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Review

# Autogenous shrinkage of high performance concrete: A review

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## HIGHLIGHTS

- The autogenous shrinkage can be well modelled by capillary tension theory.
- Internal humidity and pore structure are major influential factors in autogenous shrinkage of HPC.
- Low water-to-binder ratio increases the autogenous shrinkage in HPC.
- Highly reactive supplementary cementitious materials increase the autogenous shrinkage.
- Internal curing is an effective means to reduce the autogenous shrinkage of high performance concrete.

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## ABSTRACT

Autogenous shrinkage is a major concern in early age cracking of high performance concrete (HPC). Low water-to-binder ratio and incorporation of supplementary cementitious materials (SCMs) can remarkably affect the pore structure, relative humidity, self-stress, degree of hydration, and interface structure; hence, increase the shrinkage in the matrix. In this paper, the mechanism of autogenous shrinkage of HPC and influential factors in its development are discussed. In general, autogenous shrinkage is more pronounced in HPC, albeit, using low heat cement, fly ash, shrinkage reducing agents, lightweight aggregates, and fibers can effectively reduce it. The effects of SCMs on autogenous shrinkage, relationship between different types of shrinkage and autogenous shrinkage as well as the effect of internal curing on autogenous shrinkage need to be further studied.



**Contents**



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## 1. Introduction

Autogenous shrinkage refers to reduction of apparent volume or length of cement-based materials under seal and isothermal conditions [1]. It is caused by further hydration of cement after the formation of initial structure of the cement matrix and can be best explained by capillary tension theory [2]. In concrete with water-to-cement ratio lower than 0.40, the internal moisture is insufficient to fully hydrate cement particles; thus, the occurrence probability of autogenous shrinkage may increase [3]. Therefore, autogenous shrinkage is a major concern in early age cracking of high performance concrete (HPC) [4]. Generally, the early-stage autogenous shrinkage occurs within the first 24 h after mixing with water. The matrix is more prone to cracking during the first 12 h [5]. During this time period, tensile strength of concrete is too low to resist the crack propagation caused by shrinkage stresses. Addition of some supplementary cementitious materials (SCMs) such as silica fume to the mixture may further increase the autogenous shrinkage as the hydration and pozzolanic reactions accelerate the water consumption at early ages [6]. Autogenous shrinkage leads to micro-cracks in the matrix and lowers the durability of the structure. Ineffective curing of concrete in dry environments may cause simultaneous occurrence of drying shrinkage and autogenous shrinkage [7].

In general, shrinkage can be measured based on changes in volume and length. Regardless of test methods, the measured shrinkage is a combination of autogenous shrinkage, dry shrinkage, and chemical shrinkage [8]. The autogenous shrinkage of HPC is a complex phenomenon influenced by many factors including: fineness of cement, cement type, SCMs, aggregate, fiber, water-to-cement ratio, admixtures, and curing. No uniform mechanism has yet explicated the autogenous shrinkage, albeit, the capillary pressure was introduced as the main driving force [9]. A thorough understanding of the mechanism is indispensable in order to apply methods to reduce the autogenous shrinkage and to improve the early-age cracking resistance of cement-based materials.

In this paper, the autogenous shrinkage mechanism is discussed and its different nature in comparison to other shrinkage types is elaborated. Furthermore, the influential factors in autogenous shrinkage of HPC are discussed. Meanwhile, problems involved in autogenous shrinkage of HPC and possible solution are also deliberated.

## 2. Shrinkage of concrete

Shrinkage of concrete can occur in two different stages: early and later ages. The first stage (within the first 24 h) is defined as a duration in which concrete is setting and starting to harden. Second stage, on the other hand, refers to the age beyond 24 h. Shrinkage at both stages mainly include autogenous shrinkage, drying shrinkage and thermal shrinkage which have overlapping results but with different mechanisms. In long term, the carbonation shrinkage is also added which has an accumulated effect. It was observed that autogenous shrinkage accounts for the most significant volume change in HPC at early ages compared to other types of shrinkage[10] . A quick glance at differences can help to better elaborate the mechanism and influential factors in the autogenous shrinkage of HPC.

### 2.1. Autogenous shrinkage

In general, the part of shrinkage which does not include any volume change due to loss or ingress of substances, temperature variation, and application of an external force and restraint can be considered as autogenous shrinkage. Therefore, it is also referred to as self-desiccation shrinkage. A technical committee on autogenous shrinkage at the Japan Concrete Institute (JCI) defined autogenous shrinkage as the macroscopic volume reduction of cementitious materials when cement hydrates after initial setting [11]. However, Mehta and Monteiro referred to it as the measured deformation of cement paste in a closed system [12]. Some studies consider the critical influence of autogenous shrinkage only limited to high and ultra-high performance concrete in which high amount of cementitious materials and low water-to-binder ratio are applied and the self-desiccation is highly triggered in the paste [13–15]

### 2.2. Chemical shrinkage

Chemical shrinkage refers to the volume change during the early ages of hydration resulted by formation of hydration products with lower volume in comparison with the volume of the initial reactants (water and cement) during the hardening process [16]. Chemical shrinkage, as a measurement of the absolute internal volume reduction, is considered as the driving force of