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Study on Durability of the Concrete of Sanitation Network in Ouargla Algeria Under the Existence of Sulphates Attack

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ABSTRACT

The objective of this research was to evaluate pipes for domestic applications in Ouargla Algeria. The experiment procedure was done by investigating the sanitation networks as a function of type of pipes, concrete used, and waste concentration (as sulfates and hydrogen sulphide composition).The analysis was also completed by the comparison between the realistic pipe condition and the pipe specimen control in laboratium. The results showed that decreases in mechanical strength of the pipe were obtained. The compressive strength of the specimens has decreased down to 3% after 1 year. When exposing the specimen to hydrogen sulphide gas, a rapid deterioration was obtained since 90 days of expossure. Further, the worst change in compressive strength was found, in which the reduction of compressive strength was found down to 40%.

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1. INTRODUCTION

The sanitation network of Ouargla is an important system. Majority of people in this place connect the sanitary with the sewer system. Although most sewer system is classified as a domestic-type wastewater, the sanitary seemed to be beyond the standard from domestic wastewater. The main reason is because this saintary system has a correlation to the discharged wastewater from industry. Indeed, this could be from the inappropriate wastewater treatment (Boumehraz & Mellas, 2017).

The other factor obtained from this sanitation is the high contamination of sulphates and hydrogen sulfide (H_2S) (Nielsen & Hvitved-Jacobsen, 1988). It is also reported that the concentration of these contaminants depends on the temperature and relative humidity, and the maximum values are obtained in summer session (Pebriyanti *et al.*, 2016).

The gas sometimes reaches concentration of 100 ppm.

H_2S gas is usually created as a result of organic decomposition in anaerobic bacterial process. The concentration of this gas must be considered and has a threshold at 3 to 6 mg/L (Estoup & Cabrillac, 1997). Although H_2S gas can be oxidized when contacting with air by aerobic bacteria, the existence of this chemical is toxic. Further, to oxidize H_2S, 2% to 6% of oxygen (O_2) is required. Although the oxidation is good to decrease the toxicity of the H_2S, the oxidation process creates problems because of the sulphate formation that can corrode pipe (Ryckebosch *et al.*, 2011). In other problems, when H_2S gas condenses on the walls of sewer networks, H_2S is converted by anaerobic bacteria, reacting with moisture to form a strong and highly corrosive acid to the plates as sulfuric acid (H_2SO_4) (Jensen *et al.*, 2011).

In the case of pipe, most of the components are gypsum. The gypsum ($CaSO_4.2H_2O$) is obtained by the reaction between portlandite ($Ca(OH)_2$) and the outer sulphates. The ettringite formation ($C_3A.3CaSO_4.32H_2O$) is the result of the reaction between gypsum and anhydrous calcium aluminate. The reaction for the formation of these materials involved sodium sulphate (Na_2SO_4) and magnesium sulphate ($MgSO_4$) with calcium hydroxide (Bassuoni and Nehdi, 2009; Prasad *et al.*, 2006). The reaction can written as

$$Ca(OH)_2 + Na_2SO_4 + 2H_2O \rightarrow CaSO_4.2H_2O + 2NaOH$$

$$Ca(OH)_2 + MgSO_4 + 2H_2O \rightarrow CaSO_4.2H_2O + Mg(OH)_2$$

$$C_3A + 3CaSO_4.2H_2O + 26H_2O \rightarrow C_3A.3CaSO_4.32H_2O$$

The additions of pozzolane during the hydration of cement can increase the mechanical strength and reduce the reaction with the calcium aluminate (C_3A) of about to 8% (Bassuoni & Nehdi, 2009).

The contact between the sulphuric acid and portlandite ($Ca(OH)_2$) results gypsum ($CaSO_4.2H_2O$). Then, the contact between the gypsum and the anhydrous calcium aluminate (C_3A) forms ettringite ($3CaO.Al_2O.3CaSO_4.3H_2O$). Finally, ettringite is a friable material that forms from the incomplete reaction of the sulphuric acid and the cement paste (Eštokov *et al.*, 2012).

