On The Effect of Using Short-Term Data for Prediction of Long Term Creep Behavior of Concrete for Decommissioning Waste Package

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1. Introduction

Concrete for decommissioning waste package [1] continues to deform (i.e. creep) under sustained load at room temperature and it is important to understand and predict long-term creep behavior of a concrete container.

Many 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]. Kim calculated the constants of rational function based upon Ross and Lorman [8] using the least square method with short term creep test of 2800 hours, which is approximately 4 months [9].

In this study, creep tests of concrete for a waste package has been conducted for a year and the empirical creep equation was obtained by same way in [9]. In addition to rational function, logarithmic function was suggested and the creep equation using short term creep test data was compared with one using long term creep test data.

2. Creep Test Results

A 300 mm long and 150 mm diameter test specimen was used for creep tests and ASTM C512 and KS F 2453 procedures [10, 11] 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 2.3 ton/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.

Three test specimens were installed in the creep test facility in series 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. Young's modulus is 29GPa and compression strength is 49MPa [9].

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

In parallel with creep tests, drying shrinkage tests have been performed without loading and at the same test environment. The final creep strains are calculated by subtracting shrinkage strains from the obtained total strains from the creep tests.

Fig. 1 shows the creep strains from 6 channels of strain gages and the average creep strain is 0.108% after approximately one year (8822 hours in this study).

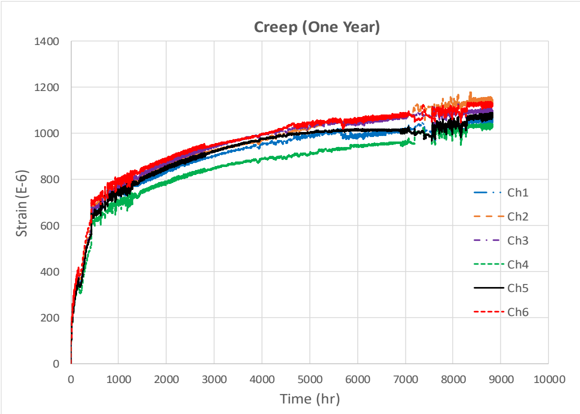

Fig. 1 Total strains of concrete for one year

3. Best Fit Creep Equation of Rational Form

To obtain 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;

$$\varepsilon_c = \frac{t}{a+bt} \tag{1}$$

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).

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

$$\frac{dR^2}{da} = 0 \quad and \quad \frac{dR^2}{db} = 0 \tag{3}$$

By applying above procedures with utilizing the results of Fig. 1, values of a and b were found as

404,413 and 919, respectively. The corresponding creep equation of concrete becomes

$$\varepsilon_c = \frac{t}{404413+919t} \tag{4}$$

In addition, the results obtained using 4-month creep data [9] and the results obtained using 8-month creep data were compared with the results using 12-month creep data in this study to analyze the effect of using short-term creep data for prediction of long-term creep behavior. Equation (5) is for using 4-month creep data and Equation (6) is for using 8-month creep data.

$$\varepsilon_c = \frac{t}{279550+1034t} \tag{5}$$

$$\varepsilon_c = \frac{t}{349129+958t} \tag{6}$$

Fig. 2 shows the comparison of creep strain between test data and the predicted values from Equations (4), (5) and (6). In Fig. 2, the legend CF-12 indicates the use of 12-month data, CD-8 for using 8-month data, and CD-4 for using 4-month data. The differences between the test results and predictions of using 12-month data, 8-month data, and 4-month data are 4.4%, 7.6%, and 13.5%, respectively.

