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Limestone Calcined Clay Cement as a Green Construction Material

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Abstract

The use of supplementary cementitious materials (SCMs) to replace part of the clinker in cement is the most successful strategy to reduce CO_2emissions in the global cement industry. Combination of calcined clay with limestone allows higher levels of substitution down to clinker contents of around 50% with similar mechanical properties and improvement in some aspects of durability. The main objective of the paper is to focus on production, techno-economic feasibility, environmental impact and cost effectiveness of the LC^3 cement. LC^3 may be a new sort of cement supported a mix of limestone and clacined clay.

Keywords: *Limestone, LC^3, Sustainable Material, Clinker, CO_2 emission, Calcined Clay*

1. Introduction

LC^3 is a new blend of limestone and calcined clay which have synergetic effect results good resistance against chemicals attack and ability to protect reinforcement by replacing 50% of clinker content for cutting up to 40% of CO_2 emissions.

It shows chemical composition of 15% limestone, 30% calcined clay, 5% gypsum and remaining all are clinkers. Limestone and Calcined clay are available in abundant quantities so, LC^3 is cost effective and does not require expensive modifications in existing cement plants.

It is need to know more about this cement regarding its production, environmental sustainability, durability, strength, techno-economic feasibility.

2. Why Limestone and Calcined Clay?

2.1 Limestone

Limestone is not calcined; thus, it does not contribute to an increase in CO_2 emissions. The calcium carbonate supplied through limestone to the system and therefore the extra alumina provided by calcined clay will further react to form alumina phases. In normal blended cements, the limit on pozzolan addition is 35%.

The limited supplies of conventional SCMs make it difficult to take this strategy further unless new types of SCMs become available. The only type of material available in the quantities needed to meet demand is clay containing kaolinite, which can be calcined to produce an effective SCM. Such clays are widely available in countries where most growth in demand for cement is forecast.

2.2 Calcined Clays

Calcinedclays have previously been used as pozzolans but calcination makes the economics ofsubstitution marginal in a conventional pozzolanic blend. The major innovation presented here is that the possibility to form a coupled substitution of cement with calcined clay and limestone. This allows much higher levels of substitution.

Blends where calcined clay is employed as a pozzolan, typically have clinker contents around 65–70%. Combination of calcined clay with limestone allows higher levels of substitution down to clinker contents of around 50% with similar mechanical properties [6] and improvement in some aspects of durability. The replacement of clinker with limestone in these blends lowersboth the value and therefore the environmental impact.

3. Differentiation in $LC^3$and OPC

Traditional Portland cement consists of 95% clinker. The production of it's energy-intensive and liable for most of the CO_2 within the cement. By reducing the clinker-content with so called Supplementary Cementitious Materials (SCMs), large CO_2 savings can be achieved.

LC^3 may be a new blend of two materials which have a synergetic effect. It can reduce half of the clinker content and hence cut up to 40% of the CO_2emissions. LC^3 uses industrial waste materials which thereby increase the resource efficiency and reduce the utilization of the scarce raw materials that are necessary for producing clinker.

LC3 may be a ternary cement which will achieve strengths almost like OPC even at clinker factors as low as 40% to 50%. The remaining cement may be a blend of crushed limestone and calcined clay. LC3 promises to support a sustainable growth by reducing emissions, energy consumption, capital and production costs, and wastage of raw materials. LC3 has been developed in a world collaboration between the University of Las Villas, Cuba and Ecole Polytechnique Fédérale de Lausanne, Switzlerand, which was funded by Swiss government.

LC3 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 inferiority limestone and clay utilized in the LC3 blend make sure that the cement are often produced at costs less than even PPC, without the danger of unsoundness. Since clays with low kaolinite contents, after calcination at relatively lower temperatures of 700°C to 800°C, are often used along the side low calcite limestones with impurities like quartz and dolomite, this cement can reduce wastage of raw materials and increase the lifetime of mines. The lower processing required in the ingredients of LC3 ensures a lower capital investment required for the same incremental increase in production capacity.

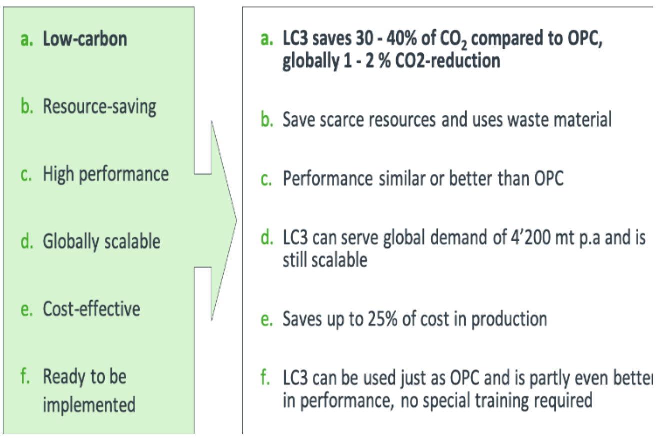

Fig. 1 Why LC3? (Reference: www.lc3.ch [accessed on,02/04/2021,08.00am])

