Evaluation of the Compressive Strength of Concrete of Reactor Containment Building in Shinwolsong Unit 1&2 NPP

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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, therefore a sulfate resistance cement (ASTM C150, Type V) has been applied to the NPP structures in order to reduce the temperature and shrinkage crack due to the heat of hydration. Questions, however, have been raised over the efficiency of Type V cement against the chloride ion, the major substances found in seawater, despite the superior sulfate resistance of Type V cement with low content of C_3A.

Hence, ordinary portland cement (ASTM C150, Type I, OPC) with 20% of the total cement weight replaced by fly ash (FA) has been used since the construction of Shinkori nuclear power plant units 1&2 (SKN 1&2). In this study, concrete samples, with the same mix proportions, from Shinwolsong nuclear power plant units 1&2 (SWN 1&2) and SKN 1&2 were compared to each other in order to offer basic data for the future design & construction of reactor containment building (RCB) and to confirm the appropriateness of concrete quality control of SWN 1&2.

2. Experimental Investigation

2.1 Materials

2.1.1 Cement

Cement used to RCB in SWN 1&2 & SKN 1&2 is OPC of "D" company (Density 3.15 g/cm^3, Fineness 3414 cm^2/g, C_3A 8.13%).

2.1.2 Aggregates

The fine aggregates used for the RCB of SWN 1&2 and SKN 1&2 are river sands from Hyeonchang, Changnyeong-gun and Naksan, Gumi-si, respectively. The coarse aggregates used for the RCB of SWN 1&2 and SKN 1&2 are crushed stone with G_{max} 3/4" produced at each construction sites. Table 1 shows physical properties of aggregates.

2.1.3 Fly Ash

Fly ash produced from Samchunpo thermoelectric power plant products that satisfy ASTM C 618, quality essential requirement of class F were used for the RCB of SWN 1&2 & SKN 1&2.

Table 1. Physical Properties of Aggregates

NPP Units	Aggregate Size	Density (g/cm^3)	Absorption (%)	Fineness Modulus	Unit Weight (kg/m^3)	Abrasion (%)
SWN 1&2	Fine	2.53	1.54	2.70	1,574	-
	Coarse (G_{max} 3/4")	2.64	0.60	6.60	1,580	9.6
SKN 1&2	Fine	2.63	1.40	2.70	1,554	-
	Coarse (G_{max} 3/4")	2.79	0.75	6.67	1,617	8.7

2.2 Mix Proportions

The mix design of RCBs in SWN 1&2 & SKN 1&2 was performed according to procedure of ACI 211.1 and the requirements of ACI 349 Code and ACI 301 Specifications. Compressive strength 5500psi, a slump 4±1 inch and an air contents 4.5±1 % were satisfied in accord to the requirements. Table 2 shows mix proportions of concrete of RCB.

Table 2. Mix Proportions of Concrete for RCB

NPP Units	Specified Strength (psi)	W/B	S/a (%)	Unit Weight (lb/yd^3)				
				Cementitious Material		Water	Aggregate	
				OPC	FA		Fine	Coarse
SWN 1&2	5,500	0.44	0.42	520	130	286	1210	1697
SKN 1&2	5,500	0.45	0.44	493	123	277	1274	1635

2.3 Test Method

2.3.1 Compressive Strength

The compressive strength test of Cylindrical Concrete Specimens ϕ 15×30cm according to ASTM C 39 was performed at 7days, 28days and 91days. Moist curing was enforced at 23±1.7℃ when the compressive strength test was accomplished.

2.3.2 Strength Control

For quality control of concrete, every 100yd^3 specimens were made and 91days compressive test results according to ACI 214R were evaluated with $\overline{X}$-R control chart after calculating standard deviation (s) and coefficient of variation (V_1).

Standard deviation $s = \sqrt{\dfrac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}}$ (1)

Coefficient of variation $V_1 = \dfrac{s_1}{\overline{X}} \times 100$, $s_1 = \dfrac{1}{d_2} \times \overline{R}$ (2)

where, s : sample standard deviation, s_1: sample within-test standard deviation, V_1 : within-test coefficient of variation, X_i : strength test result, $\overline{X}$: average of strength test results, d_2 : factor for computing within-test standard deviation from average range, $\overline{R}$: average range.

