Civil and Environmental Research www.iiste.org
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) DOI: 10.7176/CER
Vol.11, No.1, 2019

Development Program to Estimate the Suitable of Raw Materials to Produce Cement

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Abstract
Raw material composition plays an essential role on the lining life of cement rotary kiln.They are obtained from hard rock quarries that represent the first step in the cement manufacturing process. That raw materials are transported to Al- Kufa cement plant then crushed and ground to very fine powder and then blended in the correct proportions.This research aims to study suitable rations of raw materials to produce cement in al Kufa cement plant in Iraq. Through a software program, suitale raw materials ratios for the clinker were estimated, then chemical and physical tests for clinker and cement according to Iraqi Standard Specification were done to recognize the effects on the properties of cement such as the ratios of major and minor oxides, Lime saturations factor (LSF), Silica Modulus (SM) Alumina Modulus (AM), compressive strength, setting time and soundness.
Keywords: Portland Cement, Raw material, Cement industry, Rotary kiln and Factors Affective of clinker
DOI: 10.7176/CER/11-1-06

1. Introduction

Portland cement is a gray non- metallic, inorganic powder, the result of a mixture of calcium silicate (mainly limestone) and aluminoferrites. When cement is mixed with water it forms a paste that sets and hardens due to the formation of calcium silicate hydrates and or calcium aluminates hydrates as a result of the exothermic reaction (RailiKajasteand MarkkuHurme, 2016; - L. M. Aksel'rod, I. G. Maryasev and A. A. Platonov, 2013)

The raw materials used in the manufacture of cement are limestone, clay, gypsum, slag and pozzolanic materials. The basic stages of cement manufacturing include limestone quarrying, the preparation and pyroprocessing of the raw meal (clinkerization), clinker cooling and cement grinding. The chemical process of cement manufacturing can be described as a calcinations process that initiates with a decomposition of calcium carbonate ($CaCO_3$) at about 900°C to produce calcium oxide (CaO, lime) with subsequent liberation of carbon dioxide (CO_2). Following, the clinkering process is conducted in the rotary kiln by reacting calcium oxide at a high temperature (1400-1500°C) with silica, alumina and ferrous oxide to form the silicates, aluminates and ferrites of calcium which are tha main component of clinker. The clinker cooled and is milled along with gypsum and other additives to produce the gray powder known as cement (Adem Atmaca and RecepYumrutas,2014; Azad Rahman, M.G. Rasul, and S. Sharma,2016)

A cement rotary kiln is a distributed parameter process system which has a highly complex behavior due to chemical reactions. Raw meal for cement production is a mixture of predetermined proportions of limestone, silica and small quantities of alumina and iron oxide. The primary function of a rotary kiln is to provide a high-temperature environment to drive solid- soild and solid-liquid reactions for clinker formation. In the beginning section of a kiln, starting from solid entrance, the calcination of raw material is completed. Thereafter, the soilds undergo soild-soild reactions as they move forward. Then, the solid enters a higher temperature zone where it melts to form a liquid phase. The final reactions take place in this phase. So that it causes formation of coating over the refractory lining in the remaining part of the kiln. In this higher temperature section, called burning zone, the refractory of the kiln is under severe damage because of high temperature. Moreover, the high-coating thickness creates serious problem for the flow of soilds along the kiln. Therefore, the thickness of the coating in the buring zone is momentous because of the protection of the refractory lining from damaging which increases the life of the refractory and movement of feed through the kiln (Azad Rahman, M.G. Rasul, and S. Sharma,2016; Junli Zhang, Jianguo Liu and Cheng Yiying,2009; A.M. Castañón, S. García-Granda, and M.P. Lorenzo, 2015) Methods based on measuring the thermal radiation from the shell surface were conventional for checking and estimating the coating thickness and lining in the rotary cement kilns (M. Pisaroni, R. Sadi and D. Lahaye,2012)

1.1 Factors Affecting Burnability:

The following are the important parameters which affect the burnability of araw mix (Guoxiang Yin,2012; José Luis Aguirre González, 2005; Jacek Szczerba,2010)

a.Chemical Composition:

Each component of the raw mix has individual and combined [(Lime SaturationFactor (LSF), Silica Modulus (SM), Alumina Modulus (AM),] effects on burnability. The formula, limiting range and the preferable range of the LSF, SM and AM is shown in Table1

b. Thermal Treatment:

Burning of the raw mix is generally carried out at 1450-1500°C. Excessive high burning temperature results in a great stress on the kiln and the refractory lining, more fuel consumption,reduction in cement strength and larger alite crystal .

On increasing holding time, C_3A content may decrease, C_4AF may increase, C_2S may decrease, C_3S may increase. Rapid burning is always favored as because fine grains of C_2S formed which accelerate theinteraction of C_2S, CaOand liquid. Thermal activation can be enhanced by either with mechanical (vibratory mill) or chemical (mineralizer) activation. Mechanical activation gives better results than chemical.

Table 1: The Formula, Limiting Range And The Preferable Range Of The LSF, SM And AM

Parameter	Formula	Limiting range	Preferable range
LSF	$\frac{\% CaO}{28x\ \%SiO2 + 1.2x\ \%Al2O3 + 0.65x\%Fe2O3}$	0.66-1.02	0.92-0.96
SM	$\frac{\%SiO2}{\%\ Al2O3 + \%Fe2O3}$	1.9-3.2	2.3-2.7
AM	$\frac{\%\ Al2O3}{\%\ Fe2O3}$	1.5-2.5	1.3-1.6

c. Liquid Phase Formation:

The amount of liquidformed, its appearance temperature, viscosity, surface tension and ionic mobility in the clinkerization process.

d. Clinker Quality:

The burnability becomes worse as C_3S content increases while an increasing C_3A and C_4AF, the burnability improves.

e. Kiln Atmosphere:

A reducing atmosphere during burning affect the colour of the clinker by reducing iron oxide,enhancing C_3A, decreasing C_4AF, C_3S.

