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# Flexural Strength and Ultrasonic Pulse Velocity of Crushing Sand-Lime-Cement-Phosphogypsum Building Bricks Grade SW

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## **Abstract**

*The present work focuses on the flexural strength and ultrasonic pulse velocity of crushing sand –lime-cement-phosphogypsum building bricks grade SW. It is observed that these bricks have sufficient Ultrasonic pulse velocity. The relationship between ultrasound pulse velocity (UPV) with strength and water absorption of bricks was studied. The results suggest that there is a close relationship between UPV and mechanical properties and water absorption of full bricks. The correlations indicate the homogeneity of phosphogypsum and crushing sand based bricks grade SW produced under a pressure of 27 MPa.*

**Keywords:** static compaction, ultrasonic pulse velocity, water absorption, homogeneity

## I- Introduction

Phosphogypsum (PG) from Tunisia, crushing sand (CS), natural hydraulic lime (NHL), cement (C) and water are used in solid bricks production. phosphogypsum, crushing 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 CS-NHL-C-PG bricks are found

to be conforming to physical requirements of clay or shale building brick grade SW (severe weathering), bricks intended for use when high and uniform resistance to damage caused by cyclic freezing is desired and where the brick may be frozen when saturated with water [1].

This study addressed the flexural strength, ultrasound pulse velocity (UPV) and relations of UPV with strength properties of CS-NHL-C-PG bricks grade SW.

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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 flexural and the ultrasound pulse velocity (UPV) of full bricks grade SW. 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*

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

Table I. Mix proportions of CS-NHL-C-PG full bricks grade SW [1]

Mix désignation	Constituant materials (Weight %)			
	Phosphogypsum	Sand (CS)	Cement	Lime
M-1	60	33	5	2
M-2	60	30.5	7.5	2
M-3	60	28	10	2
M-4	70	23	5	2
M-5	70	20.5	7.5	2
M-6	70	18	10	2
M-7	80	13	5	2
M-8	80	10.5	7.5	2
M-9	80	8	10	2

The 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 [1].

### *B. Testing of Bricks*

Flexural strength tests on the bricks were performed according to ASTM C 67[17]. Test specimens were taken as full-size

brick units. Three bricks for each different mixes and testing condition were tested. Bricks were tested simply supported at each end with supports and subjecting them to a beam loading. The load was applied at the mid span in the direction of depth of the brick unit.

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. Flexural Strength*

The results, obtained as an average of measurements performed on three specimens, are shown in Figs. 1-3. 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) [19]. These Figures also shows increase in the flexural strength with the phosphogypsum and cement additions.

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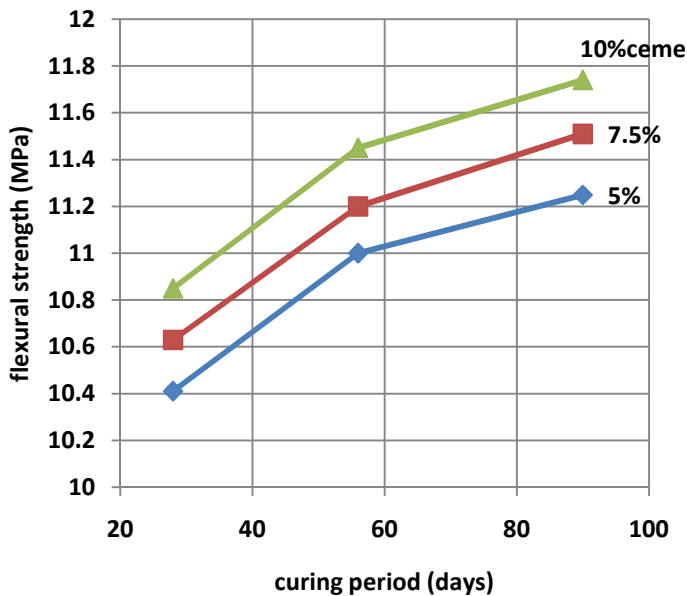


