Determination of Optimum Quantity of Raw Gypsum Addition for Atbara Cement Clinker

by

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Abstract:

When the cement clinker is ground to result in product of particle sizes less than 45µm, the product will be called then cement. Mixing the cement product with water will result a paste of cement. This paste will start to harden immediately; the time at which cement became hard is called initial setting time. This time is usually very short for concreting operation, i.e. transportation and replacing the mixture. Therefore, some minerals are added to the clinker during its grinding to prolong the setting time. Raw gypsum is always candidated for this purpose, since it is cheaper and very soft, hence small quantity of energy for grinding is required. In addition to gypsum will react with the tricalcium aluminate mineral (C_3A) which is the compound mainly responsible for the early setting time of cement. The reaction of gypsum with (C_3A) will retard the setting time of cement (i.e. prolong the setting time) which is necessary for concreting operations to be completed perfectly, if the amount of gypsum is small the setting time will be short, however, addition large amount of gypsum to the clinker during its grinding will delay the harden of the cement paste and producing a large amount of heat during the reaction and solidification of concrete. Therefore the amount of gypsum should be controlled to achieve the proper setting time and decreasing the percentage of SO_3 in the concrete, and to avoid steel corrosion and concrete structure deformation. It was found from the experimental results which presented in this article that the most proper quantity of gypsum additive to Atbara clinker would be around 4% by weight to produced Ordinary Portland Cement.

Key words: *Setting time retarding, Gypsum additive to cement, Effect of gypsum on concrete properties.*

Introduction:

Portland cement is an extremely ground material yielded from grinding the clinkers. It has adhesive and cohesive properties, which provide a binding medium for the discrete ingredients. The clinker is manufactured by heating together in a definite proportion a mixture of naturally calcareous material, which may be in the form of chalk, limestone, shell, calcareous mud, marble, etc., and clay material which again may be in many forms, clay, shale, slate, etc. and a small amount of slag or silica and iron oxide to a partial fusion at high temperature.

The kilns are mounted with the longitudinal axis inclined in such a way that the raw materials are fed at the higher end at about 420 ^oC, the crystallization water of the raw materials is driven off, and then further along the kiln, at 875^oC, the calcareous materials decompose into calcium oxide and carbon dioxide Finally at about 1400^oC to 1450^oC, sintering takes place within this range of temperature producing the clinkers. The clinkers are cooled to 100 ^oC and ground to produce the cement. The composition of clinker is rather complicated but basically it consists of the following four main compounds:

Tricalcium Silicate ($3CaO.SiO_2$).

Dicalcium Silicate ($2CaO.SiO_2$).

Tricalcium Aluminates ($3CaO.Al_2O_3$).

Tetracalcium Alumino ferrite ($4CaO.Al_2O_3.Fe_2O_3$).

These compounds are usually given as symbols (C_3S), (C_2S), (C_3A) and (C_4AF), respectively. The first two silicates constitute about 70 to 80 % of the cement. They are controlling the most of the strength giving properties, while the Tricalcium aluminates react very fast with the addition of water to the cement which would lead to an immediate stiffening of the resulted paste. Tetra calcium aluminate ferrite (C_4AF) also hydrates rapidly after the addition of the water to cement but its individual contribution to the overall hardring of cement is insignificant. However, it is more stable than (C_3A), (1, 2, 3 and 4). The period of time during which the cement changes from paste to a hard mass after its mixing with water is called cement setting time (initial setting time), i.e. the cement loses its plasticity, This time is very short, hence for proper concreting, the initial setting time should be sufficiently long for finishing operation, i.e., transporting and placing the concrete. To retard the faster setting time of cement resulted from (C_3A) compound a percentage of raw gypsum (selenite) is added during the grinding of the clinker. Gypsum will react with the (C_3A), since it dissolves in water yielding sulphate ions (SO_3) in the solution which react with (C_3A) to form insoluble calcium sulphoaluminate which would deposit on the surface of the (C_3A), to form a protective colloidal membrane and thus retard its direct rapid hydration reaction(1,3,5,6 and 7). In this research work reported here ,clinker produced from Atbara cement factory and raw gypsum used by the same factory added to the clinker during the grinding process to yield the cement of Atbara were employed to carry out the experimental tests. The aim was to determine the optimum quantity of gypsum for the clinker of Atbara, which should retard the setting time to give practical period for concreting operations. Also to find out the percent of sulphur trioxide (SO_3) which the yielded cement will be contained due to these additions of gypsum. It was found from the gained results that a range of 3% to 5% addition of gypsum would result the initial optimum setting time (60 minutes), and sulphur trioxide contents, 1.47,1.87 and 2.2% SO_3 ,respectively. The factory of Atbara uses 5% gypsum addition for the same clinker to have 60 minutes setting time, however, the produced cement contains 2.2% SO_3, which is 1.2 times of that optimum percent of addition was determine in this research (4% gypsum addition).

