# Feasibility of efficient RS Portland cement from an optimization combination of raw materials

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**Abstract**: The sulfate resisting (SR) Portland cement is a hydraulic binder designed for works in rich sulfate environments such as swamps, seawater, lakes and industrial plant discharges. These special cements have a very particular mineralogical composition: $C_3A \leq 3\%$ and $(2C_3A+C_4AF) \leq 20\%$, which makes the cementitious matrix resistant to the aggressiveness of sulfate ions. The company "La Société les Ciments de Bizerte" (SCB), to face against the competition in national and international markets, finds in the production of SR Portland cement a solution in order to diversify its range of production, especially that its selling price is higher than for ordinary Portland cements. In this context, a study aims to optimize a raw meal that obeys the normative requirements of a SR Portland cement from only the raw materials (ordinary limestone, marl, iron ore...) specific to the SCB. This work is done essentially by means a program of the calculation of raw meal and on the analysis of the chemical composition of the selected raw materials by X-ray fluorescence (XRF).

**Key words**: Sulfate resisting Portland cement, $C_3A$, $C_4AF$, raw materials, raw meal, calculation program, XRF.

## INTRODUCTION

Portland cement is the most common example of a hydraulic cement. Its manufacturing process occurs in three principal steps: Firstly, the raw meal preparation which is an admixture of marl, limestone and other additives (iron ore, sand, Bauxite..)[1, 2]. Then, the raw meal is fed into a rotary kiln tube where burned at about 1450°C. This burning process results the Portland clinker formation which immediately air cooled by removal from the furnace[3]. Finally, the production of Portland cement is made by milling the clinker with a small amount of gypsum (3 to 5%) [4].

The Portland clinker can be described as a four component system consisting of the four major oxides: CaO, $SiO_2$, $Al_2O_3$ and $Fe_2O_3$. When the clinker cools, an assemblage is formed consisting of four main mineralogical phases: Alite ($C_3S$), belite ($C_2S$), Aluminate ($C_3A$) and ferrite ($C_4AF$) [1, 2].

In the last few years, the Tunisian market of hydraulic binders showed a very high demand, even exceeded by far the installed capacities. This encouraged the private investors and major multinational cement companies known worldwide to come to settle in Tunisia. In this context, a new cement plant in Sidi Bouzid region in the form of a public limited company under name Power King international (Middle East and Africa), was already installed. Therefore, the competition between the different cement plants in Tunisia (eight cement industries) will be very strong.

The company SCB, to face against this competition, only finds the diversification of its production range is a solution in order to maintain their position as leader in national and even international markets. The sulfate resisting (SR) Portland cement[5]is considered as a binder that increase the competitive capacity of the markets. However, these cement type manufacturing is delicate owing to a special raw materials. In fact,

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**Table I**: Raw materials extracted from BC factory quarry.

| Raw materials | Availability |
|---|---|
| **Ordinary limestone** | These raw materials are exploited in the manufacturing of Portland cement within SCB factory. |
| **Black and gray marls** | |
| **Pink limestone** | These resources are located in abandoned deposits in SCB quarry. The pink limestone is characterized by a pinkish coloration. |
| **Flint** | The flint is a hard sedimentary rock; it is rich in silica oxide. These materials are not used in cement production within SCB factory. |

the sulfate resisting Portland cement is a product destinated to works in a high sulfate concentration environments which characterized by a very specific mineralogical composition ($C_3A \leq 3\%$ and $2C_3A+C_4AF \leq 20\%$). This composition allows the concrete to confer against the external sulfate attack[1, 2].

The aim of this present paper is to optimize different combinations of RS raw meals from SCB raw materials in order to produce a SR Portland. This optimization was ensured by means a calculation program. This tool used the burning modulus (LSF, SIM and ALM) [1, 2]variation to estimate a sulfate resisting raw meal (SR Portland clinker/cement).

## EXPERIMENTAL

### 1.The choice of samples

The choice of samples is based on the availability and the quantity of raw materials (RM) in SCBquarry. In this study, ordinary limestone, pink limestone, gray and black marls and flint rock (see **table I**).