2. Experimental Materials:

Field visits were implemented during 2016 to Al-Kufa Cement plant in Iraq to view the rotary kiln of cement manufacturing. Chemical and physical tests for clinker and cement according to Iraqi Standard Specification were done to recognize the effects on the properties of cement. A software program was achieved to calculate the ratios of the raw materials of clinker.

3. Results and Discussion

3.1 Calculations of Mixing Ratios For Raw Materials:

A software program is achieved to calculate the mixing ratios of raw materials for the production of the final mixture of the resistant clinker and this program requires:

1- Chemical analysis tests for the raw materials, shown in table 2 that represents the chemical tests of the raw materials.

Table 2: Chemical Tests of Raw Material

Compound	Limestone	Clay	Sand	Iron ore
SiO2	2.52	39.06	87.91	16.90
Al2O3	0.23	11.42	3.14	4.05
Fe2O3	0.56	7.60	1.88	62.20
CaO	53.12	15.35	3.24	2.48
MgO	0.64	5.39	0.86	1.38
SO3	0.64	1.59	1.22	0.50
L.O.I	41.43	17.52	1.36	10.94
Total	99.14	97.83	99.61	98.45

2- Specifying the target of LSF = 0.92 , AM=0.75 and SM= 2.6.

3- Calculating the CaO of the raw materials under this equation

CaO max = 2.8* SiO_2 + 1.2*Al_2O_3 + 0.56* Fe_2O_3

According to Table 2 :

C1 of lime stone = CaO of lime stone – (LSF* CaOmax of lime stone)

C1= 46.04

C2 of clay= CaO of clay – (LSF* CaOmax of clay)

C2=128.012

C3of sand= CaO of sand– (LSF* CaOmax of sand)

C3= 227.81

C4of Iron= CaO of Iron– (LSF* CaOmax of Iron)

C4= 82.721

Calculation of percentage of primary materials

Mix 1

% C2 = C1/ C1+C2 , %C2

%C2 = 46.039/ 43.039+128.012= 0.31 of clay

[% C1= 1-0.31= 0.69 of limestone]

Mix2

% C1= C3/C1+C3

% C1=227.81/46.039+227.81= 0.83 of limestone

% C3= 1-0.83= 0.168 of sand

Mix3

% C1= C4/C1+C4

%C1= 82.721/82.721+46.039= 0.64 of limestone

% C4 = 1- 0.64 = 0.36 Iron ore

4- Calculating of the main oxides of mixtures:

Mix 1

Limestone + clay

0.69+ 0.31

SiO_2= 0.69*2.52+0.31*39.06 =13.85

Al_2O_3= 0.69*0.23+0.31*11.42=3.7

Fe_2O_3= 0.69*0.56+0.31*7.6=2.74

CaO = 0.69*53.12+0.31*15.35=41.41

Mix2

Limestone+Sand

0.83+0.168

SiO_2 = 0.83*2.52+0.168*87.91 =16.88

Al_2O_3= 0.83*0.23+0.168*3.14 = 0.72

Fe_2O_3= 0.83*0.56+0.168*1.88 = 0.78

CaO = 0.83*53.12+0.168*3.24 = 44.73

Mix3

Limestone+Iron ore

0.64 + 0.36

SiO_2 = 0.64 *2.52+0.36 *16.9 =7.66

Al_2O_3= 0.64 *0.23+ 0.36 * 4.05 = 1.60

Fe_2O_3= 0.64 *0.56+0.36 * 62.20 = 22.60

CaO = 0.64 *53.12+0.36 * 2.48 = 35.01

From the mixtures above we get mixtures 4 and 5:

Determination of alumina coefficient (AM) = 0.75

AM = Al_2O_3/Fe_2O_3

Al_2O_3 = 0.75* Fe_2O_3

For Mix 1 (limestone+Clay)

A1= Al_2O_3 - 0.75* Fe_2O_3

A1= 3.7-0.75*2.74=1.64

For Mix 2 (limestone+sand)

A2= 0.72- 0.75* 0.78= 0.132

For Mix 3 (limestone+Iron ore)

A3= 1.6- 0.75* 22.6= 15.36

Calculation of percentage of primary materials

Mix 1
% A3 = A3/ A1+A3 ,
%A3 = 15.36/ 1.64+15.36= 0.9035% of limestone + clay
1-0.9035 = 0.096% limestone+Iron
Mix3
% A2= A2/A2+A3
% A2 = 15.35/ 15.35+0.1327= 0.9914% of limestone+sand
1-0.9914= 0.0087% limestone+Iron
of the above ratio, the main oxides can be calculated by mixing No.4 and
Mix 4
SiO_2= 0.9035*13.85+ 0.096*7.66=13.85
Al_2O_3= 0.9035*3.70+0.096*1.6=3.5
Fe_2O_3= 0.9035*2.74+0.096*22.6 = 4.66
CaO= 0.9035*41.41+0.096*35.01= 40.79
Mix5
SiO_2= 0.991*16.88+ 0.008*7.66 =16.80
Al_2O_3= 0.991*0.72+0.008*1.6 =0.73
Fe_2O_3= 0.991*0.78+0.008*22.6 = 0.97
CaO= 0.991*44.73+0.008*35.01= 44.65
To calculate the final mixture for the production of the resistant clinker by combining mixing No.4 and 5 by setting the coefficient of silica to be 2.6
SM= SiO_2/ (Al_2O_3+Fe_2O_3)
S= SiO_2 - SM (Al_2O_3+Fe_2O_3)
S4= 13.25-[2.6(3.5+4.66)] = -7.96
S5= 16.8- [2.6 (0.73+0.97)] = 12.39
% S5= S4/ S5+S4
% S5= 7.96 / (7.96+12.39) = 0.3912% of [(lime+Iron)+ (lime+sand)]
% S4 = 1-0.3912 = 0.6088 % of [(lime+clay)+ (lime+iron)]
Mix 6
SiO_2= 0.3912*16.80+ 0.61*13.25 =14.639
Al_2O_3= 0.3912*0.73+0.61*3.5 =2.41
Fe_2O_3= 0.3912*0.97+0.61*4.66 = 3.22
CaO= 0.3912*44.65+0.61*40.79= 42.30
The percentages of the mixing of the raw materials in the process of production of the Al-Kufa Cement plant in Iraq during 2016 is listed in tables below using the software program.

