LC^3 – THE GREEN CEMENT

HIGH QUALITY, LOW CO_2

Photo: LC^3 Industrial trial at Cementos Progreso facilities

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WHAT IS LC^3?

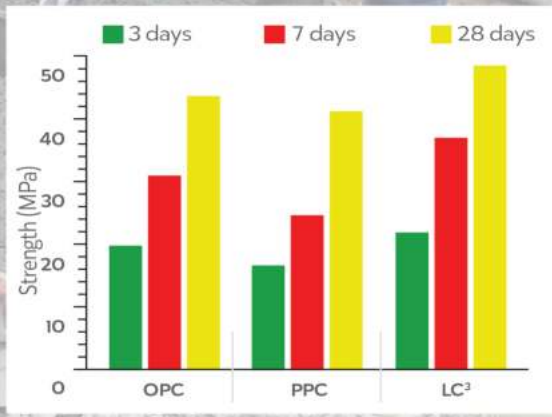
LC^3 or Limestone Calcined Clay Cement is a family of composite cements containing Portland clinker, calcined clay and limestone. The LC^3 technology promises a sustainable growth of economies around the world by reducing up to 40% CO_2 emission compared to Ordinary Portland cement at lower investment and production costs. LC^3 uses raw materials and technologies that are already used by the cement industries. The production process is similar to the way of producing normal cements. Thus, they provide a practically viable solution to improve sustainability in the cement industry.