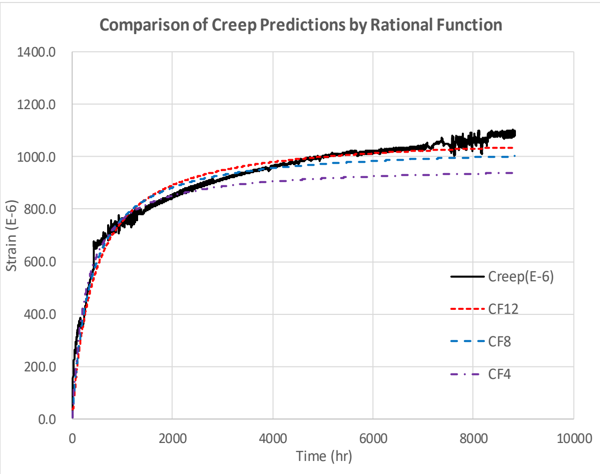

Fig. 2 Comparison of creep strains between test data and predictions by rational function

With these equations, long-term creep strain after 300 years under 19.6MPa of loading which is 40% of compression strength are 0.109%, 0.104%, and 0.097% for CF-12, CF-8, and CF-4, respectively. Considering that the result of the one-year creep test is about 80% of the total lifetime of the creep, it is predicted that the creep strain in 300 years will be approximately 0.136%. It seems that the rational creep equation underestimates the long-term creep strain and this reason is due to the characteristic of the rational function which was chosen as curve fitting. Therefore, the necessity to apply an another fitting function to follow the test data more accurately.

4. Best Fit Creep Equation of Logarithmic Form

A least square regression analysis was performed by selecting the logarithmic function to simulate the creep test data more accurately. The corresponding creep equations are shown as Equations (7), (8), and (9) for cases of CF-12, CF-8, and CF-4, respectively.

$$\varepsilon_c = 160.63\ln(t) - 373.8 \tag{7}$$

$$\varepsilon_c = 170.41\ln(t) - 447.71 \tag{8}$$

$$\varepsilon_c = 166.23\ln(t) - 410.89 \tag{9}$$

Fig. 3 shows the comparison of creep strain between test data and the predicted values from Equations (7), (8) and (9). The differences between the test results and predictions of using 12-month data, 8-month data, and 4-month data are 0.1%, 1.4%, and 1.3%, respectively. One can see that the logarithmic function simulates the test data better than the rational function as in Figures 2 and 3.

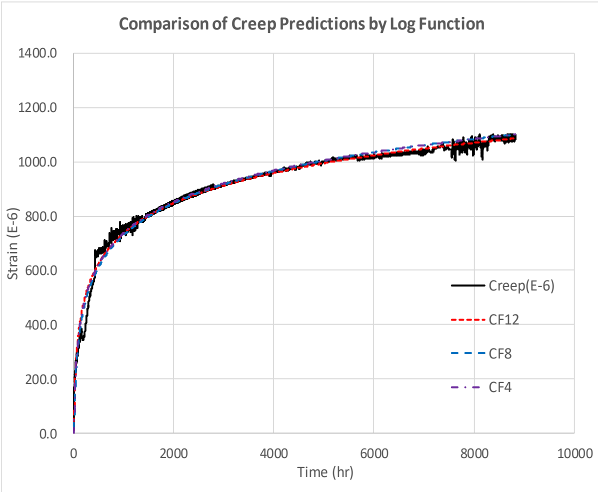

Fig. 3 Comparison of creep strains between test data and predictions by logarithmic function

With using above equations, long-term creep strains after 300 years under 19.6MPa are 0.2%, 0.207%, and 0.205% for CF-12, CF-8, and CF-4, respectively. The use of the logarithmic function shows that the one-year test data is better tracked, but the 300-year long-term creep behavior is significantly overestimated.

5. Results and Discussion

In this study, the creep test of waste package concrete was carried out per required procedures and both the rational form of creep equations and the logarithmic form of creep equations were obtained by applying the least square method and 12-month creep test data. The creep strain was 0.108% over one-year, and the logarithmic function was shown to be more closely depicted than in the rational function.

The prediction of the long-term creep strain of 300 years showed that the logarithmic function overestimates the long-term creep strain while the rational function underestimates it. Thus, it is suggested to use both the rational function and logarithmic function in parallel to predict the long-term creep behavior.

In addition, short-term creep test data such as 4 or 8 months were also considered feasible compared to the case of using 12-month creep test data from the engineering judgement.

Acknowledgement

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