Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

Mechanical and Thermal Properties of Concrete of Reactor Containment Building as using Different Cement

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1. Introduction

Korean Nuclear Power Plants (NPPs) are located along the seashore and the structures are made up of massive concrete of great dimension. In this regards, a low-heat and high sulfate-resistant portland cement mortar (Type V) has been widely used to reduce the heat from hydration which generally causes shrinkage and temperature crack. Questions, however, have been raised over the efficiency of Type V cement against the chloride attack, one of the major degradation mechanisms of the reinforced concrete structures at the seashore despite the superior sulfate resistance of Type V cement with low content of C_3A. Accordingly, the standard specifications of Korea Concrete Institute were revised in 1996 in order to limit the use of Type V cement in the construction of marine concrete structures. In this regard, Korea Hydro& Nuclear Power Co. (KHNP) performed an evaluation on durability and mechanical characteristics over various types of concrete mixtures and decided to apply fly ash cement, consisting of ordinary portland cement (OPC, 80%) and fly ash (20%), to the Shin-Kori (SKN) 1&2 NPP construction project.

In this study, an evaluation of the mechanical properties and thermal characteristics of reactor containment building (RCB) concrete has been performed for two types of concretes: Type V cement used for Ul-Chin(UCN) 5&6 NPP and the fly ash cement used for SKN 1&2 NPP.

2. Experimental Investigation

2.1 Material

2.1.1 Cement

For RCB concrete, sulfate resistance portland cement (Type V) and OPC(Type I) are used for UCN 5&6 NPP and SKN 1&2 NPP, respectively.

2.1.2 Aggregate

Fine aggregates used for UCN 5&6 and SKN 1&2 NPPs are natural sands from the Gagok stream in Sam-Chok and Naksan, Gumi, respectively. Coarse aggregates are the crushed stone of maximum size 3/4" from the NPP construction site.

2.1.3 Fly Ash

Fly-ash for SKN 1&2 NPP RCB concrete was manufactured at Samchunpo Thermal Power Plant in accordance with ASTM C 618 Class F.

2.2 Mix proportion

Mix proportions for RCB concrete of UCN 5&6 and SKN 1&2 are determined through test mix proportions. The procedures of test mix proportions are based on ACI 211.1 to meet the criteria of ACI 349, ACI 211.1 and design compressive strength (5500psi at 91 days). Table 1 shows the mix proportions.

Table 1. Mix Proportions of Concrete for Reactor Containment Structure of UCN 5&6 and SKN 1&2.

NPP Units	Specified Strength (psi)	W/B	S/a (%)	Air (%)	Slump (in)	Unit Weight (lb/yd^3)					Chemical Agent (oz)	
						Cement Material		Water	Aggregate			
						Cement	Fly Ash		Fine	Coarse	WRA	AEA
UCN 5&6	5,500	0.45	0.43	3.5~6.5	3±1	632	-	276.3	1250	1682	40.46	0.46
SKN 1&2	5,500	0.45	0.44	3.5~6.5	4±1	493	123	277	1274	1635	39.42	1.48

2.3 Test Method

2.3.1 Compressive Strength and Modulus of Elasticity

Compressive strength and modulus of concrete elasticity were tested with cylindrical specimen (15x30cm) at age 7, 28, 91, 180 days and 365 days as defined in the criteria of ASTM C 39 and C 469, respectively. All specimens were moist-cured with temperature 23±1.7℃ during the test period.

2.3.2 Thermal Expansion Coefficient

Thermal expansion coefficient was tested with cylindrical specimen (15x30cm) at age 28, 91 and 365 days in accordance to the criteria of CRD C. Test specimens are moist-cured with temperature 23±1.7℃ during the test period.

3. Results and Discussion

3.1 Compressive Strength

Figure 1 shows the compressive strength of UCN 5&6 and SKN 1&2 RCB concretes.