40% Less CO_2 Emissions

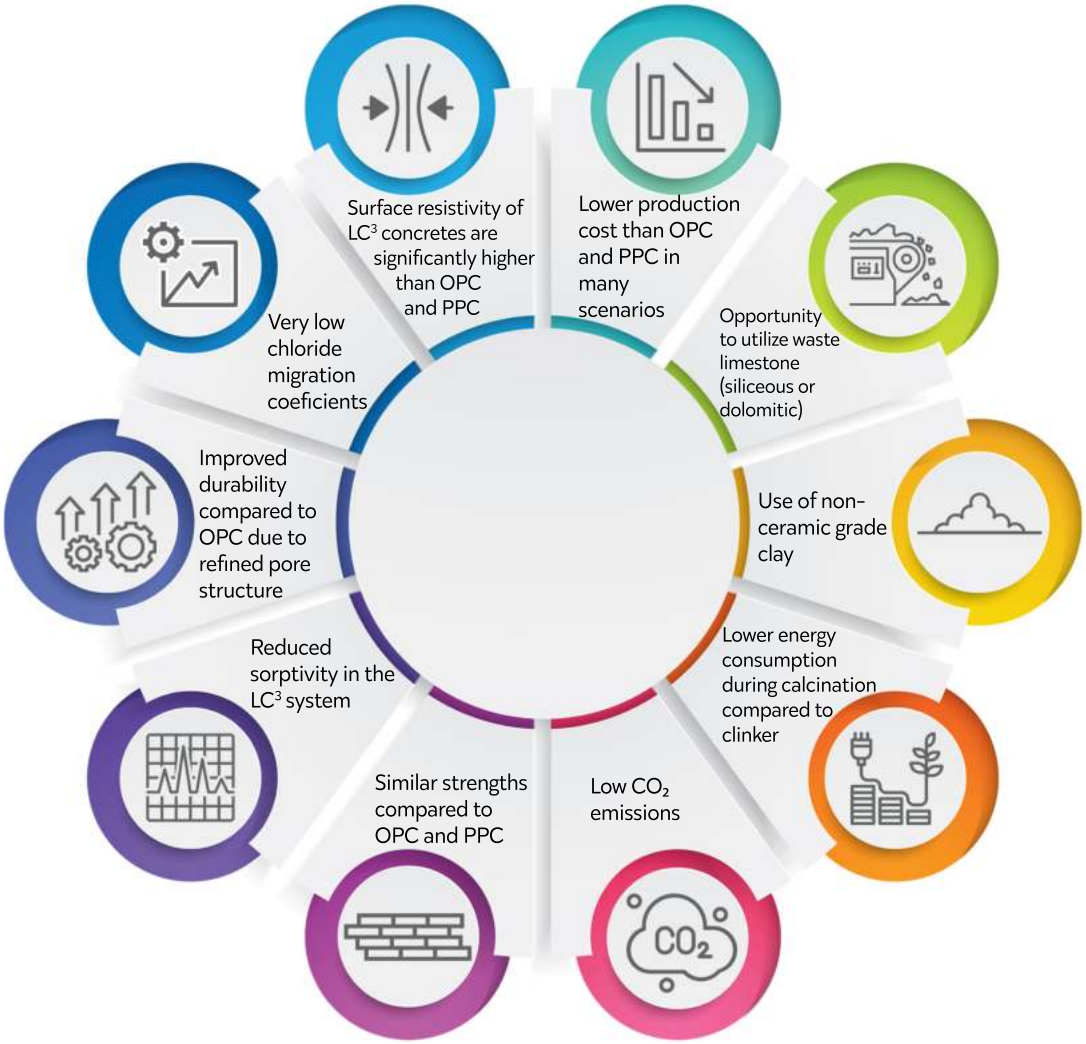
MECHANICAL AND OTHER PHYSICAL PROPERTIES OF LC^3

LC^3 has been seen to develop ultimate strengths similar to PPC produced using the same clinker. Strength development in LC^3 has generally been observed to be faster than PPC. LC^3 is expected to satisfy all the other requirements physical characteristics laid down in most of the country standards. Additionally, calcined clay and limestone improves the cohesion of fresh concrete which prevents segregation and bleeding.

A COMPARISON OF OPC, PPC AND LC^3 PRODUCED USING THE SAME CLINKER AND THE SAME PROCESS (EN-197)



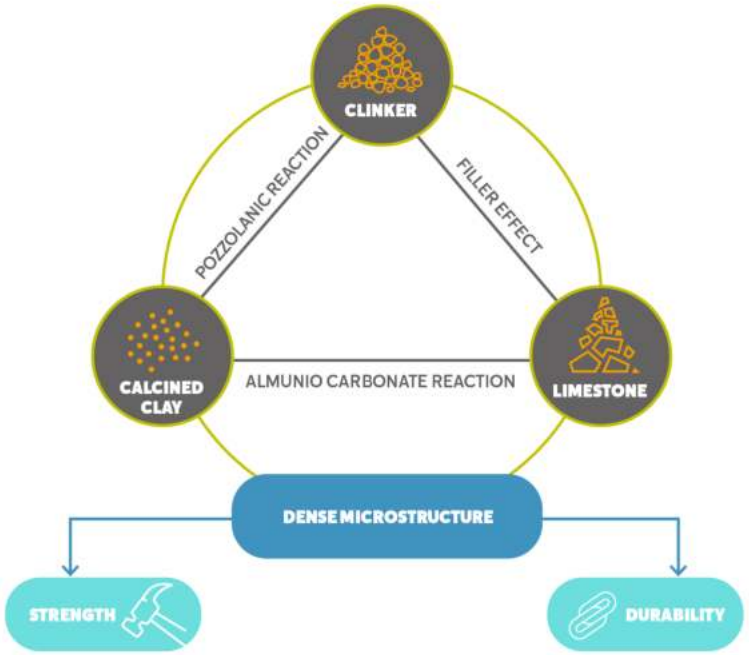
ADVANTAGES OF LC³ TECHNOLOGY



SYNERGY WITHIN LC³

LC³ works on the synergy between clinker, calcined clay and limestone phases. Calcined clay reacts with hydration products of clinker and limestone reacts with calcined clay, giving phases that make the microstructure denser. Calcined clays have been long used as pozzolanic materials in cements, and limestone is an established semi-reactive filler in cements. Recent developments have proven that lower grade kaolinitic clays (up to 40% kaolinite) can yield good results; further the synergy between calcined clay and limestone enables a higher clinker substitution for similar mechanical properties and improved durability.


