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Behavior Immersion of Wade Sand-Lime Cement-Phosphogypsum Building Bricks Grade MW

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Abstract: **A feasibility study was undertaken on the production of wade sand-natural hydraulic lime-cement-phosphogypsum (WS-NHL-C-PG) full bricks grade MW to build houses economically by utilizing industrial wastes. All full bricks were made on a bench model, semiautomatic press having a capacity of 25 tons to produce bricks of 51×95×203 mm in size under a static compaction of 27MPa.Tests were conducted to study behavior immersion of phosphogypsum- wade sand based bricks. The results suggest that these bricks have sufficient behavior immersion.**

Keywords: **Phosphogypsum; wade sand; strength; immersion**

I. INTRODUCTION

There is a general exodus of rural population to the cities with the rapid industrialization in developing countries. The infrastructure to support these cities, such as buildings for housing and industry, mass transit for moving people and goods, and facilities for handling water and sewage will require large amounts of construction materials. Enhanced construction activities, shortage of conventional building materials and abundantly available industrial wastes have promoted the development of new building materials.

Phosphogypsum is an important by-product of phosphoric acid fertilizer industry. It consists of CaSO .2H O 4 2 and contains some impurities such as phosphate, fluoride, organic matter and alkalies. In Tunisia, for several years, a set of phosphoric acid production factories have produced PG in large great quantities (approximately 10 million tons per year [1]. Currently, the PG is stored into piles in the vicinity of the factory, by dry or wet process. The storage of PG causes the pollution of the water table and the soils by acid and heavy metals infiltrations.

Its valorization leads to environmental protection and to minimization of the storage costs. Several researchers had studied the use of PG in various fields. The PG was treated to be used in the plaster manufacture. It has been found that the PG is suitable for making good quality plaster showing similar proprieties to natural gypsum plaster [2-4]. This field is advantageous for the countries which do not have natural quarries such as Japan and India. The PG has been sought also to be used in agriculture [5]. It is as effective as the crushed natural gypsum. However, the quantities used are limited and moreover the health standards became increasingly restrictive. But the most interesting use of the PG is for the cement manufacturing: either by natural gypsum substitution (about 5%), which will play the role of a set retarder [6-7], or to reduce the clinkerization temperature [8]. The PG was also used in soil stabilization [9]. Finally phosphogypsum PG has been studied to be used in hollow blocks [10] and light brick [11].

In Tunisia, the PG was studied to be used in similar fields. The most successful application so far is in the manufacture of cement; by substitution of the gypsum. The obtained product is known under the name of cement ultimo. It showed good performances but the used quantity is low [12-13]. Moussa et al [14] had studied the possibility of the use of the PG in the embankments. The PG is studied in order to use it like a fill. This study showed a behavior to the compaction not similar to that of a soil. Furthermore, the fill showed also a continuous settlement because of the PG solubility. Moreover, Kuryatnyk and Angulski- Ambroise- Pera [15] have employed the Gabes and Skhira PG to be used as a hydraulic binder. But formation of ettringite led to cracking and strength loss. Finally, Sfar [16] has explored the PG for a road use. The study proposed the following formulation: 46.5% of PG, 46.5% of sand and 7% of cement. But this study was conducted in the Tunisian south region, where the rainfall is low.

Phosphogypsum (PG) from Tunisia, wade sand (WS), natural hydraulic lime (NHL), cement (C) and water are used in solid bricks production. phosphogypsum, wade sand, natural hydraulic lime and cement were mixed, humidified, compacted and cured for periods of 28, 56 and 90 days. The compressive strength, density, water absorption, saturation coefficient and leaching test of the bricks were measured. The obtained results showed that WS-NHL-C-PG bricks are found to be conforming to physical requirements of clay or shale building brick grade MW (moderate weathering), bricks intended for use where moderate resistance to cyclic freezing damage is permissible or where the brick may be damp but not saturated with water when freezing occurs [17].This study addressed the behavior immersion of WS-NHL-C-PG bricks grade MW.

