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Evaluation On The Durability Of Concrete Sanitation Networks Of Ouargla - Algeria By Non-Destructive Testing

Mohammed-Amin Boumehraz* & Mekki Mellas

Department of Civil Engineering, Faculty of Science and Technology, University of Biskra, 07000 Biskra, Algeria.

* Corresponding Author: *amine18gc@yahoo.com*

Abstract: The expertise and the testing of structures with reinforced concrete that are existing or under construction often require the evaluation of the quality of concrete. The non-destructive test permitted to evaluate the state of their structures but also to assess the bearing capacity or to predict their durability. These techniques are generally influenced by several factors, generally humidity, for example, the speed of sound relied by varies humidity in concrete. The objective of this research is to study the durability of concrete the sanitation networks in the region of Ouargla - Algeria under the effect of sulphates agents. In this experimental, the specimen concrete conserved in different real environment, and these results were compared than those specimens curing with drinking water. Finally, they concluded the concrete specimens conserved in waste water have acceptable mechanical characteristics than those specimens curing in water, and it is obtained a regression of 3% the strength compressive to the age 365 days. But the exposure of concrete specimens to H_2S gas, it is obtained a degradation accelerated in particular after 90 days to age, where a regression to 36% of the compressive strength than specimens curing in water at the age 365 days. The sanitation networks (pipes and manholes) of Ouargla – Algeria are a low durability under the effect of H_2S gas sulphates. For increase the durability of pipes and manholes the Ouargla, it proposed the substitution by pipes and manholes in polyester materiel.

Keywords: *Durability, concrete, sanitation, waste water, H_2S gas.*

1.0 Introduction

The expertise and the testing of structures with reinforced concrete that are existing or under construction often require the evaluation of the quality of concrete. The quality testing of concrete cured by destructive testing may be difficult to achieve sometimes (heavily reinforced structure). So, the use of Non-Destructive Testing (N.D.T) methods seems sufficient (Obad, 2014). For non-destructive testing of concrete (CND), methods based on the propagation of mechanical waves frequently called acoustic waves, the most used are: auscultation sonic or ultrasonic pulse velocity UPV, the impact-echo, the acoustic emission. Other techniques such as seismic tomography or surface waves remain of limited use. Acoustic methods with visual inspection are the oldest forms of non-destructive testing. In 1920, the Russian scientist Sergei Y. Sokolov institute of electrical Leningrad in the USSR was the first who proposed to use the ultrasonic wave velocity (UPV) to find defects in metal objects. After the Second World War, was followed by a rapid change in the instrumentation of non-destructive testing, the main objective is the detection of defaults. In response to this need techniques more sophisticated using ultrasound; eddy current, radiography appeared (Hannachi *et al*., 2014). This test permitted to evaluate the state of their structures but also to assess the bearing capacity or to predict their durability. These techniques are generally influenced by several factors, generally humidity, for example, the speed of sound relied by varies humidity in concrete (Nguyen *et al*., 2013).

The sewage system of the city of Ouargla is unitary, they aso distinguish sewerage networks according to the unattended mode, but the majority of citizens are connected to the sewer system. The wastewater in the city of Ouargla is essentially a domestic type, even though this water is discharged with industrial wastewater in one collector without any prior treatment, this water is highly contaminated by sulphate and cause a high release of Hydrogen Sulfide (H_2S) gas (BG, 2004). According to H_2S gas measurements by the National Sanitation Office of Ouargla, the concentration of gas varies depending on the temperature and relative humidity; it reaches the maximum values during the summer. For example this pressure has reached more than 100 ppm in Rouiss at Ouargla. Figure 1 shows some deterioration of sanitation networks in Ouargla region under the effect of sulphates in wastewater.

Figure 1: Reinforcement corrosion and the bursting of the cover concrete sanitation pipe N'Goussa - Ouargla.

