Report on Factors Affecting Shrinkage and Creep of Hardened Concrete

Reported by ACI Committee 209

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This guide describes the effects of numerous variables on shrinkage and creep of hardened concrete, including mixture proportions, environment, design, and construction. This document is aimed at designers who wish to gain further information about factors changing shrinkage and creep but does not include information on the prediction of shrinkage and creep or structural design issues associated with shrinkage and creep.

Keywords: creep; drying shrinkage; strain.

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CHAPTER 1—INTRODUCTION

1.1—Scope

Factors affecting shrinkage and creep of hardened concrete are presented to enable those involved in the evaluation and formulation of concrete mixtures to determine the effects of these factors. Section 1.2 of Chapter 1 defines terms used by those evaluating shrinkage and creep, while Chapters 2 and 3 describe effects of various factors on shrinkage and creep. This document does not include information on the prediction of shrinkage and creep or structural design issues associated with shrinkage and creep.

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This document is not intended as a primary reference source for those studying shrinkage and creep; rather, it is aimed at designers who wish to gain further understanding of the effects of materials being used. This document also provides references that provide direction for those wishing to seek additional information about shrinkage and creep.

1.2—Terminology and range of values of strains

To discuss shrinkage and creep, it is important to define the following terms:

- Total strain;
- Shrinkage;
- Autogenous shrinkage;
- Drying shrinkage;
- Carbonation shrinkage;
- Swelling;
- Load-induced strain;
- Initial strain at loading or nominal elastic strain;
- Creep strain;
- Basic creep;
- Drying creep;
- Compliance;
- Specific creep; and
- Creep coefficient.

Various terms are shown in Fig. 1.1 and are described in detail below, together with an indication of typical value ranges. The values of total strain, shrinkage, and creep are time-dependent. A thorough discussion of definitions, basic assumptions, and standard test methods for creep and shrinkage can be found in the references (RILEM TC 107-CSP 1998; Carreira and Burg 2000).

Shrinkage and creep may occur in three dimensions; however, most research suggests that total strain, shrinkage, and creep occur in each dimension independently. Thus, changes in length will be consistently used throughout this document, rather than changes in volume.

1.2.1 *Total strain*—Total strain is the total change in length per unit length measured on a concrete specimen subjected to a sustained constant load at uniform temperature. As shown in Fig. 1.1, total strain is the sum of shrinkage and load-induced strain.

1.2.2 *Shrinkage*—Shrinkage is the strain measured on a load-free concrete specimen.

Shrinkage does not include changes in length due to temperature variations, but depends on the environment and on the configuration and size of the specimen. Shrinkage strain is usually measured by casting companion load-free specimens identical to the loaded concrete specimens used to measure the total strain. These companion specimens are cast from the same concrete batch, have the same dimensions, and are stored in the same environment as the loaded concrete specimens.

Shrinkage values are given as dimensionless strains (length change over a given length) expressed as percent, mm/mm, or in./in. It is common to describe shrinkage in microstrain or millionths, as the value of strain $\times 10^6$. Thus, 1000 microstrain is equivalent to 1×10^{-3} mm/mm.

Values of long-term concrete shrinkage are typically between 200 and 800×10^{-6} mm/mm, (200 to 800 microstrain) (Zia, Ahmad, and Leming 1997) and mortar shrinkage typically between 800 and 2000×10^{-6} mm/mm (800 and 2000 microstrain) (Heath and Roesler 1999). Cement paste

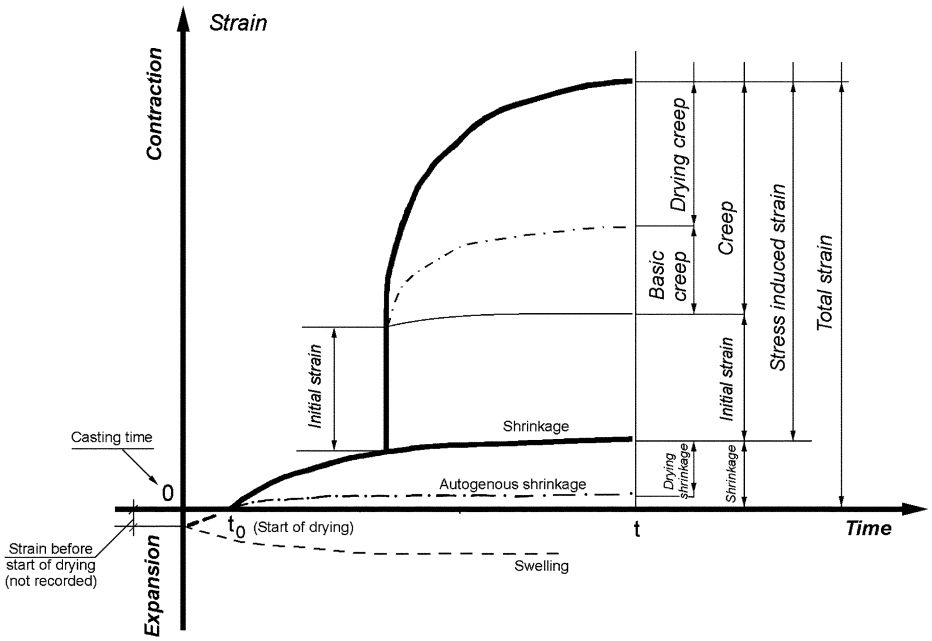

Fig. 1.1—Relationship between various measured and derived strain values. The figure shows that the concrete undergoes autogenous shrinkage before drying. Once drying commences at time t_0, drying shrinkage occurs. Upon loading, both drying and basic creep occurs in the drying specimen.