In addition to these raw material sironore, imported from Tamra region in north Tunisia, was integrated us a corrective element during the raw mill preparation in SBC industry.

### 2. Sample preparation

The samples of limestones, marls, flint and iron oxide are firstly placed in metallic recipient which dried on a heating plate at about 100°C during 24 hours to eliminate the humidity water in order to facilitate the grinding. Then, each sample was crushed by using a jaw crusher, this step consisted to reduce the particle size (~ 0.5-1 cm). After that, by means a laboratory disc mill, the material ground by impact and friction and at the same time homogenized to obtain finally a powder ready to X -ray fluorescence analysis. This powder usually gives a zero refusal on a sierve of 6 microns.

### 3. Techniques

X-ray fluorescence (XRF) was applied to quantify the elemental chemical composition of the selected raw materials. The XRF system consists of an X-ray tube which is produced the primary beam (production system) with a principals collimators, crystals, secondary collimators and detectors. X-rays produced excite the sample

**Table II:** Adopted designations used in the calculation program to estimate raw meal composition

| Chemical Compositions \ Raw materials(RM) | RM1 | RM2 | RM3 | RM4 | SR Raw Meal | SR Clinker |
|---|---|---|---|---|---|---|
| **% $SiO_2$** | $S_{RM1}$ | $S_{RM2}$ | $S_{RM3}$ | $S_{RM4}$ | S | $S_{CK}$ |
| **%$Al_2O_3$** | $A_{RM1}$ | $A_{RM2}$ | $A_{RM3}$ | $A_{RM4}$ | A | $A_{CK}$ |
| **%$Fe_2O_3$** | $F_{RM1}$ | $F_{RM2}$ | $F_{RM3}$ | $F_{RM4}$ | F | $F_{CK}$ |
| **% CaO** | $C_{RM1}$ | $C_{RM2}$ | $C_{RM3}$ | $C_{RM4}$ | C | $C_{CK}$ |
| **% MgO** | $M_{RM1}$ | $M_{RM2}$ | $M_{RM3}$ | $M_{RM4}$ | M | $M_{CK}$ |

**Table III:** Elemental chemical compositions of ordinary limestone, gray marl, black marl and iron ore.

| | % $SiO_2$ | %$Al_2O_3$ | %$Fe_2O_3$ | %CaO | %MgO |
|---|---|---|---|---|---|
| **Ordinary limestone** | 9.73 | 1.63 | 0.61 | 47.23 | 0.44 |
| **Gray marl** | 28.46 | 9.20 | 4.35 | 23.79 | 2.57 |
| **Black marl** | 34.13 | 8.86 | 5.01 | 18.79 | 4.65 |
| **Iron ore** | 10.95 | 5.50 | 66.25 | 1.41 | 0.00 |

atoms; consequently, they emit radiation when they are returning to the ground state. All XRF measurements were performed with a commercial instrument (ARL 9900 of THERMOFISHER), using monochromatic radiation $K_{\alpha 1}$of cobalt ($\lambda$=1.7890 Å) [1,2]. In this work, the milled samples are pressed with a laboratory hydraulic press of 10 tons into briquettes for XRF analysis.

## 4. Calculation tool

This section described the calculation tool used to optimize a chemical composition of raw meal of a sulfate resisting Portland cement. This calculation is assured by means a program which developed by us. This program is based on XRF analysis of studied samples (limestone, marl,..) and on the burning modulus (LSF, SIM and ALM). These modulus were used in all cement factories in the world to design the raw meal of Portland cement.

$$LSF = \frac{100 \times \%CaO}{2,8 \times \%SiO2 + 1,18 \times \%Al2O3 + 0,65 \times \%Fe2O3}$$

(I), Lime saturation factor 96≤LSF≤100

**TableIV:** Different SR clinker combinations by using materials used in the production of ordinary Portland cements in SCB plant.