II. EXPERIMENTAL PROGRAM

A. Mix Proportion:

The mix proportions of phosphogypsum, wade sand (WS), lime and cement (cement HRS 42.5) for bricks are given in table I.

The water contents of Phosphogypsum-wade sand-lime mixtures were fixed to 4 %. Bricks produced with more than 4 % showed cracks after fabrication due to excessive water.

Table I.Mix proportions of WS-NHL-C-PG full bricks [18]

Mix désignation	Constituant materials (Weight %)			
	Phosphogypsum	Sand (WS)	Cement	Lime
M-1	60	32	5	3
M-2	60	29.5	7.5	3
M-3	60	27	10	3
M-4	70	22	5	3
M-5	70	19.5	7.5	3
M-6	70	17	10	3
M-7	80	12	5	3
M-8	80	9.5	7.5	3
M-9	80	7	10	3

B. Manufacturing Process:

The weighed quantity of phosphogypsum, wade sand, lime and cement are first thoroughly mixed in dry state for a period of 10 minutes to uniform blending. The required water is then gradually added and the mixing continued for another 5 min.

All full bricks were made on a bench model, semiautomatic press having a capacity of 25 tons, to produce bricks of 0.051×0.095×0.203 m in size under a static compaction of 27MPa.

All bricks were dried to the free air for a period of 28, 56 and 90 days.

C. Testing of Bricks:

To simulate the action of the weather, the bricks are soaked in water for two days [19]. After 90 days of treatment. In this work the effect of immersion on compressive strength and flexural strength have been studied.

III. TEST RESULTS AND DISCUSSION

A. Compressive strength of studied bricks:

The compressive strength of building brick, tested after 90 days of treatment, are shown in table II [20].

For all the studied cases, the compressive strength of the 90 days cured full bricks was higher than 17.2 MPa [20] which is the minimum strength of building brick grade MW [21].

Table II.Compressive strength of WS-NHL-C-PG bricks grades MW [20]

Mix designation	Compressive strength (MPa) (90 days)
M1	17.32
M2	17.9
M3	18.2
M4	17.56
M5	18.02
M6	18.82
M7	17.9
M8	18.6
M9	19.4

B. Flexural strength of studied bricks[1]:

The Flexural strength of building brick, tested after 90 days of treatment, are shown in table III.

The code ASTM does not specify a requirement for flexural strength. However the values obtained were favorable when compared with those of clay bricks (11.2 MPa) [22].

Table III. Flexural strength of WS-NHL-C-PG bricks grades MW

Mix designation	Flexural strength (MPa) (90 days)
M1	10.8
M2	11.4
M3	11.51
M4	11
M5	11.5
M6	11.71
M7	11.5
M8	11.7
M9	11.9

3.1. Behavior immersion of bricks

3.1.1. Compressive strength of full bricks after 2 days immersion

The results, obtained as an average of measurements performed on three specimens, are shown in Figs. 1-3. The loss of compressive strength after 2 days of immersion in water is given in table IV. It is observed that loss in compressive strength decrease with phosphogypsum and cement content. So bricks with more phosphogypsum and cement have better compressive strength after 2 days immersion.

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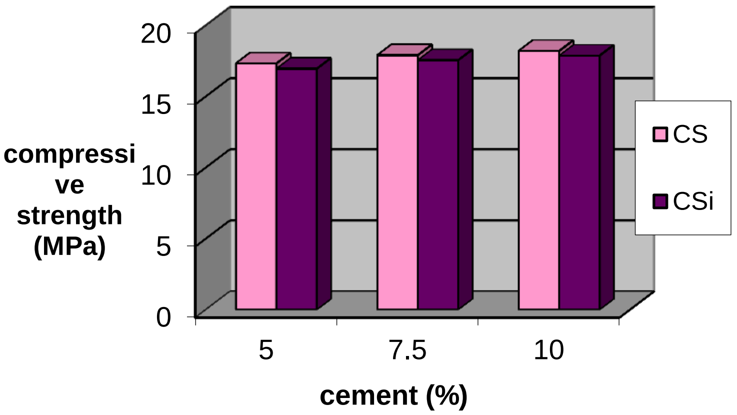

