A STUDY OF PROPERTIES OF FLY ASH BLENDED SELF-COMPACTING CONCRETE AT LOW TEMPERATURE

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1. INTRODUCTION

Self-compacting concrete (SCC) has been extensively used in many countries. In Mongolia, on the contrary, SCC is still rarely used at present time, although the country is experiencing a rapid growth of construction. Lack of labor force due to the limited population is an obstacle for constructions in Mongolia. Introduction of SCC can be a possible solution, but its high material cost is unaffordable. Mongolia, in addition, is facing air and soil pollutions caused by fly ash (FA). A bulk amount of FA is discharged from coal power plants every year but appropriate disposal or utilization is limited. The aforementioned problems can be alleviated if FA is used as mineral admixture in SCC. The biggest challenge for FA-blended SCC, however, is the low ambient temperature in Mongolia.

In this study, the properties of fly ash blended SCC at low temperature were studied in details by testing slump flow and its loss with time, flow time by v-funnel, air content, setting time, shrinkage, and compressive strength at different ambient temperatures. Moreover, comparison of Japanese and Mongolian fly ashes were done for their reactivity by conducting thermal gravimetric analysis (TG) and XRD/Rietveld analysis to obtain the content of calcium hydroxide in the paste at different temperatures, in order to seek possible implementation of FA-blended SCC into Mongolia

2. EXPERIMENTAL PROGRAM

The experimental program consists of three main stages that are listed below. Ordinary Portland cement was used and a type of Japanese II FA was blended with the ratio of 20% by weight. A type of superplasticizer that is often used for making SCC was adopted. The mix proportions and the environment temperatures were shown in Table 1.

(1) Fresh concrete properties

For fresh properties, slump flow, v-funnel time, air content, and setting times were tested and during certain time periods for each test they were repeated after storing at 5ºC, 10ºC, 20ºC. Then, the results were compared and discussed with those of the SCC without FA at 20ºC.

Table 1 Mixtures tested in fresh and hardened properties.

No.	Group Name	w/b	Weight per volume of concrete (kg/m^3)					
			W	C	S	G	FA	SP
1	OPC-20ºC	0.35	175	500	857	770	0	4
2	FA-20ºC		175	400	857	770	100	4
3	FA-10ºC		175	400	857	770	100	4
4	FA-5ºC		175	400	857	770	100	4

(2) Hardened concrete properties

For hardened properties, the tests of compressive strength at 7 days and 28 days for the each three curing conditions same as above and drying shrinkage tests for mixture No 1, 2 were performed according to Table 1.

(3) Comparison of the reactivity of two fly ashes

Pastes were made by mixing cement with 20% Japanese and Mongolian FA by weight, respectively, and water. After 28 days, the pastes were crushed into pieces and hydration was stopped by immersing the pieces into isopropanol for 3 days. Then the pieces were dried by vacuum and grinded into powder. The powders were analyzed by TG and XRD/Rietveld, respectively. The content of calcium hydroxide in the cement pastes were obtained from TG and XRD/Rietveld, respectively, and were compared for these two pastes. Test specimen details are listed below in Table 2.

Table 2 Pastes analyzed by TG and XRD/Rietveld

No.	Group Name	FA type	FA ratio by weight of total binder	Curing Temp.
1	jFA10	Japanese Type II	20%	10 ºC
2	JFA20			20 ºC
3	jFA40			40 ºC
4	mFA10	Mongolian PPT IV		10 ºC
5	mFA20			20 ºC
6	mFA40			40 ºC

By using TG-DTA test, total % of $Ca(OH)_2$ in the paste can be analyzed due to decomposition of Portlandite ($Ca(OH)_2$) to Ca and H_2O which results mass declines during temperature from 400 to 550ºC.

In the XRD/Rietveld analysis, only crystal materials can be tested by XRD and since C-H-S is not crystal, its value can be extracted from calculation based on the difference between original weight and tested crystal material weights. After analyzing intensity of X-ray for different chemical components, total % of $Ca(OH)_2$ can also be extracted so that it can be compared with previous test result and analyzed.

3. RESULT and DISCUSSION

(1) Performance of fresh concrete

According to Fig.1, due to ball bearing effect created by spherical shape of FA, flowability of SCC with 20% FA was 6% higher than mixture without FA. Since all mixtures used same mixture ratios, air content of the four mixtures were similar that was around 4.5%.

Moreover, it is observed that when curing temperature decreased, it resulted longer initial setting time of FA-

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blended SCC and it is shown in the Fig. 2.