Material science laboratory at TRC LATAM facilities



RAW MATERIALS FOR LC³

The main raw material in LC³ is kaolinitic clay. Clays containing 40% to 60% kaolinite are ideal for the production of LC³ and can produce gray concrete. Such clays are abundantly available as waste in mines where higher grade white clays are used for high value applications. The clays are calcined between 700° C to 850° C to make them reactive. Calcination requires only half the energy of clinker production. Limestone with as little as 75% calcium carbonate content can be used. These low grade limestones, as well as dolomitic limestones are often rejected in cement plant quarries. Limestone with impurities such as quartz can also be used in LC³ production. No calcination of the limestone is required. Apart from calcined clay and limestone, Ordinary Portland clinker is used in the production of LC³.

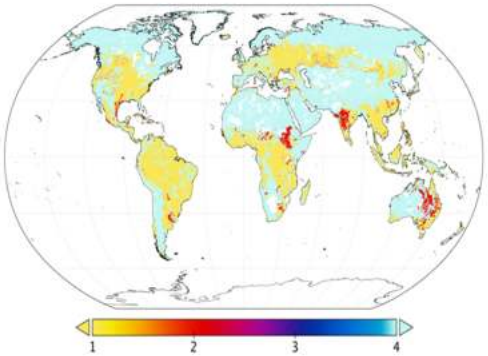
Caolinitic Clays Deposit

CLAYS ARE CALCINED BETWEEN 700°C TO 850°C

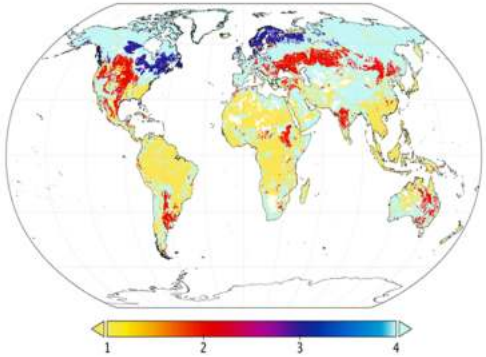
www.martirena.com

COMPARED TO CLINKERIZATION TEMPERATURE OF 1450°C FOR CLINKER PRODUCTION

UTILISATION OF LOWER GRADE LIMESTONES WITHOUT EVEN CALCINING IT



Dominant clay mineral (topsoil) (type)
Data min = I, Max = 4, Mean =3



Dominant clay mineral (subsoil) (type)
Data min = I, Max = 4, Mean =3

CHARACTERIZATION OF RAW MATERIALS

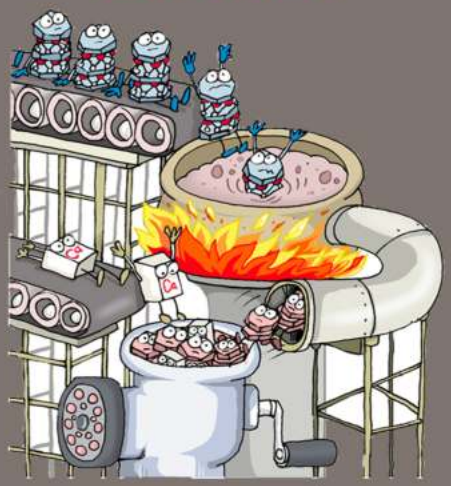
The suitability of clays and limestones required for the production of LC³ can be characterized using loss on ignition, thermogravimetric analysis, X-ray fluorescence or X-ray diffraction techniques. These techniques are available in most cement plants and are routinely used to characterize cements and other raw materials. Existing standard test methods can also be used to identify suitable combinations of clays and limestone. The reactivity of calcined clay is measured through isothermal calorimetry or the simple lime reactivity methods. Once produced, quality control of LC³ can be easily carried out by measuring strength and other methods commonly used for OPC and PPC.

