Some Recent Research and Development Activities on Cement

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Abstract

Cement is a prime building material of paramount significance contributing to the economic impetus of the nation. The need for low cost and energy efficient cements is a priority consideration of modern times in view of the fast dwindling natural resources and environmental hazards vis-a-vis ecological imbalances. Developmental work carried out recently on the various facets of cement at the Central Building Research Institute, Roorkee has been outlined here. In view of current trends, emphasis has been laid on production of cement and cementitious materials through utilization of agro-industrial wastes. Mainly, low-temperature cement, portland-pozzolana cement, portland-slag cement, supersulphated cement and allied products have been discussed. The present scenario as well as areas for interaction with the cement industry have been detailed. A bibliography on the subject has been incorporated for benefit of the prospective researchers and users of alternative cements.

Introduction

CEMENT, a prime material of significant importance in the building industry, is usually employed to bind together sand and crushed stone or other aggregates into a solid mass to yield materials, such as mortars and concretes, and various types of allied products. It may be a single chemical compound, but more often it is a mixture and the development of strength is mainly due to the formation of hydrated calcium silicates, aluminates, sulpho aluminates, or the compounds of two or more of these groups. The most conventionally used material, ordinary portland cement (OPC), is capital intensive vis-a-vis natural resources and a high energy consumption industry.

India is the fourth largest producer of cement in the world – next only to China, Japan and USA with the current annual production close to 51 million tonnes, from the large cement units possessing an installed capacity of approximately 65 million tonnes. Presently, mini-cement plants account for an additional production of about 3 million tonnes out of an installed capacity close to 6 million tonnes per annum. The planning commission has estimated the requirement of about 30 million tonnes of additional capacity by the financial year ending March 1997.

Low energy and high performance cements have been developed at the Central Building Research Institute, Roorkee from natural resources as well as industrial by-products such as fly ash, phosphogypsum, blast furnace slag, etc. The newer products and processes have been outlined here. Emphasis has been laid on the utilisation of agro-industrial wastes for cement production with a view to obviating environmental hazards and economizing on energy.

Low Temperature Cement (LTC)

Research work has been undertaken in the Institute on the development of mineralizer based cement to lower the energy consumption. The process involves effecting clinkerization at a lower temperature of 1250 - 1300°C as against the conventional (1400-1450°C) by use of the mineralizers compounded by the investigators. The cement thus prepared conforms to IS : 269- 1989, specification for ordinary, rapid hardening and low heat portland cement in terms of physical and chemical properties of the OPC. The clinker obtained by the modified process, being softer, consumes half the energy of that required in the grinding of the conventional clinker. The overall saving of energy is about 12 percent for cement manufacture. The technique has also been successfully extended to the calcareous wastes from the paper and sugar industries to produce OPC conforming to IS : 269:1989. The process has also been extended to the mixes designed by replacement of clay with flyash which holds promise of utilising this waste material in an effective manner.

Portland-Pozzolana Cement (PPC)

Suitable pozzolanas conforming to IS : 1489-1976 can be used for the production of portland pozzolana cement. Flyash, a waste from thermal power plants, has been identified to be a good pozzolana for making PPC. It can be admixed and effectively blended with OPC to the extent of 15-25 percent by weight without adversely affecting its properties and rather improving the durability of structures against sulphate attack. Other pozzolanas such as "surkhi" (burnt clay powder), rice husk ash, etc. have also been investigated to be effective. Presently about 18 percent of the total production of cement is PPC and enough scope exists for productivity enhancement.

Portland-Slag Cement (PSC)

Portland slag cement has been produced either by suitably intergrinding a mixture of portland cement clinker and granulated blast furnace slag (glass content exceeding 90 percent) with addition of gypsum (natural or by-product), or by intimate and uniform blending of portland cement and finely ground slag. Slag content in

PSC in the range of 25-65 percent by weight of the portland cement has been investigated. The early strength of PSC is no better than that of OPC, but the later stage strength certainly supercedes OPC due to the formation of more CSH gel. PSC guarantees additional protection to reinforcement wherever chloride ions are present. Presently PSC accounts for about 11.0 percent of the total cement production in the country and being a general purpose cement for all civil works, its use needs to be encouraged.

Super-Sulphated Cement (SSC)

Super-Sulphated cement has been produced by intergrinding mixture of granulated blast furnace slag, calcium sulphate and a small amount of portland cement clinker. Phosphogypsum anhydrite has been found to be suitable as an activator for the manufacture of supersulphated cement and an optimum mix proportion has been designed to produce SSC conforming to IS: 6909-1973. The supersulphated cement is well-known for its low heat of hydration, chemical resistance to a multitude of aggressive conditions generally encountered in construction industries, and sulphate resistance in particular. The hydration products of SSC mainly comprise calcium silicate hydrates and ettringite.

