Limestone Calcined Clay Cement Project

LC\textsuperscript{3} is a ternary cement that can achieve strengths similar to OPC even at clinker factors as low as 40\% to 50\%. The remaining cement is a blend of crushed limestone and calcined clay. LC\textsuperscript{3} promises to support a sustainable growth by reducing emissions, energy consumption, capital and production costs, and wastage of raw materials.

LC\textsuperscript{3} has been developed in an international collaboration between the University of Las Villas, Cuba and Ecole Polytechnique Fédérale de Lausanne, Switzerland, which was funded by the Swiss government. LC\textsuperscript{3} takes advantage of the synergetic hydration of clinker, calcined clay and crushed limestone to achieve the performance required from commercial cements, even at clinker factors as low as 0.40. The low quality limestone and clay used in the LC\textsuperscript{3} blend ensure that the cement can be produced at costs lower than even PPC, without the risk of unsoundness. Since clays with low kaolinite contents, after calcination at relatively lower temperatures of 700°C to 800°C, can be used along with low calcite limestones with impurities such as quartz and dolomite, this cement can reduce wastage of raw materials and increase the life of mines. Furthermore, the lower processing required in the ingredients of LC\textsuperscript{3} ensures a lower capital investment required for the same incremental increase in production capacity.

Funded by the Swiss Agency for Development and Cooperation, this project will carry out the research and development required to develop a standard that would allow the use of this cement in general use applications. The international, collaborative and inclusive approach makes this a unique project that will consider the interests and concerns of stakeholders from academia and industry, and the government. Most importantly, LC\textsuperscript{3} promises to support the commitment of the Indian cement industry to grow sustainably.

Researchers from IIT Delhi, IIT Madras and IIT Bombay are working together with the personnel of TARA to understand and develop LC\textsuperscript{3} for the Indian cement Industry. The current studies focus on:

- Ecology and economy including energy, emissions, resource availability and capital and production costs,
- Workability and ease of construction including water demand, admixture compatibility, rheology, setting and fineness,
- Mechanical properties including compressive, tensile and flexural strength, creep and shrinkage,
- Durability including transport properties, corrosion due to carbonation and chloride ingress, alkali silica reaction, sulphate attack and leaching.

Through this work, draft standards on LC\textsuperscript{3} will be developed and submitted to the Bureau of Indian Standards to allow the use of the cement in India.
The LC$^3$ Technology

Two pilot productions of LC$^3$, producing around 170 tonnes of five different blends of the cement, have been carried out in India. Several other blends of LC$^3$ have been produced and tested in the laboratory. Wide-ranging laboratory and field studies on LC$^3$ have been carried out in India and the current understanding of LC$^3$ is discussed below.

The production of LC$^3$ requires either inter-grinding or blending of clinker, limestone, calcined clay and gypsum. Clays, typically containing 50% to 60% of kaolinite have been found to be suitable. Such clays are widely available in India with ferruginous minerals, other clay minerals and quartz as impurities and are not suitable for use in other industries. The clays can be calcined at 700 °C to 800 °C to remove its chemically attached hydroxyl groups, making it amorphous and reactive. Suitable clays can be easily identified by measuring the weight-loss in the clay between 300 °C and 800 °C using Thermo Gravimetric Analysis (TGA) or a muffle furnace since the kaolinite phase loses 14% of its weight in this temperature range. This can be verified using X-Ray Diffraction (XRD), where the kaolinite and other peaks are visible.

Siliceous and aluminous limestones with as little as 35% CaO and dolomitic limestones with as little as 29% CaO and 21% MgO, measured using X-Ray Fluorescence have been found to be suitable for LC$^3$. Such limestone is widely available limestone mines of cement plants in India and is generally not usable for clinker production. Suitable limestones can be identified by measuring the weight-loss between 700 °C and 800 °C and by XRD. The calcined clay and limestone can be ground or blended with normal clinkers and gypsum available in India.

LC$^3$ blends containing around 50% clinker along with clay and limestone in gravimetric ratios of 2:1 have been found to give 28-day strengths similar to OPCs made using the same clinker. This is due to the synergetic reaction of all components of LC$^3$ with each other. While the early (1 to 7 day) strength of LC$^3$ has been seen to be similar to slightly lower than OPC, it is higher than that of PPC produced using the same clinker and a typical Indian fly ash. The fineness of the clay should be controlled since finer clays can increase water-demand of the cement. The presence of limestone reduces the water-demand of the cement.

LC$^3$ is understood to have a finer pore-structure than OPC and a high chloride binding capacity. It is therefore durable against corrosion, sulphate attack and other deterioration mechanisms, making it suitable in aggressive conditions.

It is expected that LC$^3$ will be economical to produce at most locations where good quality fly ash is not available easily. CO$_2$ emissions from LC$^3$ production are expected to be 30% lower than OPC and 11% lower than PPC. Energy consumption in its production is also expected to be lower than OPC and PPC.