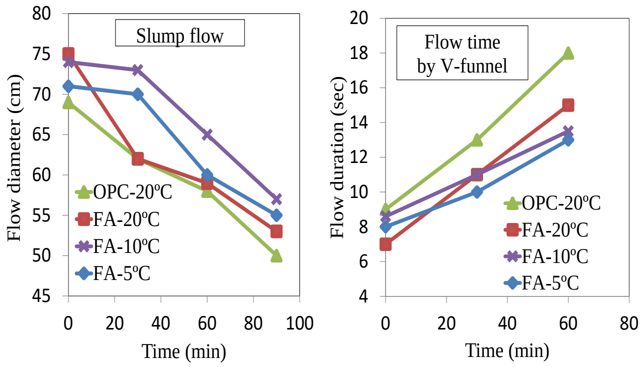

Fig. 1 Flow and V-funnel test results

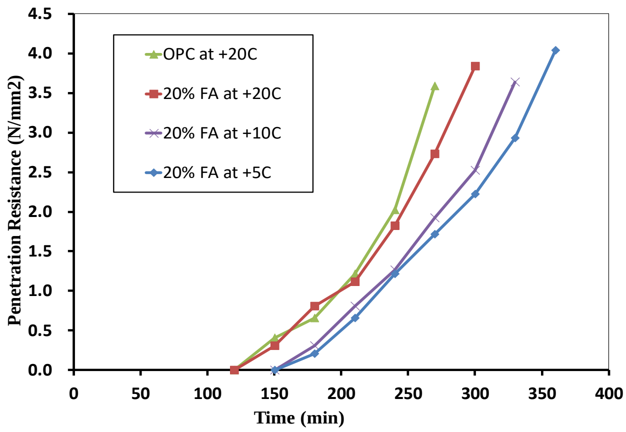

Fig. 2 Setting time test results

(2) Performance of hardened concrete

In case of strength development, according to Fig. 3, if curing condition was same as 20ºC, 20% FA content did not reduce compressive strength significantly. On the contrary, low curing temperature results significantly lower compressive strength.

Due to gradual pozzolanic reaction of fly ash after hydration products formed and low w/c ratio (0.35), initial drying shrinkage in the hardened concrete was reduced. Therefore, the FA-blended SCC shows less drying shrinkage than SCC without FA.

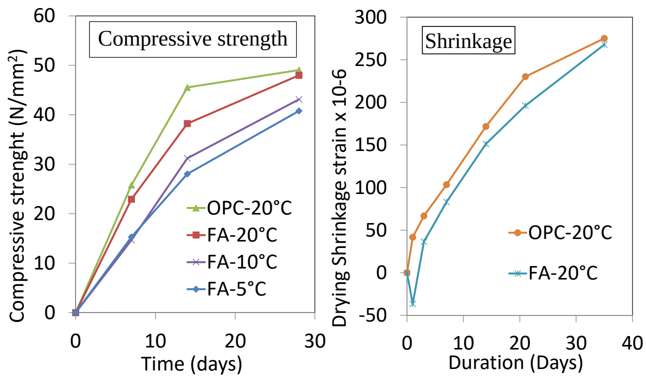

Fig. 3 Compressive strength and shrinkage test results

(3) Comparison of two fly ashes

After analyzing TG-DTA and XRD/Rietveld test results, similar behavior is clearly observed in terms on $Ca(OH)_2$% of both Japanese and Mongolian fly ashes according to Fig. 4. Both test results showed that minimum value of $Ca(OH)_2$ was at 40ºC which is due to more active fly ash pozzolanic reaction and it consumed more $Ca(OH)_2$ than 20ºC and 10ºC.

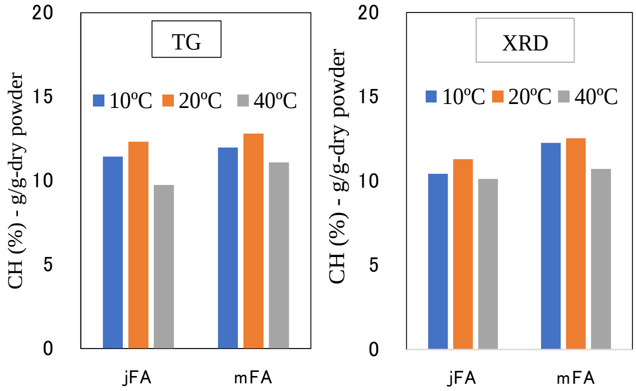

Fig. 4 $Ca(OH)_2$ obtained from TG and XRD

Since $Ca(OH)_2$% value is depends on how much OPC hydration produces and same time how much fly ash pozzolanic reaction consumes, it can be implied that influence difference between Japanese and Mongolian fly ash on OPC hydration degrees is not so significant.

4. CONCLUSION

After researching and analyzing test results of this thesis, it can be concluded that FA-blended SCC can be used in the low ambient temperature. Furthermore, fly ash improves flowability of SCC and low temperature results low flow loss but drawbacks of using fly ash in low temperature which are a retarded setting time and reduced initial strength shall be carefully handled during concrete work and after by using closure curing method.

Since comparison between Japanese Type II fly ash used for actual fresh and hardened properties testing of this study and Mongolian PPT IV fly ash shows similarity in terms of their influence on OPC hydration, hardened properties of this research work can be achieved in case of using actual Mongolian fly ash. That leads to possible implementation FA-blended SCC to Mongolian construction where previously mentioned problems are challenging.

Consequently, testing by selective dissolution method for the reaction degree of FA shall be conducted and mock up testing by using all local raw materials of Mongolia shall also be carried out in the batching plant then Mongolian national standard would be developed for FA-blended SCC in the near future.

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