The gypsum ($CaSO_4.2H_2O$) is obtained by the reaction between portlandite (Ca $(OH)_2$) and the outer sulphates such as calcium sulphates, magnesium, sodium, potassium, ammonium(Khan, 2009). The ettringite formation ($C_3A.3CaSO_4.32H_2O$) is the result of the reaction between gypsum and anhydrous calcium aluminate. Equations (01), (02) and (03) show the reaction of sodium sulfate (Na_2SO_4) and magnesium sulphate ($MgSO_4$) with calcium hydroxide (Bassuoni *et al.*, 2008.; Prasad *et al.*, 2006).

$$Ca(OH)_2 + Na_2SO_4 + 2H_2O \rightarrow CaSO_4.2H_2O + 2NaOH \quad (1)$$
$$Ca(OH)_2 + MgSO_4 + 2\,H_2O \rightarrow CaSO_4.2H_2O + Mg(OH)_2 \quad (2)$$
$$C_3A + 3CaSO_4.2H_2O + 26H_2O \rightarrow C_3A.3CaSO_4.32H_2O \quad (3)$$

The released H_2S gas condenses on the walls of sewer networks, it is converted by anaerobic bacteria in closed environments with moisture (a strong and highly corrosive acid to the plates) and will have the formation of sulfuric acid (H_2SO_4) (Baron *et al.*, 1992; Jensen *et al.*, 2011). The contact between the sulfuric acid and portlandite ($Ca(OH)_2$) form gypsum ($CaSO_4.2H_2O$), then the contact between the gypsum and the anhydrous calcium aluminate (C_3A) form ettringite ($3CaO.\ Al_2O.\ 3CaSO_4.\ 32H_2O$), finally ettringite is a friable material that forms from the incomplete reaction of the sulfuric acid and the cement paste (Eštokova *et al.*, 2012). In 2012, Messaoudene obtained a reduction of compressive strength by 41%, for mortars conserved in sulphuric acid of one year, at a concentration of 0.25 Mole. The mechanism of sulphate attack the mortars exposed to sulfuric acid that is mainly an external phenomenon, and that the expansible action of gypsum is responsible for the gradual opening of the material structure by dislocation of its surface and that the attack surface causes a reduction in the section of the test pieces.

2.0 Experimental Program

The aim of the experimental work is to study the degradation mechanism physicochemical in concrete specimens in the real aggressive environment as the building blocks of pipes and manholes used to sanitation in the Ouargla region. In this study, using prismatic mould dimensions (70x70x280) mm^3 according to European standards NF EN 12390-1 and NF P 18-427, for the manufacture of concrete specimens. After pouring the concrete, the specimens are kept in the moulds in the indoor laboratory for a period of 24 hours, for the curing of the concrete. Table 1 summarizes the concrete mixture compositions of the graphical method of Dreux Gourisse. (Dreux, 1970)

Table 1: Proportions of tested concrete mixtures

Cement (Kg/m^3)	*Fine aggregate (Sand) (Kg/m^3)*	*Coarse aggregate (Kg/m^3)*	*W / C*
400	621.53	1182.23	0.54

The cement used are Sulphate Resistant Cement (CEM I 42.5 N-ES) from the LAFARGE factory, physical and chemical properties of the used cement are illustrated in Table 2.

Table 2: Physical and chemical properties of cement

Normal consistency in cement paste (%)	26.4	K_2O (%)	0,77
Mass per unit volume (g/cm^3)	3.08	Na_2O (%)	0,27
Finesse according to Blaine's method	3320	SO_3 (%)	2,12
Compressive strength 28 days (MPa)	28.90	CaO libre (%)	0,55
Initial time of setting (min) at 20 ° C	140	Cl^- (%)	0,06
Final time of setting (min) at 20 ° C	245	C_3S (%)	57,00
SiO_2 (%)	24,85	C_2S (%)	19,00
Al_2O_3 (%)	5,28	C_3A (%)	4,00
Fe_2O_3 (%)	3,73	C_4AF (%)	14,00
CaO (%)	58,71	CaO.L (%)	1,00
MgO (%)	2,39	Gypsum (%)	5,00

The physical and chemical properties of coarse aggregate and the fine aggregate used are presented in Table 3. The nominal maximum size of coarse aggregate used was 15 mm, the nominal maximum size of fine aggregate or sand used was 5 mm. The sand is of siliceous origin, as well as the aggressive elements are contained in small quantity. The results show that the materials are comparable with existing materials and can be used in concrete production.

