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Economisation of Energy in cement Manufacture

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Introduction

In view of the depletion of energy sources, all out efforts are being made by the process industries to develop energy conserving technologies Cement industry is showing awareness and also making efforts in tackling the problem to an appreciable extent. The process technology is being changed from wet to dry. Some of the old wet process plants are being replaced and remodelled to include the dry process. Larger new units based on dry process are being installed in the country. New developments on energy conserving devices like suspension preheaters, partial or complete precalcining systems and grate coolers etc. Which promise highest efficiency are being made and adopted.

There is still enough scope for cutting down the energy requirement in cement manufacture through some other processes. Various efforts made so far by other workers for economising the energy further in cement manufacture and research results on usefulness of mineralizers obtained by the authors have been discussed in this paper.

Wet and Dry process of Manufacture

The comparison of energy consumption as given in table - 1 for the wet and dry processes[1] clearly establish that the energy consumption is considerably reduced by adoption of the dry process in cement manufacture.

According to a report of Cement Association of India[2] there are 31 Cement industries in India having 51 factories in which 141 rotary kilns are under operation to produce cement clinker. Out of these 141 kilns, 96 kilns are based on wet process,9 on semi dry process and 36 on dry process. In order to obtain an energy saving it shall be worthwhile to change or convert maximum number of the wet process kilns into the dry ones at the earliest.

The consumption of energy in different steps (processes) during cement manufacture may be summarised as shows in table - 2. [3]

It is therefore evident that 80 per cent of the energy is consumed in the manufacture of cement clinker. It is thus this field where most attention is required to be concentrated to conserve energy. Cement clinkerization is carried out in a rotary or any other kiln at a temperature around 1400°C. The theoretical heat requirement in a dry process is about 50% of the total heat consumed in the manufacture of cement clinker (table-1). If the temperature of clinkerization is lowered that will also offer an opportunity to economise the energy consumption.

Raw Meal Design and Burnability:

The chemical, physical and mineralogical behaviour of raw meal considerably influences the clinker formation and its characteristics.

To achieve proper burnability the thermal decomposition of the constituents in the raw meal fed in the kiln should take place within a close range of temperature as the decomposition products are found to be in a state of high reactivity just after the termination of decomposition. Therefore, the raw materials like limestone, clay and other constituents have to be chosen with such properties as to have a matching decomposition temperature range so as to obtain an efficient combination and solid state reaction.

Under the conditions of clinker formation, with the increase in the LSF both the reactivity and burnability of a raw mix are decreased at temperature below the liquid formation whereas above the temperature of liquid formation only burnability decreases but the reactivity practically remains unaffected. The increase in silica modulus (SM) and alumina modulus (AM) results primarily in the harder burning of the clinker. In actual practice increase of one unit of LSF is regarded as equivalent to 20°C rise in burning temperature[4]. Alumina modulus is particularly critical in liquid phase sintering. The silica modulus also has to be taken into consideration together while considering the burnability of a raw mix e.g. for the same silica modulus, the maximum formation of liquid at minimum temperature corresponds to the alumina modulus 1.38 or 1.63 depending on the MgO saturation, and for the same alumina modulus the amount of liquid increases with decrease of silica modulus. The general relationship of raw mix burnability with modulii values is illustrated in fig (A,B)[1,4]. In order to have a raw meal of optimum burnability it is desirable that the characteristic modulii be maintained in the following range e.g. lime saturation factor 0.92-0 95, silica module 2.0 2 5 and alumina module 1.4-1.6.

Use of Grinding Aids:

The particle size of raw mix plays an important role in the solid state reaction since the sintering rate is roughly proportional to the inverse of particle size. In general the fines of raw mix varies in the range 3000-5000 $Cm^2/9$ with about 9-22% particles of more than 0.07-0.09 mm size and 0-5% of over 0.20 mm size. In parctice it has generally been observed that burning is relatively easy if the coarser fraction is restricted to 0.10 to 0.20mm for the production of general purpose portland cement and 0.05 to 0.06 mm for the production of high strength cement. Larger particles in general are much harder to nodulize effectively than smaller ones.

