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Effect of polyethylene glycol addition on metakaolin-based geopolymer

Olesia Mikhailova*, Pavel Rovnaník

Brno University of Technology, Faculty of Civil Engineering, Veveří 331/95, Brno, Czech Republic

Abstract

Polyethylene glycol is a non-toxic water soluble polymer often used in many industrial applications. The aim of this paper is to study the effect of polyethylene glycol with relative molecular weight ranging between 400–20000 on the properties of geopolymer mortars composed of metakaolin and sodium silicate. Polyethylene glycol was added in the amount of 0.5 to 10% by mass of metakaolin. After 28 days of curing at ambient conditions, different tests were carried out: physico-chemical (density, porosity), mechanical (flexural and compressive strength) and structural (SEM). The results showed that a maximum compressive strength of 23.9 MPa and a maximum flexural strength of 2.9 MPa were achieved by adding 10% PEG 400.

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Keywords: Metakaolin; geopolymer; polyethylene glycol; mechanical properties; microstructure

1. Introduction

Geoplymers are novel materials, which have been rapidly developed during the last decades due to ecological reasons, environmental impact and durability [1]. Geopolymer can be synthesized by mixing aluminosilicate reactive materials with CaO component and strongly alkaline solutions. In such solutions, aluminosilicate materials are rapidly dissolved to form SiO_4 and AlO_4 tetrahedral units. During the development of the reaction, mixing water is gradually split out and SiO_4 and AlO_4 tetrahedral are linked alternatively to yield three types of monolithic geopolymer products [2].

* Corresponding author.
E-mail address: mikhailova.o@fce.vutbr.cz

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Geopolymers have many advantages compared to OPC, such as high early strength [3], good fire and acid resistance and good durability [4–6]. Additionally, they have normally low apparent porosity, which gives them very low water permeability and thus very good resistance in freezing-thawing cycles [7].

However, disadvantages also exist. Geopolymers present a typical brittle mechanical behavior with the consequent low ductility and low fracture toughness [8]. These characteristics can limit their applications as a structural material. In order to improve these drawbacks of geopolymer materials, organic polymers are often incorporated in their structure [9].

Polyethylene glycol (PEG) is a polyether compound with many applications in industrial manufacturing. PEG is one of the most well-known water-soluble polymers, while it can also be dissolved in many organic solvents including aromatic hydrocarbons. PEG is used as a plasticizer to increase lubricity and acts as a water retention agent in ceramic mass, adhesives and binders and soldering fluxes with good spreading property [9].

In a study of Catauroa et al. [11], the influence on mechanical strength of the different percentages of PEG added to geopolymer was investigated. In absence of PEG, the tests showed overall strength regularity with aging time due to the chemical composition of sample. PEG-free samples can reach final mechanical strength faster than hybrid systems. The stretching effect of PEG, that in general provides the characteristic of elasticity to the base material together with the longer time required to reach the final structural strength, justifies the increase of flexural and compressive strengths with aging time.

Colangelo et al. [12] concluded that polymer-modified mortars have improved compressive strength in comparison to unmodified ones and polymer helps restrain micro-crack propagation. They also found out that total porosity decreases with the addition of organic polymer and this may contribute in improved durability.

Hereby the aim of this work is to explore the amount of PEG that can be added to geopolymer systems, in order to improve their properties. The rather limited literature in this field of study necessitates the expansion of knowledge on this topic.

2. Experimental

2.1. Materials used

Chemical composition of metakaolin (Mefisto K_{05} – ČLUZ a.s.) used in this study is given in Table 1. It was produced through controlled thermal processes and grain size adjustments of clay stones and floating kaolin clays. Particle sizes are d_{50} = 6.34 µm and d_{90} = 11.62 µm.

Table 1. Chemical analysis of metakaolin Mefisto K05 (*% w/w*).

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	LOI
55.01	40.94	0.55	0.55	0.14	0.34	0.09	0.60	1.57

The metakaolin was activated with a water glass solution having a SiO_2/Na_2O ratio of 1.6. Quartz sand with a maximum grain size of 2.5 mm was used as aggregate. Different commercial types of polyethylene glycol (ROTIPURAN®, Ph.Eur), indicated as PEG later on, were used at different dosage from 0.5 to 10% by mass of metakaolin:

- PEG 400
- PEG 1000
- PEG 6000
- PEG 20000

2.2. Mortars preparation

Geopolymer mortars with and without PEG were prepared with an aggregate/binder ratio of 3/1. Each type of PEG was added at dosages of 0.5, 1, 2, 5, 7 and 10 % by mass of metakaolin. The activator and PEG were added in