Table 3: Physical and chemical properties of aggregate

	Fine aggregate	*Coarse aggregate*
apparent density (g/cm^3)	1,53	1,24
absolute density (g/cm^3)	2,59	2,60
Equivalent of sand (%)	73,21	-
Property of aggregate (%)	-	1,32
Brittleness of sand (%)	13,97	-
Los Angeles Coefficient (%)	-	23,57
$CaSO_4.2H_2O$(%)	1,86	4,59
$CaCO_3$(%)	1,50	77
Cl^-(%)	0,015	0,023
NaCl(%)	0,026	0,036
Insoluble (%)	90,21	30,26
SO_4^{-2}(%)	Traces	Traces

A series of specimens are curing with drinking water in the lab (20 ± 2) °C. Another series are conserved in the basin of waste water in the Ouargla region, chemical analysis of waste water the basin are illustrated in Table 4.

Table 4: Results of analysis of global mineralogical parameters of wastewater

Ca^{+2} (%)	Mg^{+2} (%)	K^{+} (%)	Na^{+} (%)	SO_4^{-2} (%)	Cl^{-} (%)
492.98	4560.00	27.50	660.00	4900.00	1247.90

The final series are exposed to hydrogen sulphuric (H_2S) gas, in a manhole closed of the Ouargla region aiming to ensure a high concentration of H_2S (The H_2S gas is varied in concentration and depending by the temperature and relative humidity, it recorded the maximum values in the summer. For example this pressure has reached more than 30 PPm in the environment of conservation). Figure 2 presented of concrete specimens curing in different environment.

A : Concrete specimens preserved in waste water

B : Concrete specimens exposed to H_2S gas

C : Concrete curing with drinking water in the lab

Figure 2: Concrete specimens curing in different environment

3.0 Results and Discussion

3.1 Sclerometer Test

Sclerometer test was conducted in the lab by applying the weight loaded with the Sclerometer on the surfaces of prismatic specimens (70x70x70) mm^3 according to European Standard NF P18-417 (Show figure 3). The results of Compressive strength by Sclerometer are presented in figure 4.

From figure 4, the compressive strength of the specimens curing with drinking water is greater than those specimens preserved in the waste water and exposed to H_2S gas. These specimens exposed to H_2S gas are lower values of compressive strength to others. These values of compressive strength for the specimens conserved in waste water are increasing continuously up to 365 days, and the value strength maximum which is 32.65 MPa, or regression of strength to 3 % than specimens curing with drinking water. For the specimens exposed to H_2S gas, these values of compressive strength are increasing continuously up to 90 days, where the value of strength its maximum to 26.86 MPa, but after 90 days the value of compressive strength is reduced up to 21.45 MPa, at the age of 365 days, or regression of strength to 36 % than others specimens. These results are explained the negative effect of H_2S gas on durability of concrete unlike these specimens curing with drinking water and the specimens conserved in waste water, in the presence of relative humidity in a manhole closed the order to 75% accompanied by an H_2S gas the pressure to 12 PPm (The value pressure of H_2S gas measured by Portable gas detector).

Figure 3: Sclerometer test on the surface of prismatic specimen’s concrete.

