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# Sulfate and Chloride Resistance of High Fluidity Concrete including Fly Ash and GGBS for NPP

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## 1. Introduction

Fly ash mixed concrete has been used for NPP concrete structures in Korea in order to prevent aging and improve durability since the Shin-Kori #1,2 in 2005. Concentrated efforts to develop technology for the streamlining of construction work and to affect labor savings have been conducted in construction. The application of high fluidity concrete for nuclear power plants has been the research subject with the aim of further rationalization of construction works. Since high fluidity concrete can have the characteristics of high density and high strength without compaction. However, high fluidity concrete can cause thermal cracking by heat of hydration [1]. For this reason, the amount of pozzolan binder should be increased in high fluidity concrete for nuclear power plants [2]. In this study, the resistance of high fluidity concrete on sulfate and chloride was compared with that of the concrete currently using for nuclear power plants.

## 2. Assessment contents and methods

To assess the sulfate and chloride resistance of high fluidity concrete, specimens were prepared by mix conditions and verification tests were done on salt damage and sulfate attack resistance. The test conditions and the properties of the binder used in the tests for the concrete assessment are as shown in Table 1 and Table 2. River sand was used as the fine aggregate and crushed stones with maximum size of 20 mm were used as the coarse aggregate.

Table 1. Concrete test categories and conditions

| Category | Test conditions |
|---|---|
| Sulfate resistance | ASTM C 1012 (10% $Na_2SO_4$ solution) |
| Chloride penetration | ASTM C 1152, 1218<br>KS F 2713, 2714, 2715 |

Table 2. Properties of binders

| Binder | Specific gravity | Fineness (㎠/g) |
|---|---|---|
| Cement (Type I) | 3.15 | 3,720 |
| Fly ash | 2.30 | 3,210 |
| Blast furnace slag | 2.93 | 6,000 |

Three mix proportions as Table 3 were used in this study. KNC is the concrete currently using for nuclear power plants and HFP and HFM are high fluidity concrete. Polycarboxylate superplasticizer is added in HFP concrete, and melaminic superplasticizer is added in HFM concrete.

Table 3. Mix proportion

| Mix | | HFP | HFM | KNC |
|---|---|---|---|---|
| Water binder ratio (%) | | 37 | 38 | 39.4 |
| S/a(%) | | 53 | 53 | 42 |
| unit weight (kg/㎥) | Water | 185 | 190 | 185 |
| | Cement | 200 | 200 | 376 |
| | Fly ash | 100 | 100 | 94 |
| | Blast furnace slag | 200 | 200 | - |
| | Superplasticizer | 6.5 | 10.5 | 2.82 |
| | Viscosity agent | 0.25 | 0.25 | - |

The specimens were prepared for the concrete quality assessment in consideration of the test categories and mixes are as Table 4.

Table 4. Concrete specimens

| Mix | HFP | HFM | KNC | Size (cm) |
|---|---|---|---|---|
| Sulfate resistance | 6 | 6 | 6 | 10x10x15 |
| Chloride penetration | 6 | 6 | 6 | 10x10x15 |

### *2.1 Sulfate Attack Resistance*

As specimens for the sulfate attack resistance, 6 specimens for each mix were prepared by using 10 × 10 × 40cm molds. These were released after one day of casting and put through a standard curing for 28 and 91 days in water at 23℃.

The testing was done in accordance with ASTM C 1012 (Test Method for Length Change of Hydraulic Mortars Exposed to Sulfate Solution). Although a 5% sodium sulfate ($Na_2SO_4$) was used in ASTM C 1012. In this test, however, a 10% solution was used to provide the more accelerated condition. The length change measurements were taken at days 28, 60 and 91.

### *2.2 Chloride ion penetration*

As specimens for the salt damage, 6 specimens for each mix were prepared by using 10 × 10 × 15cm molds. These were released after one day of casting and put through a standard curing for 28 and 91 days in water at 23℃. Moreover, to induce the chloride ion penetration in one direction, five sides were coated with epoxy.

It is known that corrosion due to chloride ion occurs most quickly at 3.6% chloride concentration. Therefore, in this test, a 3.6% NaCl solution was used, and then after 28, 60 and 91 days of immersion, the chloride ion concentration was measured in accordance with KS F 2713, 2714, 2715 and ASTM C 1152, 1218.

## 3. Results and discussion

### *3.1 Sulfate Attack Resistance*

The results of sulfate attack resistance test implemented after 28 days of curing are presented in Fig. 1. The expansion strain of HFP and HFM concrete was shown to be bigger than that of KNC concrete. Fig. 2 shows sulfate attack test results by age from the testing done after 91 days of curing. The concrete cured for 91 days was shown to have increased resistance in comparison with the concrete cured for 28 days. It is deemed that this is due to the sulfate ion penetration inside the concrete being inhibited by the increased water-tightness of the concrete resulting from strength increase. In addition, KNC is shown to have batter sulfate attack resistance than the other types of concrete.

