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Alternative Production Processes of Calcium Silicate Phases: A Review

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Abstract

Calcium silicates production by alternative methods to solid state reaction method has gained importance because of the possibility to obtain materials with higher performance and less energy consumption than the traditional process. Exploring the application of non-conventional methods for the production of cementitious materials is an interesting alternative to produce materials with high performance, as nanoparticles, which are expected to permit high reactivity of the phases. The alternative methods require more studies allowing to understand the individually and the combine effects of synthesis processes conditions over the particles properties.

Keywords: Synthesis; Alternative methods; Calcium silicates; Clinker; Portland cement; Pure cement phases

Considerations

Global demand of cement is increasing year by year in a factor of 25; therefore, greenhouse gas emissions from this industry are growing in significant amounts. Nowadays, CO_2 emissions for cement production correspond almost to 5-8% worldwide, which is a motivation to find solutions to reduce the environmental impact. Some ways to attack this problem are applying new technologies, improving current technology, and using alternative cement substitutes and alternative fuels [1].

Ordinary Portland Cement (OPC) is a popular construction material traditionally obtained by the combination of limestone and clays. The main component formed during its fabrication is the clinker, which is composed by four main phases, alite (Ca_3SiO_5 or C_3S), belite (Ca_2SiO_4 or C_2S), celite ($Ca_3Al_2O_6$ or C_3A) and ferrite ($Ca_4Al_2Fe_2O_{10}$ or C_4AF). The calcium silicate phases, alite and belite, are responsible of the development of mechanical properties, such as compressive strength in construction structures, while aluminate phases, celite and ferrite, play a role in the setting time of cement and durability of concrete [2,3].

Pure cement phases with nanometric size have been obtained by non-conventional methods such as Pechini, sol-gel and self-propagating combustion, which showed good results to the formation of the cement matrix. The first work in the study of pure cement phases was done by R. Roy and Oyefebesi in 1977 using the sol-gel method [4]. Since then, different research have been done in the study of the process effects on the formation of cement polymorphs and their reactivity, considering the anhydrous and hydrated compounds [5-12].

The study of cementitious materials, such as pure cement phases, allows the understanding of phenomena related to hydration chemical reactions of clinker, enabling the improvement of cement properties in macroscopic systems and providing more information about the influence of atomic position on the level of reactivity of the structure in single crystal systems [3,13].

Production and performance improvements of cementitious materials allow the reduction of energy consumption and mitigate the negative impacts of cement industry. Most strategies are focus on the improvement of clinker performance and alternative processes for its production. Hence, this paper shows a review of research focused on the synthesis of cementitious phases, especially the calcium silicates alite and belite, through non-conventional methods.

Polymorphs of calcium silicate phases and their hydration activity are a broad topic that is strongly studied around the world. The wide amounts of variables make of this topic a complex research, which is why there is not a single answer to the phenomena that occurs in cement phases formation and hydration.

The use of alternative synthesis methods with control over the process conditions in the production of cementitious phases allows manipulation of products features, and therefore a better understanding of the crystal structure of the cement phases and the hydration mechanism to improve the properties of the cement [14].

Alternative synthesis methods as Pechini, sol-gel and self-combustion are become important because of the possibility of reducing the energetic consumption process and produce nanoparticles with superior features than traditional powders. However, all of them are batch methods, which is a limitation to scale-up the process. Therefore, it is important the implementation of continuous methods which allows the scale-up of the process.

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