Fig.1 flexural strength of CS-NHL-C-PG full bricks (phosphogypsum=60%) grade SW

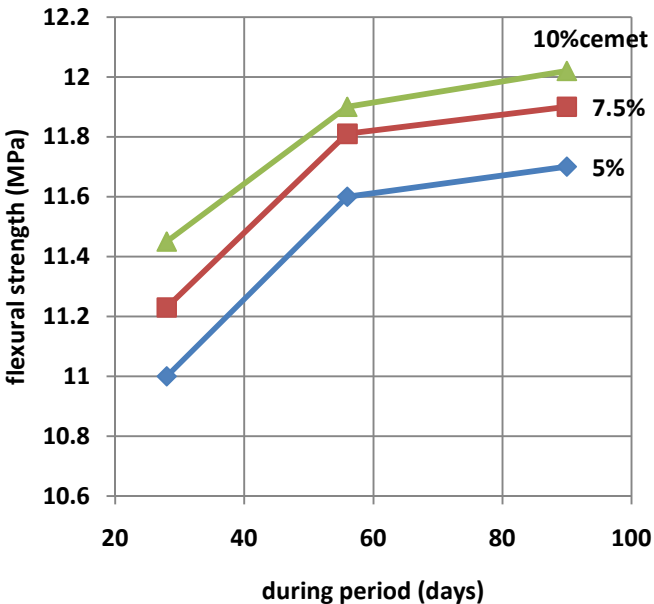


Fig.3 flexural strength of CS-NHL-C-PG full bricks grade SW (phosphogypsum=80%)

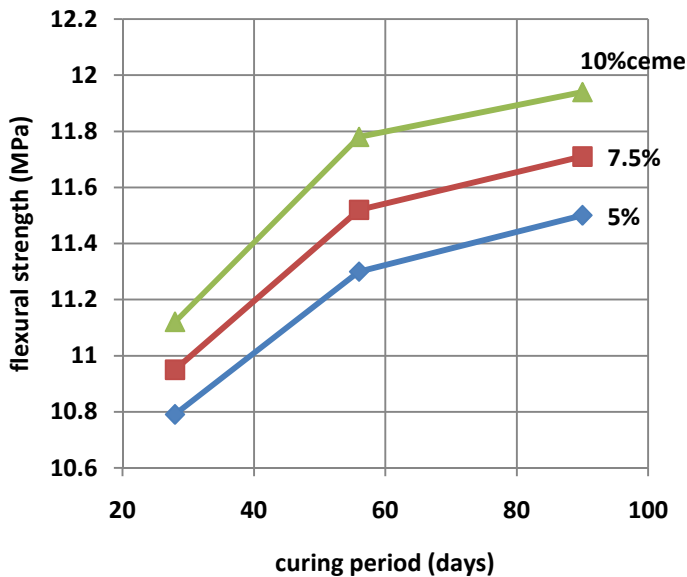


Fig.2 flexural strength of CS-NHL-C-PG full bricks (phosphogypsum=70%) grade SW

B. Ultrasonic Pulse Vlocity (UPV) Measurements of Bricks

Figures 4-6 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.

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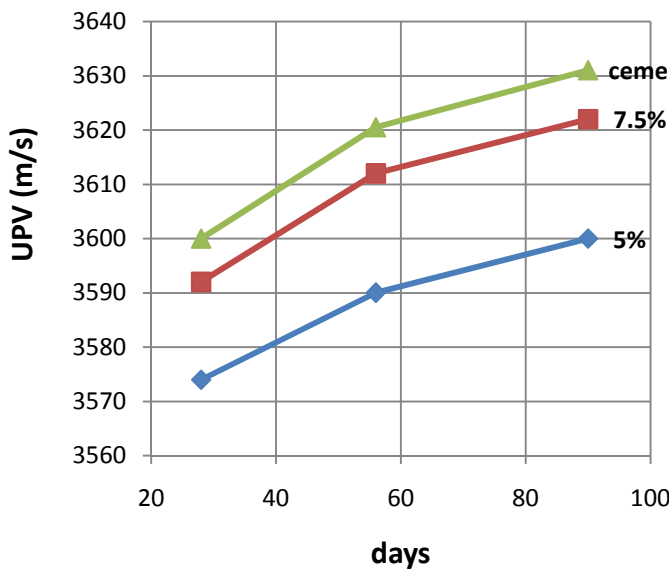


Fig.4 UPV of CS-NHL-C-PG full bricks grade SW  
(phosphogypsum=60%)

