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An Effective Analytical Model for Predicting Creep Coefficient

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Abstract

Time dependent (long–term) effects of concrete are greatly influenced and governed by creep of concrete. As a part of the study on effect of time dependent factors on the cracking behaviour of reinforced concrete flexural members, the effect of creep on the serviceability of concrete structures is studied. Based on a survey of published experimental data, equations were developed to calculate the creep coefficient of concrete at any time‘t’. This paper presents a new analytical model to predict creep of concrete, considering the main controlling independent parameters that affect creep. A parametric study of the proposed model is also included in this paper.

Keywords: Creep; shrinkage; creep coefficient.

1. Introduction

When a reinforced concrete beam sustains a load equal to or greater than the cracking load, the width of cracks increases with time. The properties like creep, shrinkage and tension stiffening influence the increase in crack width. Many codes of practice specify maximum steel stress increments after cracking and maximum spacing requirements for the reinforcement. However, few existing code procedures account adequately for the gradual increase in existing crack widths with time due to creep, shrinkage, sustained loading and tension stiffening. The determination of the time varying strains, stresses and curvatures at critical sections of reinforced concrete members is an important requisite for their serviceability analysis and design. Creep under sustained loads and shrinkage result in redistribution of strains and stresses between steel and adjoining concrete.

Creep is defined as the increase in strain under a sustained constant stress after taking into account other time-dependent deformations which are not associated with stress – shrinkage, swelling and thermal deformation. If a sustained load is removed, the strain decreases immediately by an amount equal to the elastic strain at the given age; this is generally lower than the elastic strain on loading since the elastic modulus has increased in the intervening period. This instantaneous recovery is followed by a gradual decrease in strain, called creep recovery. This recovery is not complete because creep is not simply a reversible phenomenon. It is now believed that the major portion of creep is due to removal of water from between the sheets of a calcium silicate crystallite and to possible rearrangement of bonds between the surfaces of the individual crystallites. The permanent strain that remain after the load removal is called the creep strain.

The creep strain consists of two main components. The first component is the true or basic creep, which occurs under the condition of no moisture movement to or from the ambient medium. The second is the drying creep, which is caused by drying. Normally, the creep strain that is considered in structural design is the sum of basic creep strain and drying creep strain. Creep in concrete can have both positive as well as negative effects on the performance of concrete structures. On the positive side, creep can relieve stress concentrations induced by shrinkage, temperature changes, or the movement of supports. For example, in indeterminate beam with two fixed ends, creep deformation will be very helpful in reducing tensile stress caused by shrinkage and temperature variation.

Brooks and Neville (1975) proposed equations for predicting creep and shrinkage at one year from measured values at between 7 and 28 days. Extrapolation to periods longer than 1 year is also possible with those equations. Brooks and Neville (1978) experimentally studied the creep and shrinkage of concrete for 5 years. Creep was determined on 18 types of concrete stored in water and air. The test results were compared and verified by using the data of other investigators. Bryant (1979) experimentally studied creep and shrinkage for three types of mixes. The specimens were kept at different locations to study the effect of environment on creep and shrinkage and it was found that the environment have considerable effect on creep and shrinkage. This paper presents a new analytical model to predict creep of concrete, considering the main controlling independent parameters that affect creep.

The important parameters influencing creep are:

1. Age of concrete
2. Strength of concrete
3. Water-cement ratio
4. Relative humidity
5. Size of member-expressed in terms of volume to surface ratio.

As the age of concrete increases creep also increases. Experiments have shown that creep continues for a very long time; detectable changes have been found after periods as long as 30 years. The rate is seen to decrease continuously. Strength of concrete has a considerable influence on creep and within a wide range; creep is inversely proportional to the strength of concrete at the time of application of load. The water cement ratio is the main factor influencing the porosity and hence, the strength of concrete. So a lower water cement ratio results in a higher strength. Thus, the effect of decrease in water cement ratio is a decrease in creep. One of the most important external factors influencing creep is the relative humidity of the air surrounding the concrete. When the relative humidity is lower creep is higher. When drying occurs at a constant relative humidity, creep is smaller in a larger specimen. The size effect is expressed in terms of volume/surface ratio of the concrete member.

2. Model to Predict Creep

Most design codes use the concept of an ultimate creep coefficient and a Ross-type equation to represent the effect of time. The long-term results of Gilbert and Guo, Brooks and Neville, Bryant indicate that creep does not reach an ultimate value, but continues to increase with time. Thus, a model has been developed as the product of a Ross type term and the other important factors that were thought to affect the creep.

