The Filler Effect: The Influence of Filler Content and Surface Area on Cementitious Reaction Rates

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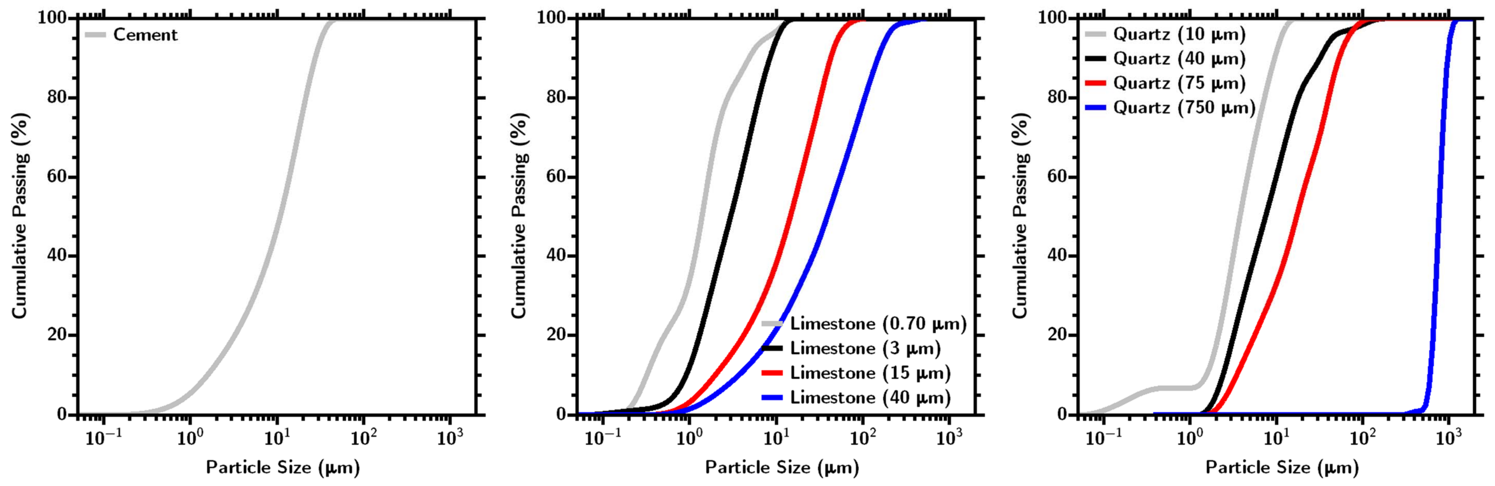
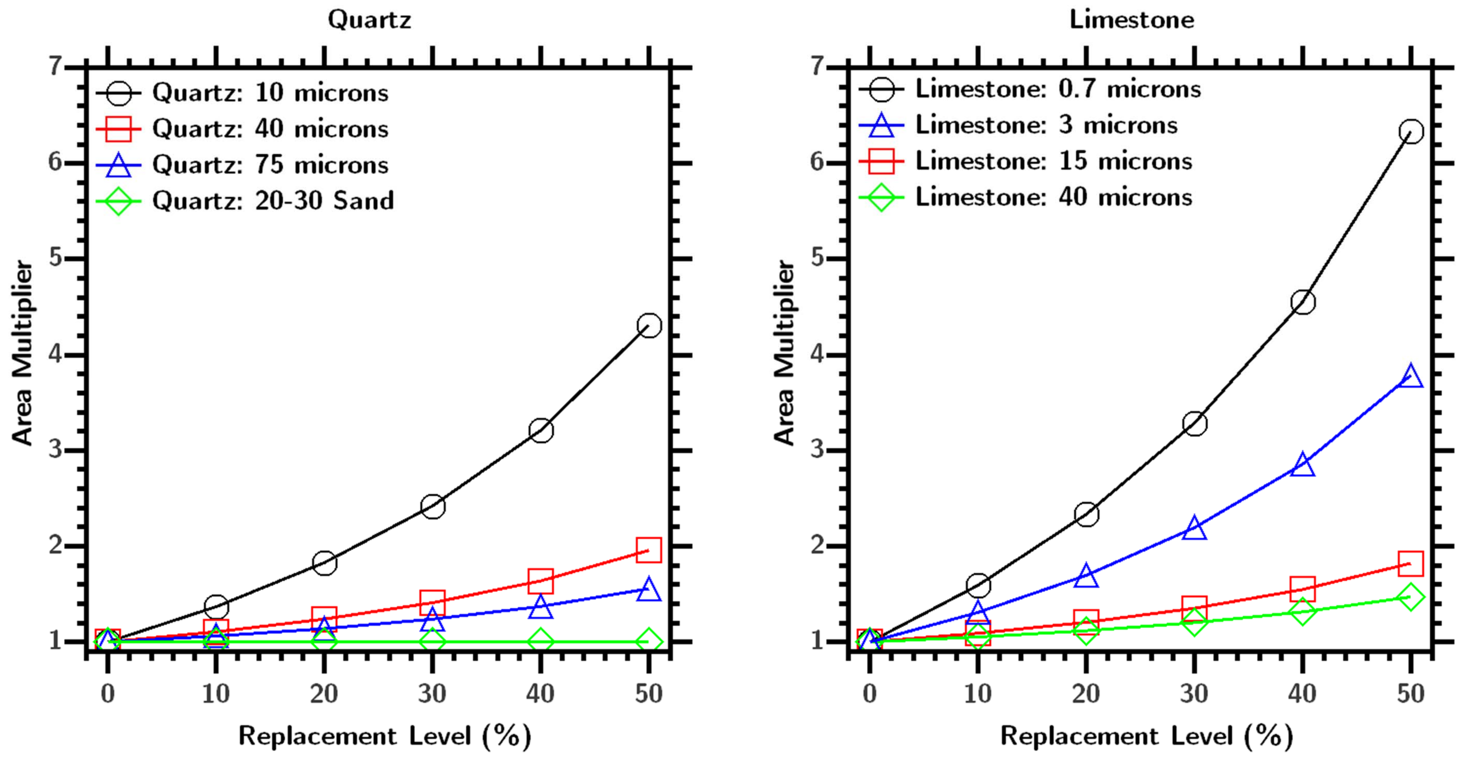
Abstract