Experimental Work:

1-Materials**:**

Clinker particles of size between 0.8 cm to 1.5 cm, having blakish gray colour and intermediate hardness produced at Atbara cement factory were used in conducting the experimental work.

Raw gypsum which being employed by the same factory to produce the commercial product of Atbara cement was also used in performing the tests

2- *Method of Testing:*

The laboratory facilities within Atbara factory for cement and mining department of Khartoum University were used to conduct this work.

Samples of clinker(5kg each) were taken and different additions of gypsum by varying the quantity of gypsum to the same weight of the clinker to produce different types of cement.

The ground materials produced were mixed with water (25% by weight) to produced the cement past for determining the setting time by the bearing needle.

The compressive strength of concrete is considered to be the most important property of concrete. Therefore, cement concrete cubes having water cement ratio 0.4 : 1 and sand cement ratio 3: 1 are prepared and tested in a compression testing machine. The compressive strength for this cubes was determined after 3 days curing. The results of the testing work are given below in Table 1 and illustrated graphically in Figs. 1 to 3.

Presentation and Discussion of the Results:

The results are given in Tables 1 and graphically plotted in Figs.1 to 3. Table1 and Fig.1 show the effect of the percentage of the gypsum additions on the setting time of cement it could be seen that varied quantities of gypsum gave different setting times. Inspection of Table1 and Fig.1 indicates that addition amount of gypsum less than 3% of the weight of clinker resulted in setting time less than that required for concreting operations, i.e. keeping the concrete workable during the entire placing period which should be sufficiently long so that the succeeding lifts can be placed without the development of cold joints or discontinuities in the structural unit. In regard to the setting time and sulphur content the results show that optimum quantity of gypsum for Atbara cement (O.P.C) ranges between 3% and 5% by weight of clinker, beyond this range, the setting of cement paste would be shortened to 6min or prolonged to reach 115min. Belittling the quantity of gypsum added (less than 3% wt) to the cement does not result into any adverse chemical effect on cement concrete, since in practice, the length of time for which a concrete mixture will remain plastic is usually more dependent on the amount of mixing water used and atmospheric temperature than on the setting time of cement(1 and 2). It can be seen that increasing the gypsum percent in cement would lead to increase the sulphur percent in the cement, i.e. portion of the added gypsum will increase the level of remained as gypsum in the concrete instead of reacting with the oxide components of the cement. This remained calcium sulphate would then react with calcium aluminate present in the hydrates forming an expansive ettringite, i.e. (calcium aluminate trisulphates) (1 and 5). An explanation could be given here to show the problems may be encountered from the addition of improper amount of raw gypsum to the clinker. The tricalciumaluminate (C_3A) is characteristically fast reacting with water leading to an immediate stiffening of cement paste and this process is called flash set. The role of the addition of gypsum is then to prevent such a fast reaction. (3, 8, 9 and 10). The reaction of the (C_3A) with gypsum could be expressed according to the amount of gypsum as follows:

At higher amount of gypsum.

$C_3A + 32H + 3CaSO_4 \longrightarrow C_3A.3CS\text{-}H_{32} \longrightarrow C_6AS_3H_{32}$ *(ettringite)*

However, at lower amount of gypsum;

$C_3A + 18H + CaSO_4 \longrightarrow C_3A.CSH_{18} \longrightarrow C_4ASH_{18}$ *(monosulphate hydrate)*

Table1. Shows the effect of the gypsum addition on the setting time, sulphur content and compressive strength of cement and concrete .

