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The effect of mechanical activation of lime putty on properties of the autoclaved calcium hydrosilicate materials

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Abstract

The lime putty is a non-Newtonian fluid that can be either thixotropic or rheopectic depending on burning process of the lime, the presence of the quartz sand and other parameters. One of the most important lime putty characteristics is its plasticity which affects its workability and use. It is possible to increase the lime putty plasticity by mechanical activation. This work focuses on the effect of the mechanical activation of the lime putty on its rheological behavior and on properties of lime hydrosilicate autoclaved materials. Fresh lime putty was activated in a high-speed mixer at 1000 RPM for 1, 3, 5 and 10 minutes. Non-activated lime putties show rheopectic behavior. Rheopectic behavior becomes slightly more distinct after 1 min. of activation and then less distinct with increasing time of activation. After 10 min. of activation, the system shows no time-dependent properties, nor even slight thixotropic behavior. This trend can be related to process where smaller and smaller aggregates are fragmented in the suspension. The hydrosilicate materials were prepared in two series from quicklime and finely ground sand with the ratio C/S 0.85, under hydrothermal conditions. The amount of xonotlite in hydrosilicate material increases with activation time as the increased amount of portlandite particles retards the reaction. 11.3 Å tobermorite crystallizes more slowly and formation of xonotlite is accelerated.

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Keywords: Calcium silicate hydrates; lime putty; mechanical activation

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Nomenclature

C	CaO
S	SiO_2
H	H_2O

1. Introduction

The lime-based hydrosilicate materials are formed as a result of reaction between sand, lime and water under hydrothermal conditions. The properties of hydrosilicate products are based on the formation of C-S-H phases during this reaction at temperatures below 180–200 °C and water vapor pressure lower than 16 bars. The main C-S-H phases are 11.3 Å tobermorite and xonotlite.

11.3 Å tobermorite ($Ca_5Si_6O_{16}(OH)_2 \cdot 4(H_2O)$) is the main binder component and contains a significant amount of water. It is stable in a range of Ca/Si ratio from 0.8 to 1. At temperatures above 300 °C, it decomposes to 9 Å tobermorite ($Ca_5Si_6O_{16}(OH)_2 \cdot 2(H_2O)$). Xonotlite ($Ca_6Si_6O_{17}(OH)_2$) is structurally very similar to 11.3 Å tobermorite but contains 5 times less water than tobermorite. It forms at higher temperatures than tobermorite under hydrothermal conditions between ~ 220 °C – 380 °C. The phase composition is the essential factor influencing strength, porosity and sorption ability of a material [1,2].

The rheological behavior of lime putty is an important parameter that influences the quality of resulting lime-based hydrosilicate materials. The lime putty is a non-Newtonian fluid that can be either thixotropic or rheopectic. It depends on burning process of the lime, presence of the sand and other parameters. Plasticity of the lime putty is essential in terms of material workability and performance. The spontaneous shape changes, bleeding, or segregation of larger particles in lime putty during measurement must be eliminated. The complete rheological study of lime putty was carried out by Ruiz Agudo et al. [3].

Various studies were carried out in order to reveal the role of different parameters on the properties of lime putties [4–7]. Studies considered the change of properties of lime putties during aging. It is possible to increase the lime putty plasticity by mechanical activation. Lime putty is a dispersion system in which the process of dissolution and re-crystallization of portlandite takes place. A decrease in particle size leads to plasticity increase. Small particles have greater surface and fewer of them is needed in mortar to coat grains of sand [8]. Vávrová and Kotlík [9], [10] studied the effect of mechanical activation of the lime putty. The intense mechanical stimulation of particles leads to particles size decrease and to increased reacting surface. The accessibility of water to the particle surface is improved which makes it easier to hydrate them. Nečas et al. [11] observed possibilities of the lime slurry plasticity affection. They confirmed viscosity increase related to mechanical activation.

This work deals with the effect of the lime putty mechanical activation on its rheological behavior and on composition and properties of lime hydrosilicate autoclaved materials.

2. Materials and methods

The quicklime produced in the rotary kiln was used for the preparation of slaked lime putties: The lime purity was higher than 97 %. Slaked lime putties were prepared in the laboratory by mixing lime and deionized water under vigorous stirring. The C/H ratio was 1:8. The fresh lime putty was activated in a high-speed mixer at speed 1000 RPM for 1, 3, 5 and 10 minutes.

The activated lime putty was mixed with finely ground sand at the ratio C/S 0.85 under vigorous stirring. The sand contained 99 % of SiO_2. This slurry was hydrothermally treated. Two series were prepared: a) temperature 195 °C and overpressure 13 bars for 24 hours b) temperature 205 °C and overpressure 16 bars for 24 h. The final product was dried at the temperature 370 °C.

The composition of the lime, sand, and hydrosilicate materials was determined by X-ray diffraction. The X-ray diffraction analysis was conducted using the Bruker D8 Advance apparatus with Cu anode ($\lambda K\alpha$ = 1.54184 Å) and variable divergence slits at Θ-Θ Bragg-Brentano reflective geometry. Quantitative phase analysis was carried out by