Table 3: Final Chemical Tests of Raw Material

Compound	Limestone	Clay	Sand	Iron ore
SiO2	2.36	40.64	88.02	2.65
Al2O3	0.26	13.89	4.22	0.9
Fe2O3	0.48	6.08	0.70	92.64
CaO	51.82	15.87	1.62	2.31
L.O.I	42.97	15.66	3.35	0.9

Table 4: Ratios Of Raw Materials For Clinker

Compound	Mix1	Mix2	Mix3
SiO2	13.89	2.48	16.402
Al2O3	4.37	0.52	0.909
Fe2O3	2.17	37.81	0.516
CaO	40.99	31.77	43.591
Compound	**Mix4**	**Mix 5**	**Mix 6**
SiO2	13.02	16.16	14.277
Al2O3	4.07	0.90	2.801
Fe2O3	4.91	1.17	3.406
CaO	40.28	43.38	41.524

Table5: Raw Materials For Clinker

Compound	Clinker
SiO2	22.27
Al2O3	4.37
Fe2O3	5.31
CaO	64.78
L.S.F	0.912

Table 6: Ratios Of Raw Materials For Clinker

Mix 1	% limestone	0.70
	% clay	0.30
Mix2	%Limestone	0.84
	% sand	0.16
Mix3	%limestone	0.595
	%iron	0.405
Mix4	%lime+clay	0.92
	% lime+iron	0.08
Mix5	%lime+sand	0.983
	%lime+iron	0.017
Mix6	% lime+iron+clay+sand	0.401
	% lime+clay	0.599

Table7: Final Ratio Of Raw Material For Clinker

Limestone	0.747
Clay	0.167
Iron	0.021
sand	0.065

3.2Physical And Chemical Tests Of Clinker And Cement:
Samples were taken for clinker and cement produced in the Al-Kufa cement plant in Iraq during 2016 .Below are the results chemical and physical tests according to Iraqi Standard Specification.

Table 8 Iraqi Cement State Company Al- Kufa Cement Plant Sulfate Resistance Clinker

