Chemical Analysis of Available Portland Cement in Libyan Market Using X-Ray Fluorescence

M. A. Elbagermia, A. I. Alajtala, M. Alkerzab

***Abstract*—**This study compares the quality of different brands of Portland Cement (PC) available in Libyan market. The amounts of chemical constituents like SiO2, Al2O3, Fe2O3, CaO, MgO, SO3 and Lime Saturation Factor (LSF) were determined in accordance with Libyan (L.S.S) and Amrican (A.S.S) Standard Specifications. All the cement studies were found to be good for concrete work especially where no special property is required. The chemical and mineralogical analyses for studied clinker samples show that the dominant phases composition are C3S and C2S while the C3A and C4AF are less abundant.

***Keywords*—**Portland cement, Chemical Composition, Libyan market, X-ray fluorescence.

I. Introduction

PORTLAND cement is a hydraulic material composed primary of calcium silicates, aluminates, and ferrites. In a rotary kiln, at temperature reaching the 1450°C, clinker nodules are produced from a finely ground, homogenized blend of limestone, shale and iron ore. The nodules are subsequently ground with gypsum, which serves to control setting, to a fine powder to produce finished Portland cement. The composition and texture of clinker phases result from complex interactions of raw feed chemical and mineralogical composition, particle size distribution, feed homogenization, and the heating and cooling regime [1] and [2]. In order to simplify these phenomena, [3] proposed an approach for the development of the clinker phases. The ferric oxide (Fe_2O_3) reacts with aluminum oxide (Al_2O_3) and lime (CaO) to form the tetracalcium alumino ferrite (Ferrite C_4AF or $Ca_4Al_2Fe_2O_{10}$). The remaining aluminum oxide reacts with lime to form the tricalcium aluminates (C_3A or $Ca_3Al_2O_6$). The lime reacts with the silicate oxide (SiO_2) to form two calcium silicates phases, the dicalcium silicate (Belite, C_2S or Ca_2SiO_4) and tricalcium silicate (Alite, C_3S or Ca_3SiO_5).

One of the important quality parameters of Portland cement is its chemical and phase composition. It is necessary to determine a complete mineralogy of clinker cement to correctly understand, interpret and predict the outcome of any plant production process [4], and [5]. Every year a huge amount of Portland cement is produced and used for the construction of building, roads and highways and other local purposes in Misurata Libya. Use of poor quality cement in structural and constructional works may cause loss of lives and properties. So, quality assurance of PC has become an important and critical factor.

There are several brands of PC available in market but their chemical compositions are same. Variations in physical properties occur due to the variation in the amount of chemical constituents.

The chemical analysis of cement is carried out to check whether the supplied product conforms to standard specifications or not. In the analysis, each oxide is usually expressed as percentage. Wet chemistry is one of the methods that are employed in the composition determination of cement [6]. In addition to wet chemistry, there are various techniques that are utilized for the composition analysis of cement [7]-[11]. As an example, application of atomic absorption spectroscopy has been reported by a number of researchers for analysis of cement [7], [8]. Another group has determined aluminum oxid in Portland cement spectrophotometrically [11]. X- ray diffraction (XRD) has been used to estimate Portland cement [12]-[13].

In spite of various techniques that are used in analyzing the components of Portland cement, X-ray fluorescence (XRF) technique continues to have a wide popularity. The accuracy of (XRF) as well as the simplicity of procedures are the top reasons for making (XRF) is used by several investigators [14-16]. The study was aimed to conduct chemical analysis of PC. Chemical constituents like silica, Al_2O_3, Fe_2O_3, Lime Saturation Factor, CaO, MgO, SO_3, and ALM were determined. No studies have been found yet in the literature regarding major components analysis of Portland cement that is used in Misurata –Libya.

II. Materials and Methods

A. Sample Collection

Three types of cement were studied; the three types of cement were obtained from the Libyan market, as they are widely used in Libya. 50g of each sample was taken in clean labeled polythene bag as soon as the cement bag was opened to avoid surface contamination and kept for further analysis.

B. X-ray Analysis of the Sample

The amount of each of the studied oxides in the three types of cement was determined by using sequential x- ray fluorescence technique model **ARL 9400**, Switzerland. In the used method, each cement sample (10g) was mixed with boric acid in 10:1 ratio in a milling machine for two minutes with 800rpm. The sample is than pressed by a briquetting press

M.A. Elbagermia is with Chemistry Department, Misurata University, Misurata/Libya (phone: 00218925506893; e-mail: M.elbagermi@yahoo.co.uk).

A.I Alajtala is with Misurata- University, Misurata/Libya (e-mail: Alajtal69@yahoo.com).

M. Alkerzab is with Misurata University, Misurata/Libya (phone: 00218914567439)

machine for 1 minute and then transferred to the X-ray fluorescence for analysis.

