PREDICTION OF LONG TERM CREEP BEHAVIOR OF CONCRETE FOR DECOMMISSIONING WASTE DISPOSAL CONTAINER

Jong-Bum Kim[a*], S.K. Kim[a], K.S. Seo[a], J.C. Lee[a]
[a]*Korea Atomic Energy Research Institute, Daedeok-daero 989-111, Yuseong-gu, Deajeon, Korea*
**Corresponding Author: jbkim@kaeri.re.kr*

1. Introduction

The development of wastage package, transportation and disposal containers for decommissioning wastes of nuclear power plant has been undergoing in Korea [1]. Concrete for disposal container continues to deform under sustained load at room temperature and it is important to understand and predict long term creep behavior of a concrete container.

When a load is applied to concrete, it experiences instantaneous elastic strain and it develops into nonlinear creep strain if the load is sustained as shown in Fig. 1. When the load is removed, elastic strain recovers immediately and the permanent inelastic strain remains. Major factors affecting concrete creep are load, temperature, humidity, aggregate, mix proportions, age of concrete, etc.

Various researchers made efforts to develop the concrete creep model to predict its long term behavior. Lee and Kim developed nonlinear 4-parameters model [2] and Cho studied a method to determine experimental variables for creep [3]. Among various methods, CEB-FIP Model Code [4] and ACI-209 Model [5] are most recognized models and KCI-2012 model [6] is close to CEB-FIP model. Park studied a comparison of CEB-FIP model and ACI model [7].

In this study, creep tests of concrete for a disposal container has been conducted and the long term creep behavior is predicted by empirical equation based upon Ross and Lorman [8]. The variables for equation are obtained by the least square method with creep test data for 5 months.

2. Creep Tests

A 300 mm long and 150 mm diameter test specimen was used for creep tests as shown in Fig. 2 and ASTM C512 and KS F 2453 procedures [9, 10] were applied to the tests. Table 1 shows the composition of concrete and it is noted that 28 days cured concrete specimens were used in the test. The coarse aggregate is less than 20mm and density is 2.3ton/m^3. Two wire type strain gages (PL-60) were attached on the opposite side of the specimen in the longitudinal directions to measure creep strains as shown in Fig. 2.

Three test specimens were installed in the creep test facility in series as shown in Fig. 3 and tests were performed at constant room temperature (20°C) and constant humidity (50%). Creep test load of 19.6MPa is applied and this corresponds to 40% of compression strength of the concrete. Creep tests were conducted at the Center for Research Facilities of Chungnam National University.

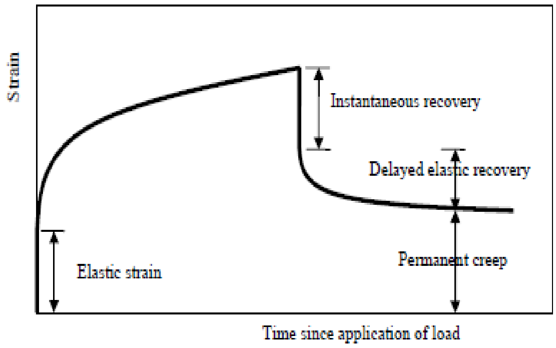

Fig. 1 General creep behavior of concrete

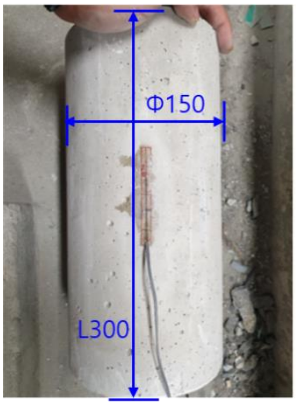

Fig. 2 Specimen for creep test (mm)

Table 1. Compositions of concrete

F_{ck} (MPa)	Air (%)	W/B (%)	S/a (%)	Unit weight (kg/m^3)				
				W	C	FA	S	G
40	3.5	40	45	163	326	82	762	964

Before creep tests, compression strength tests were performed to obtain the Young's modulus and compression strength per KS F 2405. Obtained Young's modulus is 29GPa and compression strength is 49MPa. In parallel with creep tests, drying shrinkage tests have been performed without loading and at the same test environment. The final creep strain will be calculated by subtracting these shrinkage strain from the obtained total strain from the creep tests.

Fig. 3 Creep test facility

Total strains obtained from 6 channels of strain gages from 3 specimens are shown in Fig. 4 and the current duration of test is 5 months. Average total strain is 0.12%. Fig. 5 shows the creep strains which were calculated by subtracting drying shrinkage strains from total strains, and the average creep strain is 0.09%.