Figure.1 compressive strength of WS-NHL-C-PG full bricks (phosphogypsum=60%)

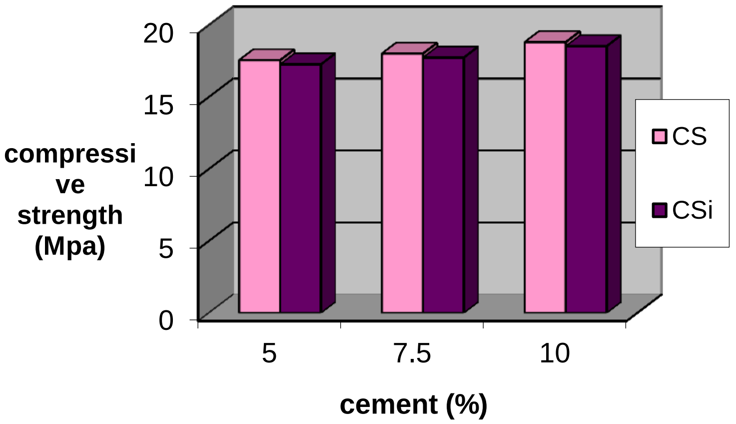

Figure.2 compressive strength of WS-NHL-C-PG full bricks (phosphogypsum=70%)

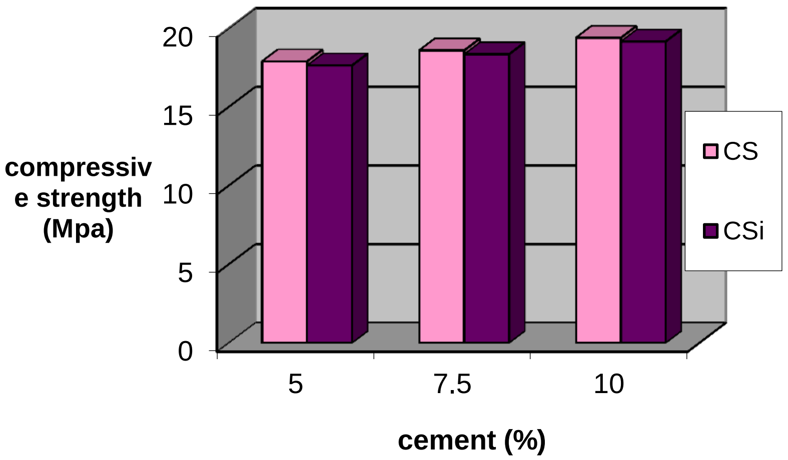

Figure.3 compressive strength of WS-NHL-C-PG full bricks (phosphogypsum=80%)

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Table IV. Loss in compressive strength of WS-NHL-C-PG bricks grades MW

Mix designation	Loss in compressive strength (%)
M1	2.1
M2	1.9
M3	1.8
M4	1.6
M5	1.5
M6	1.5
M7	1.4
M8	1.3
M9	1.2

3.1.2. Flexural strength of full bricks after 2 days immersion

The results, obtained as an average of measurements performed on three specimens, are shown in Figs. 4-6. The loss of flexural strength after 2 days of immersion in water is given in table V. It is observed that loss in flexural strength decrease with phosphogypsum and cement content. So bricks with more phosphogypsum and cement have better behavior to immersion in water.

