INFLUENCE OF PHOSPHOGYPSUM AS SETTING REGULATOR ON THE MECHANICAL PERFORMANCES OF CEMENT MORTAR

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PHOSPHORIC ACID PRODUCTION

Natural phosphate rock → Phosphoric acid → PHOSPHOGYPSUM STACKS → MILL → ACID TREATMENT → FILTER → CONCENTRATION AND PURIFICATION STEPS → Fertiliser production / Other applications

1t PHOSPHORIC ACID → 5t PHOSPHOGYPSUM
PHOSPHOGYPSUM GENERATION

100-280 Mt per year
Worldwide Phosphogypsum generation

INTRODUCTION
PHOSPHOGYPSUM GENERATION IN ANDALUSIA

INTRODUCTION
PHOSPHOGYPSUM VALORIZATION

INTRODUCTION

PHOSPHORIC ACID PRODUCTION

WASTE
Phosphogypsum

85% worldwide production disposed in open or stack yards

15% RECYCLED

AGRICULTURE
- Additive in agricultural soils

CONSTRUCTION
- Filling of embankment
- Stabilizing element of soils
- Soil-cement
- CEMENT SETTING RETARDER

WASTE UTILIZATION

LESS USE OF NATURAL RESOURCES

SUSTAINABILITY
INTRODUCTION

VALORIZATION PHOSPHOGYPSUM

CEMENT MANUFACTURING PROCESS

CLAY
LIMESTONE
OTHERS

Crusher ➔ RAW MIX ➔ Kiln ➔ CLINKER ➔ Grinding ➔ CEMENT

GYPSUM

PHOSPHOGYPSUM
OBJECTIVES

PHOSPHOGYPSUM AS SETTING REGULATOR IN CEMENT MORTAR

Few research related to phosphogypsum as a setting regulator for cement

Principal objective: study of cement mortars manufactured with different percentages of phosphogypsum (PG) sieved and without treatment and under different curing conditions to determine the optimal replacement rate to increase the economic value of PG and decrease the use of raw materials (gypsum) in cement manufacturing process

TREATMENT AND PROCESSING OF PG

- Study the influence of curing conditions
- Study the physical properties
- Study the effect on the compressive strength, flexural and shrinkage
PHOSPHOGYPSUM AS SETTLING REGULATOR IN CEMENT MORTAR

**RESEARCH DESIGN**

**PROCESSING**

- **PG-NP**: Unprocessed
- **PG-S**: Crushed - Sieved

**ADDITION**

- 2.5% CK
- 5% CK

**MORTARS MANUFACTURE**

**Curing conditions**

- **Series 1**: Underwater curing 100%/20ºC
- **Series 2**: Dry chamber curing 50%/20ºC

**PHYSICAL PROPERTIES**

- Compressive Strength
- Flexural Strength
- Shrinkage
PHOSPHOGYPSUM AS SETTING REGULATOR IN CEMENT MORTAR

MATERIALS AND EXPERIMENTAL METHODS

PHYSICAL ANALYSIS

Consistency
(UNE-EN 1015-3)

Density
(UNE-EN 1015-6)

Setting time
(UNE-EN 196-3)

MECHANICAL ANALYSIS

Compressive Strength
1-7-28 DAYS
(UNE-EN 196-1)

Flexural Strength
1-7-28 DAYS
(UNE-EN 196-1)

Shrinkage
1-7-14-28-56 DAYS
(UNE-83831)

PG-NP

PG-S

CK

NG

CONTROL

Standardized Sand + Water

PG-NP ADDITION 2,5% 5%

PG-S ADDITION 2,5% 5%
## Results

<table>
<thead>
<tr>
<th>Designation</th>
<th>Consistency (mm)</th>
<th>Density (g/cm³)</th>
<th>Setting time (minutes)</th>
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</thead>
<tbody>
<tr>
<td>Control-OPC</td>
<td>166</td>
<td>1937</td>
<td>Initial: 189, Final: 256</td>
</tr>
<tr>
<td>PG-NP 2.5</td>
<td>153</td>
<td>1974</td>
<td>Initial: 153, Final: 209</td>
</tr>
<tr>
<td>PG-S 2.5</td>
<td>156</td>
<td>1991</td>
<td>Initial: 132, Final: 197</td>
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<tr>
<td>PG-NP 5</td>
<td>146</td>
<td>1966</td>
<td>Initial: 181, Final: 246</td>
</tr>
<tr>
<td>PG-S 5</td>
<td>149</td>
<td>2023</td>
<td>Initial: 166, Final: 224</td>
</tr>
</tbody>
</table>

### Use of additive to obtain same consistency

**Plastic consistency**

<table>
<thead>
<tr>
<th>Fresh mortar</th>
<th>Consistency index (mm)</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRY</td>
<td>&lt;140</td>
<td>D</td>
</tr>
<tr>
<td>PLASTIC</td>
<td>140-200</td>
<td>P</td>
</tr>
<tr>
<td>FLUID</td>
<td>&gt;200</td>
<td>F</td>
</tr>
</tbody>
</table>
**COMPRESSIVE STRENGTH**

**PHOSPHOGYPSUM AS SETTING REGULATOR IN CEMENT MORTAR**

**MECHANICAL BEHAVIOUR RESULTS**

**Dry Chamber Curing**

**Underwater Curing**

- 5% Addition PG-NP and PG-S compressive strength increases
- Underwater curing better results
MECHANICAL BEHAVIOUR
PHOSPHOGYPSUM AS SETTING REGULATOR IN CEMENT MORTAR

**RESULTS**

**FLEXURAL STRENGTH**
PG-NP AND PG-S ADDITION FLEXURAL STRENGTH INCREASES
PG-NP BETTER RESULTS
UNDERWATER CURING BETTER RESULTS

![Graph showing flexural strength increase with underwater curing and PG-NP addition.](image)

**Dry chamber curing**
**Underwater curing**

- Control-OPC
- PG-NP 2.5
- PG-S 2.5
- PG-NP 5
- PG-S 5

**Flexural strength at 28d (MPa)**
**RESULTS**

**SHRINKAGE**

PHOSPHOGYPSUM AS SETTING REGULATOR IN CEMENT MORTAR

2,5% ADDITION PG-NP AND PG-S PRESENT VALUES OF SHRINKAGE SIMILAR THAT THE CONTROL

THE MORTARS WITH A ADDITION OF 5% HAVE HIGH SHRINKAGE VALUES
The substitution of natural gypsum by phosphogypsum accelerates the setting time in the cement mortars manufactured.

The natural gypsum replacement by phosphogypsum for the manufacture of mortar improves the mechanical behaviour, valorizing this waste and reducing the consumption of raw materials.

The curing conditions have significantly influence on the mechanical strength of cement mortars. Mortars underwater curing show better results of mechanical behaviour.

Carrying out a simple sieving treatment to the phosphogypsum does not imply significant improvements in the mechanical behaviour of cement mortar.
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THANKS FOR YOUR ATTENTION

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