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Computerised evaluation of the early age of shrinkage in concrete

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ABSTRACT

Shrinkage is a natural phenomenon accompanying drying processes occurring in nature. Particularly acute it is on dirt roads in Africa and Asia, as in the dry season, at high ambient temperatures and low relative humidity, effects of drying are surface irregularities and even landslides. Fresh and hardened concrete mix is subjected to similar phenomena. The mechanism of action of shrinkage in concrete is more complicated than in the environment of cohesive soil, since in the initial phase of hardening chemical processes associated with cement hydration, and after hardening physical processes associated with the adsorption or loss of moisture from the environment during drying, lead to volume reduction. These influences can be precisely separated and indication of their significance for the quality of the concrete structure can be performed only by setting the deformation of concrete in the phase of the laying, caring and operation. The problem of continuous strain measurements in concrete is discussed in this publication, in which a review of existing methods for measuring shrinkage was performed in the period from the start of the modern concrete structures (USA, Europe after 1900 years) to modern times, in which the simple mechanical method of measuring shrinkage was replaced by modern electronic sets of measurement, enabling highly accurate measurements since the moment of production of concrete mix. The exact description of the process of the passing time — the deformation, enables making decisions to rectify or limit unfavourable shrinkage phenomena in the concrete (adding contraction admixtures, water care, covering with foil, use of the sealing and reflecting solar radiation surfaces). Proposed and tested by the authors of the article set-up for automatic control of shrinkage phenomena occurring in the concrete meets the above mentioned functions in both scientific discovery and relevant to practice application research.

1. Introduction

The concrete shrinkage problem was raised by many authors, from concrete specialists to common chemical engineers. The development of concrete technologies in recent years, the introduction of chemical additives, plasticizers and superplasticizers, mineral additives and production of concrete with high and ultra-high strengths, necessitated the creation of a broader view of contraction and opened a new field of research, AM Neville [1], O.M. Jensen, and P.F. Hansen [2]. The authors of this publication belong to a group of people dealing with this issue both in terms of cognitive and application, with regard to industrial floors localized on the ground, J. Jasiczak, P. Szymanski [3]. Innovation in the presented results of the study is examining the various stages of contraction: the initial swelling, chemical shrinkage (contraction) and malleable, later followed by expansion and a second contraction (shrinkage during drying). The converted size and durations of plastic shrinkage, expansion and shrinkage on drying are presented in Fig. 1.

Shrinkage is dependent on many parameters which include: the w/c ratio, the type of aggregate and its amount in the concrete mix, the type and amount of cement, the climatic conditions in which the concrete is cured, the type used and the addition of mineral admixtures. The higher the w/c ratio is, the higher the amount of shrinkage. This is associated with the amount of water which must be evaporated from the concrete mix. J. J. Brooks showed that hydrated grout shrinkage is directly proportional to the w/c ratio in the range of 0.2–0.6. At higher values of the ratio, additional water is removed during drying without the effects of shrinkage [4]. Not without significant influence is the dosage of plasticizers and superplasticizers lowering the water content in the mixture. The primary effect is indirect and relies on the fact that the dopants can change the water content of the mixture or cement, or both of these components, and the combined action of these alters the influence on shrinkage. The amount and type of cement significantly influences the shrinkage of concrete, but the shrinkage of the cement paste is different from the shrinkage of the concrete itself. Greater shrinkage of the clean grout does not necessarily mean greater shrinkage of concrete made using the same cement.

Normal concrete shrinkage is a phenomenon well-known and well-documented scientifically. It is closely associated with physicochemical processes in the cement paste. Contraction is called the reduction of the volume of concrete resulting from the loss of water by drying. This view was already formulated in 1900. Le Chatelier, one of the pioneers of cement research, describes self-desiccation and started a systematic registration of the material properties of cement paste. He states that it is fundamental to distinguish between the absolute volume and the

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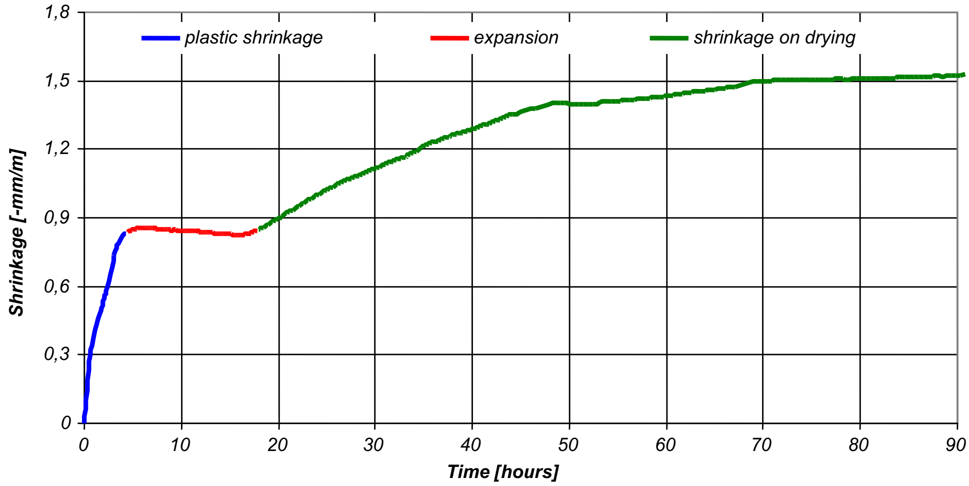

Fig. 1. Phases of concrete shrinkage.