DATE	LW(g/L)	Chemical Analysis (%)							F.CaO	Models			Clinker Compounds (%)				Factories		
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Total	F.CaO	L.S.F	SM	AM	C_3S	C_2S	C_3A	C_4AF	CI	FLUX	BF
01/01/2016	1330	21.58	4.18	5.16	63.54	3.6	1.37	99.43	0.6	0.92	2.31	0.81	52.85	22	2.35	15.7	32.77	27.23	102.96
07/01/2016	1255	22	4.04	4.78	63.89	3.6	1.21	99.52	0.7	0.92	2.49	0.85	52.62	23.38	2.62	14.55	31.4	25.95	104.56
15/01/2016	1260	21.6	4.23	5.03	63.72	3.57	1.4	99.55	0.53	0.93	2.33	0.84	53.48	21.58	2.7	15.31	32.38	26.97	103.85
31/01/2016	1310	21.62	3.81	4.77	64.03	3.48	1.43	99.14	0.47	0.94	2.52	0.8	57.95	18.27	2.03	14.52	29.73	25.5	106.05
01/02/2016	1300	21.54	4.16	4.88	64.13	3.4	1.56	99.67	0.46	0.94	2.38	0.85	56.12	19.42	2.77	14.85	31.26	26.16	106.29
07/02/2016	1250	21.56	4.12	4.84	64.03	3.5	1.65	99.7	0.58	0.94	2.41	0.85	55.14	20.21	2.73	14.73	31.18	26.03	106.19
15/02/2016	1290	21.64	4.09	5.02	64.09	3.44	1.53	99.81	0.58	0.93	2.38	0.81	55.07	20.5	2.34	15.28	31.76	26.14	106.07
28/02/2016	1390	21.84	3.72	5.16	63.95	3.6	1.35	99.62	0.53	0.93	2.46	0.72	55.98	20.38	1.13	15.7	31.23	25.67	105.38
1/03/2016	1350	21.8	4.22	5.22	63.59	3.6	1.09	99.52	0.49	0.92	2.31	0.81	52.28	23.06	2.35	15.88	33.29	27.39	102.35
07/03/2016	1306	21.54	4.2	5.02	63.4	3.57	1.65	99.38	0.66	0.92	2.34	0.84	51.61	22.82	2.64	15.28	32.52	27.03	103.19
15/03/2016	1283	21.68	4.06	4.68	63.88	3.67	1.4	99.37	0.6	0.93	2.48	0.87	54.88	20.75	2.84	14.24	30.59	26.02	105
31/03/2016	1296	21.66	4.03	4.64	64	3.5	1.55	99.38	0.66	0.93	2.5	0.87	55.11	20.52	2.83	14.12	30.33	25.67	106.05
01/04/2016	1288	21.64	4.05	5.03	64.09	3.45	1.4	99.66	0.58	0.93	2.38	0.81	55.69	20.03	2.22	15.31	31.59	26.2	105.72
07/04/2016	1356	21.58	4.24	5.15	63.91	3.4	1.27	99.55	0.53	0.93	2.3	0.82	54.54	20.72	2.52	15.67	32.64	27.07	104.24
15/04/2016	1385	21.7	4.3	5.2	64.26	3.2	0.86	99.52	0.49	0.93	2.28	0.83	55.91	20.03	2.6	15.82	32.83	27.18	104.53
30/04/2016	1309	21.58	4.27	5.15	63.9	3.6	0.98	99.48	0.53	0.93	2.29	0.83	55.13	20.28	2.6	15.67	32.63	27.43	103.3
01/05/2016	1343	21.62	4.26	5.1	64.17	3.59	0.73	99.47	0.66	0.93	2.31	0.84	56.24	19.55	2.66	15.52	32.29	27.3	103.79
07/05/2016	1370	22.04	4.21	4.95	63.56	3.69	1.09	99.54	0.38	0.91	2.41	0.85	51.23	24.54	2.78	15.08	32.65	26.87	102.44
15/05/2016	1330	22.06	4.12	4.7	63.79	3.75	1.16	99.58	0.45	0.91	2.5	0.88	52.49	23.64	2.97	14.3	31.4	26.11	103.93
31/05/2016	1345	22.1	4.13	5.25	62.9	3.74	1.49	99.61	0.41	0.9	2.36	0.79	46.93	27.95	2.06	15.98	34.13	27.23	100.71
01/06/2016	1346	22.18	4.09	5.21	63.12	3.6	1.2	99.4	0.45	0.9	2.38	0.79	48.21	27.22	2.02	15.85	33.74	27.1	100.91
07/06/2016	1335	21.82	4	5.4	63.42	3.5	1.25	99.39	0.49	0.91	2.32	0.74	52.2	23.18	1.46	16.43	33.33	27.13	102.26
15/06/2016	1220	21.64	4.05	5.19	63.38	3.63	1.58	99.47	0.58	0.92	2.34	0.78	52.06	22.77	1.95	15.79	32.68	26.9	103.03
30/06/2016	1250	21.34	4.29	4.99	63.42	3.6	1.8	99.44	0.53	0.93	2.3	0.86	52.75	21.39	2.93	15.18	32.37	27.21	103.58
01/07/2016	1240	22.02	4.07	4.85	63.21	3.57	1.68	99.4	0.33	0.91	2.47	0.84	49.56	25.74	2.58	14.76	32.19	26.27	102.87
07/07/2016	1373	21.94	4.24	4.92	63.18	3.6	1.67	99.55	0.49	0.91	2.4	0.86	48.18	26.55	2.91	14.97	33.03	26.8	102.42
15/07/2016	1360	21.94	4.24	5.26	62.98	3.59	1.32	99.33	0.41	0.9	2.31	0.81	48.21	26.53	2.34	16.01	34.17	27.71	100.36
31/07/2016	1380	21.94	4.18	5.38	63.06	3.5	1.4	99.46	0.53	0.9	2.29	0.78	48.05	26.65	1.97	16.37	34.44	27.55	100.99
01/08/2016	1293	22.12	4.11	5.13	62.89	3.62	1.9	99.77	0.62	0.9	2.39	0.8	45.02	29.45	2.21	15.61	33.97	26.64	101.97
07/08/2016	1343	22.02	3.96	5	63.33	3.55	1.54	99.4	0.49	0.91	2.46	0.79	50.32	25.17	2.03	15.22	32.28	26.23	103.04
15/08/2016	1280	21.66	3.82	5.08	63.83	3.5	1.66	99.55	0.62	0.93	2.43	0.75	55.05	20.57	1.53	15.46	31.26	25.77	105.62
DATE	LW(g/L)	Chemical Analysis (%)								Models			Clinker Compounds (%)				Factories		
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Total	F.CaO	L.S.F	SM	AM	C_3S	C_2S	C_3A	C_4AF	CI	FLUX	BF
Max.	1390	22.18	4.30	5.40	64.26	3.75	1.90	99.81	0.70	0.94	2.52	0.88	57.95	29.45	2.97	16.43	34.44	27.71	106.29
Min.	1220	21.34	3.72	4.64	62.89	3.20	0.73	99.14	0.33	0.90	2.28	0.72	45.02	18.27	1.13	14.12	29.73	25.50	100.36
Ave.	1315	21.77	4.11	5.04	63.63	3.56	1.39	99.51	0.53	0.92	2.38	0.82	52.61	22.74	2.38	15.33	32.32	26.66	103.67

Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) DOI: 10.7176/CER
Vol.11, No.1, 2019

