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# CRI TECHNOLOGY DIGEST

## NCBM-REACTIVE BELITE CEMENT

National Council for Cement and Building Materials

# NCBM-REACTIVE BELITE CEMENT

## INTRODUCTION

Reactive Belite Cement is a newer class of cement of importance in the Indian context. It incorporates enhanced hydraulicity of $C_2S$, as a result of which the conventional requirement of alite phase is minimized, if not eliminated, and consequently use of low grade limestone and lower temperature of sintering is made possible. This Technology Digest briefly highlights the R&D work done by NCBM towards the development of reactive belite cement.

## CHEMISTRY OF BELITE CEMENT

Among the five polymorphs $\alpha$, $\alpha_H$, $\alpha_L$, $\beta$, and $\gamma$ of $C_2S$ phase, the $\beta$ form is found to be most hydraulic. $\alpha$-$C_2S$ stabilised with $C_6AF_2$ is less hydraulic than $\alpha$ and $\beta$ forms. In portland cement, dicalcium silicate occurs as belite. This is a product of imperfect crystallization and is stabilized by the inclusion of foreign ions such as $N_a^+$, $K^+$, $M_g^{2+}$, $B_a^{2+}$, $M_n^{2+}$, $A_l^{3+}$, etc, in the crystal lattice. In the first place, these minor oxides are precipitated out as microscopic but discrete phases, thereby producing stress conditions in the crystal lattice. Secondly, the $SiO_4^{4-}$ ions in the lattice may be replaced by the other ions and depending upon the requirement of electrical neutrality, anionic or cationic vacancies are created. The stabilization of $\beta$—$C_2S$ can be summarized due to two reasons:

a) *Crystal Chemical Stabilization* — This is obtained by the addition of suitable "stabilizers" forming solid solutions with $C_2S$. The $SiO_4^{4-}$ is replaced $BO_4^{3-}$, $PO_4^{3-}$, $VO_4^{3-}$, and $SO_4^{2-}$ with suitable charge compensation by bringing additional positive charge by trapping extra $C_a^{2+}$ ions interstitially or by the removal of some $SiO_4^{4-}$ ions from the lattice. The substitution process is more or less dependent on the size of the $RO_4$ group which is, in turn, controlled by the O-O bond distances.

b) *Physical Stabilization*—This is obtained by the external influence on the crystallite, eg, by solidifying a fused mass under rapid cooling. The fused mass surrounding the crystallite may have little or no reactivity towards the crystallite or sometime it may even aid to the crystal growth.

In any realistic situation, the physical or crystal chemical mechanism can not be isolated and therefore the effects of pressure and rate of nucleation must be simultaneously considered along with any crystal-chemical mechanism.

## R&D WORK AT NCBM

After intensive research and development work, NCBM has developed the Reactive Belite Cement using raw materials and semi-dry and dry process pilot plant rotary kilns. Physico-Chemical and performance tests on this cement have been performed and the results show that a low alitic cement using suitable raw materials can be manufactured at a sintering temperature range 1325°-1365°C with usual air quenching. No manufacturing problems, such as choking of preheater system in the four stage suspension preheater or dusting of clinker or balling or ring formation was observed. X-ray diffraction study, microscopy, chemical analysis, physical testing, etc, were performed on clinker and the resulting cement (4-5% gypsum added). Test data show that the cement possesses the performance characteristics, equal to or better than normal portland cement, inspite of the fact that the alite content in this cement is considerably lower than in normal OPC and the firing temperature is about 100°C lower than that of OPC.

### Raw Materials

In the laboratory and pilot plant studies, two component raw mix passing 170 mesh (> 90%), similar to that for OPC was used. The average composition of the marginal grade limestone was:

| LOI | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | CaO | MgO |
|---|---|---|---|---|---|
| 35-38% | 12-14% | 1-2% | 2-3% | 42-44% | 2-3% |

The normal size nodules were made in a pan nodulizer. For dry-process plant, same raw mix design was used. It is to be noted that limestone used in this work contained 42-44% CaC. The silica content works out to be ~ 15 percent and lime content~39% in raw mix.

**Manufacturing on Pilot Plant Scale**

About 2 tonnes of clinker was produced by dry process in the rotary kiln pilot plant with 4-stage suspension preheater at NCBM-Ballabgarh (Fig 1). The plant is oil-fired and incorporates normal rotary cooler. The firing temperature was in the range of 1325°-1365°C. The resulting clinker was well burnt with bulk density 1.36 g/cc. Insoluble residue was < 1% and free lime also < 1%. The Bond's grinding energy of the resulting clinker was about 10 kWh/tonne.

