Guide for Modeling and Calculating Shrinkage and Creep in Hardened Concrete

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This guide is intended for the prediction of shrinkage and creep in compression in hardened concrete. It may be assumed that predictions apply to concrete under tension and shear. It outlines the problems and limitations in developing prediction equations for shrinkage and compressive creep of hardened concrete. It also presents and compares the prediction capabilities of four different numerical methods. The models presented are valid for hardened concrete moist cured for at least 1 day and loaded after curing or later. The models are intended for concretes with mean compressive cylindrical strengths at 28 days within a range of at least 20 to 70 MPa (3000 to 10,000 psi). This document is addressed to designers who wish to predict shrinkage and creep in concrete without testing. For structures that are sensitive to shrinkage and creep, the accuracy of an individual model's predictions can be improved and their applicable range expanded if the model is calibrated with test data of the actual concrete to be used in the project.

Keywords: creep; drying shrinkage; prediction models; statistical indicators.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Background

To predict the strength and serviceability of reinforced and prestressed concrete structures, the structural engineer requires an appropriate description of the mechanical properties of the materials, including the prediction of the time-dependant strains of the hardened concrete. The prediction of shrinkage and creep is important to assess the risk of concrete cracking, and deflections due to stripping-reshoring. As discussed in ACI 209.1R, however, the mechanical properties of concrete are significantly affected by the temperature and availability of water during curing, the environmental humidity and temperature after curing, and the composition of the concrete, including the mechanical properties of the aggregates.

Among the time-dependant properties of concrete that are of interest to the structural engineer are the shrinkage due to cement hydration (self-desiccation), loss of moisture to the environment, and the creep under sustained loads. Drying before loading significantly reduces creep, and is a major complication in the prediction of creep, stress relaxation, and strain recovery after unloading. While there is a lot of data on shrinkage and compressive creep, not much data are available for creep recovery, and very limited data are available for relaxation and tensile creep.

Creep under variable stresses and the stress responses under constant or variable imposed strains are commonly determined adopting the principle of superposition. The limitations of this assumption are discussed in Section 1.3.

Further, the experimental results of Gamble and Parrott (1978) indicate that both drying and basic creep are only partially, not fully, recoverable. In general, provided that water migration does not occur as in sealed concrete or the interior of large concrete elements, superposition can be used to calculate both recovery and relaxation.

The use of the compressive creep to the tensile creep in calculation of beam's time-dependant deflections has been successfully applied in the work by Branson (1977), Bažant and Ho (1984), and Carreira and Chu (1986).

The variability of shrinkage and creep test measurements prevents models from closely matching experimental data. The within-batch coefficient of variation for laboratory-measured shrinkage on a single mixture of concrete was approximately 8% (Bažant et al. 1987). Hence, it would be unrealistic to expect results from prediction models to be within plus or minus 20% of the test data for shrinkage. Even larger differences occur for creep predictions. For structures where shrinkage and creep are deemed critical, material testing should be undertaken and long-term behavior extrapolated from the resulting data. For a discussion of testing for shrinkage and creep, refer to Acker (1993), Acker et al. (1998), and Carreira and Burg (2000).

1.2—Scope

This document was developed to address the issues related to the prediction of creep under compression and shrinkage-induced strains in hardened concrete. It may be assumed, however, that predictions apply to concrete under tension and shear. It outlines the problems and limitations in developing prediction equations, presents and compares the prediction capabilities of the ACI 209R-92 (ACI Committee 209 1992), Bažant-Baweja B3 (Bažant and Baweja 1995, 2000), CEB MC90-99 (Muller and Hillsdorf 1990; CEB 1991, 1993, 1999), and GL2000 (Gardner and Lockman 2001) models, and gives an extensive list of references. The models presented are valid for hardened concrete moist cured for at least 1 day and loaded at the end of 1 day of curing or later. The models apply to concretes with mean compressive cylindrical strengths at 28 days within a range of at least 20 to 70 MPa (3000 to 10,000 psi). The prediction models were calibrated with typical composition concretes, but not with concretes containing silica fume, fly ash contents larger than 30%, or natural pozzolans. Models should be calibrated by testing such concretes. This document does not provide information on the evaluation of the effects of creep and shrinkage on the structural performance of concrete structures.

1.3—Basic assumptions for development of prediction models

Various testing conditions have been established to standardize the measurements of shrinkage and creep. The following simplifying assumptions are normally adopted in the development of prediction models.

1.3.1 *Shrinkage and creep are additive*—Two nominally identical sets of specimens are made and subjected to the same curing and environment conditions. One set is not loaded and is used to determine shrinkage, while the other is generally loaded from 20 to 40% of the concrete compressive strength. Load-induced strains are determined by subtracting the measured shrinkage strains on the nonloaded specimens from the strains measured on the loaded specimens. Therefore, it is assumed that the shrinkage and creep are independent of each other.

Tests carried out on sealed specimens, with no moisture movement from or to the specimens, are used to determine autogenous shrinkage and basic creep.