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DATE	LW(g/L)	Chemical Analysis (%)										Models			Clinker Compounds (%)				Factories		
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3		Total		F.Cao	L.S.F	SM	AM	C_3S	C_2S	C_3A	C_4AF	CI	FLUX	BF
31/08/2016	1293	22.12	3.8	4.96	64.21	3.04	1.28		99.41		0.49	0.92	2.53	0.77	55.02	21.91	1.68	15.09	31.07	25.15	106.46
01/09/2016	1260	22.18	3.96	5.2	63.68	3.04	1.28		99.34		0.66	0.91	2.42	0.76	50.3	25.65	1.7	15.82	33.05	26.19	103.78
07/09/2016	1275	22.02	3.66	5.22	64.03	3.11	1.29		99.33		0.7	0.92	2.48	0.7	54.73	21.84	0.87	15.88	31.56	25.41	105.67
15/09/2016	1286	22.14	3.8	5.28	64.09	3.04	1.06		99.41		0.7	0.92	2.44	0.72	53.69	22.97	1.14	16.07	32.36	25.8	105.07
30/09/2016	1346	22.22	3.84	5.38	64.17	3.06	0.68		99.35		0.66	0.91	2.41	0.71	54.25	22.78	1.07	16.37	32.76	26.21	104.22
01/10/2016	1328	22.16	3.88	5.16	64.26	3.08	0.82		99.36		0.52	0.92	2.45	0.75	55.29	21.82	1.55	15.7	31.94	25.89	105.08
07/10/2016	1330	22.08	3.94	5.15	64	3.1	1.01		99.28		0.45	0.92	2.43	0.77	54.19	22.42	1.73	15.67	32.18	26.14	104.39
15/10/2016	1323	22.04	3.8	5.15	64.2	3.12	1.00		99.31		0.62	0.92	2.46	0.74	55.59	21.26	1.36	15.67	31.58	25.72	105.41
31/10/2016	1300	22.08	3.78	5.44	64.16	2.88	0.97		99.31		0.62	0.92	2.39	0.70	54.92	21.87	0.81	16.55	32.62	26.01	105.03
01/11/2016	1307	22.1	4.01	5.15	64.01	3.12	0.91		99.3		0.66	0.91	2.41	0.78	53.04	23.35	1.91	15.67	32.55	26.35	104.06
07/11/2016	1283	21.78	4	5.1	64.35	2.95	1.15		99.33		0.62	0.93	2.39	0.78	56.47	19.84	1.97	15.52	31.66	26.02	106.2
15/11/2016	1300	21.86	4.02	5.2	64.62	3.06	0.63		99.39		0.41	0.93	2.37	0.77	59.02	18.15	1.85	15.82	31.71	26.34	105.8
30/11/2016	1300	21.88	4.04	4.92	64.71	3.18	0.63		99.36		0.62	0.93	2.44	0.82	58.65	18.48	2.38	14.97	30.89	25.97	106.32
01/12/2016	1295	21.92	3.98	4.84	64.53	3.1	1.09		99.46		0.53	0.93	2.49	0.82	57.18	19.7	2.36	14.73	30.71	25.45	107.05
07/12/2016	1285	21.9	3.99	4.86	64.4	3.00	1.12		99.27		0.53	0.93	2.47	0.82	56.63	20.07	2.35	14.79	30.87	25.61	106.53
15/12/2016	1295	21.82	4.00	4.88	64.39	3.1	1.15		99.34		0.7	0.93	2.46	0.82	56.32	20.07	2.34	14.85	30.97	25.71	106.52
31/12/2016	1227	21.9	3.9	4.9	64.64	3.11	0.91		99.36		0.62	0.93	2.49	0.8	58.38	18.74	2.04	14.91	30.5	25.44	107.07
DATE	LW(g/L)	Chemical Analysis (%)										Models							Factories		
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3		Total		F.Cao	L.S.F	SM	AM	C_3S	C_2S	C_3A	C_4AF	CI	FLUX	BF
Max.	1346	22.4	4.08	5.44	64.71	3.25	1.72		99.57		0.95	0.93	2.57	0.83	59.02	26.1	2.45	16.55	33.05	26.42	107.26
Min.	1112	21.78	3.66	4.8	63.68	2.88	0.63		99.24		0.41	0.91	2.37	0.70	50.3	18.15	0.81	14.61	30.50	25.15	103.68
Ave.	1258	22.05	3.91	5.08	64.18	3.09	1.05		99.36		0.62	0.92	2.45	0.77	54.63	22	1.78	15.45	31.78	25.82	105.37

ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) DOI: 10.7176/CER
Vol.11, No.1, 2019

