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# Investigating the Most Important Physical and Mechanical Properties of Phosphorus Slag Cement

A. Allahverdi[1*] M. Mahinroosta[2]

## 1-Introduction

The development of the cement industry and related products in the framework of the principles of sustainable development has been discussed in many research studies. These principles include saving natural resources, saving energy, reducing environmental pollution, and improving the durability of the cement and the concrete. The development of the cement industry in addition to its usefulness to humankind is also associated with the consumption of a large amount of resources and energy. Portland cement production is associated not only with the use of limestone, clay, thermal and electrical energy, but also with emission of gases such as carbon dioxide, sulfur trioxide, and nitrogen oxides into the atmosphere, causing the greenhouse effect and acid rain. Therefore, the development of the cement industry should be bounded by a sustainable development strategy. When modern concrete structures are exposed to corrosive environments, major problems that can eventually lead to early destruction occur. During the twentieth century, the carbon dioxide concentration which is one of the byproducts of the steel and Portland cement factories, has risen to 50% in the environment. Therefore, finding suitable materials that can replace cement in concrete are a promising way to reduce the release of this gas. These materials should not contaminate the environment, increase energy consumption and reduce the durability of structures. This suitable solution can expand the recycling of industrial solid wastes such as blast furnace slag, steel slag, phosphorus slag, chromium slag, copper slag and fly ash as additives to cement. The purpose of using these industrial solid wastes as additives to cement is to expand the consumable resources, save energy and reduce environmental pollution. It can also reduce production costs and improve cement durability. In this paper, phosphorus slag (PHS) is used as a supplementary cementing material for the preparation of a blended cement, which is both mechanically and chemically activated.

## 2-Experimental Program

In order to prepare test specimens and perform experiments, first phosphorus slag cement containing 80 wt.% of PHS and 20 wt.% of the Portland cement based-compound chemical activator were mixed and were homogenized by mechanical treatment. The above-mentioned cement mixture was then milled by a laboratory ball mill to desirable Blaine fineness of 2050, 3030, and 4500 $cm^2/g$. The most important physical and mechanical properties of phosphorus slag cement, which are discussed in this paper, are changes of bulk density in terms of Blaine fineness, initial and final setting times, water-to-cement ratio, and compressive strength of mortar specimens at three Blaine fineness of 2050, 3030, and 4500 $cm^2/g$. Then, the Blaine fineness of 3030 $cm^2/g$ will be selected to investigate the effect of curing temperature (45, 85, and 200 °C) on the development of compressive strength of the mortar specimens.

## 3-Resutls and discussion

The bulk density of phosphorus slag cement decreased with increasing the Blaine fineness. This means that by increasing the fineness, the porosity of the phosphorus slag cement increases and, as a result, the bulk density decreases. The decreased initial and final setting times by increasing the Blaine fineness can be attributed to the specific surface area and the number of cement grains in a certain volume of cement paste. Phosphorus slag cement has a longer final setting time than type II Portland cement. The remaining phosphorus in the form of $P_2O_5$ in phosphorus slag may be due to condensate orthophosphates and phosphates. Orthophosphates are highly soluble and increase the setting time. The water-to-cement ratios for PHS cement mortar at Blaine of 2050, 3030 and 4500 $cm^2/g$ were 0.36, 0.37 and 0.386 respectively, and for the pastes they were 0.25, 0.27 and 0.286, respectively. The water-to-cement ratio is influenced by the characteristics of PHS slag cement such as particle size, particle shape and specific surface area. The 7-, 14-, 28-, 90-, and 180-day compressive strengths of PHS slag cement mortar at three Blaine finenesses are given in Fig. 1. As it can be clearly observed, the compressive strength of PHS cement mortar increases at a certain aging time (e.g., 7, 14, or 28 days) with increasing the Blaine fineness. This can be related to the increased reactivity of PHS particles and their improved filling properties. By increasing the surface area, the available contact area for the

[1*]Corresponding author: Professor, Research laboratory of Inorganic Chemical Process Technologies, School of Chemical Engineering, Iran University of Science and Technology.
Email: ali.allahverdi@iust.ac.ir
[2]Ph.D. candidate, Research laboratory of Inorganic Chemical Process Technologies, School of Chemical Engineering, Iran University of Science and Technology.

hydration reactions increases. Also, by increasing the Blaine fineness which results in smaller particles, the particles fill the matrix's pore spaces much better than before. As a result of the effect of these two factors, the compressive strength increases with the enhancement of Blaine fineness.

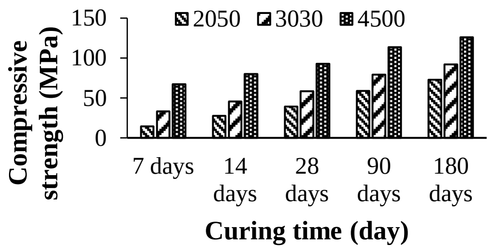


**Fig. 1 Compressive strengths of phosphorus slag cement mortar at three Blaine finenesses and various curing times**

Also, Fig. 2 depicts the compressive strength results observed at three curing temperatures of 45, 85, and 200 °C at different ages of curing.

#### 4-Conclusions

The results showed that the compressive strength increases with increasing the Blaine fineness. Also, compressive strength increased in terms of curing times at three temperatures, with the difference being that at the two considered temperatures above 45 °C, the compressive strength at the end of the curing time was reduced. Water-to-cement ratios of mortar and paste of phosphorus slag cement at low Blaine fineness were higher than those at a higher Blaine fineness. The initial and final setting times of phosphorus slag cements were longer than those of type II Portland cement. In morphological studies, it was observed that Portlandite crystals that resulted from the hydration of slag and Portland cement at different temperatures had different morphologies.

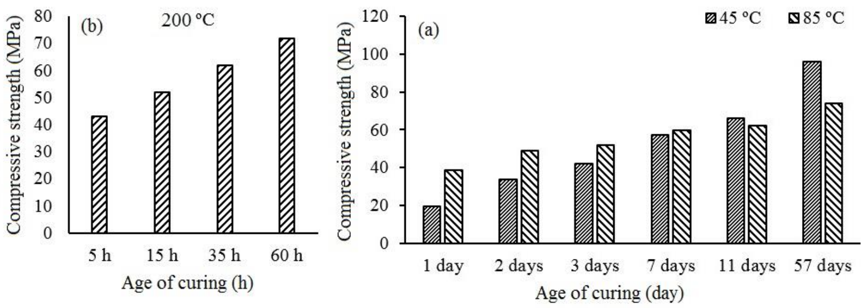


**Fig. 2 Compressive strengths of phosphorus slag cement mortar at various curing temperatures**