Opinion

Alternative cement production methods would reduce its environmental footprint

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Opinion

The Cement and Construction Materials Research Group (CEMATCO) of the UN Medellín School of Mines is exploring new ways in cement production to reduce its environmental impact and even improve its characteristics. Our lives are shaped in many ways by cement and its properties of strength, durability and versatility, which are fundamental in the construction of works such as buildings, bridges, tunnels and dams. As demand for new infrastructure grows, so does the production of this material and its environmental footprint. "Around five billion tons of cement are manufactured every year," explains Jorge Juan Payá, professor at the Institute of Concrete Science and Technology at the Polytechnic University of Valencia. "And this means very large CO_2 emissions into the atmosphere." This is why there is growing interest in seeking more efficient production processes, and this is where the knowledge and capabilities of the School of Mines at the Universidad Nacional de Colombia, Medellín campus come in. "Our research seeks to carry out industrial developments that reduce fuel consumption and/or gas emissions" says Professor Oscar Jaime Restrepo Baena, Mining and Metallurgy Engineer and CEMATCO researcher.

Alternative synthesis methods

Portland cement is the most common cement and one of its main components is clinker. This material is composed of silicates and calcium aluminates, the former giving the cement its mechanical strength, i.e., its ability to resist forces or loads without failing. Clinker is formed when limestone and clays are calcined in rotary kilns that reach temperatures of up to 1500 degrees Celsius. It is a process of high energy consumption to reach these temperatures and also emits an amount of carbon dioxide in a ratio of approximately 1:1, for each ton produced, almost a ton of CO_2 would be generated. For this reason, the research group has focused on alternative clinker production methods that allow clinker synthesis at lower temperatures while maintaining the desired properties. One of these projects was carried out by Juan Camilo Restrepo Gutiérrez, professor at the School of Architecture of the UN in Medellín and current Vice Rector of the Medellín campus**.**

Synthesis of calcium silicates by chemical combustion methods

Previous research by the group identified the self-combustion process as an option for the generation of pigments, and with this background, Professor Juan Camilo Restrepo began to explore the possibility of producing calcium silicate phases - known as alite and belite - by this method. "The process we developed consisted of mixing silica and calcium plus the reagents for ignition, diluted in water," says the professor. This was heated to 200 degrees Celsius, at which point combustion occurred and the mixture reached a temperature between 900 and 1200 degrees Celsius, the range in which these calcium silicates are formed. The advantage is not only that less energy is consumed by not having to reach a temperature of 1500 degrees Celsius for the production of belite and alite as in the traditional process, but also that when analyzing the reaction with a gas chromatograph, a reduction of between 70% and 90% in CO2 production was identified. In addition, the silicates produced are more reactive because they are highly porous. This is an important step in the investigation of alternative methods of calcium silicate synthesis because the possibility of using a self-combustion process for the production of these compounds had only been established theoretically. "We started working at the laboratory level and we really succeeded in doing it," concludes Prof. Restrepo.

Flame spray pyrolysis

Another alternative method investigated by CEMATCO is flame spray pyrolysis, used in its work on ceramic pigments. Natalia Betancur Granados, chemical engineer and member of the group recalls that this process "was not used in cements. There was only one report but the results were not good". For her PhD in Materials Science and Technology, she decided to test this method for the production of calcium silicates such as belite on a nanometer scale. The nanoparticles, being so small, have a surface area that represents a higher percentage of their total mass, accelerating, in this case, their hydration processes. How do you get the nanoparticles? A continuous process was designed in which reagents containing silicon and calcium are mixed in an organic solvent liquid that is pumped through a nozzle like an aerosol. The small droplets that emerge pass through a flame into a gas phase, forming a cloud of silicon, calcium and oxygen ions. These ions seek to stabilize by binding in micro nucleation processes that form particles and, as they advance, undergo a temperature reduction that limits their growth potential to about 10 - 50 nanometers. These nanoparticles are electrically charged with an electrostatic precipitator so that they adhere to the surface of a tube for collection. The advantages of this method is that the belite increased its hydration rate, making the time required to reach its higher mechanical strength less and may even be higher than that of the traditional process. This would be very useful in the development of ultra-resistant cements, necessary in high-rise skyscrapers and works that withstand extreme pressures. The research also evaluated how changing the conditions of flaming aerosol pyrolysis affected the final properties of the material. It was analyzed what happened to the reactivity, particle size and mineralogy of the belite if the concentration of the mixture, the dispersion pressure, the feed rate, the type of fuel used and the dispersion gas in the aerosol were changed. This identified the belite structures that favored better mechanical strength and shorter time to reach it, a fundamental plus for a composite that would have applications even outside of cement production, as a biomaterial for bone repair.

What's next?

This research is just the initial steps on a path that would potentially improve cement industry processes by reducing the energy consumption needed for clinker synthesis and the time to achieve components such as belite. This would mitigate the negative environmental impact, reduce costs and could provide improvements in the mechanical response of cement. The results obtained at laboratory scale are promising and encourage experimentation at larger scales. That is why it is essential to strengthen the relationship between academia and industry so that the cutting-edge knowledge built at the University generates benefits that impact the community at a local and global level. And that is why the CEMATCO group continues its research.[1–7]

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None.

Conflicts of interest

The authors declare that there is no conflict of interest.

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