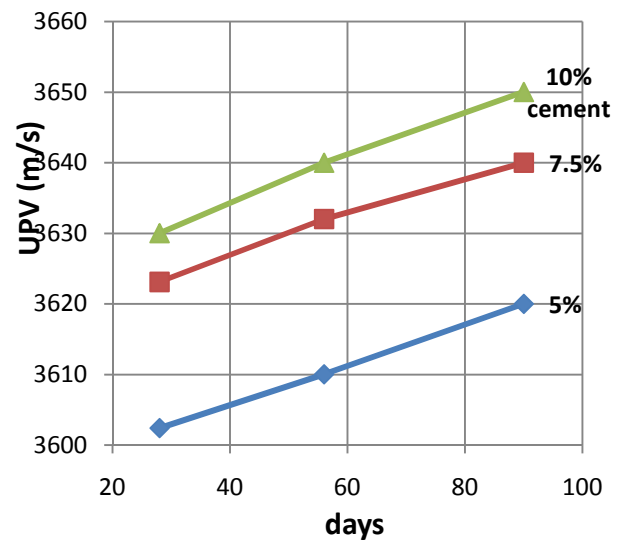


Fig.6 UPV of CS-NHL-C-PG full bricks grade SW  
(phosphogypsum=80%)

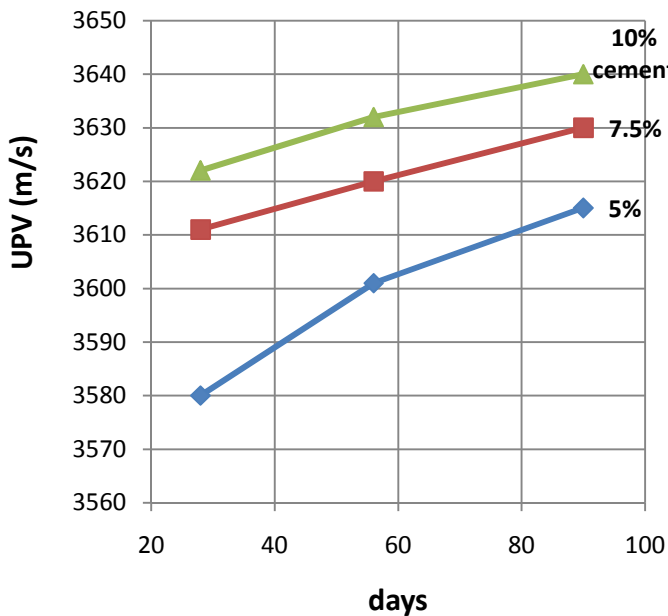


Fig.5 UPV of CS-NHL-C-PG full bricks grade SW  
(phosphogypsum=70%)

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.

### C- Relationship between Sound Velocity and Flexural Strength

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 60, 70 and 80%



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phosphogypsum mixed brick within ( $r^2 = 0,932, 0,959$  and  $0,997$ , respectively) (Figure 7).

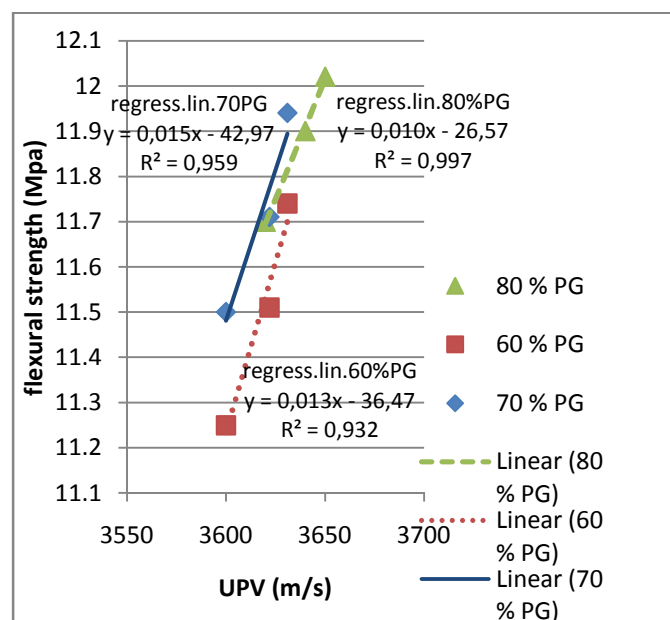


Figure.7 The correlation between UPV and flexural strength of CS-NHL-C-PG full bricks grade SW

### D- Relationship Between UPV and Compressive Strength

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

Table II. Compressive strength of CS-NHL-C-PG full bricks grade SW [1]

Mix designation	Compressive strength (MPa) (90 days)
M1	20
M2	21

M3	21.4
M4	20.8
M5	21.5
M6	21.91
M7	22
M8	22.6
M9	23.4

UPV- $R_c$  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 ( $R_c$ ) of the correlation between UPV and compressive strength of bricks containing 60, 70 and 80 % phosphogypsum, NHL, C and crushing sand were determined  $r^2 = 0,927, 0,998$  and  $1$ , respectively (Fig.8). Strong correlation coefficient indicates a strong relationship between compressive strength and values of UPV bricks. The correlation indicates the homogeneity of bricks.