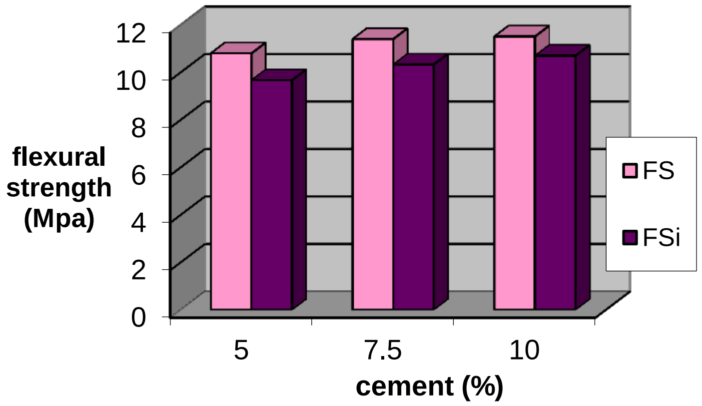

Figure.4 Flexural strength of WS-NHL-C-PG full bricks (phosphogypsum=60%)

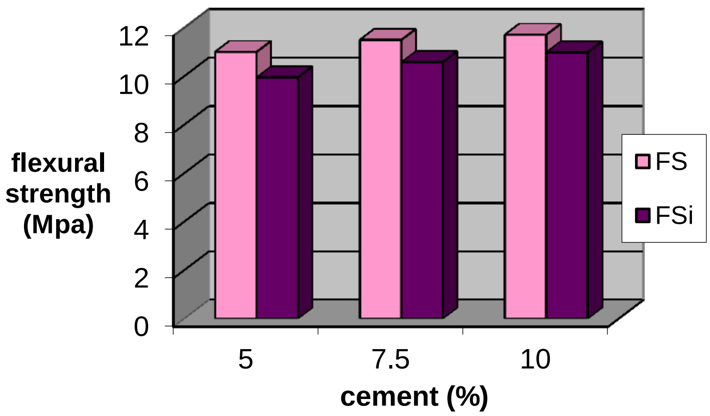

Figure.5 Flexural strength of WS-NHL-C-PG full bricks (phosphogypsum=70%)

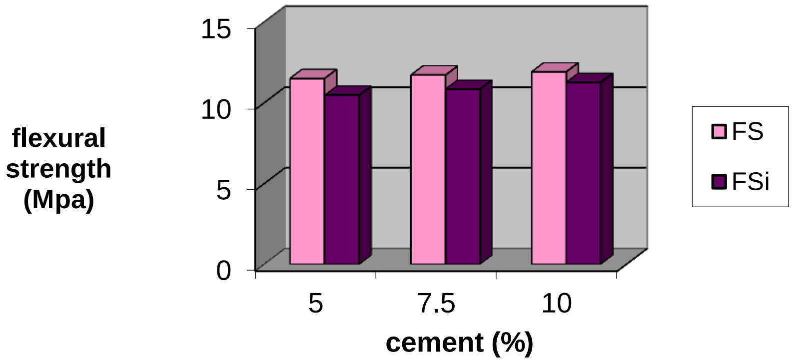

Figure.6 Flexural strength of WS-NHL-C-PG full bricks (phosphogypsum=80%)

Table V. Loss in flexural strength of WS-NHL-C-PG bricks grades MW

Mix designation	Loss in flexural strength (%)
M1	10.4
M2	9.35
M3	7
M4	9.5
M5	8
M6	6.1
M7	9
M8	7.3
M9	5.3

IV. CONCLUSION

Based on the experimental investigation reported in this paper, following conclusions are drawn:

(1) The WS-NHL-C-PG PG bricks grades MW have sufficient Behavior immersion.

(2) The increase of the percentages of PG and cement resulted in increase in the compressive and flexural strength of WS-NHL-C-PG bricks grades MW after 2 days of immersion in water.

(3) Cementations binder with 80% phosphogypsum content shows low loss of compressive and flexural strength after immersion.

(4) Loss of flexural strengths is lower than those of compressive. Therefore the WS-NHL-C-PG bricks grades MW immersed in water perform better in flexure than in compression.

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