To attain the required fineness it is sometimes desirable to use grinding aids which also help to save energy to achieve the desired fineness. The grinding aids favour the dispersion of the ground material and check the agglomeration of the finer particles. The widely used materials for this purpose are a mines and related salts, alcohols, lignosulphonates, fatty acids and related salts. All these grinding aids are usually employed in very small amounts, generally between 0.01 and 0.1 weight per cent. The presence of grinding aids increases the specific surface on an average by about 20% for equal grinding times.

Grinding aids modify the particle size distribution of cement raw mix. For instance some workers have found that addition of surfactant increases the amount of particles of medium size (3-30 mm) by 10-20 per cent. The economic advantage is obtainable as the grinding time required to achieve a certain fineness can be reduced by 10-50%, and the production can be increased by 10-50%, and the production can be increased by 17-34%[5] The energy consumption can decrease by 15 per cent[6] and grinding efficiency can be raised by 30-40%[7].

The clinkering of cement raw mix can be enhanced by the use of cartain substances. The substances which lower the temperature of melt formation are called fluxes while those which accelerate the rate of reaction through the modification of solid and liquid state sintering are called mineralizers. The effect of fluxes and mineralizers in clinkerization can be summarised as below:

1) Lowers the temperature of liquid formation
2) Accelerates the rate of reaction
3) Influences the melting, viscosity and surface tension which in turn determine nodulization and solid-liquid interface reactions.
4) Completes sintering at lowest possible temperature and with smallest quantity of melt phase.
5) Affects improvement in over all burnability.

The selection and use of mineralizers and fluxes is determined on the consideration of the following (a) nature of raw materials (b) process employed for cement manufacture (c) extent of reaction desired and other (d) economic considerations.

The compounds generally used as mineralizers in cement manuacture can be grouped in the following i) fluorides ii) sulphates iii) Chlorides and iv) Oxides, Some of the effective fluorides as mineralizers are NaF, MgF_2, CaF_2, Na_3 AlF_6, Na_2SiF_6, Mg Si F_6 $6H_2O$, Ca SiF_6 $6H_2O$, H_2SiF_6. The effectiveness of these F bearing mineralizers have been studied by a number of workers[8,9] The study by the authors[10] on these F bearing and some other mineralizers showed that the effectiveness is in the order of Na_2 Si F_6 $>M_g$ Si $F_6 >$ $CaF_2 >$ ZnO $>$ Ca Cl_2 + $CaF_2 >$ Ca Cl_2.

The F^- containing compounds were found effective at all temperatures.

The presence of free lime in the cement although indicates to a fair degree the progress of clinkerization but the determination of compressive strength indicate more clearly the presence of hydraulic constituents in clinker formed in the presence of mineralizers. Besides determining the free lime in the clinkers prepared at different temperatures in presence of mineralizers, from a raw mix with LSF 0.99S.M. 1.99 and A.M. 0.74 the authors also studied the compressive strength of the cements prepared from these clinkers. Results of free lime as well as of compressive strength at different temperatures are given in table-3. The samples with higher free lime contents were moist cured upto seven days, which otherwise crumbled in water, and then placed under water for determining strength for longer curing periods.

Calcium flouride (CaF_2) is the most studied mineralizer but there is difference of opinion on the effective percentage and appropriate corresponding temperature of clinkerization. The effect of CaF_2 in the range of 0.5 to 5% on a cement raw meal (LSF-0.92,SM 2.80 and AM 1.65) has been studied at this institute at different temperatures [11]. The results of free lime and compressive strength determinations show that there is an optimum content of CaF_2 mineralizer at each temperature which produces maximum strength of cement at that temperature.

The addition of calcium sulphates as such or in the form of floorogypsum and phosphogypsum also lower the temperature of clinkerization[12]. Authors have also studied[13] the effect of gypsum and phosphogypsum as mineralizer and found that addition of gypsum or phosphogypsum doesnot produce advantageous effect as compared to the fluorides and also is much indicated in the literature, as far as the compressive strength is concerned. Some workers[11] have expressed the apprehension of adverse effect e.g.unsoundness in such cement due to the formation of C_4A_3S in the clinker.