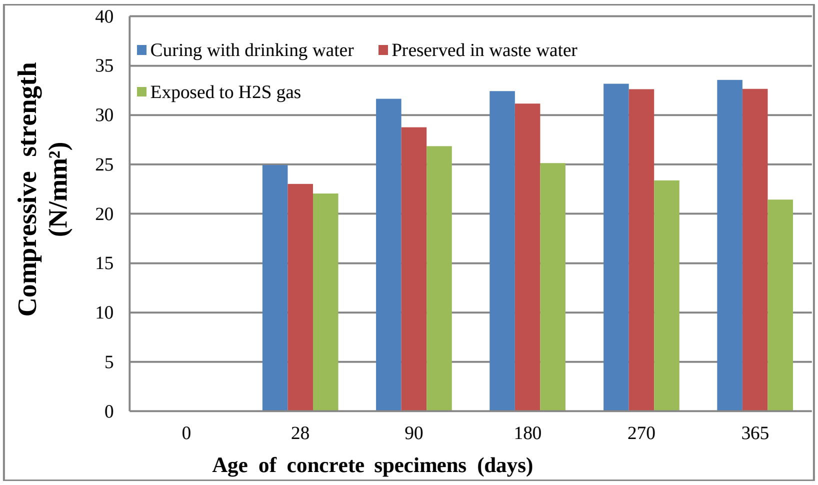

Figure 4: Compressive strength by sclerometer of concrete specimens curing in different environments.

3.2 *UPV Test*

This test is to determine the propagation speed of sound waves in concrete test pieces according to the European standard P 18-418 using an ultrasonic pulse velocity UPV material. This test was carried out in the lab by using concrete prismatic specimens with dimensions (70x70x280) mm^3 exposing in different environment (Show figure 5). The results of the UPV test are presented in figure 6.

From figure 6, the speed of sound for specimens curing with drinking water is higher than to others. The specimens exposed to H_2S gas are lower values the speed of sound than those specimens curing with drinking water and it preserved in waste water. The speed of sound for specimens curing with drinking water and the specimens preserved in waste water is increased from time, but the speed of sound for specimens exposed to H_2S gas is decreases from the age of 90 days. These results are explained the higher density of the specimenscuring with drinking water and the lower density for the specimens exposed to the H_2S gas from the age of 90 days to the age of 365 days. They explain the accelerated degradation for the specimens exposed to H_2S gas than those specimens conserved in the waste water; these results confirm the results obtained in the sclerometer test.

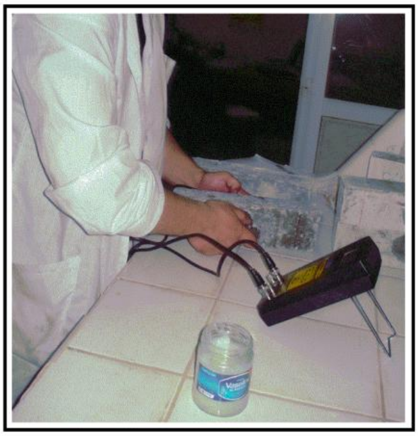

Figure 5: UPV test on the surface of prismatic concrete specimens

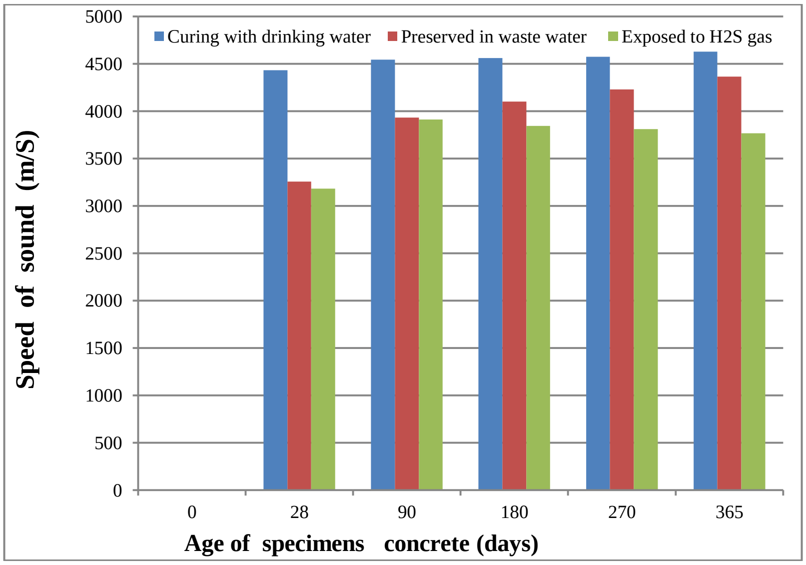

Figure 6: Speed of sound of concrete specimens cured in different environments.