The proposed model was developed with the test results of Gilbert and Guo, Brooks and Neville, Bryant and Vadhanavikkit. A total of 390 test results were considered for the regression analysis. The constants of regression function were statistically evaluated.

The mathematical model, thus obtained is given as

$$\phi = 12\left(\frac{t}{30+0.1t}\right)^{0.7} \frac{w^{0.9}}{h^{0.4}\left(v/s\right)^{0.12}} \tag{1}$$

where, Φ = creep coefficient
t = age of concrete
h = relative humidity (%)
w = water-cement ratio
v/s = volume to surface ratio.

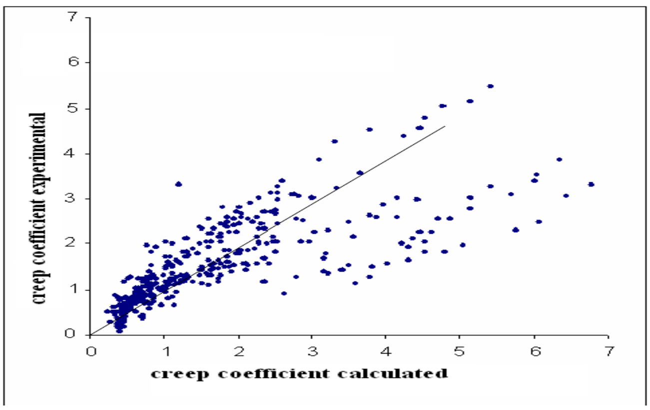

Figure 1: Comparison of calculated creep coefficient with the experimental values.

An attempt was made to compare the proposed model with the experimental results. The experimental values of creep coefficient have been plotted against the calculated values of the creep coefficient. A line of equality was drawn in the plot along with it. Fig.1 shows a satisfactory agreement between the computed and experimental values. Average value of ratio of calculated creep coefficient to experimental creep coefficient was obtained as 1.05 with correlation coefficient 0.85.

3. Parametric Study

The effect of different design parameters on creep coefficient was studied. Creep coefficient has been plotted against each design parameters. The creep time curve in Fig.2 shows that the creep increases continuously with time. The rate of increase is more at early stages, which decreases gradually with time.

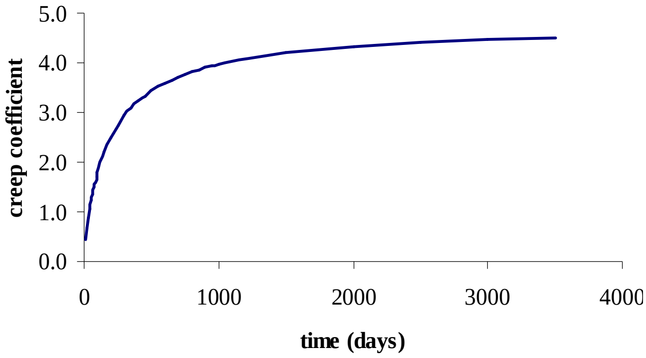

Figure2: Variation of creep coefficient with time.

For studying the effect of humidity, creep-time curve has been drawn for different values of humidity (expressed as %) as shown in Fig.3 and creep has been plotted against humidity as in Fig.4. Both curves show the inverse relation between creep and humidity. For lower values of humidity the rate of decrease in creep is more, which gradually reduces as humidity increases.

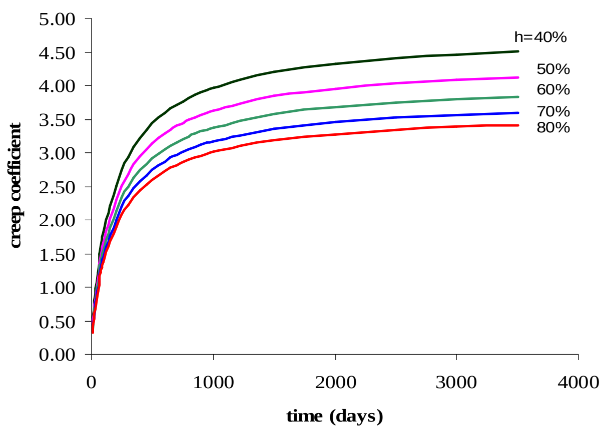

Figure 3: Effect of humidity on creep coefficient.