Material science laboratory at TRC LATAM facilities

COMPOSITION AND PRODUCTION OF LC³

For calcination of clays, normal rotary kilns are most used solution. Due to lower temperatures and lower energy, the capital investment required for these rotary kilns is likely to be much less than that of cement kilns of the same capacity. Flash calcination and fluidized bed reactor technologies are also suitable for clay calcination. The choice depends on productivity, CAPEX, familiarity and ease of operation. LC³ can be produced in a similar manner as OPC by intergrinding or blending. The softer nature of the materials considerably reduces grinding energy, although, as is the case with many composite cements, separate grinding may be desirable. Ball mills or vertical roller mills can be used for grinding.

Easier to Grind



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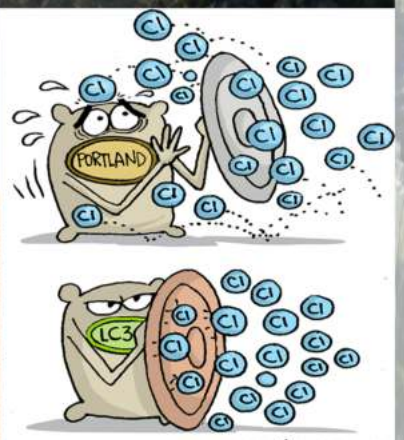
THE SOFTER NATURE OF THE MATERIALS CONSIDERABLY REDUCES GRINDING ENERGY

LC³ Cement Plant in Ivory Coast

Concrete blocks made with LC³/PPC. Exposure Site at Cayo Santamaría, Cuba

HIGH CHLORIDE RESISTANT
+
DENSE MICROSTRUCTURE
+
HIGH RESISTIVITY
=
IDEAL FOR HARSH CONDITIONS



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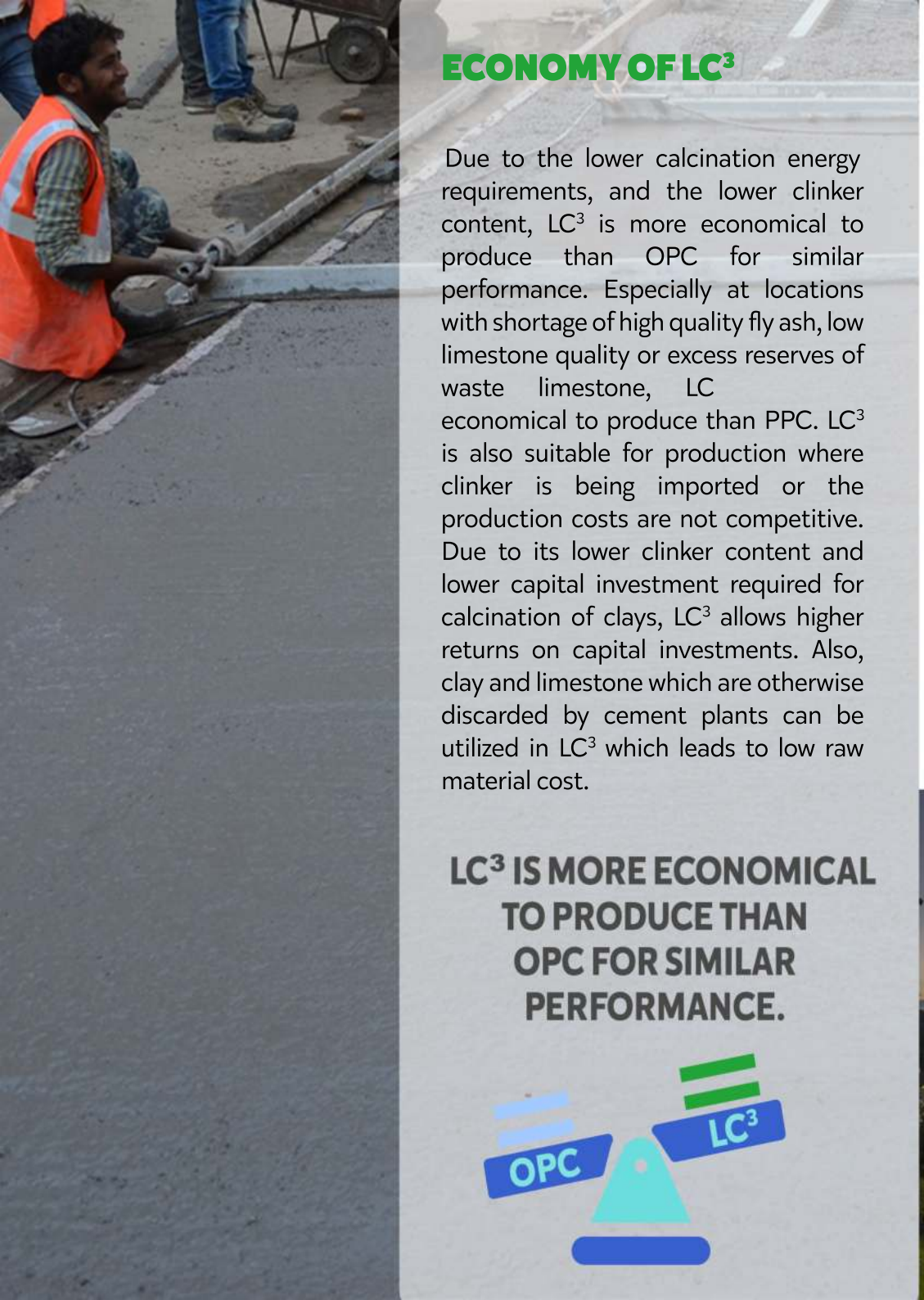
DURABILITY OF LC³