3.3 *Chemical Analysis*

The results of chemical analysis of the skin of specimens conserved in different environment to the age of 365 days are presented in table 5.

Table 5: Chemical analysis of the skin of specimens conserved in different environment

	Specimens curing with drinking water (%)	*Specimens preserved in wastewater (%)*	*Specimens exposed to H_2S gas (%)*
Insoluble	23,59	23,08	26,00
$CaSO_4.2H_2O$	5,12	7,00	6,34
SO_4^{-2}	0,90	1,30	0,99
$CaCO_3$	64	65	67
Cl^-	0,07	0,11	0,03
NaCl	0,12	0,18	0,05

From the two preceding tables4 and 5, the waste water of basin are contained a high concentration of chloride to 1247.90 mg / l and the 660 mg / l of sodium. The skin of specimens conserved in wastewater is contained a high concentration of sodium chlorides to 0.18 % and 0.11 % of chlorides than those specimens curing with drinking water, which explains the formation of a protective skin the chlorides on the surface of the concrete specimens preserved in the waste water.

3.4 Capillary Absorption Test

In capillary absorption test used of concrete specimens conserved in different environment and the dimensions (70x70, 100 < H < 280) mm^3. These specimens are deposited horizontally on the swing face a duration to 72 hours, from a container of sand saturated water the height to 2 cm and the other faces of specimen are plastered with paraffin (Show figure7) (Gorisse, 1978). The results of the capillary absorption test of specimens conserved in different environment to the age of 365 days are presented in figure 8.

Figure 7: Capillary absorption test of prismatic concrete specimens.

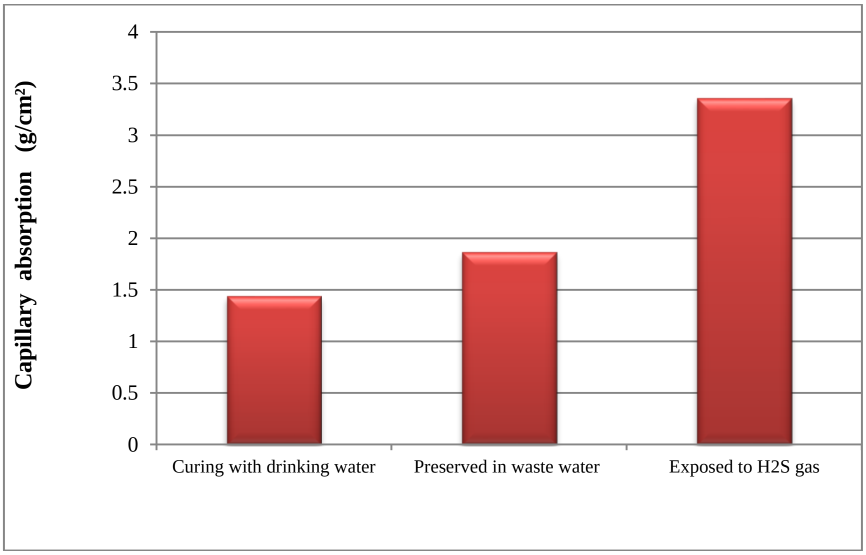

Figure 8: Capillary absorption of concrete specimens conserved in different environments.

