How to solve the autogenous shrinkage problem of geopolymers/alkali-activated concrete?

Geopolymers or alkali-activated materials (AAMs), as eco-friendly alternatives to Ordinary Portland Cement (OPC), have attracted increasing attention of researchers in the past decades. Unlike cement, which requires calcination of limestone, AAMs can be made from industrial by-products, or even wastes, with the use of alkali-activator. The production of AAMs consumes 40% less energy and emits 25 - 50% less CO_2 compared to the production of OPC.
Despite the eco-friendly nature of AAMs, doubts about these materials as an essential ingredient of concrete exist, regarding, for example, their volume stability. Autogenous shrinkage is the reduction in volume caused by the material itself without substance or heat exchange with the environment. If the autogenous shrinkage of a binder material is too large, cracking might happen, which will seriously impair the durability of concrete.

The aim of the study of Dr. Zhenming Li (TU Delft) was, therefore, set to understand and mitigate the autogenous shrinkage and the cracking tendency of AAMs.
At first, the autogenous shrinkage of AAMs is studied experimentally. It is shown that self-desiccation is not the exclusive mechanism of autogenous shrinkage of AAMs. Other driving forces, such as the steric-hydration force between colloids associated with the change in ion concentrations in the pore solution, also play a role, especially in the very early age. Besides, AAMs show pronounced viscoelasticity, which means a large time-dependent deformation or creep. Based on the clarified mechanisms, two strategies are proposed aiming at mitigating the driving forces of autogenous shrinkage: internal curing with superabsorbent polymers (SAPs) and the incorporation of metakaolin (MK).
Experiments in this study prove that the strategies proposed above are very effective to reduce the cracking tendency of alkali-activated slag and fly ash concrete. This result indicates that SAPs and MK can be promising ingredients for large-scale use in AAMs mixtures. The numerical approaches developed in this study are also useful in future studies or applications to estimate the creep and relaxation in AAMs.

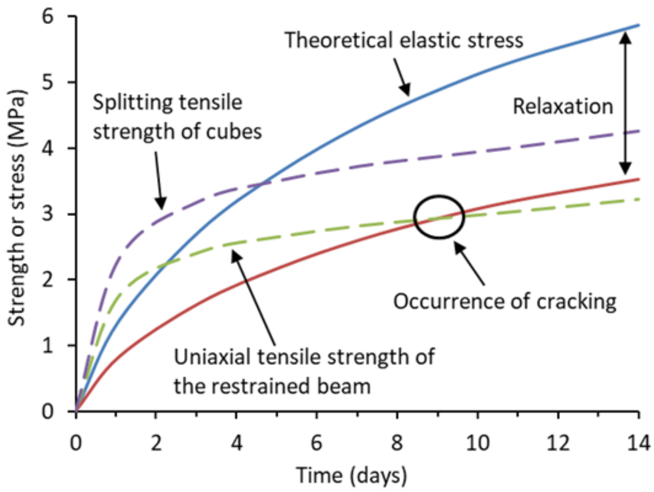

Figure 2. A schematic diagram of the stress development and the resultant cracking of concrete due to restrained shrinkage

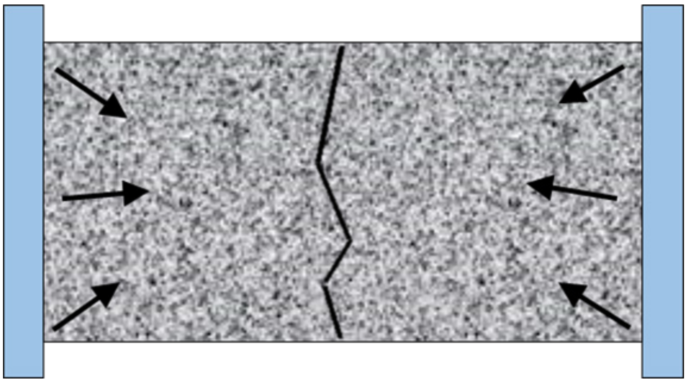

Figure 1. Schematic representation of cracking induced by restrained shrinkage

The PhD research of dr. Zhenming Li was carried out in the Department of Materials, Mechanics, Management & Design, Civil Engineering and Geosciences, Delft University of Technology. He was supervised by dr. Guang Ye and prof.dr.ir. Klaas van Breugel. He successfully defended his thesis on the 15th of March 2021. The title of his dissertation is: 'Autogenous shrinkage of alkali-activated slag and fly ash materials: From mechanism to mitigating strategies.'

The thesis can be found here>