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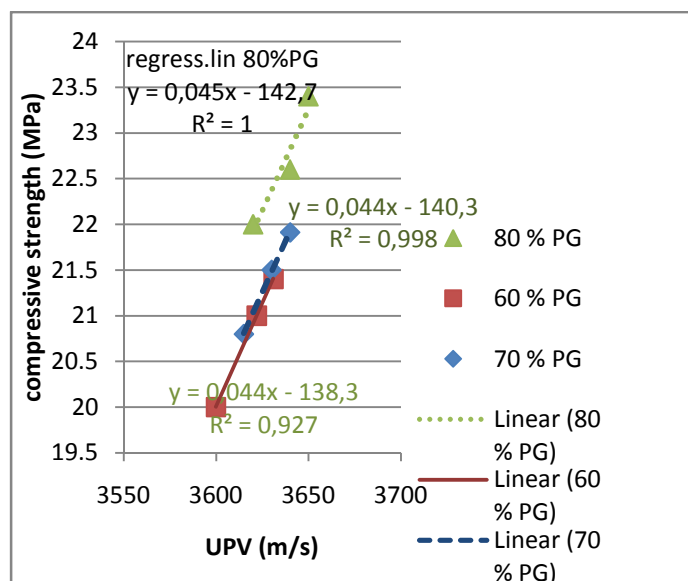


Figure.8 The correlation between UPV and compressive strength of CS-NHL-C-PG full bricks grade SW

Flexural strength, such as compressive strength also indicates the homogeneity bricks based phosphogypsum grade SW produced under a pressure of 27 MPa.

### E- Relationship Between Sound Velocity and Water Absorption

The water absorption of building brick grade SW are shown in table III[1].

Table III. Water absorption of CS-NHL-C-PG full bricks grade SW [1]

Mix designation	Water absorption (%)
M1	13.38
M2	11.32

M3	10.36
M4	12.1
M5	10
M6	9.1
M7	9.1
M8	8.7
M9	7.5

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 ( $r^2$ ) of the correlation between UPV and water absorption bricks containing 60%, 70% and 80% phosphogypsum, CHN, C and crushing sand was determined  $r^2 = 0,81, 0.88$  and  $0,999$ , respectively (Fig. 9). Strong correlation coefficients indicate a strong relationship between water absorption and values of VS bricks.



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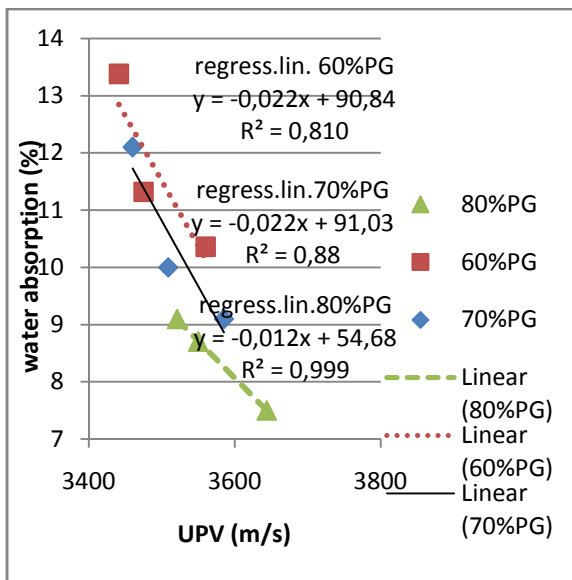


Figure.9 The correlation between UPV and water absorption of CS-NHL-C-PG full bricks grade SW

### IV. CONCLUSION

Following conclusions are drawn:

- 1-The CS-NHL-C-PG bricks grades SW have sufficient flexural strength.
- 2-There is generally a close relationship between UPV values and mechanical properties of full bricks grade SW. Mechanical properties of full bricks grade SW 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 grade SW.