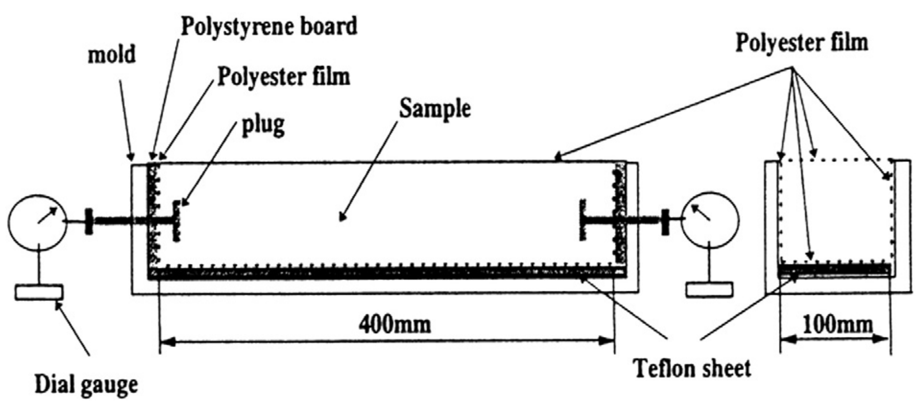

Fig. 2. Test set up for free and restrained shrinkage [10].

apparent volume of a hardening cement paste [4]. Early reported measurements can be found in literature from the beginning of the 1900s [5]. In 1927 L. Jesser [6] reported measurements of autogenous RH-change for cement mortars with w/c-ratios of 0.24–0.36 and noted that the internal relative humidity may be 90% after 1 month of hardening. In 1928, H.A. Neville and H.C. Jones [7] described an apparatus for measurement of volumetric deformations of cement paste during sealed hardening at a constant temperature.

Measurements of volumetric shrinkage of cement paste were also used much later, for example, back in 1995, S. Miyazawa, E. Tazawa and T. Kasai [8,9] used a dilatometer for the measurement of chemical shrinkage. Even in the 1930s, strain measuring devices were used for cement mortar and concrete, such as Graf–Kaufman's camera or Amsler instruments. Devices were equipped with clock readers and allowed readings of linear contraction with an accuracy of 0.01 mm, but in the case of fully hardened concrete, the earliest readings were taken 24 h after mixing the ingredients with water. These devices did not measure the early phases of concrete shrinkage, chemical and plastic shrinkage, contraction, etc. The prevalence of HPC concretes and later UHPC, with plenty of cement and a low w/c ratio, forced early shrinkage deformation measurements and, consequently, automatic measurement of contraction immediately after the manufacture of the concrete. The first device to measure the early deformation of concrete meeting these requirements was used by E. Tazawa and S. Miyazawa [10] in 1999. It was a horizontal steel casing with dimensions of 100 × 100 × 400 mm, with internal Styrofoam inserts allowing the deformability of concrete. Measurements of deformation allowed installation on the ends of micrometres with clocks (analogue) Fig. 2. These instruments are used to this day by different centres [11]. After 2000 there was a significant breakthrough in measurement methods. Strain sensors began to sink in concrete mix and lead measurements to have automatic registration of contraction results in specially designed computer software. This type of system was applied by D. Saje, F. Saje, J. Lopatić [12] and T. Nawa and T. Horita [13].

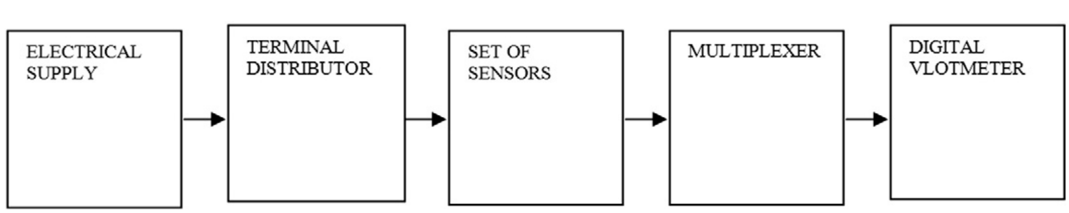

Fig. 3. Measurement equipment flow chart.