| Combinations | LSF | SIM | %X1= Integration level of ordinary limestone | %X2= Integration level of Marl mix (50% Black marl +50% gray marl) | %X3= Integration level of iron ore | %$C_3A$ | 2×%$C_3A$+%$C_4AF$ | ALM |
|---|---|---|---|---|---|---|---|---|
| **SR $CK_1$** | 100 | 2.5 | 81.90 | 16.90 | 1.71 | 5.53 | 22.17 | 1.21 |
| **SR $CK_2$** | 99 | 2.5 | 81.47 | 16.85 | 1.69 | 5.64 | 22.41 | 1.22 |
| **SR $CK_3$** | 98 | 2.5 | 81.03 | 17.31 | 1.67 | 5.75 | 22.65 | 1.23 |
| **SR $CK_4$** | 97 | 2.5 | 80.58 | 17.77 | 1.65 | 5.87 | 22.90 | 1.24 |
| **SR $CK_5$** | 96 | 2.5 | 80.12 | 18.25 | 1.63 | 5.98 | 23.14 | 1.25 |
| **SR $CK_6$** | 100 | 2.1 | 81.88 | 14.92 | 3.20 | 2.94 | 21.58 | 0.86 |
| **SR $CK_7$** | 100 | 2.2 | 81.89 | 15.33 | 2.78 | 3.66 | 21.46 | 0.94 |
| **SR $CK_8$** | 100 | 2.3 | 81.89 | 15.71 | 2.40 | 4.33 | 21.72 | 1.02 |
| **SR $CK_9$** | 100 | 2.4 | 81.90 | 16.06 | 2.04 | 4.95 | 21.95 | 1.11 |
| **SR $CK_{10}$** | 100 | 2 | 81.88 | 14.47 | 3.65 | 2.16 | 20.89 | 0.79 |
| **SR $CK_{11}$** | 99 | 2 | 81.49 | 14.97 | 3.64 | 2.25 | 21.11 | 0.79 |
| **SR $CK_{12}$** | 98 | 2 | 81.07 | 15.36 | 3.36 | 2.34 | 21.34 | 0.80 |
| **SR $CK_{13}$** | 97 | 2 | 80.57 | 15.80 | 3.63 | 2.43 | 21.57 | 0.81 |
| **SR $CK_{14}$** | 96 | 2 | 80.12 | 16.26 | 3.62 | 2.52 | 21.81 | 0.81 |

**Table V:** Different SR clinker combinations after replacement the marl mix by black marl.

| Combinations | LSF | SIM | %X1= Integration level of ordinary limestone | %X2= Integration level of black marl | %X3= Integration level of iron ore | $\%C_3A$ | $2\times\%C_3A+\%C_4AF$ | ALM |
|---|---|---|---|---|---|---|---|---|
| SR $CK_{15}$ | 100 | 2 | 83.25 | 12.85 | 3.89 | 1.27 | 19.78 | 0.72 |
| SR $CK_{16}$ | 99 | 2 | 82.87 | 13.24 | 3.90 | 1.34 | 19.97 | 0.73 |
| SR $CK_{17}$ | 98 | 2 | 82.47 | 13.63 | 3.90 | 1.40 | 20.17 | 0.73 |
| SR $CK_{18}$ | 97 | 2 | 82.07 | 14.03 | 3.90 | 1.46 | 20.37 | 0.73 |
| SR $CK_{19}$ | 96 | 2 | 81.66 | 14.43 | 3.91 | 1.56 | 20.57 | 0.74 |

$$SIM = \frac{\%SiO2}{\%Al2O3+\%Fe2O3}$$

(II), Silicaratio2≤SIM ≤3

ALM= $\frac{\%Al2O3}{\%Fe2O3}$ (III), Alumina modulus 0.8≤ALM ≤1.2

The problematic is to know how much we will mix from the different raw materials to obtain a SR raw meal, for achieving this work, we used in this procedure:

Determination of chemical analysis (% CaO, % $SiO_2$, $\%Al_2O_3$, % $Fe_2O_3$,..) of raw materials (limestones, marls, iron oxide, ...), this step is assured by the XRF analyses.

**Table II** presents the different designations used to understand this calculation. In this work, we used four raw materials at most (RM1, RM4), where RM1 is can be an ordinary limestone, gray marl.

For example, $S_{RM1}$ is the silica content in RM1which determined from XRF analysis.

S is the silica amount in optimized sulfate resisting raw meal; A is the alumina amount in optimized sulfate resisting raw meal…

S, A, F, C and M will be calculated thanks to this calculation raw meal program.