### REFERENCES

- [1] Lamia Bouchhima, Mohamed Jamel Rouis, Mohamed Choura , Valorization of Phosphogypsum in Crushing- Sand-

Phosphogypsum -Cement-Lime Solid Bricks Grade SW, international journal of research in applied science and engineering technology ( IJRASET) Vol. 1 Issue IV, November 2013, pp: 32-42

- [2] Popovics, S., Rose, J.L., Popovics, J.S., "The behavior of ultrasonic pulse in concrete", *Cement and Concrete Research*, 20: 259–270 (1990).
- [3] Vasconcelos, G., Lourenço. P.B., Alves, C.A., Pamplona, J., "Ultrasonic evolution of the physical properties of granites", *Ultrasonic*, 48: 453-466 (2008).
- [4] Yaman, I.O., Aktan, H., Hearn, N., "Active and nonactive porosity in concrete-part II: evaluation of existing models", *Mater. Struct.*, 35: 110–116 (2002).
- [5] Philippidis, T.P., Aggelis, D.G., "Experimental study of wave dispersion and attenuation in concrete", *Ultrasonics*, 43: 584–595 (2005).
- [6] Aggelis, D.G., Polyzos, D., Philippidis, T.P., "Wave dispersion and attenuation in fresh mortar: theoretical predictions vs. experimental results", *J. Mech. Phys. Solids*, 53: 857–883 (2005).
- [7] Demirbo a, R., Türkmen, ., Karakoç, M.B., "Relationship between ultrasonic velocity and compressive strength for high-volume mineral admixtural concrete", *Cement and Concrete Research* 34: 2329-2336 (2004).

## INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

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- [8] Mishra, S.R., Kumar, A., Park, A., Rho, J., LosbyHoffmeister, B. K., "Ultrasonic characterization of the curing process of PCC fly ash-cement composites", *Materials Characterization* 50: 317-323 (2003).
- [9] Raman, S.N., Safiuddin, M.D., Zain, M.F.M., "Nondestructive evaluation of flowing concretes in cooperating quarry waste", *Asian journal of civil engineering (Building and Housing)*, 8(6): 597- 614 (2007).
- [10] Lourenço, P.B., Feio, A., Machado, J.S., "Chestnuts wood in compression perpendicular to the grain: non-destructive correlation for new and old wood", *Construction and Building Materials* 21(8): 1617-1627 (2007).
- [11] Feio, A., Lourenço, P.B., Machado, J.S., "New and old chestnut wood parallel to the grain: mechanical behavior and non-destructive evaluation", *International Journal of Architectural Heritage* 3(1): 272-292 (2007).
- [12] Postacio lu, B., Yapı Malzemesi Esasları (The Principles of Building Materials, Section 1: General Features of Materials), *istanbul Technical University*, 141 (1966).
- [13] De Belie, N., Grosse, C., Baert, G., "Ultrasonic Transmission to Monitor Setting and Hardening of Fly Ash Concrete", *ACI Material Journal*, 105 (3): 221-226 (2008).
- [14] Labouret, S., Looten-Baquest, I., Bruneel, C., Forhly, J., "Ultrasound method for monitoring rheology properties evolution of cement", *Ultrasonic* 36: 205-208 (1998).
- [15] Faiz, B., Maze, G., Decultot, D., Moudden, A., Assif, E.H., Ezzaidi, M., "Ultrasonic characterization of the quality of an epoxy resin polymerization", *IEEE Trans Ultrasound Ferroelectr Freq. Control*, 46: 188-196 (1999).
- [16] Yazıcıo lu, S., Demirel, B., "The effect of the Elazı Region used as a pozzolanic additive on the compressive strength of concrete increasing cure ages", *Journal of Firat Univ. Science and Eng.* 18(3): 367-374 (2006).
- [17] Ahmadi BH. (1989) *Use of high strength by product gypsum bricks in masonry construction*. PhD dissertation, University of Miami, Coral Gables, Florida, USA. 245p.
- [18] BS 1881. Recommendations for measurement of pulse velocity through concrete. London: British Standards Institute; 1997 (Part 203).
- [19] Paki Turgut. 2012, Manufacturing of building bricks without Portland cement. *Journal of Cleaner Production* 37, 361-367
- [20] Lafhaj, Z., Goueygou, M., Djerbi, A., Kaczmarek, M., "Correlation between porosity, permeability and ultrasonic parameters of mortar with variable water/cement ratio and water content", *Cement and Concrete Research*, 36: 625–633 (2006).
- [21] Hernández, M.G., Izquierdo, M.A., Ibanez, A., Anaya, J.J., Gomez-Ullate L., "Porosity estimation of concrete by ultrasonic NDT", *Ultrasonics*, 38: 531–536 (2000).

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