Modification Additives and Their Influence on Volume Changes of Fresh Cement Pastes

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Abstract. One of the main factors that influence durability and water-proof ability of concrete structures is crack development in the hydration phase. This problem influences also massive concrete structures such as foundation slabs and underground walls. It is possible to avoid failures that occur during building process by elimination of volumetric changes in concrete structures.

The main purpose of this project was to describe the influence of different components, mineral and chemical admixtures on volumetric shrinkage of concrete. In addition concrete mix design that would not suffer from micro cracks formation was purposed.

Keywords: volume changes, autogenous shrinkage, microcracks.

1. Introduction

Cracks in concrete are of great concern in civil engineering worldwide. The consequence of crack formation is usually reduced structure quality or durability. This paper investigates the problem of autogenous shrinkage from the stage of concrete setting further, using experimental data. During the cement hydration, the absolute volume of cement, hydration products and water decreases. This phenomenon is called chemical shrinkage.

Let us denote $V_{wh}$ as the water consumed during the hydration, $V_{ch}$ as the volume of hydrated cement, $V_h$ as volume of hydrates and $V_{cs}$ the “missing volume” of chemical shrinkage:

$$V_{wh} + V_{ch} = V_h + V_{cs} \quad (1)$$

If the designed mix does not contain sufficient excess of water, voids necessarily appear in the structure of hardening cement paste. Water loss in this case is not caused by evaporation, but by binding into hydration products. This phenomenon is called self-desiccation and the voids correspond to chemical shrinkage $V_{cs}$. Additional water loss from the voids may set off additional drying shrinkage, which is not examined here. When some kinematic restrains exit in a construction, the shrinkage results in the stress initialization, exceeding several times the tensile strength of young concrete. After mixing concrete with water, a fast reaction of tricalciumaluminate occurs, accompanied by a strong exothermic effect. This reaction results in the formation of a thin film on dispersed cement grains formed by fine ettringite crystals. As a consequence, further hydration is suppressed, the temperature drops - a period of incubation occurs during which the concrete mix continues to behave as a quasi-liquid. The exothermal hydration implies a rapid growth of temperature within the system. Inside, shrinkage probably occurs, manifested by the voids growth in the system.

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By definition, autogenous shrinkage is combined from two different mechanisms: self-dissociation shrinkage and expansion due to salts. These two mechanisms are hard to separate in practical experiments. Usually, autogenous shrinkage is measured in a closed system under sealed conditions, in isothermal environment without any external load. Possible temperature rise and dilatation may be subtracted from the total, coming to pure isothermal autogenous shrinkage.

Described technique is possible to use in every case when a better cohesion between the layers during casting is required. Mainly foundation desk design far below the underwater level is typical case. Modifying concrete mixture as well as the surface adjustment contributes to the better desk resistance against the leakage caused the pressure of underground water.

Reaching the volume stability results in a significant reduction of crack evolution. The compact concrete therefore provides protection for reinforcement, and so these structures can also be used in an aggressive environment.

2. Experiment

2.1. Proposed technique

Volume changes in concrete are mostly investigated by dilatometric gauges applied to already solidified testing samples. It follows that the volume changes produced in the process of solidification would not be detected. In this stage, a crystalline microstructure comes to being and the first microcracks emerge thus affecting the final state of concrete elements and structures.

The proposed method (fig. 1) of using rubber wavy-line false mould gauges the linear variation by monitoring length changes of a coupled cement paste-rubber mould system [1, 2]. The test equipment comprised a holder preventing from a rubber mould misalignment in the horizontal direction and a movement laser sensor supporting the structure. The vertical deformation of test specimen is measured using a contactless distance measurement by optical method which allows continuous length measurement. Specimen size is: high 160 mm and average 70 mm.

![Fig. 1: Proposed method of measuring of volume changes](image)

2.2. Materials and cement binder mix design

Mixtures in Table 1. are used to demonstrate how the proposed experimental technique can be used to analyse the effect and difference between the standard cement binder and cement modified with polyvinylalcohol (PVA) and polypropylene fibres (PP), superplasticizer Glenium 505 and Addiment BV4 and with H Krystal M on the autogenous shrinkage (tab. 1).

Table. 1: Constitution of cement pastes.
3. Measurements results

To describe the behavior of early age cement pastes namely their response to hydration processes, a set of 32 mixtures was prepared and analyzed. Our attention was paid to the application of different sorts of cement (CEM I 32,5R, CEM I 42,5R, CEM I 52,5R), superplasticizers (Addiment BV4, Stachement 2000, 2090, Melcret 500FM, Glenium 505), microfibers (PP, PVA), additives (microsilica, limestone powder, fly ash (blast-furnace slag), the H-Crystal catalyst) and, of course, water/cement ratio (w).

To compare the effect of individual components a subset of six mixtures containing CEM I 42,5R, Stachement 2090, PP, PVA and limestone powder, respectively was selected.

As evident from Fig. 2, the highest values of volume changes were attained when applying superplasticizers. This admixtures made the cement pastes more susceptible to the creation of the first cracks. In contrast utilizing the PP and/or PVA microfibers diminishes autogenous shrinkage and decrease the risk of the cracks formation and propagation. The H-Crystal catalyst shows similar beneficial effect.

As for the effect of admixtures and additives on evolution of temperature, we found out that the PP and PVA microfibers decreased maxima of temperature, while the impact of superplasticizers was rather detrimental (rise of temperature owing to hydration) – see Fig. 3.
It is worth pointing out that the application of superplasticizers shifts the temperature maximum by about 3 hours. The H-Crystal catalyst exhibits similar only a little bit weaker retarding effect.

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5. References
