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Influence of low pressure steam curing on development of strength of mortars based on cement with high-calcium fly ash

Małgorzata Gołaszewska[a]*, Tomasz Ponikiewski[a]

[a]*Silesian University of Technology, Faculty of Civil Engineering, Akademicka 5, Gliwice 44-100, Poland*

Abstract

Due to sustainable development policy, concrete additives such as high-calcium fly ash (HCFA) are nowadays used more often than ever and in wider range of possible uses. Therefore, research into characteristics of HCFA and its influence on the properties of cement and concrete is extremely relevant in current concrete technology. In this paper, Authors present the results of research into influence of low-pressure steam curing on compressive strength of mortars with HCFA. Samples of five different cements (CEM II/B-M(S-W) 10/20, CEM II/B-M(S-W) 20/10, CEM II/B-W, CEM II/B(V - W), CEM II/B(LL-W)) were steam-cured in temperatures 40ºC, 60ºC and 80ºC. Conducted compressive strength tests confirmed the possibility of using cements with HCFA in mortars undergoing low-pressure steam curing in this aspect.

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Keywords: low pressure steam curing; high-calcium fly ash; mortars; compressive strength

1. Introduction

Increasing environmental awareness and sustainable development policy pose a number of challenges for the entire cement industry due to a high emission of CO_2 in cement production. Currently, production of 1 ton of clinker causes an emission of about 0.8 ÷ 1.0 ton of carbon dioxide, depending on the exact technological parameters of process of production [1]. This places cement industry among the leaders in CO_2 production in industrial sector [2].

* Corresponding author. Tel.: +48 602 130 265.
E-mail address: malgorzata.golaszewska@polsl.pl

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This fact caused an upsurge in use of mineral additives which exhibit pozzolanic and hydraulic properties to cement, as a more environmentally friendly substitute for a portion of clinker. Mineral additives, such as granulated blast furnace slag and fly ashes are byproducts of factory processes and therefore their use not only does not require an substantial amount of CO_2 for its production, but also is a way of disposing of the waste. Therefore, using mineral additives creates technological, environmental and economical advantages [3]. European standard PN-EN 197 - 1 [4] describes the mineral additives for cement and sets the requirements the materials need to meet in order to be used as a substitution of a portion of cement.

High-calcium fly ash, which is the subject of the following paper, up to this point has been largely underused material in Polish cement industry, due to the fact that its composition and properties vary significantly between points of its production as well as different batches from the same production plants, high water demand and high content of free CaO and sulphur compounds [5, 6]. Moreover, there has not been many research conducted in scope of its use and properties [5].

Following paper deals with a issue of using high calcium fly ash as a constituent of cement in a process of low pressure steam curing in terms of development of its compressive strength. The process is used in production of pre-cast concrete as a way of increasing speed of hydration and the early compressive strength of cement and concrete [7]. The aim of the research was to check the strength development of chosen cements with high-calcium fly ash after the process of low pressure steam curing, what could open a new possibilities for pre-cast concrete production.

The research included test of compressive strength of mortars after 1, 2, 7, 28 and 58 days made of cements: CEM II/B-M (S-W) 10/20, CEM II/B-M (S-W) 20/10, CEM II/B-W, CEM II/B (V - W), CEM II/B (LL-W) which were a part of a larger study into properties of cements with HCFA, and CEM I, steam-cured in three temperatures (40^{o}C, 60^{o}C, 80^{o}C) and cured in room temperature 20^{o}C.

2. Low pressure steam curing

The process of low pressure steam curing is a process of speeding up the hardening of concrete by early curing by steam of temperature below 100 ^{o}C. This process does not require any additional water curing, as the humidity form the steam is sufficient for the concrete. In practical use, the necessity of using specialized chambers or tunnels for the process, means that it is most commonly used in precast concrete plants [8].

2.1. Influence on compressive strength of cement and concrete

The influence of low pressure steam curing on strength development of Portland cements and concretes with Portland cements are described in various publications [8, 9, 10, 11]. Generally speaking, low pressure steam curing causes the early compressive strength to increase, at the cost of lower final strength in comparison to non-steam cured samples.

It can be also stated, that the higher temperature of steam-curing, the faster is the initial strength development and the lower final compressive strength of the cement and concrete [9, 10, 11]. The explanation of this dependence can be found in the process of hydration. The faster rate of hydration, caused by the high temperature causes the hydration products to conglomerate around the grains of cement, blocking the access of water to the grains. This leads to the cement not fully hydrating, and not using the whole potential of cement paste. Created hydrates' structure does not provide full possible strength [8].

Another explanation lies in physical aspects of the process of cement hardening. The air entrapped in the concrete mix or fresh mortar has higher expansivity than the cement paste – the high temperature during the low pressure steam curing causes fast expansion of air pockets, what causes additional tension in the cement paste. That causes cracks to appear in the structure of cement, lowering its compressive strength. This effect in present through the entire process of hardening of cement, however in early phase of hardening it is masked by sudden increase of compressive strength caused by fast hydration [9]. The thermal expansion of mortars and concretes itself also plays a role in the lower final strength of concretes [12]. Process of heating up the samples causes the difference in temperature between inner and outer parts of the sample, causing the different expansion rate and introducing new tensions in the structure of mortar or concrete, what leads to cracking and decreased cohesion between aggregate and cement paste. This in turn lowers the final compressive strength of concrete.