Correlation of Ultrasound Pulse Velocity with Mechanical Properties and Water Absorption in Phosphogypsum- wade Sand-Lime-Cement Building Bricks produced under a static compaction of 20MPa.

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Abstract: **- Phosphogypsum (calcium sulfate) is a naturally occurring part of the process of creating phosphoric acid (H3PO4), an essential component of many modern fertilizers. For every tonne of phosphoric acid made, from the reaction of phosphate rock with acid, commonly sulfuric acid, about 3 t of phosphogypsum are created. There are three options for managing phosphogypsum: (i) disposal or dumping, (ii) stacking, (iii) use-in, for example, agriculture, construction, or landfill.The need to reduce solid waste volume has caused scientists to invent new construction materials produced using waste materials. The present work focuses on the ultrasonic pulse velocity of wade sand –lime-cement-phosphogypsum building bricks produced under a static compaction of 20MPa. It is observed that these bricks have sufficient Ultrasonic pulse velocity Tests were also conducted to study the relationship between ultrasound pulse velocity (UPV) with strength of bricks.. The results suggest that compressive and flexural strength values of phosphogypsum-wase sand-lime-cement-building bricks produced undera static compaction of 20 MPa, may approximately be determined without a destructive testing by using the non-destructive UPV measurements.**

***Keywords: Bricks, strength, ultrasonic pulse velocity*.**

I. INTRODUCTION

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, flexural strength, density, water absorption, 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 load-bearing concrete masonry units. [1].

This study addressed the ultrasound pulse velocity (UPV) and relations of UPV with strength properties of WS-NHL-C-PG bricks.

Analyzing the properties of materials and establishing relationships between them through non-destructive tests is an active area of study and many different methods were developed for this purpose. One of these is the measurement of ultrasound pulse velocity (UPV) which provides important information about the internal structure of materials. With this technique, relationships between internal structure and mechanical properties of numerous materials can be studied. UPV is commonly used to predict and evaluate the mechanical properties of various materials in a non-destructive way [2]. Many studies were made on the relationships between UPV and strength and, elastic properties of natural [3] and artificial stones, especially those of cement-binder concrete and mortars [4-9] as well as wood materials [10,11]. Studies on checking pozzolanic activity with UPV and evaluating the relationship between the two are inadequate in the literature.

Propagation speed of sound waves within materials changes in accordance with the type and inner characteristics of the material. Due to this behavior, information about the inner structure of the material can be obtained. A high transmission rate of sound means less pores and, thus higher strength. When the pulse is transferred to the material by a transducer, it undergoes multiple reflections at the boundaries of different phases within the material.

By conducting in-field tests on historical and modern structures important information about the state of the materials in the structure can be obtained. Many structural properties such as microstructure, distribution of micro cracks, the quality of bonding at interfaces between different components forming the material and rheological and mechanical properties of components can be evaluated by ultrasonic methods. The ultrasonic method was used to predict the hydration activity of fly ash cement binder composites [8]. The velocity of ultrasonic waves is sensitive to the additives and admixtures accelerating the setting and hardening behavior of concrete and mortar [13]. Ultrasound may be used to characterize the mechanical properties of cement and epoxies as well as other materials [14, 15].

Because the speed and attenuation of sound waves are sensitive to the viscoelastic properties of the material, ultrasound can be used to monitor the curing process of cement composites [8]. Mineral admixtures increase the UPV value of concrete [16].

In this paper, we start work the ultrasound pulse velocity (UPV) of full bricks. We deal in the second part with the relationship between ultrasound pulse velocity (UPV) with strength and water absorption of bricks.

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

Mix désignation	Constituant materials (Weight %)			
	Phosphogypsum	Sand (WS)	Cement	Lime
P-1	60	32	5	3
P-2	60	29.5	7.5	3
P-3	60	27	10	3
P-4	70	22	5	3
P-5	70	19.5	7.5	3
P-6	70	17	10	3
P-7	80	12	5	3
P-8	80	9.5	7.5	3
P-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 20MPa.

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

C. Testing of Bricks

The direct UPV values are measured on the flexural strength samples having direct path length required by BS1881 [18].

III. TEST RESULTS AND DISCUSSION

A. Ultrasonic pulse velocity (UPV) measurements of bricks

Figures 1-3 shows the results of the direct UPV values obtained from the tests. The figures show also increase in the direct UPV with the cement and phosphogypsum additions and curing time.