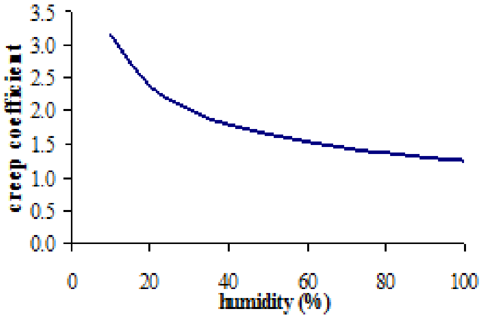

Figure 4: Variation of creep coefficient with humidity.

For studying the effect of size, creep-time curve has been drawn for different values of volume/surface ratio and also creep has been plotted against volume/surface ratio as shown in Fig.5 and Fig.6. Both curves show an inverse relation between creep and size. For lower values of volume/surface ratio the rate of decrease in creep is more, which gradually reduces as volume/surface ratio increases.

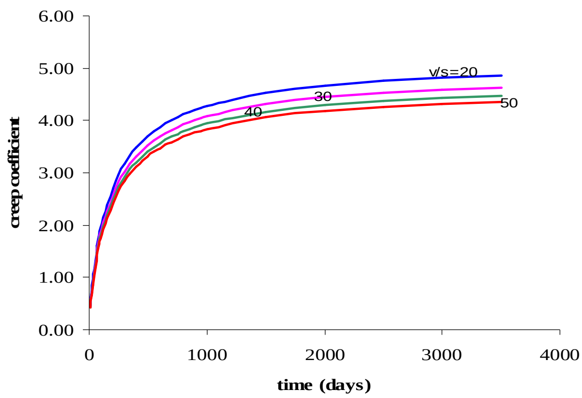

Figure 5: Effect of size on creep coefficient.

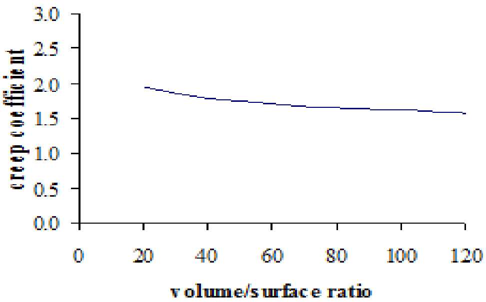

Figure 6: Variation of creep coefficient with size.

For studying the effect of water cement ratio, creep-time curve has been drawn for different values of water cement ratio as in Fig.7 and also creep has been plotted against water cement ratio in Fig.8. Both curves show a direct relation between creep and water cement ratio.

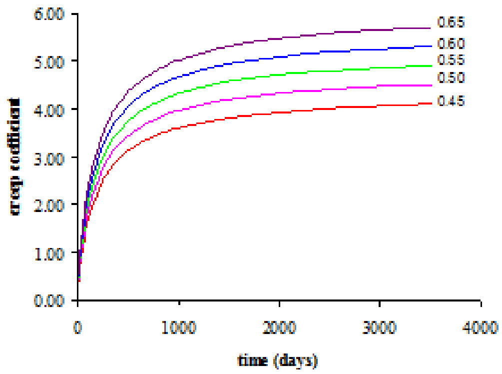

Figure 7: Effect of water-cement ratio on creep coefficient.

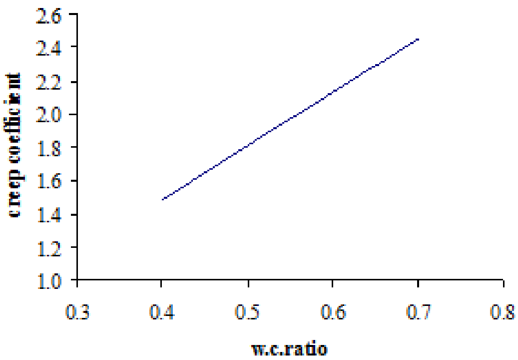

Figure 8: Variation of creep coefficient with water-cement ratio.

4. Conclusion

The model proposed for calculating the creep coefficient was compared satisfactorily with the experimental data from literature. The average ratio of calculated Creep coefficient to experimental Creep coefficient was obtained as 1.05. The correlation coefficient was 0.85. The parametric study of the proposed model indicates the effect of different design parameters on creep coefficient.

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