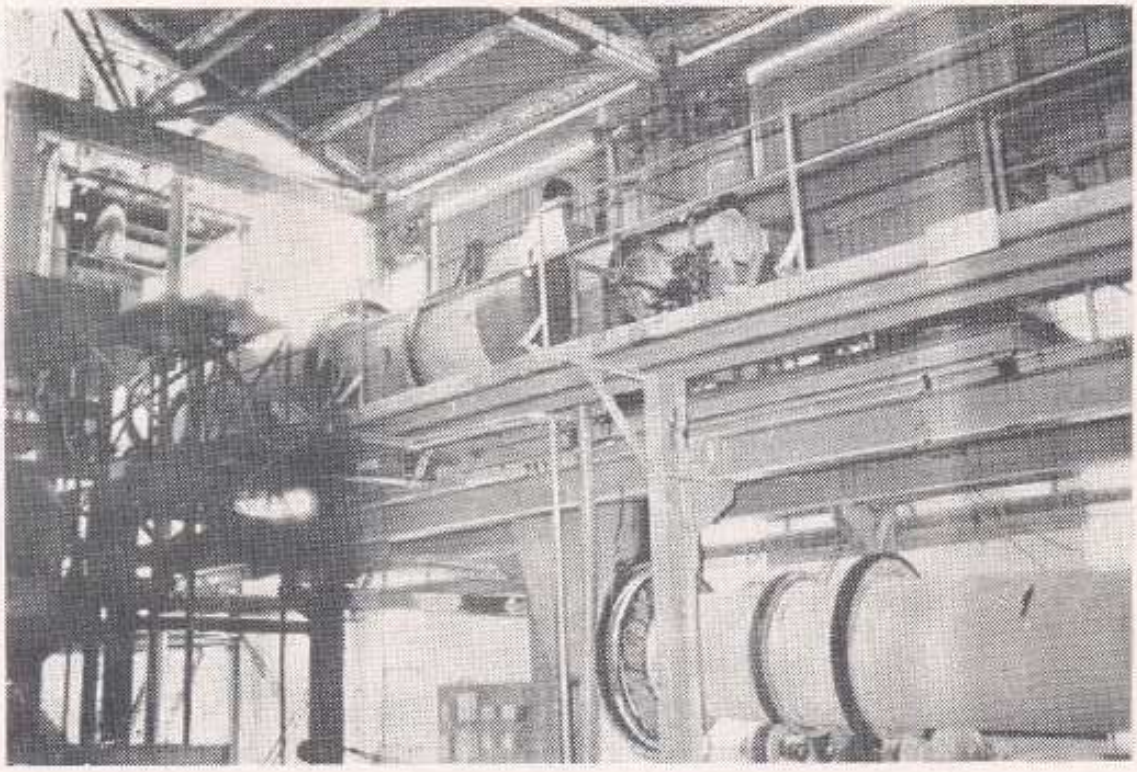

*Fig 1 NCBM Pilot Plant (2·5 tpd) with 4-stage suspension preheater*

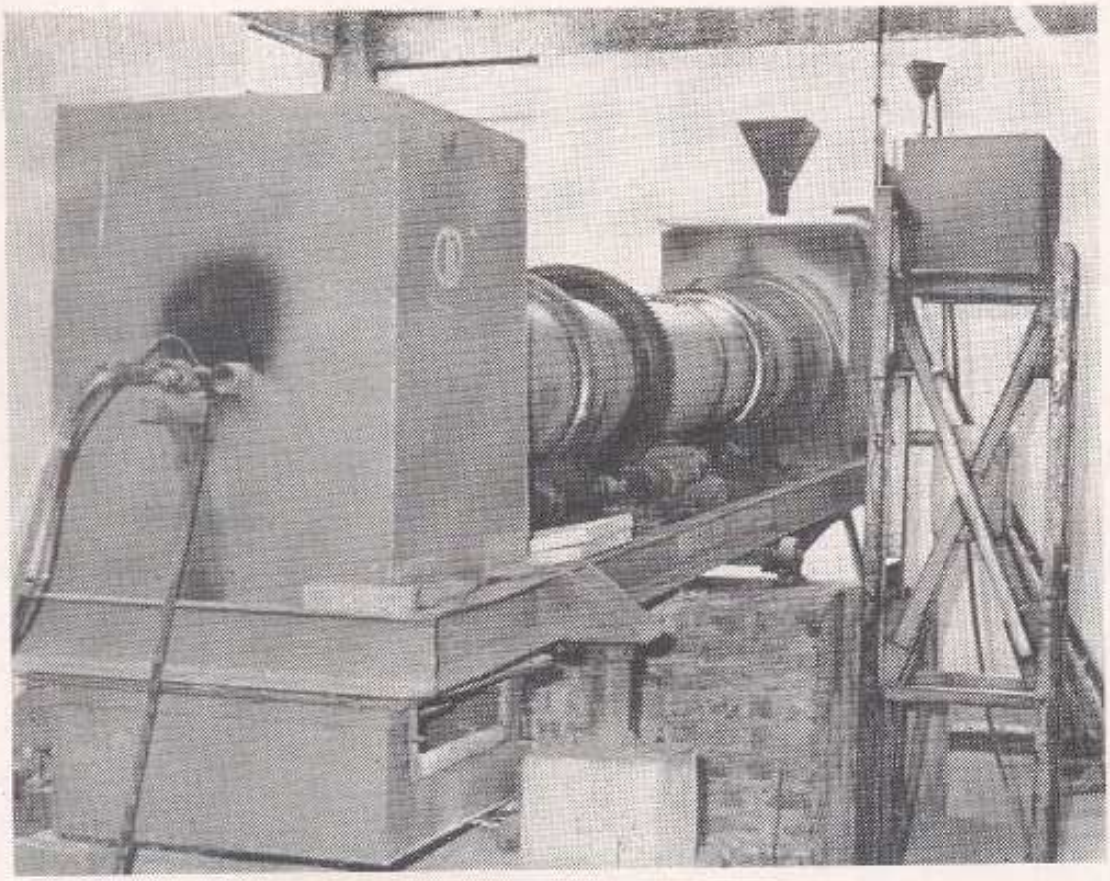

*Fig 2 NCBM bench scale rotary pilot plant (2 kg/h)*

In the semi-dry process, raw mixes in the form of nodules were fired in a laboratory bench rotary kiln heated to 1325°-1365°C by oxy-acetylene flame and normal air cooling was done. About 30-40 kg clinker was obtained and no dusting was observed. The resulting cement (4-5% gypsum added) was similar to OPC as per IS : 269-1976. In all the cases, well burnt clinkers were obtained in the temperature range of 1325°-1365°C (Fig 2). Free lime and insoluble residue were less than 1 percent.

**Engineering Properties of Reactive Belite Cement**

The properties of belite cement are similar to normal OPC conforming to IS: 269-1976. The properties pertaining to one particular batch of pilot plant-fired cement (5% gypsum added) are given below:

| | |
|---|---|
| True density of cement | 3·33 g/cc |
| Bulk density of clinker | 1·785 kg/l |
| Initial setting time | 53 min |
| Final setting time | 93 min |
| LeChatelier's expansion | 2 mm |
| Autoclave expansion | 0·27 per cent |
| Fineness | 2800 $cm^2/g$ |

Compressive strength:

| | |
|---|---|
| 3 days | 140 $kg/cm^2$ |
| 7 days | 235 $kg/cm^2$ |
| 28 days | 395 $kg/cm^2$ |

Range of compressive strength (in $kg/cm^2$) of mortar cubes with cement-sand ratio of (1 : 3) is given below:

| *3 days* | *7 days* | *28 days* |
|---|---|---|
| 194-300* | 235-280* | 395-465* |

The x-ray diffraction pattern of the belite clinker is presented in (Fig 3).

It will be seen that the x-ray diffraction pattern in the region 32-34° ($2\theta$) is different from normal pattern of OPC. The scanning electron microphotograph of the belitic clinker is shown in Fig 4. The predominant belitic crystals with striations and some deformation in crystal shape can be seen at a magnification of 5000×.

*Range of strength values of about 10 batches of assorted clinkers.

