

GEOPOLYMERS AND INORGANIC MULTIBINDER SYSTEMS

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INTRODUCTION

Geopolymers are large 3D molecules that are formed of aluminates and silicates. The term "geopolymer" was invented by Joseph Davidovits as a consequence of combining inorganic monomers ("geo") to a large molecule ("polymer") [1].

As raw materials silicon and aluminum containing materials like fly ash, metakaolin or blast furnace slag are used. Aluminates and silicates have to be dissolved, which is done by high alkaline sodium or potassium silicate solutions and/or sodium or potassium hydroxide solutions. The monomers in the solution poly-condensate to the 3D structure and build up mechanical strength.

Fly ash is obtained at flue gas treatment of coal power stations. Blast furnace slag is a side product of iron production. Metakaolin is formed from kaolin by a thermal treatment at about 750°C [2]. These materials are more environmentally friendly than Portland cement because the materials are waste products and/or need less energy for production (CO₂ footprint) [3].

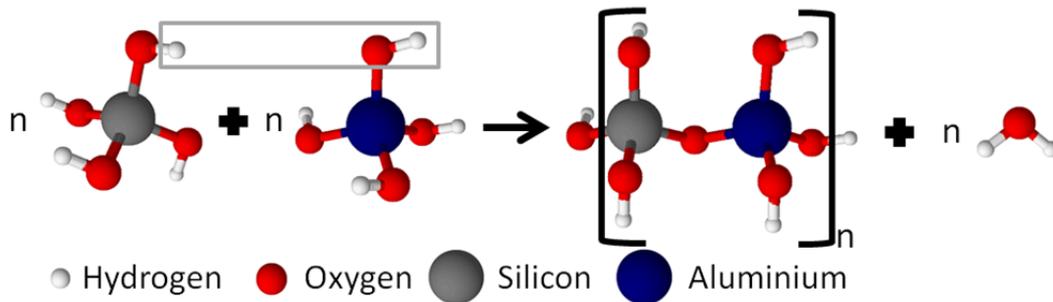


Fig. 1: Condensation reaction

Aluminate and silicate have a tetrahedral structure and react in a condensation reaction to a chain of geopolymer (Fig. 1). In this reaction water is a side product. This is contrary to cementitious reactions where water is chemically fixed in hydrates ("hydration") [4]. As a result of that, one big disadvantage is the high drying shrinkage and crack formation of geopolymer mortars. But geopolymers also have a lot of advantages. They have a high final strength, a heat resistance up to 1200°C and a very good chemical resistance. It is possible to immobilize toxic and radioactive materials in geopolymers because the 3D-structure of the geopolymer confines the harmful substance [5].

The goal of this work is to produce a geopolymer based on metakaolin, because of its good working performance and to characterize it by TGA-DSC and IR spectroscopy. An additional aim is to improve the geopolymer mortar by combining it with other inorganic binders.

RESULTS

Different metakaolines and activator solutions have been tested. According to a fast strength development, a geopolymer mortar produced from metakaolin, potassium silicate solution with a pH of about 13,5 and a solid content of 45% and quartz sand 0,1-0,7 mm was chosen allowing comparison with other inorganic binders. Fig. 2 shows the drying shrinkage through water evaporation of the geopolymer mortar as a function of different onset times under a poly-ethylene

(PE) sheet. It shows that there is a nearly constant drying shrinkage after the geopolymer reaction has finished.

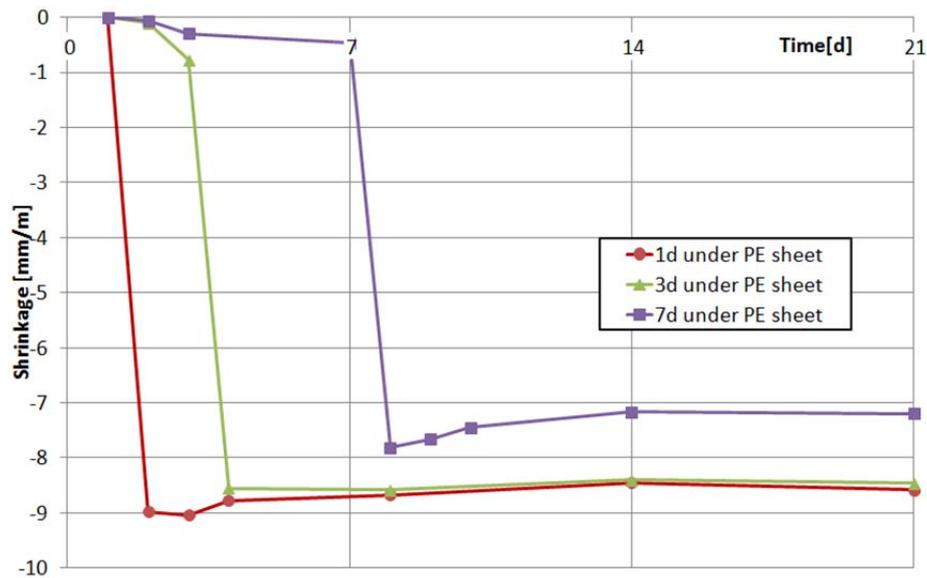


Fig. 2: Shrinkage of a geopolymer mortar during drying after onset times of 1, 3 and 7 days under a PE sheet

The Infrared wavenumber-shift of the asymmetric stretch bond of Si-O-T (T...Si or Al) is characteristic for the geopolymer formation [3][6]. By means of FTIR-spectroscopy with ATR cell, the geopolymer formation was measured. With addition of blast furnace slag to the mortar the shrinkage could be lowered. This can be explained by forming calciumsilicatehydrates C-S-H with the CaO from the slag and the silicate from the activator solution. Also gypsum was added which result in a very fast hardening. Probably this is due to formation of syngenite ($K_2Ca(SO_4)_2 \cdot H_2O$) as a reaction-product of gypsum with potassium from the activator solution.

DISCUSSION AND FORECAST

It was possible to produce a metakaolin based geopolymer and to characterize it by IR spectroscopy. The shrinkage during drying can be reduced by adding blast furnace slag. In the next steps other inorganic binders will be tested.

REFERENCES

- [1] Joseph Davidovits, Properties of Geopolymer Cements, published in Proceedings First International Conference on Alkaline Cements and Concretes, Kiev, 1994, pp. 131-149.
- [2] Christine Pélegris, Axel Compere, Ralph Davidovits, „Indirect 3D-printing of MK-750-based geopolymer ceramic“, Geopolymer Camp 2016, St. Quentin.
- [3] E. Gasparini *et al.*, “Geopolymers from low-T activated kaolin: Implications for the use of alunite-bearing raw materials,” *Appl. Clay Sci.*, vol. 114, pp. 530–539, Sep. 2015.
- [4] Verein Deutscher Zementwerke e.V. (Hrsg.), Zement-Taschenbuch, 51. Auflage, Verlag Bau+Technik GmbH, 2008.
- [5] Martin Leute, Präsentation, Geopolymer eine neue Generation zementfreier Bindemittel, Wöllner Austria GmbH, 8111 Gratwein-Strassengel.
- [6] P. Rovnaník, “Effect of curing temperature on the development of hard structure of metakaolin-based geopolymer,” *Constr. Build. Mater.*, vol. 24, no. 7, pp. 1176–1183, Jul. 2010.