**Table VI:** Elemental chemical compositions of flint and pink limestone.

| | % $SiO_2$ | $\%Al_2O_3$ | $\%Fe_2O_3$ | %CaO | %MgO |
|---|---|---|---|---|---|
| **Pink limestone** | 15.17 | 1.89 | 0.73 | 44.57 | 0.64 |
| **Flint** | 72.45 | 0.78 | 0.91 | 15.37 | 2.13 |

The determination of different proportions (X1, X2...) from different selected raw materials was assured by equations. These equations were determined by means of burning modulus (LSF, SIM and ALM) and considering that X1+X2+… =100. The LSF, SIM and ALM ratio were considered as variable parameters.

$S = X1S_{RM1} + X2S_{RM2} + \ldots$ (1)
$C = X1\,C_{RM1} + X2C_{RM2} + \ldots$ (2)
$A = X1A_{RM1} + X2A_{RM2} + \ldots$ (3)
$F = X1F_{RM1} + X2F_{RM2} + \ldots$ (4)
$M = X1M_{RM1} + X2M_{RM2} + \ldots$ (5)

After that, these formulas were integrated on (me), (II) and (III) to obtain finally these equations:

**• Integration three raw materials (RM1, RM2 and RM3):**

The parameters variables are LSF and SIM.

This calculation is adopted in the raw preparation in Bizerte cement factory.

X1+X2+X3=100 (I-1)

$a_1 \times X1 + a_2 \times X2 + a_3 \times X3 = 0$ (I-2)

$a_4 \times X1 + a_5 \times X2 + a_6 \times X3 = 0$ (I-3)

Where $a_1 = 100 \times C_{RM1} - LSF \times (2{,}8 \times S_{RM1} + 1{,}18 \times A_{RM1} + 0{,}65 \times F_{RM1})$,

$a_2 = 100 \times C_{RM2} - LSF \times (2{,}8 \times S_{RM2} + 1{,}18 \times A_{RM2} + 0{,}65 \times F_{RM2})$,

$a_3 = 100 \times C_{RM3} - LSF \times (2{,}8 \times S_{RM3} + 1{,}18 \times A_{RM3} + 0{,}65 \times F_{RM3})$,

$a_4 = S_{RM1} - SIM \times (A_{RM1} + F_{RM1})$; $a_5 = S_{RM2} - SIM \times (A_{RM2} + F_{RM2})$;

and $a_6 = S_{RM3} - SIM \times (A_{RM3} + F_{RM3})$.

**• Integration four raw materials (RM1, RM2, RM3 and RM4)**

The parameters variation are LSF, SIM and ALM.

**Table VII:** Calculated combinations of SR clinker after flint integration.

| Combinations | LSF | SIM | ALM | %X1= Integration level of ordinary limestone | %X2= Integration level of marl mix | %X3= Integration level of iron ore | %X4= Integration level of flint | $\%C_3A$ | $2\times\%C_3A+\%C_4AF$ |
|---|---|---|---|---|---|---|---|---|---|
| **SR $CK_{20}$** | 100 | 2 | 0.91 | 80.71 | 17.75 | 2.73 | -1.19 | 3.59 | 22.37 |
| **SR $CK_{21}$** | 100 | 2.3 | 0.91 | 82.93 | 13.87 | 2.42 | 0.78 | 3.24 | 20.15 |
| **SR $CK_{22}$** | 100 | 2.5 | 0.91 | 84.17 | 11.69 | 2.25 | 1.89 | 3.04 | 18.90 |
| **SR $CK_{23}$** | 100 | 3 | 0.91 | 86.66 | 7.32 | 1.90 | 4.12 | 2.63 | 16.36 |
| **SR $CK_{24}$** | 99 | 3 | 0.91 | 86.32 | 7.55 | 1.92 | 4.12 | 2.65 | 16.48 |
| **SR $CK_{25}$** | 98 | 3 | 0.91 | 85.97 | 7.79 | 1.93 | 4.31 | 2.66 | 16.59 |
| **SR $CK_{26}$** | 97 | 3 | 0.91 | 85.61 | 8.04 | 1.95 | 4.40 | 2.68 | 16.70 |
| **SR $CK_{27}$** | 96 | 3 | 0.91 | 85.25 | 8.28 | 1.97 | 4.50 | 2.70 | 16.82 |