Percentage of gypsum addition	Sulphur content*(% SO_3)*	*Setting time-min.*	Compressive Strength (Mpa)
1	0.75	*4*	12
2	1.13	*5*	9
3	1.47	*60*	14
4	1.87	*60*	22
5	2.2	*60*	10
6	2.45	*90*	5
7	2.91	*115*	3

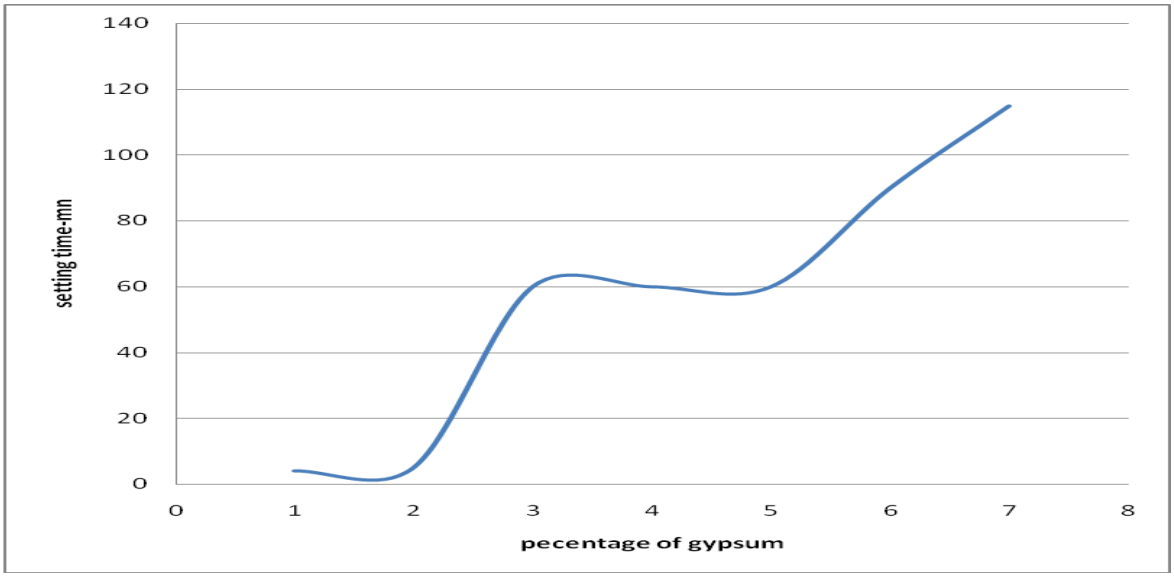

Fig.1 Shows Effect of Percentage of Gypsum Additions on Setting time of Atbara Cement.