Under most severe conditions e.g. marine, desert and others, the performance of LC³ is better than or at par with OPC. LC³ has a high chloride penetration resistance and produces a dense microstructure with high surface resistivity making it ideal for harsh conditions like in marine or desert environment. LC³ is also highly suitable for use with reactive aggregates that are normally rejected for concrete production.

LC³ concrete blocks laid at 2013 at an exposure site offshore in the northern coast of Cuba under very harsh conditions confirm the superiority of LC³ concrete in a very harsh environment. The blocks show no sign of corrosion. Similar blocks made with portland cement present significant degree of corrosion.



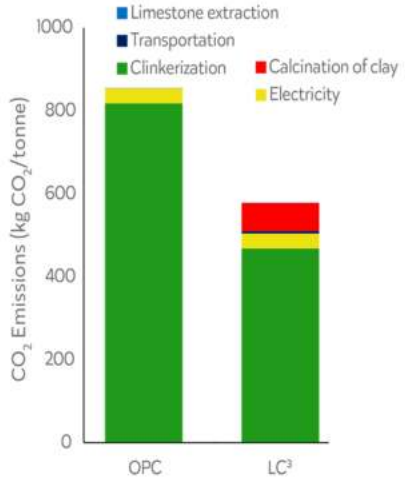
ECONOMY OF LC³

Due to the lower calcination energy requirements, and the lower clinker content, LC³ is more economical to produce than OPC for similar performance. Especially at locations with shortage of high quality fly ash, low limestone quality or excess reserves of waste limestone, LC
economical to produce than PPC. LC³ is also suitable for production where clinker is being imported or the production costs are not competitive. Due to its lower clinker content and lower capital investment required for calcination of clays, LC³ allows higher returns on capital investments. Also, clay and limestone which are otherwise discarded by cement plants can be utilized in LC³ which leads to low raw material cost.

LC³ IS MORE ECONOMICAL TO PRODUCE THAN OPC FOR SIMILAR PERFORMANCE.

EMISSIONS AND RESOURCE EFFICIENCY FROM LC³

The production of LC³ emits as much as 40% less CO_2 than OPC and 11% less CO_2 than PPC. The production of LC³ implies less energy consumed in comparison with OPC. LC³ also offers an interesting solution for the utilization of low grade quarry rejects widely available with the cement and ceramic industry. Thus, while it reduces GHG emissions from the cement industry, it also helps in utilization of waste materials, thereby promoting resource efficiency of materials.



