Crack-Free Concrete – An Understanding of Creep

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ABSTRACT

A durable structure of concrete is achieved when no cracking occurs during the young ages of the hardening process. Therefore, it’s of importance to address shrinkage and creep correctly. Drying is the primary source of shrinkage, and the time development in shrinkage is an effect of the balance between drying and creep. Therefore, creep is to be measured on sealed and non-sealed specimens in order to investigate the nature of drying creep. Measurements will be performed for loading ages up to 1 year. These experimental data will be used to create accurate models, including both short and long term effects.

Key words: concrete, cracking, creep, shrinkage.

1. INTRODUCTION

1.1 General

Crack-free concrete is needed to achieve durable and functional structures, since cracks frequently lead to shortened lifetime unless costly repairs and maintenance are done. To counteract this destructive process, a Nordic research project, CFC (Crack-Free Concrete), has been started with several partners in Sweden and Norway.

To fulfil the task to achieve a crack-free concrete structure, one must analyse cracking during the young ages of the hardening process thoroughly. Therefore it is of importance to address and understand shrinkage correctly since its one of the main crack inducing factors. Standardized tests for shrinkage are not designed to be a proper base for theoretical analyses, and there is a general need to develop new test procedures.

Creep tests are planned to be performed on sealed and non-sealed specimens in order to investigate the nature of drying creep. These experimental data will be used to create models for drying creep, including both short and long term effects. In the end the project will contribute to a better understanding of the influential mechanisms and how to avoid crack related concerns,
i.e. by taking relevant measures to reduce the cracking risk. Research findings gained will be transformed and implemented for practical use.

1.2 Definition of shrinkage and creep

A concrete specimen will shortly after casting start to shrink due to chemical reactions, which after final setting is considered as the driving force of autogenous shrinkage. At sealed conditions the corresponding decrease in pore humidity is denoted self-desiccation or “internal drying”. If the specimen is not sealed and the environmental humidity is less than the humidity inside the concrete, shrinkage is increased due to external loss of water from the surfaces of the concrete body. This part of the shrinkage may be regarded as effects of “external drying”. Thus, in general terms, drying is the primary source of shrinkage.

Upon placing the specimen under constant load there is a quick deformation, see c in Figure 1 and [1] and [2]. When specimen is under constant load, deformation will increase over time; this process is known as creep. If the specimen is not sealed, the time development in deformation will be an effect of the balance between drying and creep. Since the amount of creep depends on load and drying conditions it is traditionally divided into basic and drying creep.

![Figure 1](image)

*Figure 1 – At left a basic schematic over deformation in an unsealed concrete specimen depending on a) autogenous shrinkage, b) drying shrinkage, c) instantaneous (elastic) response to load, d) load induced basic creep and e) load and drying induced drying creep. The figure to the right corresponds to a sealed specimen.*

The experimental measurement of the parameters in Figure 1 has in its simplest form been separated by using sealed specimens in loaded and unloaded conditions. Autogenous shrinkage is then assumed to be the same in both. A comparable unsealed specimen gives information about differences in deformation due to drying shrinkage and drying creep.

The elastic response upon loading is dependent on the strength and therefore the maturity level of the concrete specimen. Thus creep has to be measured on different maturity ages, for instance 1, 3 and 7 days [1]. Additionally there is many parameters affecting the maturity level, for instance in [3] it is shown how temperature is affecting the strength growth. In the LTU research group different creep and shrinkage models have been developed, [1], [3], [4], [5], [6] and [7], but still there is a need of analyses and models concerning drying shrinkage and drying creep.

Thus, it is important that the authors of this article will look into the behaviour of drying creep and create new, verify or modify existing models that include this phenomenon when predicting long and short term effects.
2. EXPERIMENTAL SETUP

For early age creep tests, i.e. loading at 1, 3 and 7 days old specimens, the measurements will be performed with hydraulic test rigs, see A in Figure 2. The mould is seen in B, diameter 80 mm and height 340 mm. In each of the rigs two specimens are placed, one for loaded and one for unloaded state. The unloaded specimen will give information about the total “free” shrinkage, i.e. the sum of autogenous and drying shrinkage. The loaded subject will give information about creep.

Two strain gauges of type Schaewitz LVD10 MHR [1] (C in Figure 2) is placed symmetrically on opposite sides of the specimen. Upon strain, the primary core is moved in or out from the two secondary coils, and the differential voltage is measured; every μm in either direction corresponds to 20mV. The measurement equipment is made of invar since it shows little effect to temperature change, 2μ/°C. The relative humidity and temperature is continuously logged in each of the rigs so that movement compensation can be taken into account. Load is adjusted with a hydraulic pump.

Creep measurements on mature concrete (loading age 28 days or more) will be conducted using the mechanical rigs seen in Figure 2 (D). Three pairs of bowels (Figure 3) are placed symmetrically around the test specimen on 200 mm distance with strain stable glue. The glue merges into the near surface pores of the specimen and hardens within minutes. The gauge measurement device type is STAEGGER and it measures changes in position with one μm accuracy. To ensure the precision of the measurement a reference bar is used before and after each measurement. When tests are conducted with sealed specimens the dowels are placed after the covering of the concrete body. The load is adjusted by using a hydraulic pump. Moisture and temperature will be continuously measured.
3. **FINAL COMMENTS**

The concrete laboratory at LTU that have been used for more than 20 years to conduct tests of concrete regarding heat of hydration, strength development, shrinkage, thermal dilation and stress, is currently under upgrade. All gauges have been calibrated and old cables are replaced with new. The major change is the up to date computers together with National Instruments USB measurement devices. The functionality of the previously used control software [8] is transferred to Lab View with improvements in how measurement is performed and how data is retrieved. In addition, a climate room is under construction, which will be suitable for tests on mature concrete.

**REFERENCES**