Pilot Scale Production of Limestone Calcined Clay Cement

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Abstract. Limestone Calcined Clay Cement (LC^3) was produced on a pilot scale in a cement grinding unit. Raw clay was obtained from mines in Gujarat. Raw material that was otherwise unusable in applications like paint and paper was found to be suitable for the production. While most of the calcination of clay is being carried out using furnace oil and bio-mass, even petcoke was found to be suitable for application to LC^2 to achieve cost reduction. Quality control was carried out using XRD, TGA and visual observation and the clay was carefully sorted into batches based on the test results. LC^3 and LC^2 were produced by inter-grinding the raw materials and a normal ball mill was found to be adequate for the production process. The test results showed that while Blaine's fineness test may be a good initial measure to control the grinding process, due to differential grindability, laser diffractometry can provide a better assessment of grinding of all components of the cement. It was found that both LC^3 and LC^2 can be produced using widely available technologies with very little modifications. Physical tests on LC^3 and LC^2 were carried out and both were found suitable for general applications and some special applications.

1 Introduction

LC^3 is a new family of ternary cements that is being developed in a large international collaboration [1]. The cement provides several benefits such as improved durability along with lower emissions and a better utilisation of resources. While pilot productions of LC^3 have been carried out earlier in Cuba and India [2, 3], the first worldwide production of LC^3 by a cement company was carried out by JK Lakshmi Cement Ltd. in India. It is expected that both LC^3 and LC^2 can be produced as commercially viable products [4]. A detailed testing and pre-production programme was implemented to ensure a good quality of production. The measures taken, challenges faced and the lessons learnt are discussed in this article.

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2 Identification and Preparation of Raw Materials

It was decided to source the clinker, limestone and gypsum from the cement plant of JK Lakshmi at Sirohi in Rajasthan. Large quantities of unused limestone of grade lower than that required for clinker production are available at this plant. The limestone was characterised and it was found to contain approximately 60% of calcite content. The impurities were mainly composed of quartz, kaolinite, muscovite, etc. The clinker was found to contain approximately 50% of alite and XXX% of belite. Imported mineral gypsum was used.

Clays were sampled from several mines in Rajasthan and Gujarat. The approximate kaolinite content was estimated from the TGA measurements. A clay with approximately 60% kaolinite content was selected for the production. Calcination of the clay was carried out in a rotary kiln in Bhuj. The firing in the kiln was carried out using petcoke. Although the kiln was designed for higher temperatures, with some adjustment, it was possible to maintain its temperature at a level that was suitable for the calcination of clay. It was found that an air temperature of 900 °C to 950 °C was required to maintain a solid temperature of 800 °C to 850 °C, which is required for a proper calcination of the clay. Samples of calcined clay were drawn every 10 min initially and tested using XRD and TGA to check if they were properly calcined. Since the samples had to be sent outside the plant for XRD and TGA, loss on ignition measurements between 450 °C and 800 °C were used to approximately assess the calcination. Interestingly, it was found that the plant operators, who were experienced in calcination of clays, were able to assess the quality of calcination visually and that their assessment matched well with laboratory characterisation results.

A large variation in the calcination was observed initially with some samples found to be over calcined and some under calcined. However, after some trials, it was possible to control the temperature in the kiln by controlling the feeding rate of the fuel and the raw material and the rotational speed of the kiln. Around 200 tonnes of clay were calcined using this process.

3 Production of LC^3

All raw materials were packed and transported to the Jhajjar unit of JK Lakshmi Cement Ltd. for the production of LC^3 by inter-grinding in a closed circuit ball mill. The entire process of production was planned in advance and electrical and mechanical maintenance teams were kept on stand-by for adjustments that may be required. The quality control laboratory was set up to measure the retention on 90 μm and 45 μm sieves and to carry out the Blaine's fineness measurement of the cement.

The ball mills were first cleaned and purged with the raw materials to remove residual materials from earlier productions. Blends of LC^3 were prepared by intergrinding 50% clinker, 31% calcined clay, 15% limestone and 4% gypsum. Clinker and gypsum were fed first into the mill and the feeding of the other materials was started once the clinker had been ground to sufficient fineness. The feeding of limestone and calcined clay was then started. It was found that it took approximately 15 min for the product to be stabilised. The stability was assessed from the slightly red colour of the product.