C. Mineral Content of the Cements

The mineral content of the cements were calculated based on Bogue's formula as outline by Taylor [17].

$$C3S = 4.07CaO - 7.6024SiO_2 - 6.7187Al_2O_3 - 1.4297Fe_2O_3$$
$$C2S = -3.07CaO + 8.6024SiO_2 + 5.0683Al_2O_3 + 1.08Fe_2O_3$$
$$C3A = 2.6504Al_2O_3 - 1.692\ Fe_2O_3$$
$$C4AF = 3.0432\ Fe_2O_3$$

III. Result and Discussion

The results of the analysis carried out on the samples as shown in Tables I and II. As shown in Table I, the percentage compositions of the various major and minor constituents of the cement samples are within the specifications of American Standard for testing materials (ASTM C150). This means that the cement samples were of certain quality.

The SiO_2 content for all the samples is in the range of 20.87– 25.89% with Al-Ethadia recording the highest value i.e. Al-Ethadia > Adana Cemento > AS Çimento> Al-Qumeas. SiO_2 content is an index for fineness or coerciveness and it determine the grind ability of the cement clinker, level of water intake and strength of concrete [18]. Percentage of the studies oxides AS Çimento is illustrated in Fig. 1. It can be seen from Fig. 1, the CaO present with the greatest amount, while MgO appeared with the smallest quantity.

Al-Ethadia cement had the highest Al_2O_3 content which will lead to high content of C_3A (Table II) that contribute to early strength development, while Adana Cemento cement had the least Al_2O_3 content. Thus more setting decelerating additives are needed for Al-Ethadia in a long period of cementing job.

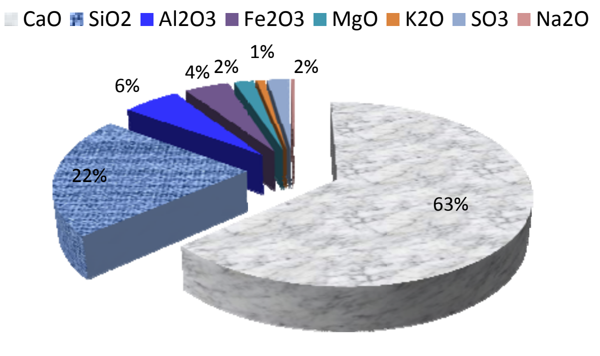

Fig. 1 Oxides in AS Çimento

Adana Cemento had the highest value of SO_3 and AS Çimento the least SO_3 content which also favors formation of C3S mineral compound which is responsible for initial set and early strength. The lower the SO_3 value the better [17].

Adana Cemento had the highest value of Lime Saturation Factor (LSF), whilst Al-Ethadia had the least (LSF). The LSF controls the ratio of alite to belite in the clinker. A clinker with a higher LSF will have a higher proportion of alite to belite than will a clinker with a low LSF. Adana Cemento cement shows the highest percentage of Fe_2O_3. The Fe_2O_3 is one of the parameters responsible for cement colouration which explain why Adana Cemento Cement is darker grey than all the cements. High free lime content results in expansion due to formation of $Ca(OH)_2$, Adana Cemento is therefore unsound due to the higher content of free CaO. It can be seen from Table I that CaO is present with the greatest amount (50.52-63.36%), whereas Na_2O appeared with the smallest quantity (0.22 -0.61%).

TABLE I
Percent Composition of Major Constituent of the Cement Samples by XRF Method

Parameter	AS Çimento	Al-Ethadia	Adana Cemento	Al- Qumeas
CaO	62.16± 0.05	50.52± 0.02	63.36± 0.07	63.19± 0.05
SiO_2	21.16± 0.01	25.89± 0.04	21.72± 0.05	20.87± 0.03
Al_2O_3	5.50± 0.02	8.05± 0.01	4.20± 0.03	5.53± 0.07
Fe_2O_3	4.30± 0.05	3.52± 0.02	4.34± 0.01	3.31± 0.01
MgO	1.78± 0.07	1.30± 0.05	1.30± 0.01	2.14± 0.05
K_2O	0.75± 0.04	1.45± 0.07	0.90± 0.02	1.32± 0.03
SO_3	2.09± 0.01	2.54± 0.05	2.60± 0.04	2.14± 0.02
Na_2O	0.22± 0.01	0.50± 0.05	0.31± 0.03	0.61± 0.01
LSF	88.59± 0.03	57.83± 0.08	90.58± 0.05	83.65± 0.06
SIM	2.16± 0.02	2.24± 0.04	2.88± 0.06	2.69± 0.05
ALM	1.28± 0.02	2.29± 0.03	1.26± 0.05	1.27± 0.04

where are: SIM: silica ratio; ALM: Alumina ratio

In the hydration of the cement powder, it is C_3A that causes the sudden hardening of the cement paste. Hence it is usually retarded by addition of gypsum. High amount of C_3A is undesirable. The C_3S and C_2S hydrate to form the calcium silicate hydrate that brings about the adhesive and the cohesive strengths of the cement structure. [19] The calcium alumino ferrite (C_4AF) does not have significant role in the hydration of cement. However along with C_3A, it serves as a reservoir for the removal of some deleterious ions like Cl- and SO_4^{2-} that cause the rusting of steel reinforced concrete. [17]