4. Mechanical Attributes of LC3 Cement

4.1.Compressive Strength

LC3 60% - OPC 40% mix compressive strength gives 3.98% quite conventional concrete.Investigation of influence of the gypsum content on the compressive strength of a LC3 cement. For the accomplishment of the study 6 mortors were produced. In three of them the cement used was produced with 3,5,7% gypsum, without SCM's [3]. In three mortors, a 45% replacement cement was used (30% calcined clay and 15% limestone). The proportion of gypsum in these cements was 3,5 and 7% in reference to the entire mass. For the hardened state analysis, the compressive strengths were compared at the ages of 1,3,7,28 and 91 days. From the result obtained it had been possible to verify that gypsum content influencethe compressive strength of the LC3 cement. The highest mechanicalstrengths were obtained with the utilization of larger quantities of gypsum.

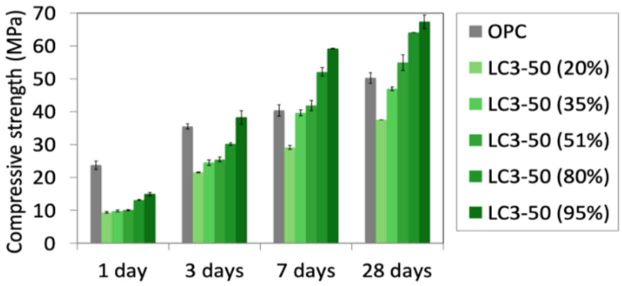

Fig. 2 Compressive strength (Reference: https://lc3.ch/why-lc3/ [accessed on 02/04/2021, 09.10am])

4.2.Fineness

The effect of fineness of the various components during a blend containing 55% hydraulic cement, 30% calcined clay and 15% limestone. The calcined clay originates from a natural deposit in Cuba and contains but 50% kaolinite [4]. The particle size distribution (PSD) of every of the three components was varied by using different grinding times and therefore the consequences on heat release, strength development, pore structure.Higher fineness of both clinker and calcined clay can considerably improve compressive strength in the least ages while limestone fineness only plays a task at early age.

4.3. Flexural Strength

The flexural strength of LC3 100% mix improved as 3.81% quite conventional concrete cured at 28 days, it had been found that LC3 50% - OPC 50% has lower percentage of improvement as compared to other combinations. From the test results [5] LC3 60% - OPC 40% mix flexural strength gives 6.73%quite conventional concrete.

4.4. Sturdiness

An extensive testing program is underway, including both laboratory and natural exposure studies [10]. The results thus far indicate:

- Good protection of reinforcement
- Excellent resistance to chloride penetration
- Good mitigation of ASR with reactive aggregates
- Good performance in presence of sulphates
- Carbonation like other blended cement

The phases present in LC3 cements are same as those present in blended cements currently widely utilized in practice. However, there's high degree of refinement. The kinetics of pore refinement depends on the first kaolinite content of the calcined clay. In fact, at 28 days, all cement pastes made with calcined clays, even those with very low original kaolinite content; have a pore structure finer than pastes made with hydraulic cement.

5. Utilizations of LC^3

1) Utilized in Hydraulic structures, marine structures, construction near the ocean shore, dam construction etc.
2) Utilized in pre-stressed and post-tensioned concrete members.
3) Utilized in masonry mortars and plastering.
4) Utilized in decorative and art structures.
5) Utilized in manufacture of precast sewage pipes.
6) Utilized under harsh concrete conditions.

6. Economical efficiency of LC^3

LC^3 isvery competitive in performance and economic terms. It shows very similar performance characteristics compared to standard hydraulic Cement and even outperforms traditional cement in some regards like resistance to chloride and alkali-silica reaction (called ASR or "concrete cancer"). Aside from the laboratory testing at EPFL and therefore the IITs, several applications are constructed and that they showed very positive results.

LC^3 is up to 25% cheaper in production thanks to the reduction of the energy-intensive clinker content with widely available and fewer energy-intensive materials. Investment costs also are low since already existing technologies [2] are often used for the assembly of LC^3.Moreover, this existing economic attractiveness are often further increased by governments through incentives like tax-reductions so as to accelerate the assembly of LC^3.

7. Overall effect of LC^3

On a worldwide level, it is estimated that the use of LC^3 rather than regular cement can save to 400million tons [7] of CO_2 annum by 2050. This amount equals France's entire yearly CO_2 emissions.

When watching LC^3 in terms of frameworks like the United Nations Sustainable Development Goals (SDGs), its potential to contribute to climate action efforts becomes clear. Among other contributions, LC^3- Low Carbon Cement are often directly related to 5 of the 17 Sustainable Development [2]Goals.

Conclusion

Climate protection and development efforts are essential for sustainable environment.LC^3 is that the answer to both of those important goals together. Constructions projects can now be realised with a more efficient material which thereby saves 30% of CO_2 emissions. Hence, LC^3 may be a solution for well-adapted sustainable development ambitions.

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