Table 9: Iraqi Cement State Company Al- Kufa Cement Plant Supplied Cement

DATE	Part No.	Chemical Analysis (%)										Models			Cement Compounds (%)				Physical Test								
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	L.O.I	Total	Ins. Res	F.Cao	L.S.F	SM	AM	C_3S	C_2S	C_3A	C_4AF	Fineness Residue (%) 90µ	180µ	Blaine (cm^2/gm)	Water	Setting time I (min)	F(h)	Comp. Strength (N/mm^2) 3day	7day	Soundness Autoclave %
01/01/2016	±1	21.84	4.06	4.72	62.41	3.14	2.00	1.33	99.5	0.83	0.78	0.88	2.49	0.86	45.18	28.33	2.77	14.36	3.9	0.15	3150	25.5	150	03:40	20.2	28.2	0.15
07/01/2016	±2	21.58	4.16	4.8	62.01	3.04	2.51	1.64	99.54	0.72	0.7	0.88	2.41	0.87	44.19	28.54	2.9	14.61	4.25	0.2	3108	25.5	150	03:20	21.8	28.6	0.1
15/01/2016	±1	21.78	3.94	4.51	61.91	3.32	2.10	1.88	99.44	0.56	0.95	0.88	2.58	0.87	45.73	29.45	2.81	15.72	4.2	0.2	3150	25.5	130	03:20	22.2	29.2	0.11
31/01/2016	±3	21.72	4.04	4.9	61.83	3.11	2.39	1.43	99.42	0.65	0.95	0.87	2.43	0.82	41.81	30.75	2.42	14.91	3.62	0.12	3205	25.5	120	03:10	22.4	28.4	0.1
01/02/2016	±2	21.58	4.1	4.76	61.92	3.22	2.19	1.63	99.4	0.73	0.78	0.88	2.44	0.86	44.5	28.45	2.81	14.48	3.5	0.14	3172	25.5	120	03:10	22.2	29.4	0.07
07/02/2016	±3	21.82	4.04	4.62	62	3.14	2.14	1.5	99.26	0.73	0.74	0.88	2.52	0.87	45.71	29.59	2.89	14.06	4.92	0.18	3065	25.5	120	03:30	21.00	29.8	0.08
15/02/2016	±1	21.98	4.06	4.84	62.18	3.15	2.02	1.17	99.58	0.75	0.74	0.87	2.47	0.84	45.12	30.49	2.57	14.75	4.75	0.18	2943	25.5	140	03:30	23.4	30.2	0.09
28/02/2016	±2	21.78	4.2	4.84	62.1	3.1	2.4	1.06	99.48	0.65	0.74	0.87	2.41	0.87	42.29	30.54	2.94	14.75	4.45	0.18	3119	25.5	140	03:30	21.2	29	0.1
1/03/2016	±3	21.96	3.87	4.83	61.87	3.25	2.00	1.59	99.57	0.65	0.74	0.87	2.52	0.8	43.55	30.25	2.08	14.7	4.22	0.2	3108	25.5	150	03:30	21.6	29.2	0.08
07/03/2016	±1	21.7	3.87	5.00	61.65	3.1	2.33	1.8	99.47	0.56	0.97	0.87	2.45	0.77	42.26	30.33	1.8	15.22	4.62	0.18	3052	25.5	150	03:20	20.6	28.4	0.12
15/03/2016	±2	21.7	4.00	4.8	61.9	3.15	2.00	1.88	99.43	0.52	0.74	0.88	2.47	0.83	44.62	28.33	2.48	14.61	4.66	0.2	3086	25.5	120	03:10	18.6	27.6	0.07
31/03/2016	±3	21.66	4.22	4.84	61.93	2.93	2.27	1.36	99.41	0.7	0.78	0.88	2.39	0.87	42.58	29.98	2.99	14.73	4.28	0.17	3086	25.5	140	03:20	20.4	28.6	0.07
01/04/2016	±1	21.26	4.21	4.83	61.94	3.2	2.16	1.63	99.27	0.64	0.93	0.89	2.33	0.87	45.54	26.75	2.95	14.76	4.22	0.17	3097	25.5	110	03:00	22	29.2	0.1
07/04/2016	±2	21.2	4.16	4.82	62.09	3.2	2.23	1.53	99.23	0.64	0.74	0.9	2.36	0.86	47.44	24.99	2.87	14.67	3.48	0.16	3065	25.5	160	03:30	21.6	30	0.08
15/04/2016	±3	21.12	4.10	4.69	61.02	3.3	2.23	2.84	99.52	0.6	0.86	0.89	2.4	0.87	45.75	27.36	2.93	14.27	3.48	0.16	3172	25.5	150	03:40	22.2	31.4	0.12
30/04/2016	±1	21.28	3.98	4.78	62.18	3.3	2.1	1.63	99.27	0.7	1.03	0.9	2.43	0.83	47.65	25.06	2.46	14.55	4.82	0.21	2943	25.5	150	03:40	22.4	30.2	0.11
01/05/2016	±2	21.14	3.92	4.78	62.12	3.2	2.37	1.96	99.49	0.65	1.07	0.9	2.43	0.82	47.94	24.44	2.5	14.55	4.54	0.2	2976	25.5	150	03:20	21.2	29	0.08
07/05/2016	±3	21.52	3.88	4.68	62.44	3.08	2.29	1.64	99.53	0.52	1.03	0.9	2.51	0.83	47.16	26.12	2.36	14.24	4.4	0.17	3010	25.5	120	03:10	20.6	28.6	0.08
15/05/2016	±1	21.22	4.2	4.87	62.36	3.34	1.8	1.56	99.35	0.56	0.74	0.9	2.34	0.86	49.27	25.67	2.89	14.82	4.51	0.21	2943	25.5	140	03:30	18.2	28.2	0.08
31/05/2016	±2	21.56	4.00	5.08	62.18	3.09	1.88	1.51	99.3	0.6	0.82	0.89	2.37	0.79	46.44	26.76	2	15.46	4.2	0.18	3076	25.5	150	03:20	20.6	28.4	0.1
01/06/2016	±3	21.02	4.09	4.83	62.36	3.1	2.27	1.63	99.34	0.56	0.9	0.91	2.33	0.84	49.57	22.87	2.63	14.76	4.3	0.16	3097	25.5	150	03:40	23.8	30.4	0.09
07/06/2016	±1	21.6	4.08	5.04	62.36	2.98	2.06	1.4	99.52	0.7	0.82	0.89	2.37	0.81	45.88	27.32	2.28	15.34	5.24	0.25	2951	25.5	150	03:20	21.2	28.6	0.09
15/06/2016	±2	21.4	4.1	4.94	62.11	2.98	2.39	1.43	99.35	0.55	1.07	0.89	2.37	0.83	44.45	27.84	2.51	15.03	4.2	0.18	3054	25.5	140	03:30	22.2	29.4	0.08
30/06/2016	±3	21.9	3.88	4.88	61.99	2.95	1.9	2.08	99.58	0.59	0.99	0.88	2.5	0.8	45.45	30.03	2.03	14.85	4.6	0.17	3076	25.5	130	03:20	22.0	29	0.08
01/07/2016	±1	21.26	3.76	5.02	62.36	3.1	2.05	1.9	99.45	0.66	0.9	0.91	2.42	0.75	50.54	22.97	1.47	15.28	4.96	0.22	2951	25.5	140	03:30	20.2	29.2	0.13
07/07/2016	±2	21.58	4.18	4.96	62.18	2.9	2.5	1.32	99.42	0.65	0.95	0.88	2.36	0.84	45.53	29.03	2.68	15.09	4.36	0.18	3065	25.5	140	03:30	18.2	27.5	0.1
15/07/2016	±3	21.66	3.86	5	61.99	2.9	2.13	1.78	99.52	0.56	0.95	0.88	2.44	0.77	44.72	28.36	1.77	15.22	4.55	0.19	3076	25.5	160	03:40	22.6	29.1	0.14
31/07/2016	±1	21.54	4.14	4.88	62.08	3.1	2.29	1.48	99.51	0.6	0.9	0.89	2.37	0.85	45.56	26.81	2.71	14.85	4.11	0.2	3076	25.5	150	03:40	22.2	28.6	0.08
01/08/2016	±2	21.34	3.92	4.92	62.17	3.17	2.17	1.6	99.29	0.71	0.86	0.9	2.41	0.8	47.85	25.08	2.06	14.97	4.38	0.17	3065	25.5	140	03:30	22.6	28.8	0.12
07/08/2016	±3	21.32	4.03	4.97	62.34	2.95	2.1	1.62	99.33	0.65	0.95	0.9	2.37	0.81	47.72	25.13	2.27	15.12	5.03	0.24	3010	25.5	150	03:40	21.3	27.4	0.14
15/08/2016	±1	21.5	3.71	4.91	61.85	3.1	2.4	1.82	99.29	0.45	0.9	0.89	2.49	0.76	45.94	26.99	1.52	14.94	4.62	0.18	3076	25.5	140	03:30	22.8	29.1	0.13
		Chemical Analysis (%)										Models			Cement Compounds (%)				Physical Test								
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	L.O.I	Total	Ins. Res	F.Cao	L.S.F	SM	AM	C_3S	C_2S	C_3A	C_4AF	Fineness Residue (%) 90µ	180µ	Blaine (cm^2/gm)	Water	Setting time I (min)	F(h)	Comp. Strength (N/mm^2) 3day	7day	Soundness Autoclave %
virifed	Max.	21.98	4.22	5.08	62.44	3.34	2.4	2.84	99.58	0.83	1.07	0.91	2.58	0.87	50.54	30.54	2.99	15.46	5.24	0.25	3203	25.50	160	03:50	23.80	31.40	0.14
	Min.	21.02	3.71	4.51	61.02	2.9	1.8	1.06	99.23	0.45	0.7	0.87	2.34	0.75	42.26	22.87	1.47	13.72	3.48	0.12	2931	25.50	110	03:00	18.20	27.60	0.07
	Ave.	21.52	4.02	4.85	62.07	3.12	2.16	1.65	99.39	0.63	0.87	0.89	2.43	0.83	45.44	27.42	2.46	14.76	4.38	0.18	3063	25.50	136	03:26	21.36	29.13	0.10
IQS 5 1984	Max.					5	2.5/2.8	4		1.5		1.02					3.5 S.R.C							10			0.80
	Min.											0.66									2500/2300		45		15.00	23.00	

