. M.Lachemi, K.M.A Hossain, V. Lambros, P-C. Nkinamubanzi, and N. Bouzoubaa, Performance of new viscosity modifying admixtures in enhancing the rheological properties of cement paste, Cement and Concrete Research, 34 (2004), 185-193