Messaoudene obtained a reduction of compressive strength by 41% (Messaoudene et al., 2012). When temperature is lower then 15°C, the thaumasite ($CaSiO_3.CaCO_3.CaSO_4.15H_2O$) was formed. This material is produced by reactions between the hydrated calcium silicates (CSH), sulfates, and carbonates ions (Bassuoni & Nehdi, 2009).

$$SO_4^{-2} + 3Ca^{+2} + 3CO_3^{-2} + 3SiO_3^{-2} + 15H_2O \rightarrow 3CaOSiO_2.CO_2.SO_3.15H_2O$$

Here, the present work was to investigate degradation mechanism and physicochemical of organic material in concrete specimens in the real aggressive environment as the building blocks of pipes and manholes used to sanitation in the Ouargla region. This information is important since the organic material can results other chemicals and can not be predicted easily (Permatasari *et al.*, 2016; Anshar *et al.*, 2016). The organic materials can be changed by the additional oxygen and light (Nandiyanto et al., 2016). We believe that this research will give information regarding the strategies for against corrosion phenomena.

2. METHOD

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This study used prismatic mold 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 were kept in the molds in the indoor lab for 24 hours, for curing concrete. **Table 1** summarizes the concrete mixture compositions of sample. The cement used are Sulphate Resistant Cement (CEM I 42.5 N-ES) from the Lafarge company. Physicochemical properties of the cement are shown in **Table 2**.

Table 1. Proportions of tested concrete mixtures

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

Table 2. Physical and chemical properties of cement

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

The physical and chemical properties of coarse aggregate and the fine aggregate used are presented in **Table 3**. The maximum size of coarse aggregate was 15 mm, and the maximum size of fine aggregate or sand was 5 mm. The sand is silica.

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	-
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 were cured with drinking water condition (temperature of 20 ± 2 °C). Other specimens were conserved in the basin of waste water in the Ouargla. Chemical analysis of waste water in the basin is shown in **Table 4**.

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

Ions	Unit
Ca^{+2} (mg/L)	492.98
Mg^{+2} (mg/L)	4560.00
K^+ (mg/L)	27.50
Na^+ (mg/L)	660.00
SO_4^{-2} (mg/L)	4900.00
Cl^- (mg/L)	1247.90

The last specimen is exposed to hydrogen sulphuric (H_2S) gas, which is placed in a manhole closed of the Ouargla aiming to ensure a high concentration of H_2S. Figure 1 presents concrete specimens curing in different environment conditions.

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A: concrete specimens conserved in wastewater — B: concrete specimens exposed to H_2S gas — C: concrete specimens cured in water (control)

Figure 1. Concrete specimens curing in different environment.

3. RESULTS AND DISCUSSION

Compression test was conducted in the lab by using of prismatic specimens (70x70x70 mm) according to European Standard EN 12390-3. The results of compressive strength the concrete specimens conserved in different environment are presented in Figure 2.

As shown in **Figure 2**, the compressive strength of the specimens control is greater than those specimens preserved in the waste water. The specimen exposed with H_2S gas is the lowest for compressive strength value. The compressive strength for specimens conserved in waste water increases continuously up to 365 days, and the maximum value of strength reaches is 32.65 MPa. For the specimens exposed to H_2S gas, the value of compressive strength increases continuously up to 90 days, where the maximum strength is 37.04 MPa. But, from 90 to 365 days, the value of compressive strength reduced down to 20.41 MPa. The results confirmed the negative effect of H_2S gas on durability of concrete.

The X-ray diffraction analysis shows the skin of concrete specimens preserved in different environment conditions (**Figure 3 and 4**). As shown in the figures, the formation of ettringite was found in specimen exposed with H_2S gas (detected in peaks of 43, 48, and 50°). The formation of portlandite for specimen conserved in waste water was found at peaks of 12 and 32°. The results confirmed the acceleration for degradation of the specimens exposed to H_2S.

4. CONCLUSION

The conservation of pipe must be considered since the physicochemical properties of pipes change when contacting with chemicals. It is found that the concrete specimens in wastewater decreases by 3% for compressive strength after 365 days. For concrete specimens exposed to H_2S gas, rapid deterioration was found after 90 days. Then, when exposing H_2S gas from 90 to 365 days, reduction in strength to 40% was found. The change of mechanical strength is due to corrosion phenomena as an impact from the existence of H_2S. Thus, for increasing durability of pipe and manholes in Ouargla, substitution of pipe and manhole by other material is important.

