Accelerated Carbonation of Construction Materials by Using Slag from Steel and Metal Production as Substitute for Conventional Raw Materials

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Abstract : Due to the high CO_2 emissions, the energy consumption for the production of sand-lime bricks is of great concern. Especially the production of quicklime from limestone and the energy consumption for hydrothermal curing contribute to high CO_2 emissions. Hydrothermal curing is carried out under a saturated steam atmosphere at about 15 bar and 200°C for 12 hours. Therefore, we are investigating the opportunity to replace quicklime and sand in the production of building materials with different types of slag as calcium-rich waste from steel production. We are also investigating the possibility of substituting conventional hydrothermal curing with CO_2 curing. Six different slags (Linz-Donawitz (LD), ferrochrome (FeCr), ladle (LS), stainless steel (SS), ladle furnace (LF), electric arc furnace (EAF)) provided by "thyssenkrupp MillServices & Systems GmbH" were ground at "Loesche GmbH". Cylindrical blocks with a diameter of 100 mm were pressed at 12 MPa. The composition of the blocks varied between pure slag and mixtures of slag and sand. The effects of pressure, temperature, and time on the CO_2 curing process were studied in a 2-liter high-pressure autoclave. Pressures between 0.1 and 5 MPa, temperatures between 25 and 140°C, and curing times between 1 and 100 hours were considered. The quality of the CO_2-cured blocks was determined by measuring the compressive strength by "Ruhrbaustoffwerke GmbH & Co. KG." The degree of carbonation was determined by total inorganic carbon (TIC) and X-ray diffraction (XRD) measurements. The pH trends in the cross-section of the blocks were monitored using phenolphthalein as a liquid pH indicator. The parameter set that yielded the best performing material was tested on all slag types. In addition, the method was scaled to steel slag-based building blocks (240 mm x 115 mm x 60 mm) provided by "Ruhrbaustoffwerke GmbH & Co. KG" and CO_2-cured in a 20-liter high-pressure autoclave. The results show that CO_2 curing of building blocks consisting of pure wetted LD slag leads to severe cracking of the cylindrical specimens. The high CO_2 uptake leads to an expansion of the specimens. However, if LD slag is used only proportionally to replace quicklime completely and sand proportionally, dimensionally stable bricks with high compressive strength are produced. The tests to determine the optimum pressure and temperature show 2 MPa and 50°C as promising parameters for the CO_2 curing process. At these parameters and after 3 h, the compressive strength of LD slag blocks reaches the highest average value of almost 50 N/mm^2. This is more than double that of conventional sand-lime bricks. Longer CO_2 curing times do not result in higher compressive strengths. XRD and TIC measurements confirmed the formation of carbonates. All tested slag-based bricks show higher compressive strengths compared to conventional sand-lime bricks. However, the type of slag has a significant influence on the compressive strength values. The results of the tests in the 20-liter plant agreed well with the results of the 2-liter tests. With its comparatively moderate operating conditions, the CO_2 curing process has a high potential for saving CO_2 emissions.

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