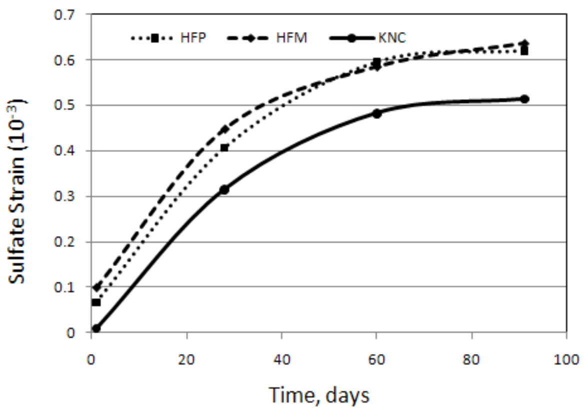


Fig. 1 Sulfate resistance after 28 days curing

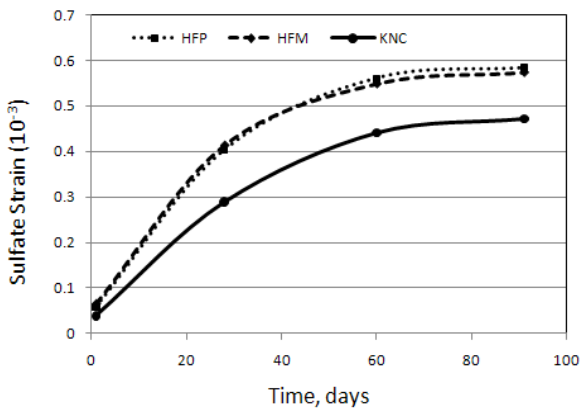


Fig. 2 Sulfate resistance after 91 days curing

### *3.2 Chloride ion penetration*

The results of the chloride ion penetration test implemented after 28 days of curing are presented in Fig. 3. From the results, the salt content for KNC was measured to be higher than for other concrete. Fig. 4 shows results by age from the testing done after 91 days of curing. From the test results, the salt content was measured higher for KNC in comparison with the other types of concrete. When the impact of the curing age is considered, a large difference was shown between the salt diffusion coefficients for the ages of 28 days and 91 days. This occurs because the chloride ion penetration is deemed to be inhibited by the increased concrete density resulting from the greater concrete strength due to the longer curing period.

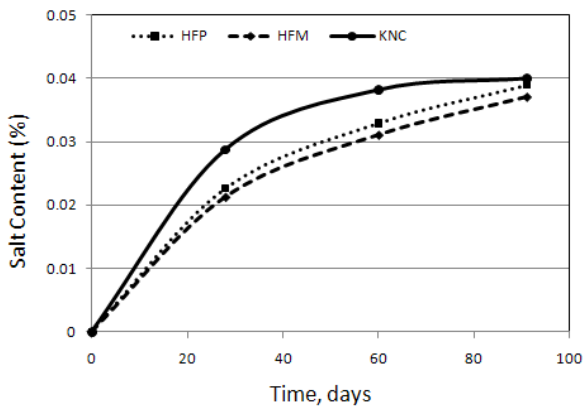


Fig. 3 Chloride ion content after 28 days of curing

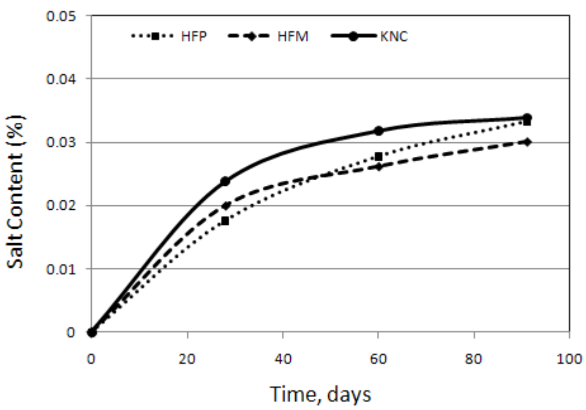


Fig. 4 Chloride ion content after 91 days of curing

## 4. Conclusions

High fluidity concrete, HFM and HFP, containing fly ash and blast furnace slag was shown to have the better durability against chloride ion penetration than KNC, but relatively low sulfate resistance. In addition, there is no significant difference on sulfate and chloride resistance as changing superplasticiser type.

## REFERENCES

[1] A. M. Neville, 'Properties of Concrete', Pitman Press, 1981

[2] Masahiro Ouchi, Yoshimitsu Nakajima, 'A Guide for Manufacturing and Construction of Self-Compacting Concrete - Learning from Real Troubles', CMOS Engineering Corporation, Japan, 2001