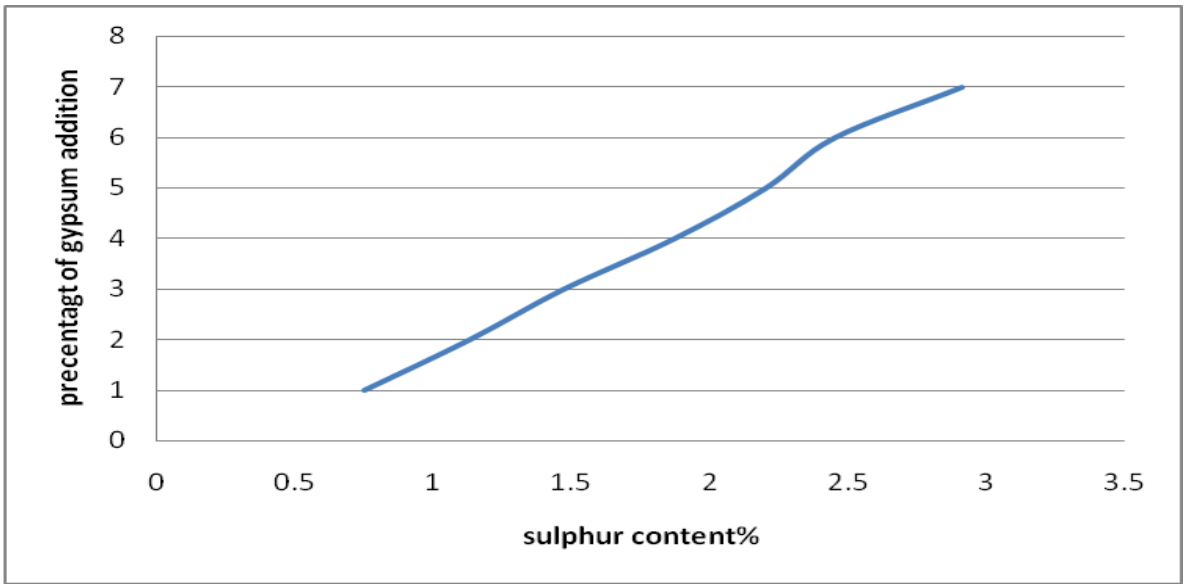

Fig.2 Shows Effect of Gypsum Addition on Content of Sulphur in Cement

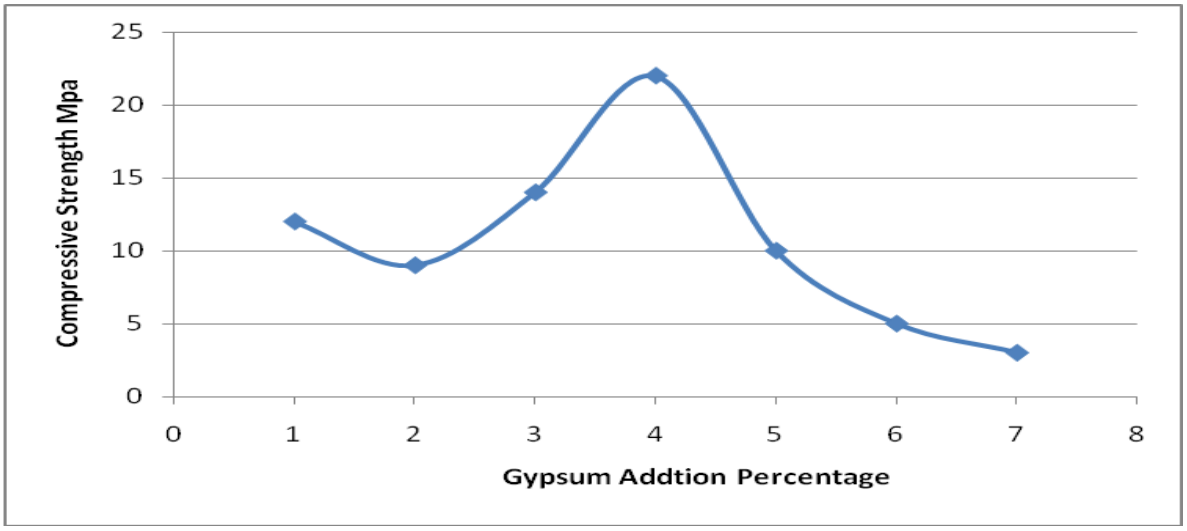

Fig.3. Effect of Gypsum Addition on Compressive Strength of Concrete

In the presence of gypsum, depending upon the concentration of aluminuate and sulphate ions in the solution phase, the precipitating crystalline product is either as it is shown in the above equations, either, calcium aluminate trisulphate hydrate ($C_6S_3H_{32}$) known as ettringite or calcium aluminate monosulphate hydrate($C_4A\ SH_{18}$). Gypsum ground with clinker would dissolve immediately in water and the sulphate ions will react with C_3A to form insoluble calcium sulphoaluminate which deposits on the surface of the C_3A to form a protective colloidal membrane and thus retards the direct hydration reaction, however,when all the sulphates are consumed, hydration can then accelerate. The amount of the sulphate must, therefore, be carefully controlled to leave little excess C_3A to hydrate directly.
Table 1 and Fig 3, however, demonstrate the results of compressive the strength of the cement in (Mpa) for the different quantity of gypsum mixed with the clinker of Atbara. These results show that after 3 days curing different values for the strength are given. The most quantity of gypsum could easily be seen it would be 4% of the clinker weight which gives 22 Mpa. This figure is greater than that recommended by various standards being cited in the literature (11 an 12)., The recommended figure shall not be less than 16 Mpa. Comparing this value with those in Table 1 indicates that additives less than 3% of gypsum or 5% and above would lead to decrease the strength of the produced mortar or concrete.

***Conclusions**:*
The conclusions could be withdrawn from the results of this research work are:

1) *Various additions of gypsum to the clinker of Atbara would give different setting time.*
2) *Additions less than 3% by the weight of clinker would give setting time for the concrete operation less than 6 minutes which would not be long enough for finishing concreting operation, i.e. Transporting and placing the concrete.*
3) *The range of raw gypsum addition (between 3% and 5%) would give initial setting time around 60 minutes.*
4) *Increasing the quantity of gypsums from 5to 7 % increases the setting time from 60 to 115minutes.*
5) *The results indicate that by increasing the amount of gypsum in the cement, the sulphur content in the cement will be increased from 1.47%SO_3 for 3% gypsum addition, to 2.91% SO_3 for7% addition.*
6) *From these results of setting times and sulphurthe optimum addition of gypsum for Atbara clinker would be in the range of 3% to 5%, since these percentages of addition gave setting times and sulphur contents the optimum addition of gypsum for Atbara clinker would 4 % since this quantity gave setting times sulphur content and compressive strength optimum and producing concrete of good quality.*

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