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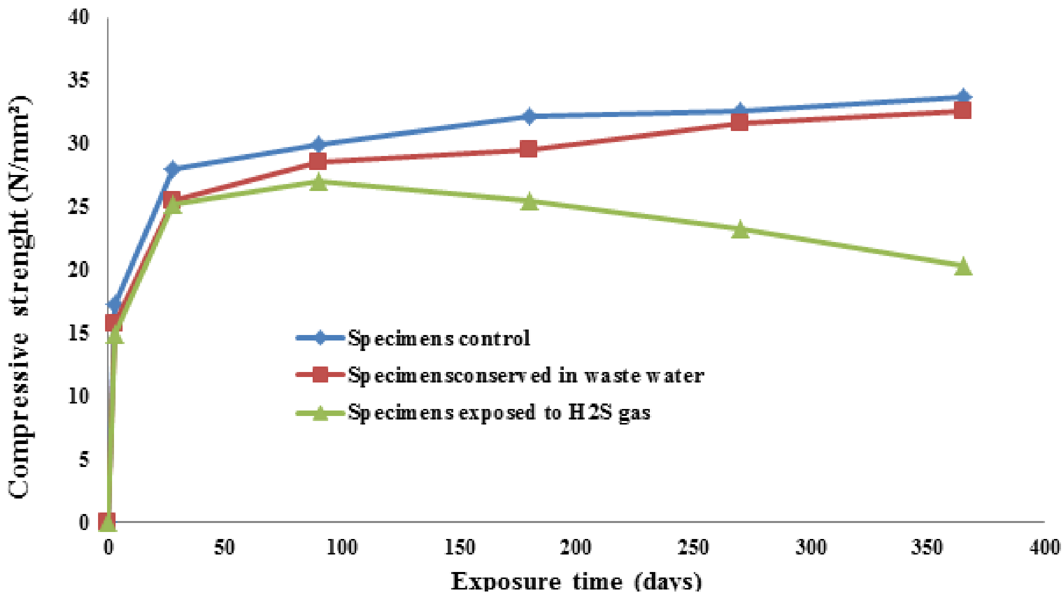

Figure 2. Compressive strength of concrete specimens conserved in different environments.