Addition of chlorides has also been reported by some workers for cement clinkerization[15,16]. The addition of Ca Cl_2 in higher amounts is reported[17] as effective as mineralizer with formation of alinite phase in such cements. The work carried out at the CBRI laboratories [10] suggest that Ca Cl_2 in low percentages is not an effective mineralizer. If it is present in higher quantities in cement, corrosion of the reinforcement in the concrete structure may take place due to the presence of chloride ions in cement.

The presence of some oxides such as Cr_2O_3, ZnO, TiO_2, BaO, SrO, B_2O_3, P_2O_5,MgO, Li_2O within limits in cement raw mixes is desirable as they lower the temperature for the appearance of liquid phase and effect the viscosity of the liquid phase and in some cases enhance the rate of alite formation[18].

A mineralizer (designated MTM) has been prepared by the authors and studied its efficacy in clinkerization at low temperatures of 1250°-1300°C. It has been found that with the use of the mineralizer MTM the clinker obtained at 1250°C is softer to grind and the dusting is checked and the cement produced confirm to the requirement of IS 269-1976.

Low Energy Modified Cements

Another approach wich is being followed by some workers is to produce modified cements. They are reactive modified portland cements, e.g. alinite cement, belite cement, porsal cement and blended cements.

Modified Portland cement :

It may be noted that 50% of the total heat is required for the dissociation of $CsCO_3$ so the substitution and lowering of calcium carbonate content in cement raw mix may be one of the ways to save energy. The Portland cement consists mainly of C_3S, C_2S, C_3A and C_4AF phases and each one require 75.7.65.1, 62.3 and 46.2 per cent lime respectively. The presence of C_3S and C_3A mainly responsible to give early setting and hardening characteristics. Therefore. replacement or partial substitution of these compounds with other phases requiring less lime and possessing similar properties of early setting and hardening may result in the saving of energy. The compounds with low lime contents and possessing such properties are C_4A_3S and CS and lime requirement for them is 36.7 and 41.2 per cent only. These compouuds are formed at lower temperatures, between 950-1300°C.

The modified cement containing C_2S (25-65) C_4A_3S (10-20), C_4AF (15-40), CS (10-20) per cent are reported. These are produced by firing a raw mix containing pure $CaCO_3$, silicic acid, hydrated alumina, iron oxide and gypum at 1200°C for about an hour. The energy saving potential of such cements may work out to be in the range of 120 K Cals/kg of Clinker[19].

Alinite Cement

In another study conducted in Russia a new cement called the alinite cement has been reported where $CaCl_2$ produced the mineralizing effect and the clinkering temperature lowered by 400-500°C. This technology haa been named the low temperature salt technology. The clinker contains alinite[20], a compound having composition C_{11} $(Si_{0.75}\ AL_{0.25})_4$ 018 CL. It is softer than alite because of the weak Ca-CL bonds and thus requires less energy for grinding. Gypsum addition is reported to intensify strength development.[21]

The escape of substantial quantities of chlorine into the gas phase, however, requires by-passing of 100% of the exit gases as well as recovery of chlorine from the kiln gases. Such a procedure upsets the saving in energy due to wastage of the sunsible heat in the exit gases.

Belite Cement

Belite portland cement mainly contains C_2S in a highly reactive form. This is produced by alkaline sintering of raw materials containing alumina as predominant constituent[22].

High reactivity in C_2S is obtained by introducing crystal defects and lattice dislocations by controlling heating and cooling cycles. A highly reactive C_2S is also reported[23] to form on pumping a fine mist of calcium nitrate solution and aqueous collodial silica into long hot zone at a temperature of 750° to 1050°C.

Porsal Cement

Porsal Cement is reported to possess the combined properties of portland cement, sulphate resisting cement and high alumina cement. It is generally prepared from limestone, anorthosite, gypsum and minerlizer and firing at 1300-1350°C. It may also be prepared by firing a cement raw mix having limestone, clay, bauxite, gypsum and mineralizer (CaF_2). The phases in the porsal cement are C_2S (60%), C_4AS_3 (15%), C (7%), $C_{12}A_7$ (9%) and glass (9%). C_3S is not found present in this cement. Siliceous limestones are highly suitable as raw material for this type of cement manufacture[24].