3. Results and Discussion

3.1 Compressive Strength

Fig. 1 shows compressive strength of the RCB concrete samples from SWN 1&2 & SKN 1&2.

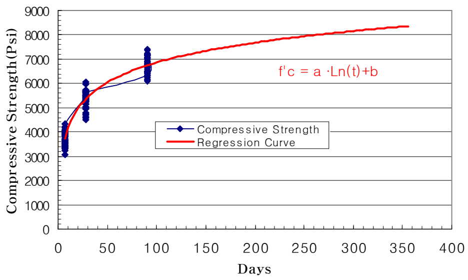

Fig. 1 Compressive Strength of Concretes

The compressive strength of the concrete samples increases with the age of concrete according to this result. As a result of regression analysis, the correlation coefficient (R) of compressive strength is greater than 0.93 and a regression graph formula as follows:

$$f'c = a \cdot \mathrm{Ln}(t) + b \quad (3)$$

where, f' c : compressive strength(psi), t : age(days),
a,b : coefficient value (ref. Table 3)

Table 3. Regression Analysis Results of Compressive Strength

NPP Units	Correlation Coefficient(R)	Standard Error	Coefficient Value	
			a	b
SWN 1&2	0.9314	338.48	1181.2	1420.5
SKN 1&2	0.9483	313.64	1272.5	813.89

The concrete compressive strengths of SWN 1&2 and SKN 1&2 containment buildings exceeded the design strength of 5500psi after 28days. The concrete compressive strength of SWN 1&2 appeared greater than SKN 1&2 about 1～4%(40～200psi).

3.2 Compressive Strength evaluation for quality control

Fig.2 shows normal frequency curves and quality control chart of compressive strength for the RCB concrete samples of SWN 1&2 at 91days. For the RCB concrete samples of SWN 1&2, the average compressive strength ($\overline{X}$ =6750psi) exceeded the design strength (f_{ck}=5500psi) about 22.7% with standard deviation of 349.4psi (s=349.4psi) and coefficient of variation 1.6% (V_1=1.6%). This is the level of "Excellent" (classification of ACI 214R). Also, the entire control test values from the $\overline{X}$-R control chart by $\overline{X}$ ±3s didn't deviate the extent between upper limit (UCL) and lower limit (LCL). This shows that quality control was properly performed with stable values from the tests.

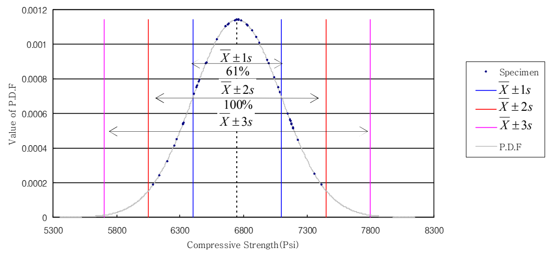

Fig. 2 Normal Frequency Distribution Curve of Compressive Strength in SWN Unit 1&2

4. Conclusions

The evaluation of compressive strength of concrete of SWN 1&2 can be summarized as follows :

(1) The compressive strengths of the RCB concrete samples from SWN 1&2 and SKN 1&2 exceeded the design strength of 5500psi after 28days. Considering W/B and cement portion, it is conformed that the concrete compressive strength of the RCB of SWN 1&2 and SKN 1&2 are different a little (within 4%).

(2) The average compressive strength exceeded the specified strength about 22.7% with standard deviation of 349.4psi and coefficient of variation 1.6%. This is the level of "Excellent" (classification of ACI 214R). Also, the entire control test values from the $\overline{X}$-R control chart by $\overline{X}$ ±3s didn't deviate the limitation between upper limit (UCL) and lower limit (LCL). This shows that quality control was properly performed with stable values from the tests.

References

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