From figure 8, the capillary absorption of specimens exposed to H_2S gas is higher than those specimens curing with drinking water and the specimens preserved in the waste water. The specimens curing in water is lower values of the capillary absorption, it is regression to 23% than those specimens conserved in the waste water and to 57% than those specimens exposed to the H_2S gas. The capillary absorption of specimens exposed to H_2S gas confirmed the higher internal porosity of the concrete, due to the diffusion of sulfuric acid inside the pores of the concrete and the formation of ettringite and creation of surface cracks which increase the internal porosity of the concrete. These results are confirmed to previous researcher that the degradation was due to the expansion of ettringite by Messaoudene in 2012.

3.5 X-Ray Diffraction Analyss

The results of X-ray diffraction analyses the skin of concrete specimens preserved in different environment to the age of 365 days are presented in figure 9 and figure 10.

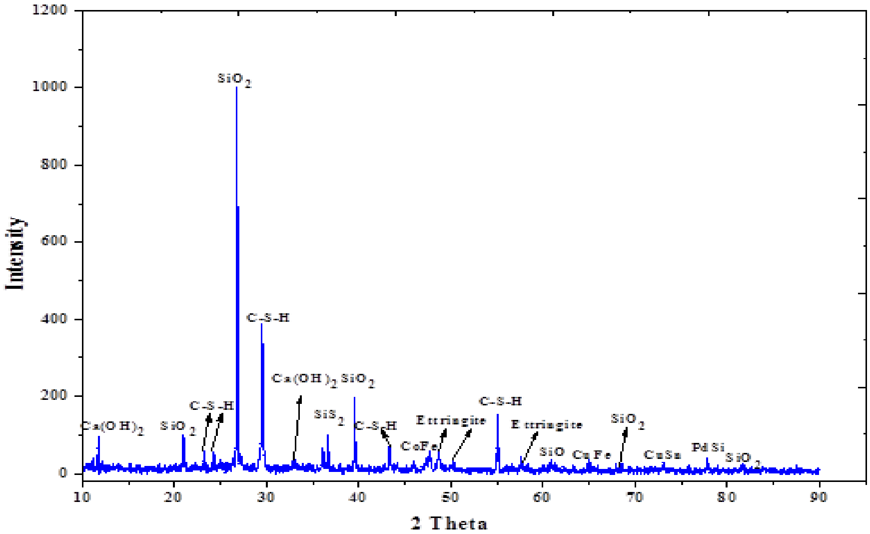

Figure 9: X-ray diffraction of specimens conserved in the waste water.

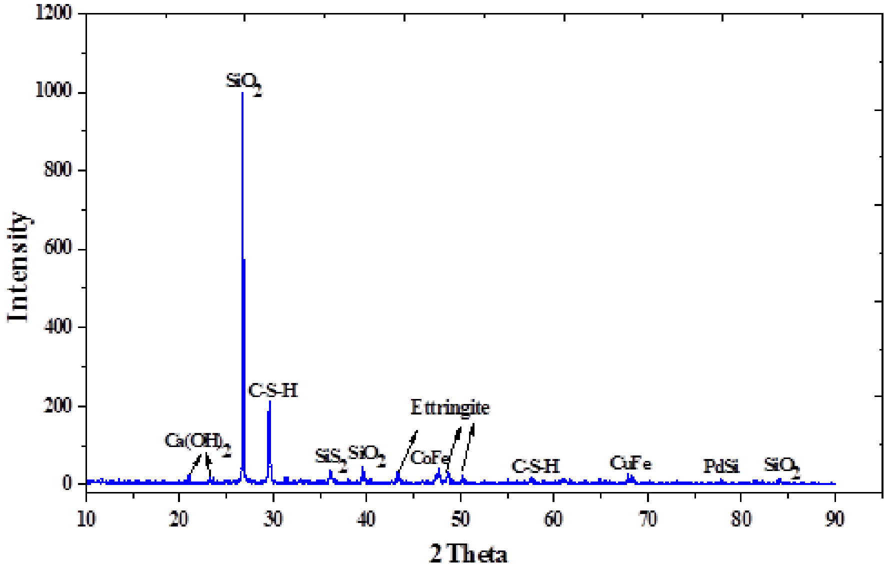

Figure 10: X-ray diffraction of specimens exposed to H_2S gas.