DATE	Part No.	Chemical Analysis (%)										Models			Cement Compounds (%)				Physical Test								
																			Fineness Residue (%)		Blaine (cm^2/gm)	Water	Setting time		Comp. Strength (N/mm^2)		Soundness
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	L.O.I	Total	Ins. Res	F. Cao	L.S.F	SM	AM	C_3S	C_2S	C_3A	C_4AF	90μ	180μ			I (min)	F(h)	3day	7day	Autoclave %
31/08/2016	z2	21.2	3.9	4.5	61.7	3.20	2.45	2.49	96.24	0.69	1.07	0.9	2.52	0.87	46.08	26.02	2.72	13.69	4.78	0.22	2988	25.5	140	03:30	22.2	30	0.06
01/09/2016	z3	21.42	3.78	5.12	62.08	3.15	1.99	1.76	99.3	0.72	0.99	0.89	2.41	0.74	47.51	25.57	1.35	15.58	4.52	0.18	3097	25.5	140	03:30	20.6	30.2	0.12
07/09/2016	z1	21.6	3.7	5.14	62.17	3.13	2.38	1.5	99.62	0.86	0.9	0.89	2.44	0.72	46.28	27.02	1.11	15.64	5.09	0.14	2943	25.5	130	03:30	22.4	29	0.11
15/09/2016	z2	21.74	4.14	5.04	61.9	2.92	2.32	1.39	99.45	0.6	1.11	0.87	2.37	0.82	40.62	31.69	2.44	15.34	4.52	0.18	3054	25.5	120	03:10	22.2	30.2	0.1
30/09/2016	z3	20.9	4.14	4.84	62	3.14	2.12	2.21	99.35	0.58	1.11	0.91	2.33	0.86	48.26	23.51	2.78	14.73	4.09	0.12	3097	25.5	160	03:50	20.8	28.6	0.08
01/10/2016	z1	21.52	4.08	4.88	61.84	3.1	1.8	2.23	99.45	0.65	0.99	0.89	2.4	0.84	44.65	28.02	2.56	14.85	4.84	0.21	3032	25.5	120	03:10	22.4	30	0.08
07/10/2016	z2	21.68	3.8	4.9	61.56	3	1.9	2.6	99.44	0.5	0.78	0.88	2.49	0.78	44.71	28.42	1.78	14.91	4.8	0.18	3076	25.5	140	03:30	22	29	0.08
15/10/2016	z3	21.58	3.82	5.16	61.83	2.9	2.11	2.1	99.5	0.6	0.89	0.88	2.4	0.74	45.02	27.91	1.39	15.7	4.44	0.18	3129	25.5	140	03:30	22.8	30	0.1
31/10/2016	z1	21.38	4.02	4.94	61.66	2.9	2.38	2.3	99.58	0.65	0.9	0.88	2.39	0.81	44.01	28.1	2.29	15.03	4.65	0.22	3010	25.5	150	03:40	21.8	30.2	0.09
01/11/2016	z2	21.54	3.98	4.88	61.71	3	2	2.37	99.48	0.68	0.99	0.88	2.43	0.82	44.07	28.51	2.29	14.85	4.86	0.2	3086	25.5	150	03:40	21	29.2	0.12
07/11/2016	z3	21.6	4.06	4.7	62.28	3.05	1.99	1.79	99.47	0.62	0.9	0.89	2.47	0.86	46.05	27.19	2.81	14.3	3.93	0.16	3119	25.5	140	03:40	22	28.2	0.09
15/11/2016	z1	21.58	4.05	4.97	62.32	3.08	1.85	1.71	99.56	0.72	1.03	0.89	2.39	0.81	45.91	27.23	2.32	15.12	3.42	0.14	3054	25.5	160	03:50	22.4	30.2	0.08
30/11/2016	z2	21.18	4.1	4.72	62.56	3.1	2.03	1.8	99.49	0.56	0.95	0.91	2.4	0.87	49.76	23.18	2.88	14.36	4.48	0.22	3010	25.5	130	03:20	23	30	0.1
01/12/2016	z3	21.54	3.78	4.86	62.13	3	2.21	2.07	99.59	0.65	0.74	0.89	2.49	0.78	47.57	25.87	1.79	14.79	4.87	0.23	2999	25.5	140	03:30	22.6	30	0.1
07/12/2016	z1	20.98	4.12	4.76	62.07	2.8	2.26	2.36	99.35	0.75	0.78	0.91	2.36	0.87	49.13	23.08	2.86	14.48	4.34	0.18	3076	25.5	140	03:30	22.2	30	0.07
15/12/2016	z2	21.38	3.99	4.57	61.84	3	2.3	2.31	99.39	0.59	1.03	0.89	2.5	0.87	45.17	27.22	2.84	13.91	4.31	0.18	3119	25.5	140	03:30	22.2	31.4	0.1
31/12/2016	z3	21.42	3.72	4.64	62.07	3.1	2.08	2.46	99.49	0.55	1.15	0.9	2.56	0.8	47.66	25.46	2.01	14.12	3.3	0.18	3097	25.5	120	03:10	22.4	29	0.08
		Chemical Analysis (%)										Models			Cement Compounds (%)				Physical Test								
																			Fineness Residue (%)		Blaine (cm^2/gm)	Water	Setting time		Comp. Strength (N/mm^2)		Soundness
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	L.O.I	Total	Ins. Res	F.Cao	L.S.F	SM	AM	C_3S	C_2S	C_3A	C_4AF	90μ	180μ			I (min)	F(h)	3day	7day	Autoclave %
verified	Max.	21.78	4.14	5.16	62.56	3.30	2.46	2.6	99.7	0.86	1.27	0.91	2.56	0.88	49.76	31.69	2.95	15.7	5.8	0.34	3285	25.50	160	03:50	23.4	31.4	0.14
	Min.	20.90	3.70	4.50	61.50	2.80	2.80	1.39	96.24	0.46	0.74	0.87	2.33	0.72	40.62	23.08	1.11	13.69	3.3	0.12	2719	25.50	120	03:10	19.0	28.2	0.06
	Ave.	21.43	3.95	4.83	61.94	3.04	3.04	2.12	99.37	0.64	0.98	0.89	2.44	0.82	45.75	26.91	2.29	14.69	4.47	0.19	3059	25.50	137	03:28	22.16	29.73	0.1
IQS 5	Max.					5	2.5/2.8	4		1.5		1.02					3.5 S.R.C							10			0.80
1984	Min.											0.66									2800/2300		45		15.0	23.00	