Rice Husk Cement (RHC)

A highly reactive ash (mostly amorphous silica) is obtained by the controlled burning of rice husk in the boilers. Different types of cementitious materials have been produced from rice husk in view of the pozzolanic properties of its ash. An intimate mix of rice husk and clay has been fired to produce better quality pozzolana without using any additional fuel. The finely ground pozzolana on mixing with hydrated lime produces an effective binder for masonry and plaster works.

Lime Sludge Cement (LSC)

Hydraulic cement produced by using the waste lime sludges from acetylene generator (carbide plant), paper and sugar mills, as replacement of limestone, and flyash from thermal power plants, is suitable for masonry mortars and stone building blocks for use in place of portland cement in flooring and foundation concrete.

Masonry Cement (MC)

Masonry cements have been produced by intergrinding mixtures of portland cement clinker with inert materials. A masonry cement conforming to IS : 3466-1983 has been produced at CBRI from granulated blast furnace slag and flyash. A mortar (1:4) of this cement has been found to give higher compressive strength, bending and bond strength than the cement – sand (1:6) mortar. These cements in general possess greater plasticity, workability and water retentivity compared to the one obtained with the OPC and have been found to be suitable in masonry works.

Magnesium Oxychloride Cement (MOC)

This cement also known as "Sorel Cement" has been developed in the Institute based on partial calcination of magnesite in dolomite at lower temperature followed by reacting the same with an aqueous solution of magnesium chloride. The calcium carbonate serves as a filler in the product. The conventional process involves the reaction between the magnesium oxide powder and an aqueous solution of magnesium chloride. Thus the emphasis has been on the development of cheaper cement from the abundantly available source of MgO. This process has been utilised by a number of industries.

Phosgyp Cementitous Binder (PCB)

Phosphogypsum is a by-product of the phosphatic fertilizer plants. About 4.5 million tonnes of this material is being produced annually in the country. It is replete with harmful impurities of P_2O_5, F, organic matter, etc. The duly processed and beneficiated phosphogypsum has been utilized to develop a suitable water resistant cementitious binder using slag/flyash, cement additives. This binding material is equally useful for indoor as well as outdoor applications for masonry mortars and for making glass fibre reinforced composites. The energy consumed for the production of this binder is a small fraction of that required for portland cement. Thus production of this useful cementitious material needs to be encouraged on the basis of extensive inhouse research and development work undertaken in CBRI.

Modified Portland Cement (MPC)

Ever since the invention of portland cement about 170 years ago no significant efforts have been reported on the modification of its compound composition with similar setting, hardening and water resisting qualities. It is important to note that 50 percent of total heat is required for the dissociation of limestone. Thus research needs to be undertaken to produce low energy consuming alternative OPC, by decreasing the $CaCO_3$ content in the cement raw mix and to further modify the mix proportions to obtain the final phase compositions comprising C_3S, C_4A_3S, C_4AF and CS instead of the normal phases such as C_3S, C_2S, C_3A and C_4AF.

Multi-Blend Cement (MBC)

Multi-blend cements are the new types of low cost and low energy products recently introduced in the world building materials market in countries such as Russia, Germany, France, Canada, China etc. Three or more ingredients, generally granulated slag, fly ash, micro silica (Condensed silica fume) and calcareous fillers like limestones, kiln dust, etc. are involved. Utilization of major industrial wastes results in providing solution to problems of environmental pollution and waste disposal. Multi-blend cements, in general, are known to possess higher strength, low permeability, and

depict better resistance to aggressive environments. Extensive financial support from the cement industry is urgently called for to develop appropriate multi-blend cements suiting indigenous conditions and environment.

Industrial Collaboration Vis-a-vis Infrastructure

On the basis of the research and development work carried out and also the inhouse current projects, the following grey areas have been identified for intensive interaction and support from the cement industry :

i) Pilot scale production/field trials for the manufacture of low temperature cement.

ii) Development of low cost, energy efficient multi-blend cements from industrial wastes, and their long term performance and durability studies.

iii) Pilot scale production of the phosgyp cementitious binder based on CBRI process know-how.

iv) Low temperature clinkerisation of high strength cement clinker.

v) Development of environment friendly speciality cement/value added products for specific application such as quick setting cements, white cements, coloured cement clinkers, etc.

vi) Process diagnostics, kiln performance estimation and upgradation.

vii) Productivity enhancement in existing cement plants.

viii) Technologies absorption and adaptation of newer cements for indigenous conditions.

ix) Quality assurance and certification for all cementitious materials.

x) Environmental considerations, performance and durability of cement products.

xi) Investigations on secondary/alternative fuels for cement manufacture.

The infrastructural facilities available in the institute are as follows :

a) Modern instrumentation laboratory for pollution monitoring techniques and chemical analysis.

b) Analytical laboratory for physico-chemical analysis of hardened or fresh mortars and concretes.

c) Assessment and protection of steel and concrete in aggressive environment.

d) Evaluation of raw materials including industrial wastes for cement and cementitious products.

e) Thermal and XRD analysis of cements.

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