Samples of LC^3 were drawn every 10 min and the fineness of the cement was measured using sieve analysis and Blaine's fineness. The fineness of the cement was consistently found to be over 600 m^2/g. Approximately 6% to 7% of the cement was found to be retained on the 90 μm sieve, while approximately 25% of the material was found to be retained on the 45 μm sieve. Around 200 tonnes of LC^3 and 140 tonnes of LC^2 were produced and packaged separately. Due to the high capacity of the mills, the entire process took less than 4 h. Only minor adjustment of feed and rotational speed of the mill were required during the production process and no major issues were faced. Through this production process it was found that it is possible to produce LC^3 without major changes to existing technologies.

4 Properties of LC^3 Produced

The physical properties of LC^3 were measured. Although the strength of the cement was found to meet the requirements of pozzolanic cements, its strength was lower than that typically observed for the cement. When the particle size distribution of the cement and the composition of various fractions of the cement was analysed, it was found that a significant fraction of the clinker remained in sufficiently ground. This is due to the relatively higher hardness of the clinker compared to the other components. Upon regrinding, acceptable strengths were obtained from the cement. This result shows the importance of controlling that not only the overall fineness, but also the particle size distribution of the cement. Figure 1 shows the influence of further grinding on the particle size distribution of the cement. Figure 2 shows the influence of grinding on the heat of hydration of the cement.

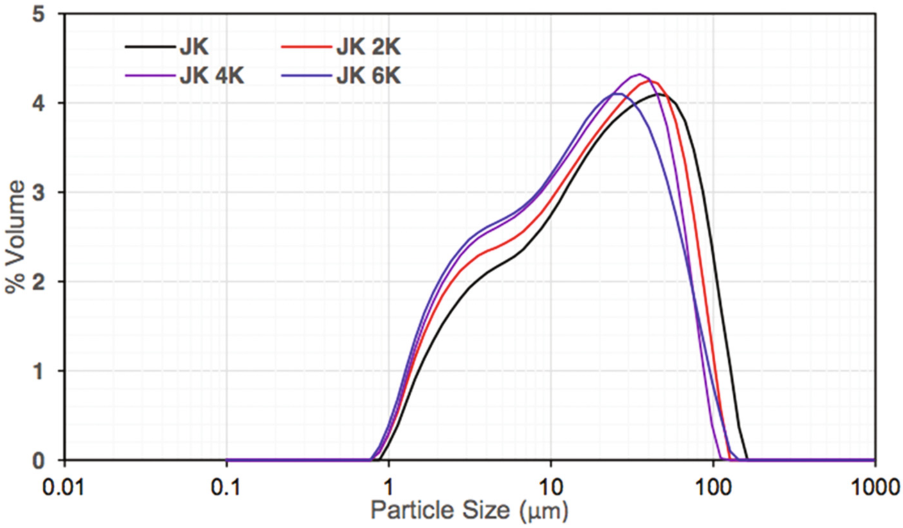

Fig. 1. Influence of additional 2000, 4000 and 6000 revolutions of grinding on particle size distribution of LC^3

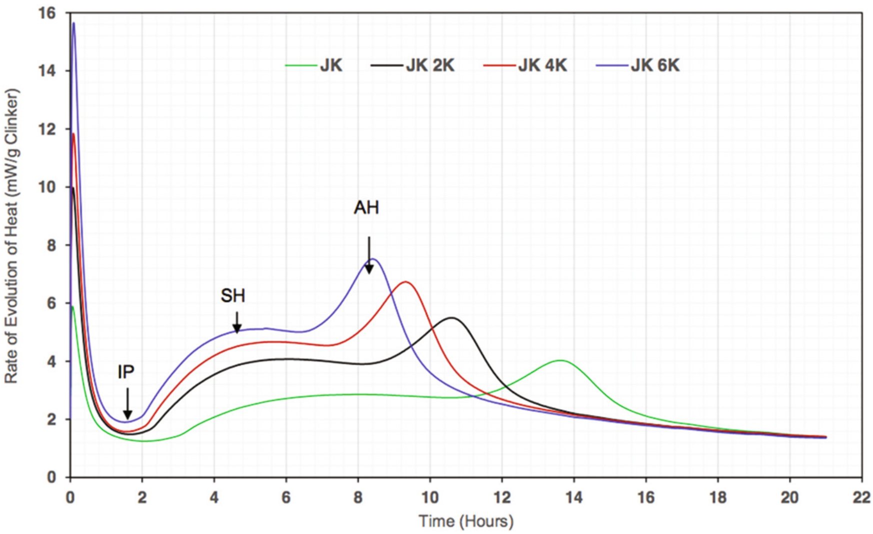

Fig. 2. Influence of additional 2000, 4000 and 6000 revolutions of grinding on isothermal heat of hydration of LC^3

