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ScienceDirect

Procedia Engineering 171 (2017) 572 – 583

Procedia Engineering

www.elsevier.com/locate/procedia

Sustainable Civil Engineering Structures and Construction Materials, SCESCM 2016

Effect of curing temperature and fiber on metakaolin-based geopolymer

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Abstract

This paper presents mechanical properties of geopolymer mortar with metakaolin as a base material. Cylindrical specimens were prepared with a diameter of 5 cm and 10 cm height. Four compositions of geopolymer paste varied with adding polyvinyl alcohol fiber (PVA) from 0% to 1% by volume of paste. After casting, steam curing method was conducted at 40°C, 60°C and 80°C for 24 hours. A control specimen was cured at room temperature. Some tests were performed for setting time, compressive strength, split-tensile, direct-tensile and porosity. It showed that the strength of fibrous specimens was 67.29 MPa at of 56 days without steam curing. When curing temperature was risen from room temperature 80°C, the strength increased up to 14% at 28 days. Ratio of split to compressive strength was about 10% when 1% fiber was applied. However, an optimum result was shown by specimens containing 0.6% fibers according to direct-tensile test. It is recommended to apply steam curing at 60°C-80°C to increase the tensile strength.

Peer-review under responsibility of the organizing committee of SCESCM 2016.

Keywords: Metakaolin; geopolymer; PVA; curing temperature.

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Peer-review under responsibility of the organizing committee of SCESCM 2016.
doi:10.1016/j.proeng.2017.01.376

1. Introduction

Global warming has become a major topic in the wide range of science and engineering research, within the last decade. The problem is related with exhaust emissions such as CO_2 from human activities. It is about 65% of greenhouse gases caused by CO_2 where Portland cement production contributes in a range of 7-8% [1]. Therefore, it is necessary to obtain green concrete materials as an innovative solution. One of the solutions is geopolymer manufacture, which is also known as zero-cement concrete. Most of geopolymer mixtures use by-products in their composition. Fly ash is the most favorable material for making geopolymer concrete [2]. Mud, clay and slag are also utilized as the raw material in geopolymer binders [3-5]. However, in Indonesia, some by products such as fly ash and bottom ash are considered as hazardous materials. It comes to being the application limitation to develop geopolymer products from laboratory to industry scale. In addition, physical characters of by-product vary in some aspects such as origin materials treatment, shape, size, etc. [6-8]. Kaolin is one of the natural pozzolanic materials, which is rich in silica and alumina. With a proper calcination, metakaolin can be produced from 75%-80% by mass of kaolin, which contains soluble silica. Since it consists of reactive oxides, metakaolin requires low concentration of alkali activator [9].

In this paper, polyvinyl alcohol fiber (PVA) is introduced to improve tensile strength of metakaolin geopolymer paste. In addition, variations of curing methods were also introduced to investigate the effect of temperature to increase compressive strength. Some influential factors to the mechanical strength of fresh and hardened paste were analyzed and discussed comprehensively. Therefore, this study will be a bench-mark formalization of environmental friendly material using kaolin as one of the alumina-silicate sources.

2. Experiment

2.1. Materials and mix proportions

Kaolin with 2.5 g/cm^3 of density adopted in this study was obtained from Bangka Belitung, Indonesia. Its chemical composition is listed in Table 1.

Table 1 Chemical composition of source materials

Oxides (%)	SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	TiO2	MnO2	SO3	LOI
	50.26	43.00	0.73	0.04	0.12	0.04	0.57	0.28	0.01	4.72	4.72

Calcination method to activate raw material from kaolin to metakaolin is based on an experimental work developed by Triani [10]. Kaolin with particle size of 75 μm was immersed and stirred in distilled water for 10-15 minutes. It was kept in room temperature for 24 hours until sedimentation occurred. This precipitated materials were not used for making the geopolymer mixture since it may contain unreactive quartz. The top part of silt was collected to be dried in oven. Calcination process is illustrated in Fig. 1 as temperature history of furnace setting. Temperature target of 700^{o}C was set constant for six hours. Metakaolin was then pulverized until its maximum particle size of 75μm as shown in Fig 2.