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Effects of Additives on Magnesium Silicate Hydrate Formation for Low-Carbon Cement

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The construction sector urgently demands sustainable materials to address cement's substantial CO_2 footprint (4% of global emissions).[1] With cement production rising 1.8% annually, the NetZero2050 initiative mandates reducing cement CO_2 emissions by 3% yearly until 2030 to meet Paris Climate Accord targets.[2] Cement emissions predominantly originate from CaO-based clinker production (60-70% of cement's carbon footprint). Alternative binders present promising replacements for traditional Portland cement clinker. Magnesium-based cements utilizing MgO have emerged as viable alternatives, particularly magnesium-silicate-hydrate (M-S-H) binders, which mirror calcium silicate hydrate (C-S-H) while delivering a lower carbon footprint. M-S-H binder materials can be produced by calcinating magnesite $MgCO_3$ at approximately 600°C, from magnesium silicate rocks, or from desalination brines. However, M-S-H cement encounters challenges including slow ambient curing and higher water requirements compared to Portland cement.

In this study, we investigate key steps in M-S-H phase formation (brucite formation and M-S-H formation) using two distinct experimental approaches: homogeneous formation in solution and heterogeneous formation from solids. We examine the effect of additives on this process, aiming to accelerate the reaction. Our research evaluates brucite formation in the presence of both inorganic and organic additives, considering it a potential rate-limiting step in M-S-H formation at ambient temperature.[3] Various additives were tested to determine their influence on brucite formation. The study further investigates how these same additives affect the overall formation process of M-S-H from MgO.

We employed conventional mineralogical analytical techniques including SEM-EDX, ATR-FT-IR, ICP-OES, pXRD, and TGA coupled with PHREEQC geochemical software to analyze reaction kinetics and structural characteristics of the obtained materials at reaction different times. Our results demonstrate that brucite formation from MgO was not significantly affected by the additives, but M-S-H formation accelerated with certain additives. Additionally, secondary phases of Mg-additive compounds formed throughout the process.

[1] Cement – Analysis - IEA.

[2] Technology Roadmap - *Low-Carbon Transition in the Cement Industry* - *TechnologyRoadmapLowCarbonTransitionintheCementIndustry*.

[3] H. Sreenivasan, E. Bernard, H. S. Santos, H. Nguyen, S. Moukannaa, A. Adediran, J. L. Provis, P. Kinnunen,
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