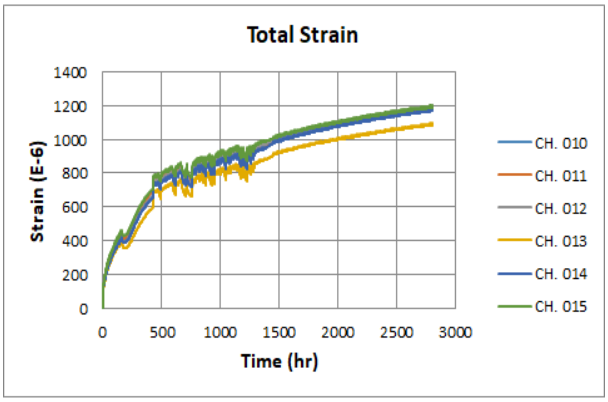

Fig. 4 Total strains of concrete for 5 months

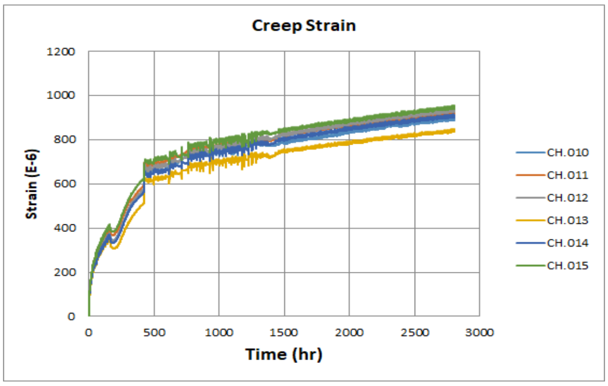

Fig. 5 Creep strains of concrete for 5 months

3. Creep Equation and Best Fitting

To obtain realistic creep strain relation of concrete, it is needed to have improved constitutive equation for creep of concrete. Among many expressions of exponential, hyperbolic, and rational functions, a simple rational equation is selected, which is well suited for long term concrete creep behavior, based upon Ross and Lorman as follows;

$$\varepsilon_c = \frac{t}{a+bt} \qquad (1)$$

where ε_c is creep strain, t is time (hr), and a and b are variables.

Variables in above Equation (1) can be obtained by least square method to minimize the differences between the experimental values and the predicted values as Equations (2) and (3).

$$R^2 = \sum_i^n [y_i - f(x_i, a_1, a_2, \cdots a_n)]^2 \qquad (2)$$

$$\frac{dR^2}{da} = 0 \quad and \quad \frac{dR^2}{db} = 0 \qquad (3)$$

By applying above procedures, values of a and b were found as 279557 and 1034, respectively. The corresponding creep equation of concrete becomes

$$\varepsilon_c = \frac{t}{179557+1034t} \qquad (4)$$

Fig. 6 shows the comparison of creep strain between test data and the predicted values from Equation (4). With this equation, long term creep strain after 300 years under 19.6MPa of loading which is 40% of compression strength is 0.097%.

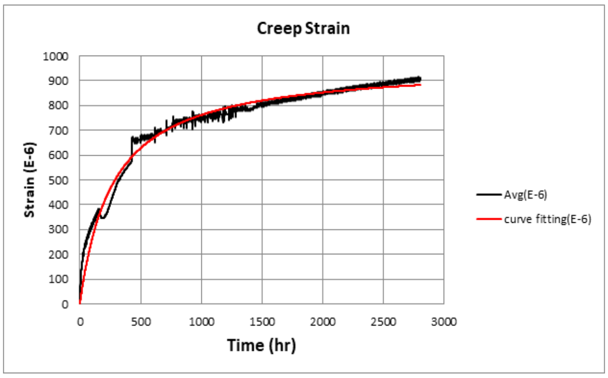

Fig. 6 Comparison of creep strains

3. Results and Discussion

In this study, the creep test of concrete for disposal container has been performed satisfying the required procedures and the rational form of creep equation is obtained by applying the least square method and 5 months of creep test data. Considering the disposal container, for cave type disposal facility, of which size and weigh are 2.73 x 2.73 x 1.14m and 18.34 tons, respectively, the maximum compression stress for 30 stories of containers is 4.3MPa. This corresponds to 9% of the compression strength and predicted creep strains for 300 years is less than 0.02% which is negligible. Although the creep strain of a concrete disposal container is not considered to be a problem at this stage, a more detailed conclusion will be made after further testing and assessment. A proposed creep equation will be revised to reflect the results of ongoing creep tests for a year.

Acknowledgement

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