Limestone Calcined Clay Cement Makes Inroads in Reducing Carbon Emissions

by Andrea Schokker and Karen Scrivener

As the effects of global warming become more evident, cement and concrete are increasingly part of the conversation, contributing as much as 6 to 8% of global CO_2 emissions.[1] The climate crisis has moved the industry to consider technologies that can successfully reduce CO_2 emissions in both the short- and mid-term. With a goal of maintaining the global temperature rise below 2°C (3.6°F) above pre-industrial levels, novel approaches are now being introduced.[2]

One process that has produced substantial results is the use of limestone calcined clay cement (LC3). LC3 contains about 50% ordinary portland cement (OPC), providing the same ease of use and strength as OPC, and is the most effective way to reduce the amount of clinker used. LC3 offers both a technological and economical approach to reducing clinker use in the cement industry on a global scale. Using LC3 can save up to 40% CO_2 emissions compared to OPC. Additionally, it is important to note that the reliability and versatility of the limestone calcined clay combination opens up the possibility of use and acceptance in markets where blended cements or mineral additions are normally used.[3]

What is LC3?

LC3 is a blend of two materials that, when combined, have a synergetic effect. It allows the reduction of as much as half of the clinker content, resulting in cutting up to 40% of the CO_2 emissions. Along with the CO_2 savings, existing equipment can be used, a huge advantage in the production process. While the production line must be adjusted—because limestone and calcined clay are added—it is a quick changeover. A positive attribute of this process, not always experienced with other solutions, is that the clays are often reject materials from the mineral extraction process, which is a resource efficiency that lowers the number of scarce materials used when producing clinker.

Color appearance of raw and calcined clays obtained with and without use of color control procedures during the cooling process (from Reference 2)

So, what are the key elements of LC3? The blend consists of the following materials:

- **Clinker**—burnt at high temperatures, between 1400 and 1500°C (2552 and 2732°F);
- **Calcined clays**—burnt at approximately 800°C (1472°F);
- **Limestone**—added without processing; and
- **Gypsum**—added to control the aluminate reaction.

LC3-50, the most widely investigated formulation, typically contains 50% clinker, 30% calcined clay, and 15% limestone; however, note that the ratio of calcined clay to limestone may vary. And clinker contents can also be higher or even lower, depending on the application.

The main factor in deciding whether a natural clay is suitable for LC3 production is the kaolinite content. Amounts between 40 and 60% are ideal, and higher-grade clays can be diluted to reduce the clay-to-limestone ratio of the mixture. In the end, the resulting strength from using LC3 is equivalent to OPC, from 3 to 7 days of age and beyond.[4]

LC3 has been used in many different regions, with more than 25 different applications already built with LC3

A block-making trial using LC3

To ensure the appropriate calcination of the clay, an ideal temperature range is between 700 and 850°C (1292 and 1562°F). Additionally, the color of the calcined clay can be controlled, when necessary, to reduce the redness of the clay and make the result look like traditional concrete. This is a technology well known in the brick industry.

The reduction of CO_2 emissions is not the only advantage of using LC3; in fact, some properties can be enhanced compared to normal OPC-based concrete. One advantage includes chloride penetration resistance, which is drastically enhanced as compared to OPC. This makes LC3 suitable for use in aggressive environments. Another notable feature is that LC3 can resist alkali-silica reaction (ASR) even when highly reactive aggregates are used.

Slag Cement and Fly Ash: Diminishing Commodities

Supplementary cementitious materials (SCMs) are generally used in conjunction with OPC to contribute to the properties of the hardened concrete. Slag cement and fly ash have been used for years as supplements with the benefit of not only providing increased properties to the concrete, but also reducing the consumption of portland cement and therefore reducing the energy and emissions associated with its production. Despite the known benefits of slag cement and fly ash, LC3 can enhance concrete mixture designs even further. One place this can be seen in is chloride penetration. A mixture with slag cement is better than just OPC, and using a mixture with fly ash is even better. Yet, LC3 surpasses them all and provides the best protection against chlorides. Additionally, because fly ash and slag cement are waste materials of coal-fired furnaces and blast furnaces, respectively, it is predicted that these materials will become increasingly less available in the next 10 to 20 years as production methods change. This increases the immediate need for LC3 technology because soon these SCMs will no longer be widely available.

Where LC3 Takes Over

From an environmental perspective, LC3 technology has the potential to substantially reduce CO_2 emissions in the concrete industry. This is evident from the change seen in initial studies. In 2009, the International Energy Agency (IEA) reported that they projected by 2050, due to the limited availability of slag cement and fly ash, it would only be possible to reduce the global average clinker factor for cement to 73%.[5] Now, with LC3, clay suitable for calcination is readily available globally, which means that the clinker factor can be even further reduced. Using LC3, a global reduction with an average of 60% would mean extra CO_2 reductions of 400 million tonnes (440 million tons) of CO_2 per year. The high performance of the combination of calcined clay and limestone allows for even greater reductions in clinker and CO_2 emissions. As mentioned, one of the greatest features is that this technology can be implemented immediately using existing plants, and production costs will remain low. Due to the urgent needs of the climate crisis, this is of significant importance.

The potential for real CO_2 reduction can vary and depends on the conditions of calcination and the proximity of the clay. Gains can be up to 40%. Because of climate change issues, it must be evaluated on a worldwide basis as well. In the last 10 years, companies that are members of the Global Cement and Concrete Association have shown a general substitution rate stagnated at around 20%. From a technical basis, it will be easy to go to an average substitution level of 40%. As mentioned, if that is done with a mixture of calcite, clay, and limestone, the savings will be 400 million tonnes of CO_2 per year. That is the equivalent of 1% of all global CO_2 emissions. This is a very conservative estimate because it is indicating a 40% substitution, and recent research has shown that amount could even be up to 60% by 2050, doubling the potential CO_2 savings to 800 million tonnes (880 million tons) of CO_2 per year.

This is a tremendous saving. Currently, there is no other single technology in the cement and concrete business that can deliver CO_2 reductions at that level. The regulations in Europe have seen a change in standards to allow for this. North America allows a clinker content of as low as 45% for a combination of calcined clay and limestone with ASTM C595, "Standard Specification for Blended Hydraulic

Cements," which is already used in much of Latin America. This would allow LC3-50.

Moving Forward

LC3 is catching on globally and has garnered the most attention from the industrial sector. Emerging economies, such as Latin America, Asia, and Africa, had the most interest initially due to the high demand for buildings and infrastructure. Now, 25 companies from more than 40 countries have shown high interest in LC3 technology. It has gained traction in Europe and is being introduced in the United States.

The topic of LC3 has attracted the interest of scientists and research groups worldwide, who are now collaborating to implement the technology and fast-track the reduction of CO_2.

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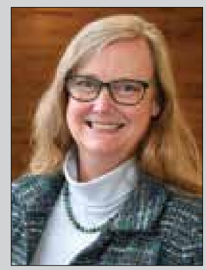
Note: Additional information on the ASTM standard discussed in this article can be found at **www.astm.org**.

Selected for reader interest by the editors.



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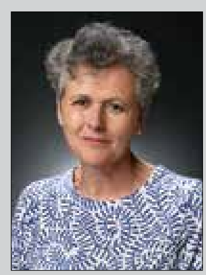

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