$b_1 \times X1 + b_2 \times X2 + b_3 \times X3 + b_4 \times X4 = 0$ (I-4)
$b_5 \times X1 + b_6 \times X2 + b_7 \times X3 + b_8 \times X4 = 0$ (I-5)
$c_1 \times X1 + c_2 \times X2 + c_3 \times X3 + c_4 \times X4 = 0$ (I-6)
$X1+X2+X3+X4=100$ (I-7)
Where :$b_1=100 \times C_{RM1}-LSF \times (2,8S_{RM1}+1,18 \times A_{RM1}+0,65 \times F_{RM1})$;
$b_2=100 \times C_{RM2}-LSF \times (2,8 \times S_{RM2}+1,18 \times A_{RM2}+0,65 \times F_{RM2})$;
$b_3=100 \times C_{RM3}-LSF \times (2,8 \times S_{RM3}+1,18 \times A_{RM3}+0,65 \times F_{RM3})$ ;
$b_4=100 \times C_{RM4}-LSF \times (2,8 \times S_{RM4}+1,18 \times A_{RM4}+0,65 \times F_{RM4})$;
$b_5=S_{RM1}-SIM \times (A_{RM1}+F_{RM1})$;
$b_6= S_{RM2}-SIM \times (A_{RM2}+F_{RM2})$;
$b_7=S_{RM3}-SIM \times (A_{RM3}+F_{RM3})$;
$b_8=S_{RM4}-SIM \times (A_{RM4}+F_{RM4})$;
$c_1= A_{RM1}-(ALM \times F_{RM1})$ ;
$c_2= A_{RM2}-(ALM \times F_{RM2})$;
$c_3= A_{RM3}-(ALM \times F_{RM3})$;
$c_4= A_{RM4}-(ALM \times F_{RM4})$.

The resolution of these equations (I-1, I-2,.., I-7) which already established was done by using Cramer method.

The knowledge of the proportions of different selected raw materials, allows us to calculate the chemical compositions of estimated SR raw meal from (1), (2), (3), (4) and (5).

From the chemical compositions of estimated SR raw meal , it is necessary to estimate the chemical composition of the clinker ($S_{CK}$, $A_{CK}$, $F_{CK}$ , $C_{CK}$ and $M_{CK}$) corresponding to the optimized SR raw meal by applying the following formulas:

$S_{CK}= S \times f$
$A_{CK}= A \times f$
$F_{CK}= F \times f$
$C_{CK}= C \times f$
$M_{CK}= M \times f$

Where f = Transformation factor between SR raw meal and SR clinker

$$f = 100 / (100 – LOI),\ LOI= M(CO_2) \times \left[\frac{\%C}{M(CaO)} + \frac{\%M}{M(MgO)}\right]$$

This step is very important to calculate finally the mineralogical composition ($C3A\leq3\%$ and $2*C_3A + C_4AF\leq2\%$) of SR clinker by using the Bogue calculation [11, 12] (IV and V).

$C_3A = 2.650 \times \%Al_2O_3-1.692 \times \%Fe_2O_3$ (IV)
$C_4AF = 3.043 \times \%Fe_2O_3$ (V)

Table III presents the principle oxides ( %CaO, $\%SiO_2$, $\%Al_2O_3$, $\%Fe_2O_3$ and %MgO) amounts of these selected raw materials determined by XRF analysis.

## RESULTS AND DISCUSSIONS

### 1. Study of the suitability of raw materials used in the production of ordinary Portland cements in SCB plant

In this part, the optimization of SR clinker was started by means the raw materials used in the production of ordinary Portland cement within Bizerte cement plant:

Ordinary limestone, marl mix = 50% black marl + 50% gray marl and iron ore.