THE ENERGY CONSUMED IN PRODUCING LC³ IS ALSO SIGNIFICANTLY LOWER THAN OPC AND EVEN LOWER THAN PPC IN MANY SCENARIOS

ARGOS Colombia cement plant

HISTORY OF LC³ DEVELOPMENT

Towards the end of the last century, at the Universidad Central de Las Villas, the investigations in blended cements began to concentrate on the use of clays. In 2004, Prof Fernando Martirena from UCLV and Prof Karen Scrivener from EPFL in Switzerland discussed for the first time about the use of calcined clays for pozzolans. In 2005, Scrivener and Martirena launched together the first research project on this topic supported by the Swiss National Science Foundation (SNSF) and the Swiss Agency of Development and Cooperation (SDC).

3rd. International Conference on Calcined Clays


Prof. J. Fernando Martirena and Prof. Karen Scrivner

In 2013, a global project on Limestone Calcined Clay Cement was formed, integrating India as second focus region. Since 2017 two Technology Research Centers in Cuba and India were set up. In the course of this phase, academic and policy circles as well as the top global cement producers widely acknowledged LC³ as the technology with the highest potential to lower CO_2-emissions in the cement sector. The investigation of economic feasibility and the possibility of color control were milestones for the industrial engagement. The technology has received high attention for example by Bloomberg and TED Talks.


TRC LATAM team at LC³ Pilot Plant

THE LATIN AMERICAN TECHNOLOGY RESOURCE CENTER

Photo: LC³ pilot plant the TRC LATAM

The LC³ Technology Resource Centre (TRC) in Santa Clara has been established to act as interface between industry and academy for a swift introduction of the new developments in LC³ technology. With a professional team of geologists, chemists, engineers and economists, and more than 40 years of field and lab experience, the LC³ TRC LATAM is a reliable provider of green solutions for the construction sector. To date the TRC has established contacts and forged business relationships for LC introduction with more than 20 cement companies and investors in Latin America, Europe, and Africa.

At present, the TRC can offers complete adviced on the scheme of Engineering, Procurement and Construction in partnership with equipment providers. The services of TRC include identification of suitable clay candidates, technical support in sample taking, mineralogical and chemical characterization of the material, assessment of clay reactivity, realization of industrial trials, evaluation of potential applications, environmental and economic feasibility studies and on equipment selection.

Since 2019 the TRC has a fully operational LC³ pilot plant able to provide experimental and training services. This pilot plant has incorporated systems to automatically control calcination and grinding parameters. It also counts with a specialized material science laboratory for characterization and evaluation of the tested materials.

The TRC maintains an active role in research on new applications for LC³ with more than 8 PhD projects and the participation in the most significant worldwide scientific events. Its members are also involved in INNOVANDI's project "Calcined Clays" focusing on knowledge exchange between academia and the industry. During the 2021 TRC Latin America has developed a new formula for a dry mix mortar based on LC³ with high expansive properties, especially designed for its application in sealing joints in water channels. Other similar products are also in development process.

LC³ IS IN THE MARKET!

As a first result of the consultancy of the TRC and its partners, two commercial productions of Limestone Calcined Clay Cement started in Colombia and Ivory Coast. Production of the new "green" cements amounted to some 3 Mt, with a CO_2 saving of more than 750 Kt at the end of 2021.

Although the pandemic has seriously slowed down investment decisions during the last 18 months, in several more countries in Latin America, Africa, India and Europe there are advanced plans to invest in setting up LC^3 production.

LC^3 has entered commercial production since 2020, with the start of the production of Cemento Verde at ARGOS in Colombia. Soon after CIMPOR started production at a plant in Ivory Coast of their product DeOHclay. Other LC3 plants have been announced in Cameroon (www.thyssenkrupp.com) and France (https://vicat.fr), and several companies are preparing investment for the launch of LC^3 production in the next five years. Application of the new LC^3 cement in real demo projects prove similar, or even improved properties compared to OPC.

EPFL

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