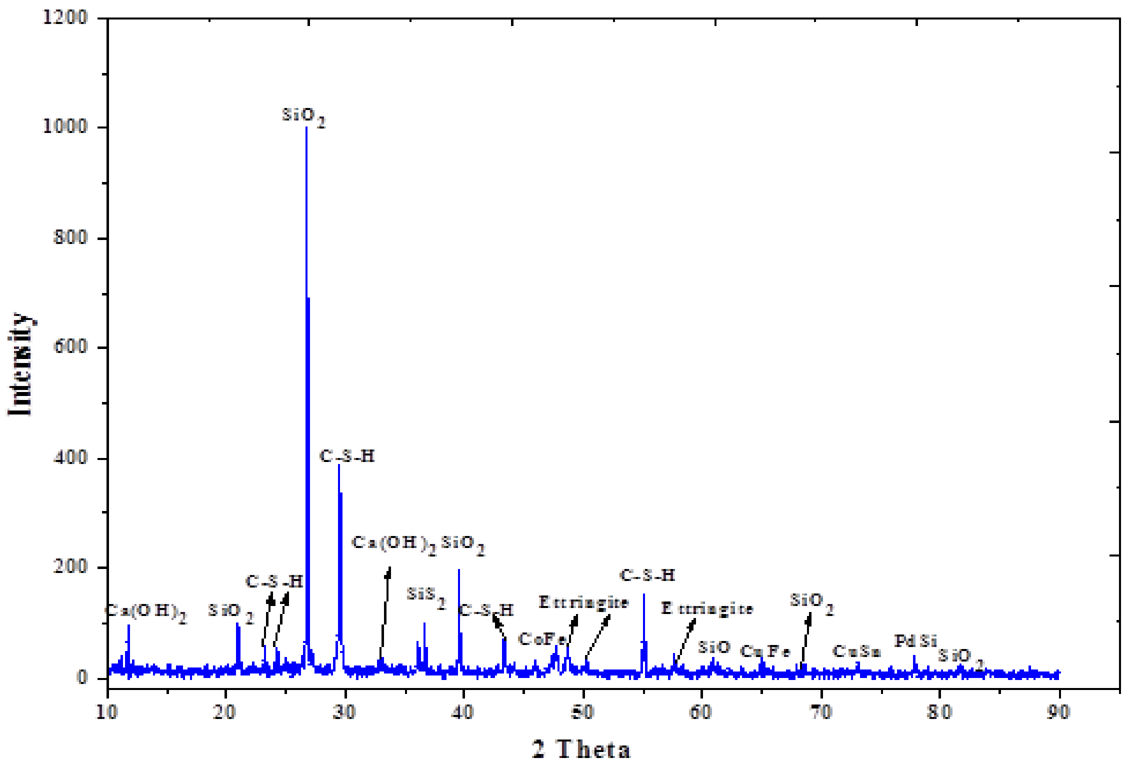

Figure 3. Analysis by X-ray diffraction of specimens conserved in the waste water.

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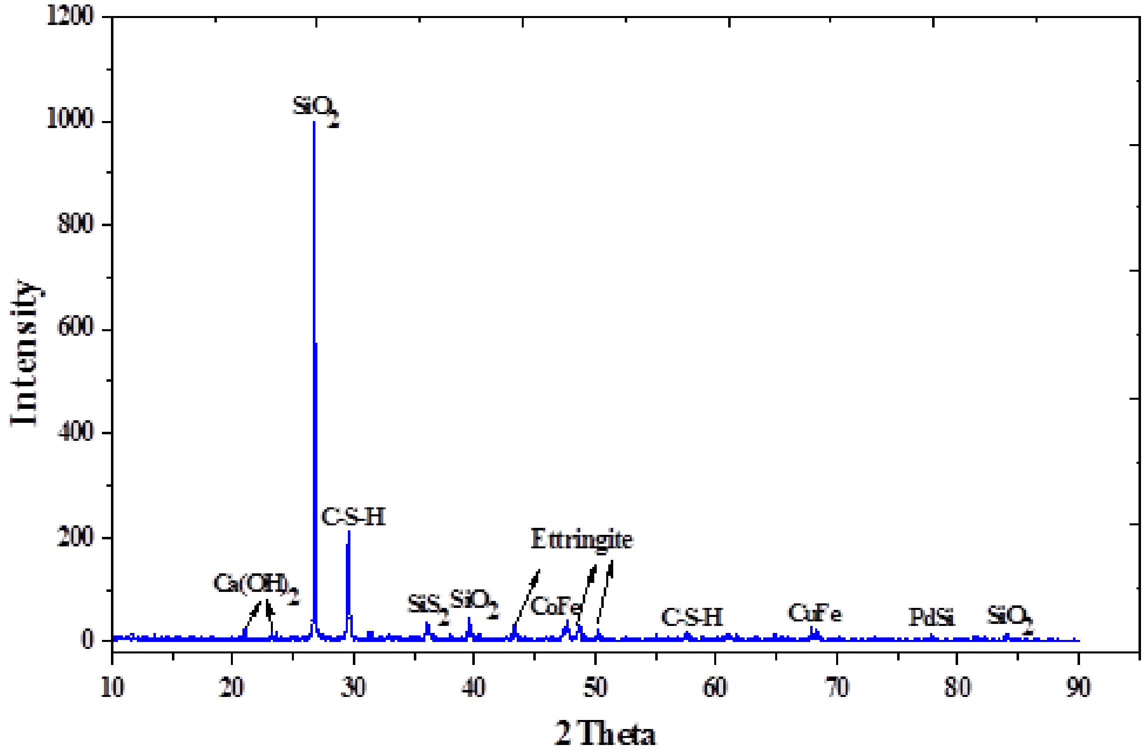

Figure 4. X-ray diffraction of specimens exposed to H_2S gas.

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6. AUTHORS' NOTE

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article. Authors confirmed that the data and the paper are free of plagiarism.

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