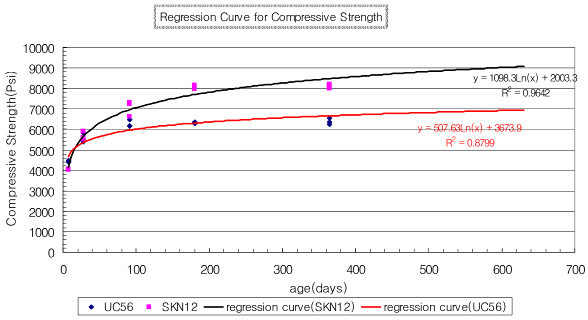

Fig. 1 Compressive Strength of Concrete

The compressive strength of concrete with Type V cement is higher than OPC with fly ash (OPC+FA20) in early age. After age 28 days, as previous studies, compressive strength of concrete with OPC with fly-ash is higher than Type V cement because of effect of filling up large capillary voids with C-S-H hydrates that were produced by Pozzolanic reaction of fly-ash.

The compressive strength of all specimens at age 28 days exceeds the design compressive strength (5500psi at 91 days). As the result of the test, it is supposed that tested mix proportions are governed with the durability criteria of ACI 349 and 301 though the reference design age of specified compressive strength development is 91 days due to reduce the hydration heats and drying shrinkage.

3.2 Modulus of Elasticity

The test results of modulus of elasticity for RCB concrete of UCN 5&6 and SKN 1&2 NPPs are showed in figure 2.

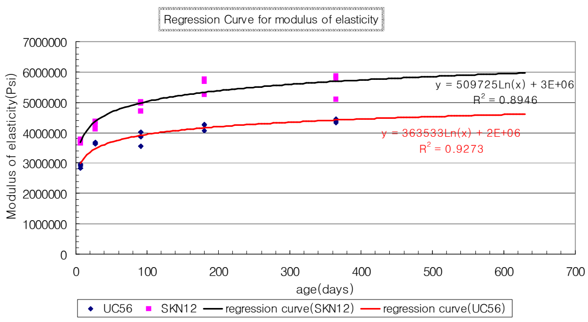

Fig. 2 Modulus of Elasticity of Concretes by using Cement Types

The test results show that modulus of elasticity of concrete using OPC with fly ash is higher than that of the concrete using Type V cement. It doesn't correspond with the tendency of similar studies. Also, the modulus of the elasticity of concrete using Type V does not meet the designed value (4,227 ksi at 91 days) for 1 year after mixing. In this reason, further study is needed to evaluate the effect of concrete using Type V cement on soundness of concrete structure.

3.3 Thermal Expansion Coefficient

The test results of thermal expansion coefficient for RCB concrete of UCN 5&6 and SKN 1&2 NPPs are shown in table 2. It is observed that thermal expansion coefficient of concrete with OPC with fly ash is lower than that of concrete using Type V cement at all time. The thermal expansion coefficients for the both cases at 91 days are lower than the designed value (5.56x10^{-6} in/in/°F). This means that the deformation of concrete due to the increase of temperature is reduced compared with considered deformation in design stage. In this regards, it is supposed that there is no influence on the concrete structures.

Table 2. Thermal Expansion Coefficient of Concrete
(unit : x10^{-6} in/in/ °F)

Curing Age (days) / NPP Units	28	91	365
UCN 5&6	**4.54**	**5.02**	**5.39**
SKN 1&2	**2.8**	**3.0**	**3.9**

4. Conclusion

The test results can be summarized as follows :

(1) Compressive strength of concrete with Type V cement was higher than that of concrete with OPC with fly ash in early age (under 28 days of age). However, fly ash concretes have higher ultimate strength, which is consistent with many other existing research results. And all of compressive strength satisfy the design criteria in 28 days of age.

(2) Modulus of elasticity of concrete with OPC with fly ash was higher than concrete with Type V cement at all ages. Further study is needed to evaluate the effect of concrete using Type V cement on soundness of concrete structure because modulus of elasticity of concrete with Type V was lower than specified value.

(3) Thermal expansion coefficient of concrete with OPC was lower than that of concrete with Type V cement at all time. The thermal expansion coefficients for the both cases at 91 days were lower than the designed value. It means that the deformation of concrete due to the increase of temperature is reduced compared with considered deformation in design stage.

References

[1] Korea Concrete Institute, "Standard Specifications for Concrete," 2003.
[2] Korea Hydro & Nuclear Power Co. Ltd., "Durability Improvement of NPP Concrete Structures through the Alteration of Cement Type," A00NJ13, 2002. 3.
[3] Korea Institute of Nuclear Safety, "Regulatory Analysis of the Technical Issues Related to the Concrete Structures in NPPs," KINS/RR-161, 2002. 12.