TABLE II
Percent Mineral Composition of Cement Samples (%)

Sample	**C3S**	**C2S**	**C3A**	**C4AF**	**Sum**
AS Çimento	49.02490	23.71518	7.30160	13.08576	93.12744
Al-Ethadia	-50.3173	112.2114	15.37988	10.71206	87.98604
Adana Cemento	59.75973	17.2229	4.5786	10.16428	91.72551
Al Qumeas	56.6345	17.14127	9.0539	10.0729	92.90257

As shown in Table I and Fig. 2, the SIM and ALM contents for all the samples is in the range of 2.16-2.88 and 1.26-1.29 respectively, a high silica ratio means that more calcium silicates are present in the clinker and less aluminate and ferrite. SIM is typically between 2.0 and 3.0. An increase in ALM means there will be proportionally more aluminate and less ferrite in the clinker. In ordinary Portland cement clinker, the ALM is usually between 1 and 4.

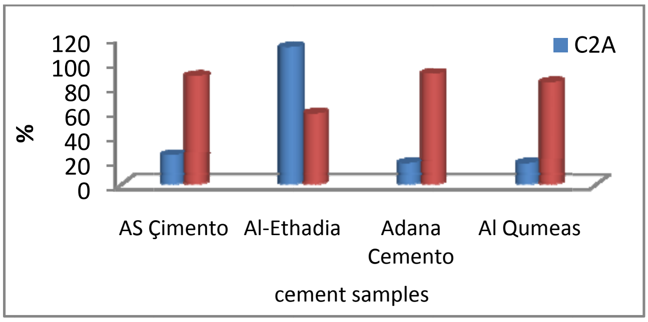

Fig. 2 Percentage of LSf and C_2S in the studied types of Cement

IV. Conclusion

The result of the analysis indicates that the cement samples under study are generally good for concrete work especially where no other special properties are required AS Çimento seems to be the best one having the lowest SO_3, whereas Al-Ethadia had the lowest Lime Saturation Factor and highest percentage of C_2A . As shown in Tables I and II, the cement has high LSF and highest C_3S while C_2S is decreased with increasing the LSF but it still an important strength-giving compound.

References

[1] M. S., Ali, I. A. Khan, and M. I., Hossain, Chemical Engineering Research Bulletin 12, 2008, pp. 7 -10.
[2] Y. C., Hwang, I., N., Hwang, Son, H., H., Kim, Jour. Of OOOOE, 107 (3), 2009; pp. 96 – 102.
[3] R.H, Bogue , Camilleri J, Montesin FE, Papaioannou S, McDonald F, Pitt.,1929, P.192–7.
[4] N. H., Deborah, D. E., Thomas, Journal of Cleaner Production. 17, 2009, pp. 668–675.
[5] S. D., Rao, T.,V., Vijayakumr, S. Prabhaka, and G., Bhaska Raju, Chinese journal of geochemistry, Volume 30, Issue 1, 2011, pp 33-39.
[6] Australian standard 2350.2/80- chemical composition of Portland cement.
[7] R.F. Crow and J.D. Connolly, j testing and evaluation 1, 1973, pp382.
[8] [Z. Marezenko ," Spectrophotometric determination of elements," (Ellis Horwood, Chichester) 1976.
[9] F.D. Snell," photometric and fluorometric methods of analysis," 1978. (part I, Wiley, New York)
[10] M. Ahmed and J. Hossan," Spectrophotometric determination of aluminium by morin," Talanta, 42, 1995, pp 1135.
[11] K. A. Idriss, E. Y. Hashem, M. S. Abdel Aziz, and H. M. Ahmed, The analyst, 125, 2000, pp 221.
[12] J. C. Taylor, Z. Rui. L.P. Aldringe, Mineral Science Forum, 329, 1993, pp 133-136.
[13] J.C. Taylor, L. P. Aldridge, Powder diffraction, 8(3), 1993, pp138.
[14] B. J. Price," process control element analysis of cement making materials using automated XRF spectrometers," World cement, 17, 1986,pp 4.
[15] S. H. Basbikian, "Raw material analysis by XRF in the cement industry, in advances in X-ray analysis," V36, Plenum press, New York, 1993.
[16] R. R. Fleming, J. D. Jefferson, "Magnesium analysis with a low cost EDXRF cement analyzer," world cement research and development, 1995.
[17] H.F.W. Taylor, (1990). "Cement Chemistry" Academic Press, London, pp10-69.
[18] M.I. Frias, and R, Sanchez, Cement and Concrete Research, 25 (2): 1995, pp 432–439.
[19] U.J. Ahmed. U.A. Birnin–Yauri, and S.M. Dangoggo, Biological and Environmental Sciences Journal for the Tropics, 6(2), 2009, pp89-91.