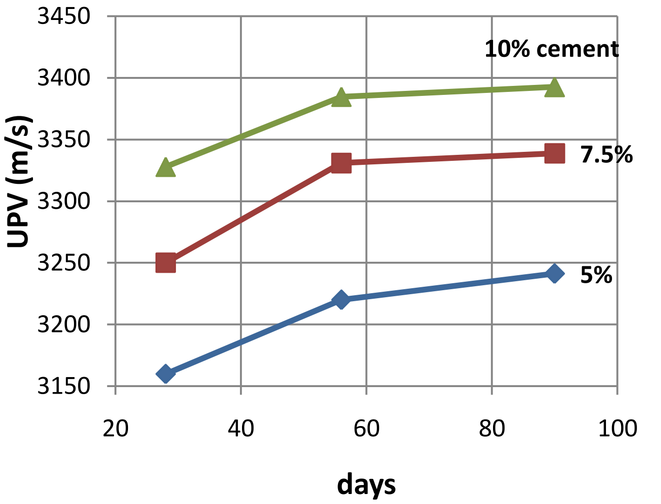

Figure 1: UPV of WS-NHL-C-PG Full Bricks (Phosphogypsum=60%)

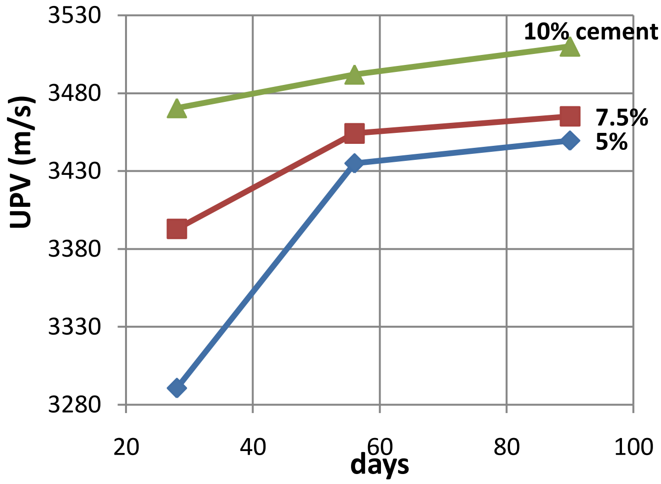

Figure 2: UPV of WS-NHL-C-PG Full Bricks (Phosphogypsum=70%)

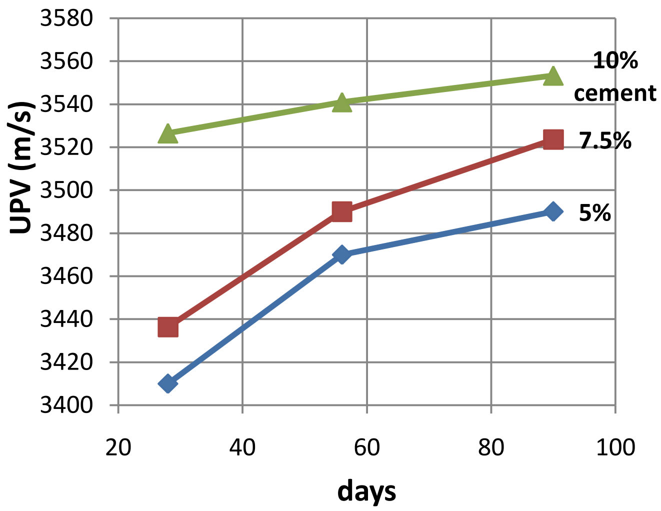

Figure 3: UPV of WS-NHL-C-PG Full Bricks (Phosphogypsum=80%)

Relationships between the UPV and mechanical characteristics of bricks have been evaluated with respect to compressive, flexural strength and significance of the correlations has been investigated.

B. Relationship between UPV and compressive strength

The compressive strength of building brick, tested after 90 days of treatment, are shown in table II [1].

Table II.Compressive strength of WS-NHL-C-PG full bricks [1]

Mix designation	Compressive strength (MPa) (90 days)
M1	12.31
M2	13.74
M3	14.24
M4	12.7
M5	13.8
M6	14.52
M7	13.2
M8	14.63
M9	15.01

UPV-Rc correlation has been investigated by using the compressive strength=f(UPV) relationship and applying linear regression to the data obtained from compressive tests of bricks.. The linear regression coefficient (Rc) of the correlation between UPV and compressive strength of bricks containing 80 % phosphogypsum, NHL, C and wade sand were determined r2 = 0,919 (Fig.4). Strong correlation coefficient indicates a strong relationship between compressive strength and values of UPV bricks. The correlation indicates the homogeneity of bricks.

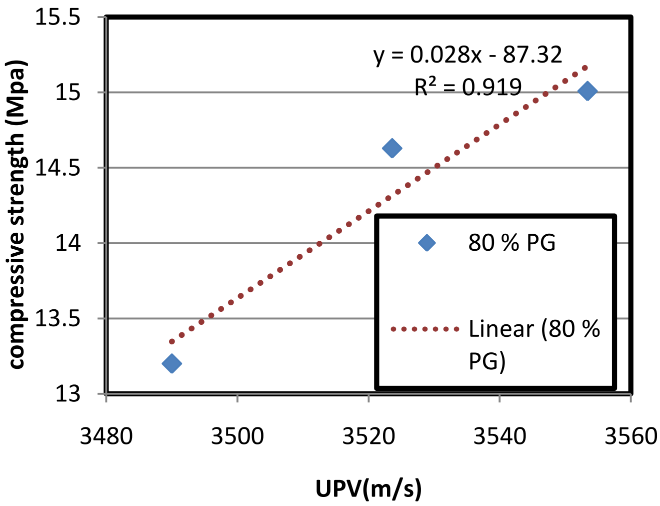

Figure 4: The Correlation between UPV and Compressive Strength of WS-NHL-C-PG Full Bricks (Phosphogypsum=80%)

C. Relationship between sound velocity and flexural strength

The compressive strength of building brick, tested after 90 days of treatment, are shown in table III [1].