4.Conclusions

1- The basis for this property is well-burned clinker with consistent chemical composition and free lime. There are only two reasons for the clinker free lime to change in a situation with stable kiln operation: variation in the chemical composition of the kiln feed or variations in its fineness. Variations in fineness depend on possible changes in raw materials or in operation of the raw mill. Variation in chemical composition is related to raw mix control and the homogenization process.

2- Refractory chemistry is important because it helps determine if a given product is compatible with certain applications. Although the chemical composition alone is not a suitable criterion to define product usage.
3- The finer the raw mix will have to be ground to ensure satisfactory combination at acceptable kiln temperatures. When decarbonation is complete at about 1100 C, the feed temperature rises more rapidly. Lime reacts with silica to form belite (C2S) but the level of unreacted lime remains high until a temperature of ~1250 C is reached. This is the lower limit of the rmodynamic stability of alite (C3S). At ~1300 C partial melting occurs, the liquid phase (or flux) being provided by the alumina and iron oxide present. The level of unreacted lime reduces as C2S is converted to C3S. The process will be operated to ensure that the level of unreacted lime (free lime) is below 3%.
4- As the clinker passes under the flame it starts to cool and the molten C3A and C4AF, which constitute the flux phase, crystallize. This crystallization is normally complete by the time the clinker exits the rotary kiln and enters the cooler at a temperature of 1200 C. Slow cooling should be avoided as this can result in an increase in the belite content at the expense of alite and also the formation of relatively large C3A crystals which can result in unsatisfactory concrete rheology .
5- Higher amount of sandstone is hard to burn in kiln because it consumes large amount of coaml and it even increases free lime.
6- Percentage of C_3S content in clinker in increased. Alite hardens the cement faster and contributes to early strength formation. It resistant to sulfur attack hence high strength of C_3S will increase the strength at all ages.
7- Lime saturations factor (LSF), Silica Modulus (SM) and Alumina Modulus (AM) and variations in clinker quality on the limit. It can be decreased by carrying out various steps at different level which reduces the deviations of blending efficiency, raw mill feed, kiln feed and clinker compositions and its minerals.
8- LSF should be in the range of 92%±1, but minimum value obtained is 89% . To determine the silica and the SM minimum value obtained is 2.3 and it goes to a maximum value of 2.65. The minimum AM value obtained is 0.7 and it goes to a maximum value of 0.9. The importance of the calculation is preparation a kiln feed mixture with a suitable content of calcium carbonate (61-65%) to avoid hard burning process at high content of calcium carbonate content, as well as to avoid friction resulting from the silica on the formed coat on the internal kiln wall when calcium carbonate content is low.
9- When the LSF is above 0.95 there is an excess of lime, which cannot be combined no matter how long the clinker is fired and this remains as free lime in the clinker. As a low level of uncombined lime must be achieved the influence of LSF on the content of C3S and C2S.
10- The higher silica modulus (SM) the less molten liquid or flux is formed. This makes clinker combination more difficult unless the LSF is reduced to compensate. The flux phase facilitates the coalescence of the clinker into nodules and also the formation of a protective coating on the refractory kiln lining.
11- High Alumina Modulus (AM) cements will have a high C3A content, and this can be disadvantageous in certain cement applications, where it is desired to minimize the concrete temperature rise.
12- The SO3 have to be closely controlled because they are volatilized in the kiln and can cause severe operational problems associated with their condensation and the formation of build-ups in the kiln.

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