Experimental Study on Creep Characteristics of Concrete for Reactor Containment Structure

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1. Introduction

Most of the reactor containment structures of nuclear power plants are the seismic first class structures that have to secure maximum safety and are composed of pre-stressed concrete structures. So, it is very important to decide the loss of pre-stressing force and pre-stressing force of tendon during post-tensioning by comparing assumed values with actual measurement values and investigating the time-dependant characteristics of concrete. In this study, compressive strength, modulus of elasticity, and creep tests were performed using concrete specimens in constructing the reactor containment structures. These results will contribute to design, construction, and safety of reactor containment structures based on a post-tension system.

2. Test procedure

2.1 Materials and test conditions

2.1.1 Materials

Ordinary Portland cement type Ⅴ(Sulfate resist), fine aggregate and coarse aggregate in Nam Dea-Cheon, North Korea were used to make concrete. AE agents and water-reducing admixture were used as admixture.

2.1.2 Mix design for concrete

Table 1 summarizes the mix design for the concrete whose compressive strength at age of 28 days is 5,500psi.

Table 1-a. Mix design

Max Aggregate Size 3 / 4”	Slump 4”± 1”	Air Content (%)	W/C (%)	S/A (%)
19	10	5.0	45	43.0

Table 1-b. Mix design

Quantities(lb/cy)					
W	C	S	G	AEA	WRA
272	604	1,277	1,692	0.0242	2.718

2.1.3 Creep test conditions

Creep test was carried out according to standard test method of the ASTM C512 under the conditions like curing temperature, humidity and ages at loading etc. shown in Table 2.

Table 2-a. Creep test conditions

Curing Temp.	Humidity	Temp.	Ages at Loading (Day)	Correction of Loading
23±2 ℃	50±4%	23±2 ℃	7, 28, 91 180, 365	When it Changes over 2%

Table 2-b. Creep test conditions

Cycle of Measurement (Day)
Before Loading, After Loading (2~6 hours) 1,2,3,4,5,6,7 Days, 2,3,4 Weeks Every Month………..1 Year

2.2 Method of the test

2.2.1 Compressive strength, Modulus of elasticity and Poisson’s ratio

The compressive strength of concrete was measured at ages of 7, 28, 91, 180 and 365 days according to ASTM C 31. For each age, total three 150mm by 300mm cylindrical concrete specimens were prepared and tested under the curing temperature of 23±2℃ in the humidifier chamber. Modulus of elasticity and Poisson’s ratio are measured from the tests using the load at longitudinal strain 0.00005 and the 40% of ultimate load for the three specimens according to ASTM C469

2.2.2 Creep tests

Creep test means the relationship between time dependant load and compressive strain. It was measured at each age according to ASTM C 512. Seven 150mm by 300mm cylindrical concrete specimens were tested for one year. Three of them were used to measure compressive strength and the others were used to measure creep and dry shrinkage deformation. Strain of creep is defined by subtracting initial elastic strain under loadings and dry shrinkage strain from measured total strain. Creep strain per unit stress(specific creep) was measured at a specific age.

3. Test results and discussion

3.1 Compressive strength, Modulus of elasticity and Poisson's ratio

The compressive strength tends to increase gradually in time. The 28-day compressive strength is 5,550psi which is averaged from three specimens. This is larger than the standard design strength, 5,500psi. Modulus of elasticity is also larger than the standard design value, 290,000kg/cm^2. Poisson's ratio remarkably exceeds standard design value 0.15. Therefore, all these values are safe when they used in design. These test results are shown in Table 3.

Table 3. Measured σ_{ck}, E and μ in curing ages

Days	7	28	91	180	365
σ_{ck} (psi)	3,626	5,550	7,027	7,277	7.290
E(psi)	2,880,900	3,597,600	4,313,400	4,668,900	4,697,300
μ	0.16	0.17	0.19	0.21	

3.2 Creep

Figure 1 shows the test results on specific creep according to different ages of loadings. It can be seen that creep strains increase dramatically up to one month, and then increase smoothly with ages. The more days increase, the more specific creep decrease. Numerical analysis was carried out by HANSEN model equation (equation 1) about test results, and the coefficient A=1.069E-7 and B=1.962E-7 were obtained.

$$\frac{\varepsilon_c}{f_c} = A\left[1 - e^{-\frac{1}{30}(t - t_o)}\right] + B\log 10\frac{t}{t_o} \qquad (1)$$

$\frac{\varepsilon_c}{f_c}$: Specific creep ($\times$ 10^{-6}) [psi^{-1}]

f_c : Stress of concrete [psi]

ε_c : Strain of concrete according to time

t : Curing ages of concrete [days]

t_o : The time at initial loading [days]

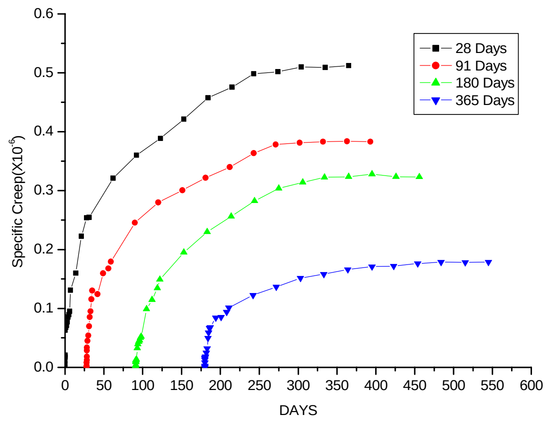

Figure 1. Specific creep from creep tests

4. Conclusion

In this study, to investigate mechanical characteristics of concrete, tests were performed on creep, compressive strength, modulus of elasticity, and Poisson's ratio. The following can be concluded.

(1) The compressive strength increases as days increase. The 91-day compressive strength is far lager than standard design strength, 5,500psi. Modulus of elasticity increases dramatically at the beginning state, but increases smoothly after 180 days where the value exceeds the standard design one.

(2) Numerical analysis using test results shows that specific creep value, 4.2E-7 after 40 years is less than the standard design one, 5.0E-7.

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