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USING METAL-ORGANIC FRAMEWORKS (MOFs) TO REDUCE THE CARBON FOOTPRINT OF CONCRETE

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Abstract

The extensive production of concrete by the construction industry has a massive impact on the environment. The process of manufacturing its main component, ordinary Portland cement (OPC), releases a considerable amount of anthropogenic carbon dioxide (CO_2). This thesis is concerned with the production of sustainable and eco-friendly concrete that integrates metal-organic frameworks (MOFs) to capture and offset the CO_2 emissions emitted during the production of cement. The main objective is to synthesize a MOF capable of capturing CO_2 in concrete through an accelerated carbonation curing process and to assess its impact on concrete performance. Different parameters were examined, including the MOF content, initial curing duration, carbonation curing duration, and carbonation pressure. The parameters were evaluated by means of CO_2 uptake, phenolphthalein indicator solution, compressive strength, water absorption, and permeable pore voids volume. The microstructure of carbonated MOF-embedded concrete was evaluated using X-ray diffraction analysis (XRD), scanning electron microscope (SEM), and Fourier transform infrared (FTIR) spectroscopy. The study revealed the possibility of incorporating MOFs in concrete to capture CO_2 gas, permanently sequester it, and increase CO_2 uptake without compromising concrete mechanical performance. The addition of MOFs promoted a higher carbonation degree of cement, especially with a longer initial curing duration and higher pressures. Incorporating up to 6% MOF, by cement mass, in concrete mix cured for 20 hours in open-air followed by 20 hours of carbonation curing at a pressure of 1 bar led to the highest total CO_2 uptake of 19.1%, carbonation depth of 11.6 mm, and highest 28-day compressive strength of 45.6 MPa. Meanwhile, its water absorption and permeable pore voids volume were the lowest at 4.28 and 11.5%, respectively. Exceeding 6% MOF addition did not seem to improve the uptake or performance. In comparison, the carbonated control mix, i.e., without the addition of MOF, showed lower compressive strength and higher porosity. Furthermore, the microstructure analysis of different mixes highlighted the formation of calcite, aragonite, calcium silicate hydrate, calcium hydroxide, and ettringite. The developed MOF-embedded concrete can be used in construction applications to mitigate the industry-related CO_2 emissions while maintaining concrete properties. Limitations of the work and recommendations for future studies are also furnished.

Keywords: CO_2 emissions, metal organic framework, MOF, concrete, cement production, accelerated carbonation, curing, pressure, CO_2 uptake, performance, microstructure.