**Table VIII:** Calculated SR clinker combinations after Pink limestone integration.

| Combinations | LSF | SIM | ALM | %X1= Integration level of ordinary limestone | %X2= Integration level of marl mix | %X3= Integration level of iron ore | %X4= Integration level of pink limestone | %$C_3A$ | 2×%$C_3A$+%$C_4AF$ |
|---|---|---|---|---|---|---|---|---|---|
| **SR $CK_{28}$** | 100 | 2.5 | 0.91 | 60.05 | 10.54 | 2.40 | 27.01 | 3.05 | 18.97 |
| **SR $CK_{29}$** | 100 | 2.6 | 0.91 | 54.20 | 6.24 | 2.36 | 34.19 | 2.96 | 18.42 |
| **SR $CK_{30}$** | 100 | 3 | 0.91 | 33.98 | 4.77 | 2.23 | 59.02 | 2.65 | 16.50 |
| **SR $CK_{31}$** | 99 | 3 | 0.91 | 35.45 | 4.95 | 2.26 | 60.34 | 2.67 | 16.61 |
| **SR $CK_{32}$** | 98 | 3 | 0.91 | 30.90 | 5.13 | 2.28 | 61.69 | 2.69 | 16.73 |
| **SR $CK_{33}$** | 97 | 3 | 0.91 | 29.32 | 5.32 | 2.30 | 63.06 | 2.71 | 16.85 |
| **SR $CK_{34}$** | 96 | 3 | 0.91 | 27.72 | 5.51 | 2.33 | 64.45 | 2.73 | 16.97 |

Table III presents the principle oxides (%CaO, % $SiO_2$, %$Al_2O_3$, %$Fe_2O_3$ and %MgO) amounts of these selected raw materials determined by XRF analysis.
These analysis (**Table III**) are the subject to estimate a SR raw meal subsequently SR Portland clinker, this step is ensured thanks to the calculation tool ( the case of integration three raw materials) as explained in the previous section. So, from the Burning Modulus (LSF and SIM) variation, the $C_3A$ and $C_4AF$ amounts were checked, in order to judge the estimated raw meal (See **Table IV**).
**Table IV** presents the different SR clinkers (SR $CK_1$, SR $CK_2$...SR $CK_{14}$) combinations, only the SR $CK_{10}$combinasion gives an approximate sulfate resisting clinker since $C_3A<3\%$, but the second condition (2C3A + C4AF <20%) seems not respected, this optimized clinker is contain the high integrate level of iron ore, that's why the aluminate phase ($C_3A$) decreased and consequently the $2C_3A$ $+C_4AF$ increased. The rise of iron oxide in raw meal affected the kiln process: it caused the increase of liquid phase density during burning process which led to the blank instability of the coating of the kiln cement.
From this part, we concluded that LSF=100 and SIM =2 were considered the suitable Burning modulus to product the SR Portland cement if the ordinary limestone, marl= 50%Black marl+50% gray marland iron ore were used. To ameliorate more this result, the marl mix was replaced by the black marl without affecting the other raw materials: this replacement gives a SR clinker combination (SR $CK_{16}$) which reply to the SR Portland cement standard as indicated in table V. So, the use of siliceous marl, it is a solution to prepare a raw meal meeting to sulfate resisting Portland cement requirements. But, the manufacturing of this combination at industrial scale posed a problem since it has a lower Alumina modulus (0.73). This value makes the burning process so hard [13].

**2. Integration of fourth raw material in addition to ordinary limestone, marl mix and iron ore**

In this part, the optimization calculation is based on the variation of all burning modulus (LSF, SIM and ALM) and integration of fourth raw material (flint and pink limestone) that extracted from the specific quarries of BC industry. These materials were characterized by a high amount of $SiO_2$ as presented in **table VI.**
From SR Portland cement standard, on the assumption that $C_3A$ = 3% and 2 × $C_3A$ + $C_4AF$ = 20% in order to estimate the maximum value of ALM (=0.91) by using Bogue calculation (IV and V equations). So, in this part the aluminate modulus was fixed on 0.91 since, on the one hand, this value gives sulfate resisting cement and it ensures the burning process without being interrupted cement, on the other hand.

