Influence of phosphogypsum as setting regulator on the mechanical performances of cement mortar

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1. Introduction

Phosphogypsum (PG) is an industrial by-product of the fertilizer industry, mainly from the production of phosphoric acid from phosphate rock. PG consists primarily of $CaSO_4 \cdot 2H_2O$, but also contains impurities such as P_2O_5, F and organic substances, the composition of impurities can be very variable depending on phosphate rock used and other factors developed according to the treatment in processing plants (Rutherford et al., 1995).
Large quantities of PG are produced around the world as inorganic waste in several industrial processes. World PG production is variously estimated to be around 100–280 Mt per year (Yang et al., 2009) and the main producers of phosphate rock and phosphate fertilisers are located in the USA, the former USSR, China, Africa and the Middle East.
In Spain, due to a large fertilizer industrial complex situated in Huelva city over 3 Mt of PG wastes were produced each year and deposited in a stack located less than 1 km away from the city (Pérez-López et al., 2010).
Several authors have researched the use of this low-cost waste. The main uses investigated have focused on the use of this by-product as additive in agricultural soils (Garrido et al., 2005). However, the valorisation of this waste is very limited. Actually only 15% of the worldwide production is recycled. The remaining 85% requires large disposal areas and may cause huge environmental problems (Pérez-López et al., 2010).
Typically, natural gypsum (NG) is used as setting retarder. However, due to environmental concerns and the lack of natural deposits of gypsum, this work studies the use of PG as setting retarders to replace the natural gypsum.
In this study, different percentages of PG untreated and sieved were added to clinker to evaluate the use of PG as a substitute of NG. Different curing conditions were studied. An ordinary Portland cement manufactured with 3% of NG was compared with the new mixes realised. Physical and mechanical properties were analysed, higher values on mechanical behaviour were obtained for higher PG additional percentage. Demonstrating that it is possible the valorisation of this by-product for use in the manufacture of cement.

2. Materials and methods

The present study evaluated two different processes of phosphogypusm, including non-processed (PG-NP) and sieving phosphogypsum to obtain the fraction 0/125 µm (PG-S) to evaluate the influence of PG as an addition to cement the properties of the cement mortars manufactured with clinker (Ck) and PG were compared to those of cement without additions manufactured with natural gypsum (Control-OPC).
Two groups of mortar were manufactured according to the curing conditions. The first batch was cured underwater and the second batch was cured in dry chamber. Each group consisted of 4 types of mortars according to the system used to process PG and the percentage of addition respect to cement (Fig. 2). To perform a comparison of results, a control mixture of mortar was added (CONTROL-OPC). The physical properties and mechanical performance were tested, with six experimental replicates of each sample.

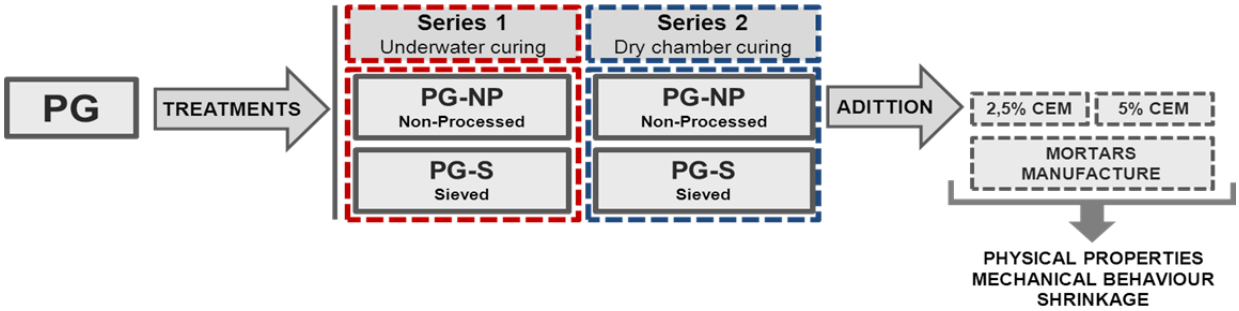

Figure 1: Experimental program

3. Results and discussion

The following tables show a list of the results obtained more characteristic of all of the materials tested. Table 1 shows fresh mortars properties and Table 2 shows hardened mortars properties.

Table 1. Fresh mortars properties

	Consistence (mm) UNE-EN 1015-3	Density (g/cm^3) UNE-EN 1015-6	Setting time (minutes) UNE-EN 196-3	
			Initial	***Final***
Control-OPC	166	1937	189	256
PG-NP 2,5	153	1974	153	209
PG-S 2,5	156	1991	132	197
PG-NP 5	146	1966	181	246
PG-S 5	149	2023	166	224

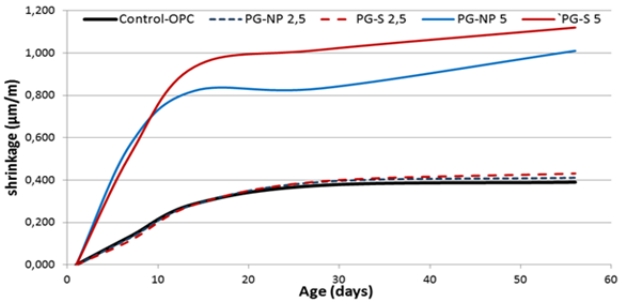

Figure 3: Shrinkage of mortar as a function of age

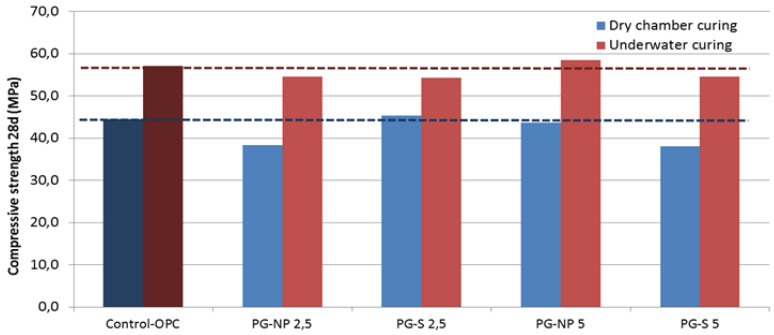

Figure 2: Compressive strength at 28days

Table 1 shows the setting time increases as the percentage of PG addition increases. The use of PG-S accelerates the setting time respect to PG-NP. Consistency similar to the control mortar mixture was obtained from all of the PG because a super-plasticizer additive was added. Density increased with the addition of PG.

According to mechanical properties, Figure 2 shows that curing conditions significantly influence, large losses of compressive and flexural strength were observed in Series 2 mortars respect to Series 1 mortars. As shown in Figure 2 at higher percentage of PG addition the compressive strength of the cement mortar increased. On the other hand, the sieved treatment applied to PG does not significantly influence the mechanical properties of mortars.

Shrinkage was similar that of control-OPC in mixes with a minimum addition percentage of PG (2,5%). However, in cement mortars made with 5% PG, the shrinkage values increased significantly (Fig.3).

4. Conclusions

This work evaluates the properties PG for manufacture cement mortars through its use as an additive of cement for setting retarder. The following conclusions were obtained:

- The substitution of NG by PG accelerates the setting time. PG addition as setting regulator does not involve large losses in compressive and flexural strength.
- The curing conditions significantly influence on the mechanical strength of cement mortars.
- Dimensional variation presents similar values to the control in mortars with addition of 2,5 of PG.
- Carrying out a simple sieving treatment to the PG does not imply significant improvements in the mechanical properties of cement mortar.

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