Blended Cements

Portland Cement and other materials possessing pozzolanic activity or bearing some hydraulic and glassyphasses may be properties like those present in the portland cement. The cements so obtained are called blended cements. The materials which are generally used for obtaining blended cements are mainly flyash, burnt clay pozzolana, granulated blast furnace slag etc. Their use cuts down the energy indirectly as the consumption of cement is reduced in preparing a certain volume of concrete. Total savings of the order of 5·8Kwh/t in power and 100-200 KCals/kg Clinker are reported.[25]

The above discussion shows that a judiceous selection of process technology for cement manufacture may economise the energy requirement, to an appreciable extent.

Conclusions:

1. The dry process technology for cement manufacture should be used to the maximum in the existing and new industries.

2. Use of mineralizers and grinding aids should be encouraged to produce softer clinkers at lower temperatures to save in the grinding as well as clinkering energy requirements.

3. Production of belite, blended and other modified cements should be undertaken.

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Table-1

Energy consumption in cement clinker production K Cals/kg clinker.

	Wet process	Dry process
Evaporation of Water	585	6
Radiation & Convection	270	143
Cement Clinkerization	430	430
Exit gases loss	150	174
Clinker Cooling	48	31
Calcinations at higher temp.	45	25
Dust Sensible heat	5	7
Total Benrgy	1533	876

Table-2

Percent energy consumption in different steps in cement manufacture.

Process	% Energy consumption
Mining	1.5
Drying	4.3
Inital Grinding of Raw Material	3.8-4.3
Cement Clinker production	80.0
Final grinding	7.0

Table - 3

Free Lime and Compressive strength of cement produced at various temperatures with different mineralizers

Mineralizer	1250°C Free Lime (%)	1250°C Comp. Strength (kg/Cm²) 3d	7d	28d	1300°C Free (%) Lime	1300°C Compressive Strength (kg/cm²) 3d	7d	28d	1350°C Free Lime (%)	1350°C Compressive Strength (kg./cm²) 3d	7d	28d
Nil	15.54	*36	*48	68	5.28	89	121	288	1.43	218	304	450
1% CaF_2	4.26	108	201	300	2.03	213	323	443	0.52	256	342	523
1% $MgSiF_6$	5.66	171	218	260	1.43	182	304	475	0.37	264	446	608
1% Na_2SiF_6	5.13	141	200	247	0.97	140	238	465	0.60	242	332	535
1% $CaCl_2$	14.50	*21	*27	75	3.50	118	133	275	1.97	237	317	470
1% ZnO	10.80	*72	100	124	2.70	118	281	403	0.97	247	437	475
1% $CaSO_4$	10.88	*31	*51	88	3.88	101	152	275	1.01	229	288	404
Mineralizer MTM	1.60	362	480	646	0.13	425	480	741	Tr.	433	524	690

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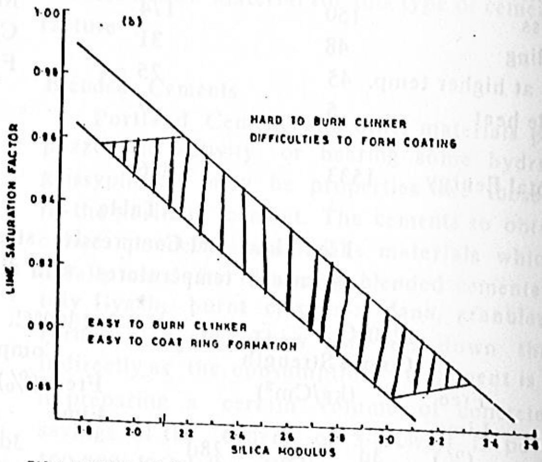

FIG.1 EFFECT OF MODULI VALUES ON CLINKERING TEMPERATURE AND BURNABILITY. (%)