**2.1. Integration of flint in raw meal preparation**

From **table VII**, the integration of flint material in raw meal enhances more the mineralogy phase ($C_3A$ ≤3% and 2×%$C_3A$+%$C_4AF$) prediction of

**Table IX:** Calculated SR clinkers combinations after integration of flint and pink limestone.

| Combinations | LSF | SIM | ALM | %X1= Integration level of ordinary limestone | %X2= Integration level of marl mix | %X3= Integration level of iron ore | %X4= Integration level of (95%pink limestone + 5% flint) | $\%C_3A$ | $2\times\%C_3A+\%C_4AF$ |
|---|---|---|---|---|---|---|---|---|---|
| **SR $CK_{32}$** | 100 | 3 | 0.91 | 56.63 | 5.86 | 2.09 | 35.42 | 2.65 | 16.44 |
| **SR $CK_{33}$** | 99 | 3 | 0.91 | 55.61 | 6.07 | 2.11 | 36.21 | 2.66 | 16.55 |
| **SR $CK_{34}$** | 98 | 3 | 0.91 | 54.57 | 6.28 | 2.13 | 37.02 | 2.68 | 16.67 |
| **SR $CK_{35}$** | 97 | 3 | 0.91 | 53.52 | 6.49 | 2.15 | 37.84 | 2.70 | 16.79 |
| **SR $CK_{36}$** | 96 | 3 | 0.91 | 52.46 | 6.70 | 2.17 | 38.67 | 2.72 | 16.90 |

estimated SR clinkers. Therefore, the manufacturing of SR Portland cement is possible from the correction with flint, but under the condition of respecting the integration level of the latter. LSF=100, SIM = 3 and ALM=0.91 is considered the best combination, since $\%C_3A$= 2.63 and $\times\%C_3A+\%C_4AF$ =16.63.

## 2.2. Integration of pink limestone in raw meal preparation

In the same way, we introduced the pink limestone in the raw meal .This material was characterized by a silica amount at about of 15% and its hardness was equal to 3 according to mohs scale. This favorite its crushing, especially during the summer season, the humidity of this rock goes from 15% to 5 % in winter. Indeed, its introduction does not pose any problem at raw materials milling operation. These combinations are presented in **Table VIII**.

The results shown that the manufacturing of SR Portland cement with these rocks is possible and its integration rates varied at about 27 to 64%,. In this case, this manufacturing is possible because the selected modules have no undesirable effects on the proper functioning of cement plant.

## 2.3. Integration of a mixture of flint and pink limestone in raw meal preparation

It is possible to produce a SR raw meal from the flint introduction, but the use of this material is posed a problem at the operation of raw materials milling. Because the flint is a very hard rock , its hardness was estimated to 7 according to mohs scale. therefore the conditions of manufacturing of SR cement will be energetically very expensive.

The only way to exploit this flint deposit is to mix a low proportion of this material with a high percentage of pink limestone, since this latter is brittle material and its milling is very easy compared to flint. So in this part , the suggested combination is " 5% silex + 95% pink limestone".

From **table IX** , it is clear that the use of the mixture of "5% silex + 95% pink limestone" present a good solution to produce a sulfate resisting Portland cement , especially that the Burning modulus are strictly in the acceptable ranges: 96≤LSF≤100, SIM≤3 and ALM =0.91.

## CONCLUSION

In the present work, different cases were studied to estimate a raw meal conformed to sulfate resisting Portland cement standard. the raw materials (ordinary limestone, black marl, gray marl and iron ore) used in ordinary Portland cement production in SCB cement plant were not sufficient to prepare a Sulfate resisting raw meal. So, by means materials abandoned in SCB quarry (Pink limestone and flint ) were a solution to make a SR raw meal. The results gives that integration of a mixture of "5% of flint with 95 % of pink limestone is considered an adequate sulfate resisting clinker combination while keeping the same raw materials, burning parameters (LSF=100, SIM=3 and ALM=0.91), and manufacturing process.

this integration is well desired to allow the plant to care for its quarries, in order to integrate all fronts abandoned in the raw meal, it will overcome the environmental problems at the quarry, allow to earn this deposit a period of exploitation of up to 20 to 30 years, and will facilitate the exploitation of the marl deposits below these rocks, which are currently classified as wastes.

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