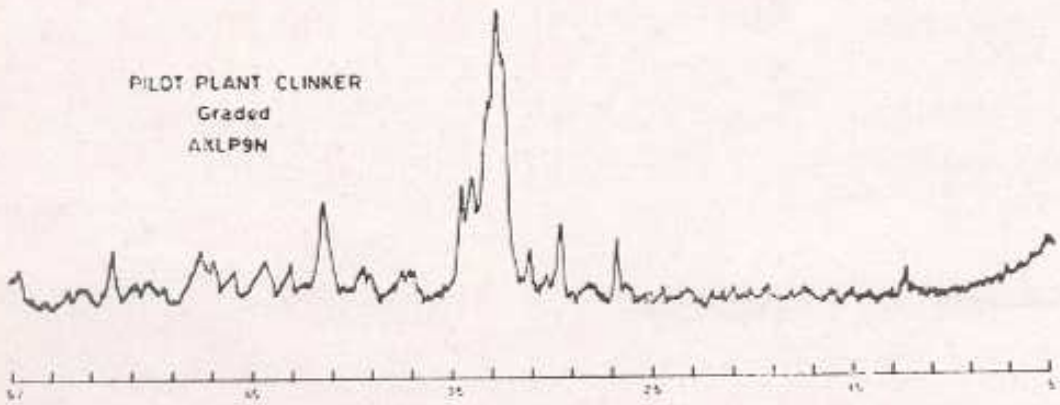


*Fig 3 X-ray diffraction pattern of belite clinker* (2θ)

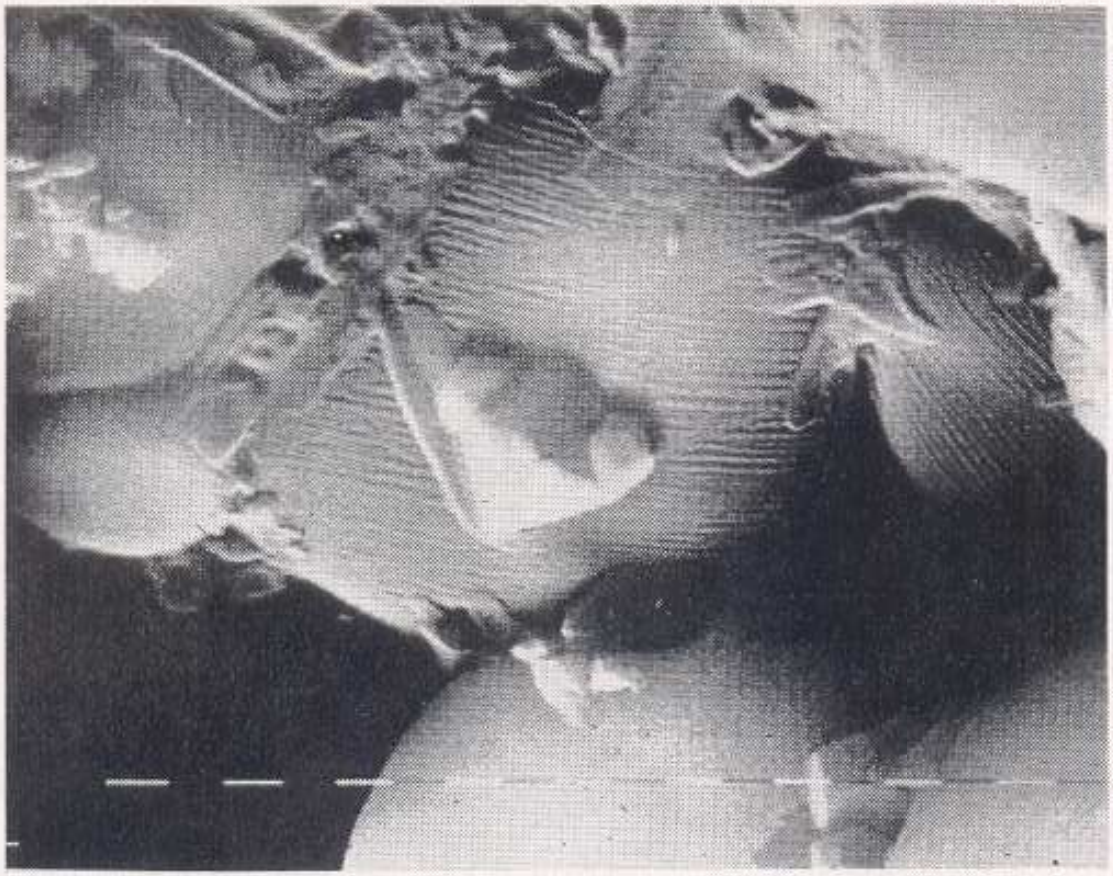

*Fig 4 Scanning electron microphotograph of belitic clinker* (5000×)

## ADVANTAGE OF REACTIVE BELITE CEMENT

The advantage of belite cement over OPC are:

a) It makes utilization of inferior grade silicious limestone possible.

b) It affords fuel economy as the clinkering temperature is less by 100°C.

c) It possesses improved chemical resistance.

The cement can be used for all purposes similar to ordinary portland cement.

## NCBM ASSISTANCE

NCBM will extend necessary technical and technological assistance to those who wish to adopt NCBM technology of manufacturing reactive belite cement.

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