From the figure 9 and figure 10, the formation of ettringite in skin of specimens exposed to H_2S gas, for to peaks 43, 48 and 50. These results confirmed the accelerated degradation of the specimens exposed to H_2S, and they confirmed these results obtained by non-destructive tests.

4.0 Conclusion

The concrete specimens conserved in the waste water have acceptable mechanical characteristics than those specimens curing in water, but to expose of specimens in H_2S gas formed a degradation accelerated than those specimens curing in water or in waste water. They concluded the sanitation networks (pipes and manholes) of Ouargla–Algeria are a low durability under the effect of H_2S gas sulphates. For increase the durability of pipes and manholes the Ouargla, it proposed the substitution by pipes and manholes in polyester materiel.

References

BG (Swiss technical design office).(2004). *Study of Wastewater, Rainfall and Irrigation Water Reclamation, Supplementary Measure to Combat the Rise of the Water Table*. Technical Report: PP 1-10.

Baron, J and Ollivier, J.P.(1992). *The Durability of Concrete.* The collection of technical association of hydraulic binders industry,edition of the School of Bridges and Roads, 49, Rue University, 75007 Paris.

Bassuoni, M.T and Nehdi, N.L.(2008). *Durability of Self Consolidating concrete to sulfate attack under combined cyclic environments andflexural loading*. Elsevier, Cement and Concrete Research, 39 (2009) 206-226.

Dreux, G. (1970). *Practical Guide to Concrete*. Chief Engineer at the Experimental Centre of Building and Public Works, edition of the broadcasting company technical building and public works. Paris.

Eštokova, A. Harbuľáková, V. O. Luptáková, A and Števulová, N. (2012). *Study of the Deterioration of Concrete Influenced by Biogenic Sulphate Attack*. Elsevier, Procedia Engineering 42 (2012) 1731-1738.

Gorisse, F. (1978). *Testing and Testing of Concrete*. Editions Eyrolles, PP 102-103, Paris.

Hannachi, S and Guetteche, M. N. (2014). *Review of the ultrasonic pulse velocity evaluating concrete compressive strength on site*. Scientific cooperation international workshops on engineering branches, University of Istanbul, Turkey, 8-9 August 2014.

Jensen, H.S. Lens, P.N.L. Nielsena, L. J .Bestera, K. Nielsena, A. H. Thorkild, H. J and Vollertsena, J. (2011).*Growth Kinetics of Hydrogen in Sulfideoxidizing Bacteria From Corroded Concrete Sewers*. Elsevier, Journal of Hazardous Materials189 (2011) 685-691.

Khan, A. R. (2009). *Performance of Different Kinds of Pakistani Cements Exposed to Aggressive Environments*. Concrete Repair, Rehabilitation and Retrofitting II - Alexander et al, London, ISBN 978-0-415-46850 -3.

Messaoudene, I. Jauberthie, R. Molez, L. Damien, R and Abdelghani, N. (2012). *Effect of Industrial By-products Fillers on the Properties of Blended Cements in Sulphate Environments*. 10th International Congress on Advances in Civil Engineering, October 2012, Ankara, Turkey.

Nguyen,. T. N. Sbartaï, M. Z. Breysse, D and Bos, F. (2012). *Evaluation Non Destructive des Bétons par Combinaison des Techniques de CND – Apport des Probabilités Conditionnelles*. 20th International Congress in Civil Engineering, Chambéry, France, 6 - 8 June 2012.

Obad, R. (2014). *Combination Of The Non-Destructive Methods For Evaluating the Quality of Concrete Used in Structures in Reinforced Concrete*. International Journal of Engineering Research and Applications.Volume 4, N° 04 (2014), PP: 01 - 04.

Prasad, J. Jain, D. K and Ahuja, K. A. (2006). *Factors Influencing the Sulphate Resistance of Cement Concrete and Mortar*.