5 Properties of LC^2 Produced

Limestone Calcined Clay Pozzolan, or LC^2, was produced by intergrinding 66% calcined clay and 34% limestone. After the grinding it was found that most of the powder passed through the 45 μm sieve. The Blaine's fineness of the LC^2 produced was more than 1000 m^2/g and was difficult to measure accurately. Due to the similar hardness of calcined clay and limestone, both were found to be properly ground in the LC^2.

6 Applications of LC^2 and LC^3

The LC^3 and LC^2 produced were used in various applications such as in ready mix concrete, paving of a concrete road. It was found that although the water demand was higher, good quality self-compacting concrete could be produced using the cement. In the RMC plants, LC^3 could be used directly in place of cement and LC^2 could be used as a pozzolan to reduce cement content in concrete. It was also found that there was a significant reduction in the sorptivity and RCPT values of concrete upon the replacement of OPC with LC^2 in concrete mixes. Figure 3 shows the influence of replacing up to 20% of OPC with LC^2 on the sorptivity of concrete. Figure 4 shows the influence of replacing up to 15% of OPC with LC^2 on the RCPT values of concrete.

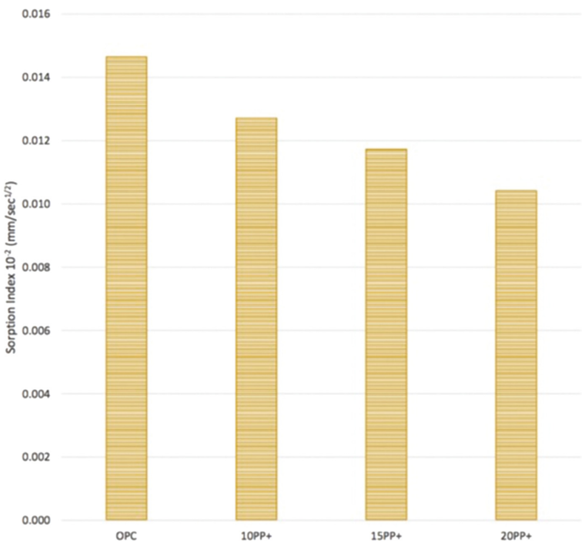

Fig. 3. Influence of replacement of 10%, 15% and 20% of OPC by LC^2 on sorptivity

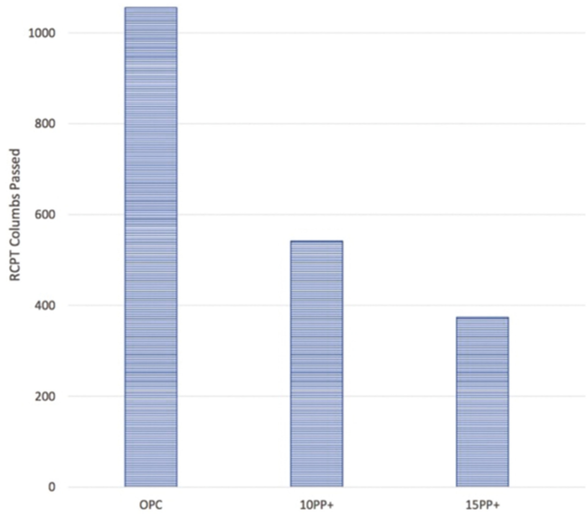

Fig. 4. Influence of replacement of 10% and 15% of OPC by LC^2 on RCPT

7 Conclusions

JK Lakshmi Cement Ltd. carried out the first production of LC^3 and LC^2 by a cement company. It was found that the cement could be easily produced using existing technologies although basic adjustments were required. Petcoke could be used as fuel to control the cost of production and the cement could be inter-ground in a commercially used closed-circuit ball mill. It was found that it is important to control the particle size distribution of the cement. Concretes with high strength and flow were produced using both LC^3 and LC^2 and it was found that there was a significant improvement in the durability indices of concrete upon the partial replacement of OPC with LC^2.

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