BASIC CHARACTERISTICS OF PORTLAND LIMESTONE CEMENT PREPARED WITH INDIAN CEMENT AND LIMESTONE

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ABSTRACT

Portland Limestone Cement (PLC) was prepared by inter-grinding and separate grinding methods using clinker, gypsum and low and high grade limestone. A number of blends with varying composition & Blaine were prepared at laboratory scale and their detailed physico-chemical characteristics were studied. The results indicate that compressive strengths of PLC blends prepared by both methods are lower than Ordinary Portland Cement (OPC) which is expected due to dilution effect caused by the limestone. However, PLC blends prepared by separate grinding show comparatively better compressive strength than those prepared by inter-grinding method.

As Blaine of limestone increases from 400 - 600 m²/kg; the percent decrease in 1 day and 28 days compressive strength of PLC made with 15 % High Grade Limestone varies from 20.18 to 8.72 and 7.47 to -1.19 respectively. PLC made with 15 % Low Grade Limestone also shows similar trend. In separate grinding and blending study of PLC, the percent decrease in compressive strength is lesser than intergrinding.

Further, work was extended to plant scale studies and PLCs manufactured by inter-grinding method using similar components with 22, 25 and 26 percent of low grade limestone shows lower compressive strength at all ages as compared to OPC. The water demand for PLC cements manufactured at plant scale are less than OPC but setting time is marginally on the higher side. Hydration study by thermal technique indicates lower release of calcium hydroxide in PLC than OPC.

1. Introduction:

The cement production process is intensive in energy as well as in raw material demand. Since, maximization of alternative raw materials have already been carried out in Indian cement plants, remaining potential to reduce environmental impacts is provided by the reduction of clinker content in cement. Replacement of clinker content can be done using fly ash, slag or other pozzolanic materials or limestone.

The limestone is calcareous sedimentary rock mainly consisting of calcium carbonate (CaCO₃), commonly called calcite. Limestone powder is produced by finely grinding limestone & has been suggested for use as an additive in Portland cement. Limestone replacement into Portland cement has been widely studied for several years (1-4).

The use of limestone in manufacturing cement products, not only does the economic benefits by reducing production & investment cost but also technically benefits by increasing early strength. In addition, it demands less water than pure cement because the fineness of clinker & limestone is strongly connected with limestone content resulted in the improvement in the clinker reactivity & exploitation of its hydraulic potential (5). Production of Portland Limestone Cement (PLC) cements results in lower emission of carbon dioxide & lower energy consumption thus reducing GHG emission and helping natural resource conservation.

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As per European Standard EN-197-1, two types of Portland limestone cement containing 6-20% limestone (Type II/ A-L) (A-LL) & 21-35% limestone (Type II/ B-L) (B-LL) are specified. The limestone must meet three requirements for manufacturing PLC cement & these requirements are: 
(a) CaCO3 content greater than 75% 
(b) Clay content determined by methylene blue test (MBA) less than 1.20g/100g 
(c) Total organic carbon (TOC) less than 0.5% (6,7)

The research work in the field of limestone cements is focussed on three areas. The first is the effect of limestone on cement & concrete performance (6, 8-14). The competitive behaviour of limestone cements is attributed to the filler effect of fine particles, the increase of the hydration rate, the formation of carboaluminates & modification of microstructure. The second one deals with the participation of limestone in the hydration reactions of clinker, while the third one with the production process and specifically the inter-grinding of clinker & limestone (9, 15-17).

As far as the cement performance is concerned, there is a disagreement whether the fine limestone tends to reduce or enhance the strength development but it is generally accepted that there is a positive effect of limestone on water demand (6, 8-10, 12).

As far as the clinker hydration is concerned, it is generally agreed that limestone participates in the hydration reactions rather than being inert filler, but there is considerable disagreement on the estimation of the limestone amount that is incorporated into a cement system (18-23).

Globally three main types of blended cements namely Portland Slag Cement (PSC), Portland Pozzolana Cement (PPC) and Portland Limestone (PLC) are being produced. Out of these three, the first two types are commonly produced in India & the third type is still not specified by Bureau of Indian Standards (BIS). However, PLC has good techno-economic potential including the use of low/marginal grade limestone.

India’s high performance of blended cements is only limited to PPC & PSC, our main objective therefore, is to explore the feasibility of introducing a third variety of cement, i.e. PLC in India.

The present work deals with the effect of inter-grinding & intra-grinding (separate grinding) of limestone, clinker & mineral gypsum on mechanical properties as well as hydration behaviour of prepared PLC. Limestone & Portland cement containing 0-26% w/w limestone are hydrated from 2 hrs to 28 days & are examined by TGA/DTA for CSH gel and Portlandite.

2. Tentative cost implications of making Portland Limestone Cement:

Assumptions and calculation basis:

1. Landed cost of Limestone: 153.60 Rs/ton,
2. Landed cost of Gypsum: 1500.00 Rs/ton
3. Clinker manufacturing cost: 1161.63 Rs/ton

- Cost of production of 1 ton of OPC: 95% Clinker + 5% Gypsum: 1103.55 + 75.00 = 1178.55 Rs
- Cost of production of 1 ton of PLC cement: 70% Clinker + 25% Limestone + 5 % Gypsum: 813.14 + 38.40 + 75.00 = 926.54

Net saving of cost of production of 1 ton of PLC cement vis-à-vis OPC: 252.01Rs/ton

3. Conclusions:

The study reports the effect of the inter-grinding & intra-grinding, amount of limestone percentage and total surface area on the properties of laboratory and plant scale prepared PLC cement. The conclusions drawn from the experiments are following:
- Method of preparation of PLC effects setting time and water requirement.
- The limestone cements prepared at lab. scale indicate normal compressive strength and generally demand less water than control cement (OPC).
- Compressive strength in PLC cements increases with age.
- Both the HGLS and LGLS PLCs exhibit similar trend in percent decrease of strength.
- Setting time is increased while water demand is decreased in plant scale manufactured PLC.
- Hydration studies also indicates continuously increase in hydration products with time indicate progressive hydration.
- Apart from competing for product performance and green value addition, PLC offers a win-win situation with net cost saving ~ 252 Rs/ton.