Table III.Flexural strength of WS-NHL-C-PG full bricks [1]

Mix designation	Flexural strength (MPa) (90 days)
M1	8
M2	8.19
M3	8.34
M4	8.26
M5	8.36
M6	8.53
M7	8.38
M8	8.72
M9	8.84

Likewise, relationships between UPV- flexural strength have been investigated using experimental data with linear regression, and the evaluations are made under conditions similar to those of the compressive strength tests.
Here, a strong relationship can be established between UPV and flexural strengths of bricks. As with the case of compressive strengths, the correlation between UPV and flexural strength has high value for 80% phosphogypsum mixed brick within (r2= 0,660) (Figure 5).

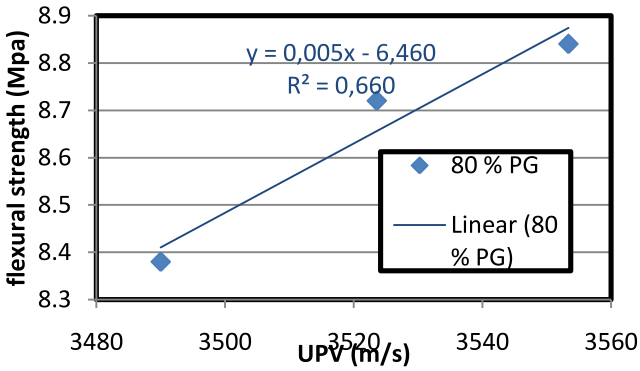

Figure 5: The Correlation between UPV and Flexyral Strength of WS-NHL-C-PG Full Bricks (Phosphogypsum=80%)

Flexural strength, such as compressive strength also indicates the homogeneity bricks based phosphogypsum produced under a pressure of 20 MPa.

D. Relationship between sound velocity and water absorption

The water absorption of building brick are shown in table IV[1].

Table IV.Water absorption of WS-NHL-C-PG full bricks [1]

Mix designation	Water absorption (%)
M1	26.97
M2	26.09
M3	24.29
M4	25.56
M5	24.05
M6	23.06
M7	24.5
M8	23.04
M9	22.33

Correlation UPV water absorption after 24 h immersion in water was studied using the relationship of water absorption = f (UPV) and applying the relationship linear regression on the data obtained from water absorption tests for bricks.
Bricks with a higher water absorption give lower values VS. There is an inverse relationship between the speed of sound and the water absorption for the bricks. Therefore there is an inverse relationship between the speed of sound and water absorption. An inverse relationship between porosity and UPV is also indicated in the literature [20-21]. The linear regression coefficient (r2) of the correlation between UPV and water absorption bricks containing 80% phosphogypsum, CHN, C and wade sand was determined r2 = 0,973 (Fig. 6). Strong correlation coefficients indicate a strong relationship between water absorption and values of VS bricks.

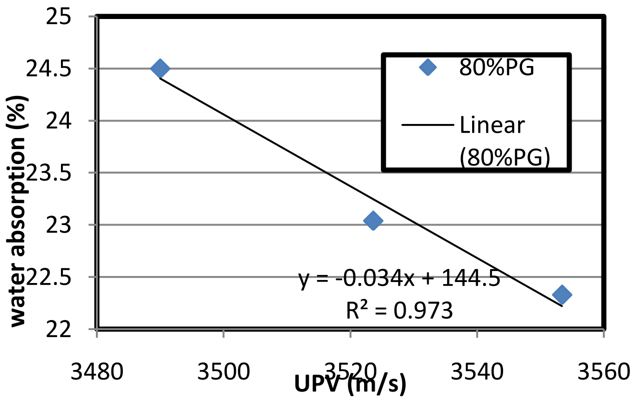

Figure 6: The Correlation between UPV and Water Absorption of CS-NHL-C-PG Full Bricks (Phosphogypsum=80%)

IV. CONCLUSION

Based on the experimental investigation reported in this paper, following conclusions are drawn:
1-The WS-NHL-C-PG bricks have sufficient UPV.
2-There is generally a close relationship between UPV values and mechanical (Rc, Rf,) properties of full bricks. Mechanical properties of full bricks can be reliably determined by means of the UPV test method.
3-There is a high degree of correlation between the UPV values and water absorption of full bricks WS-NHL-C-PG.

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