Finely ground mineral powders are known to accelerate cement hydration rates. This “filler effect” has been attributed to the effects of dilution (w/c increase) when the cement content is reduced or to the provision of additional surface area by fine powders. This work describes the influence of surface area and mineral type (i.e., quartz or limestone) on reactions. Simulations using a boundary nucleation and growth model indicate that the extent of the acceleration is linked to the: (1) surface area increase and (2a) capacity of the filler’s surface to offer favorable nucleation sites for hydration products. Other simulations using a cellular automaton model suggest accelerations are linked to: (2b) the interfacial properties of the filler which influences its ability to serve as a nucleant and (3) the composition of the filler and the tendency for its ions to participate in ion exchange reactions with the C-S-H. The research provides a mechanistic understanding of the influence of fillers on reaction rates.

Experimental Procedures

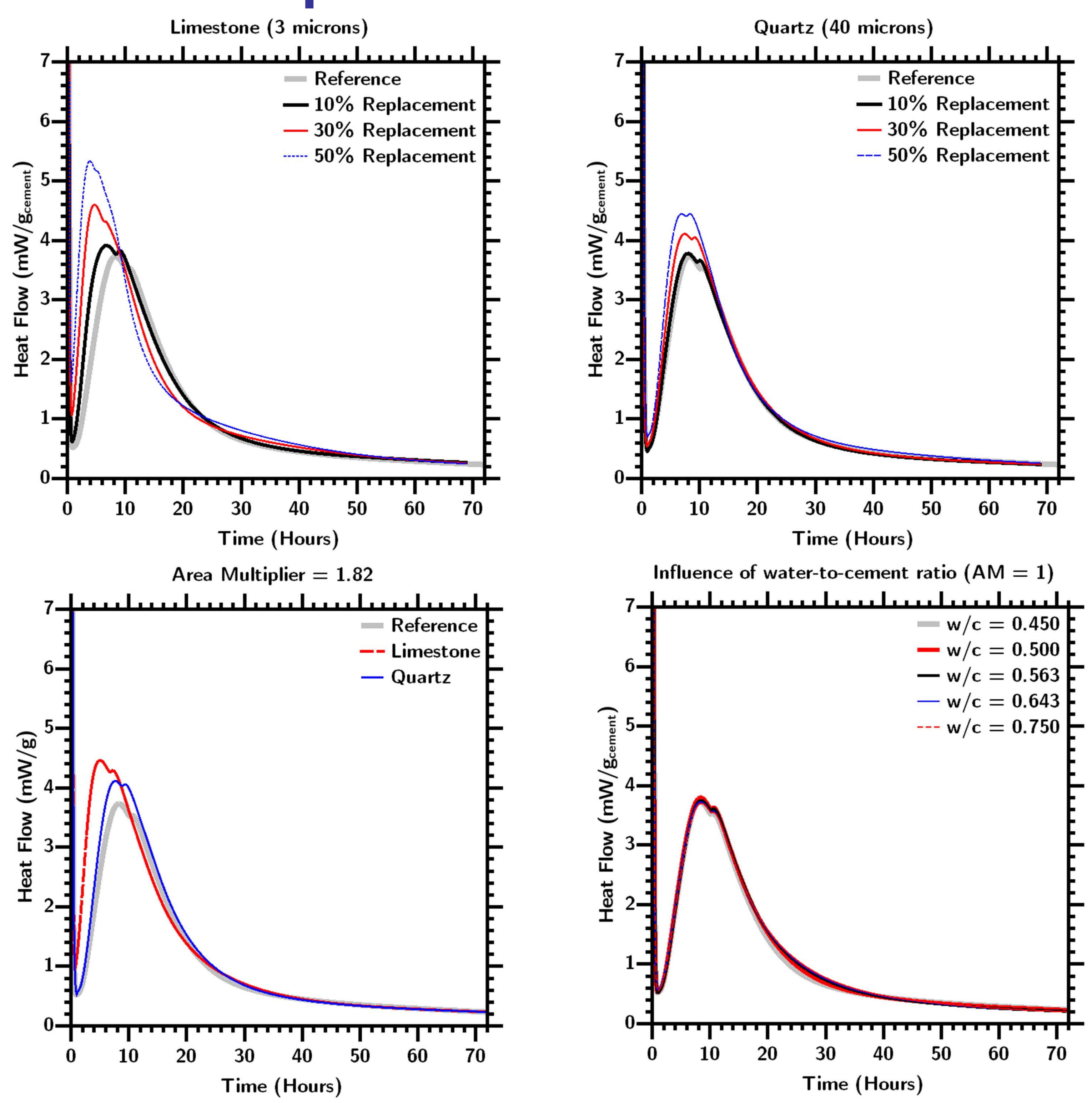
Materials and Mixtures

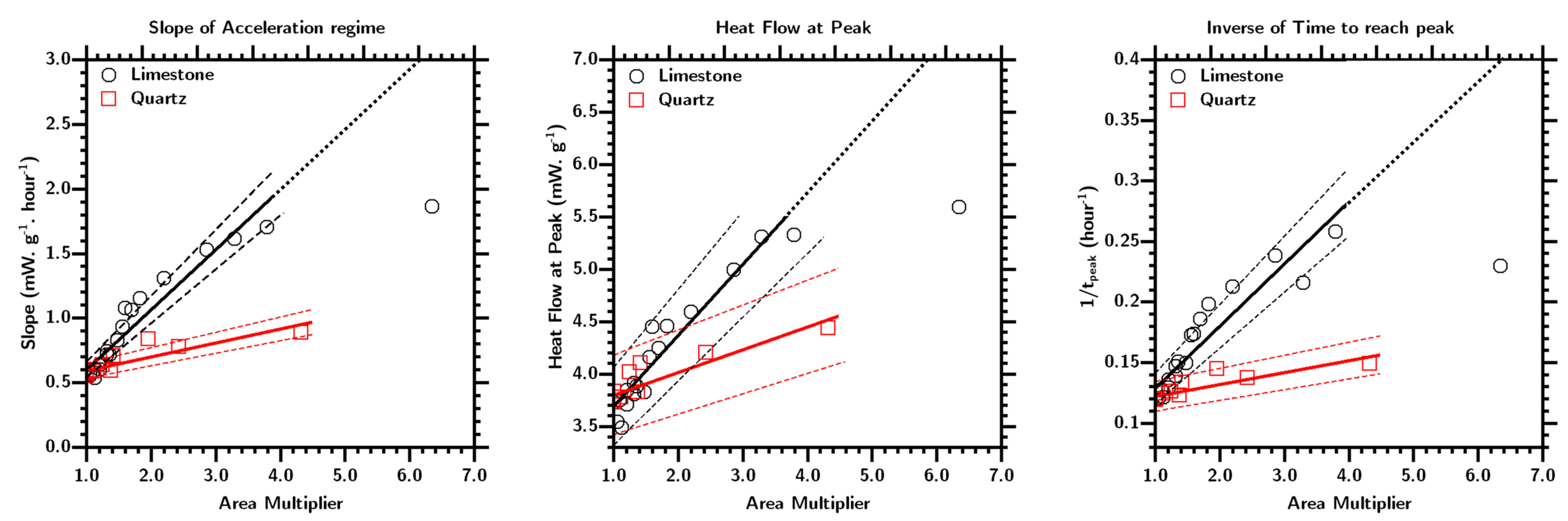




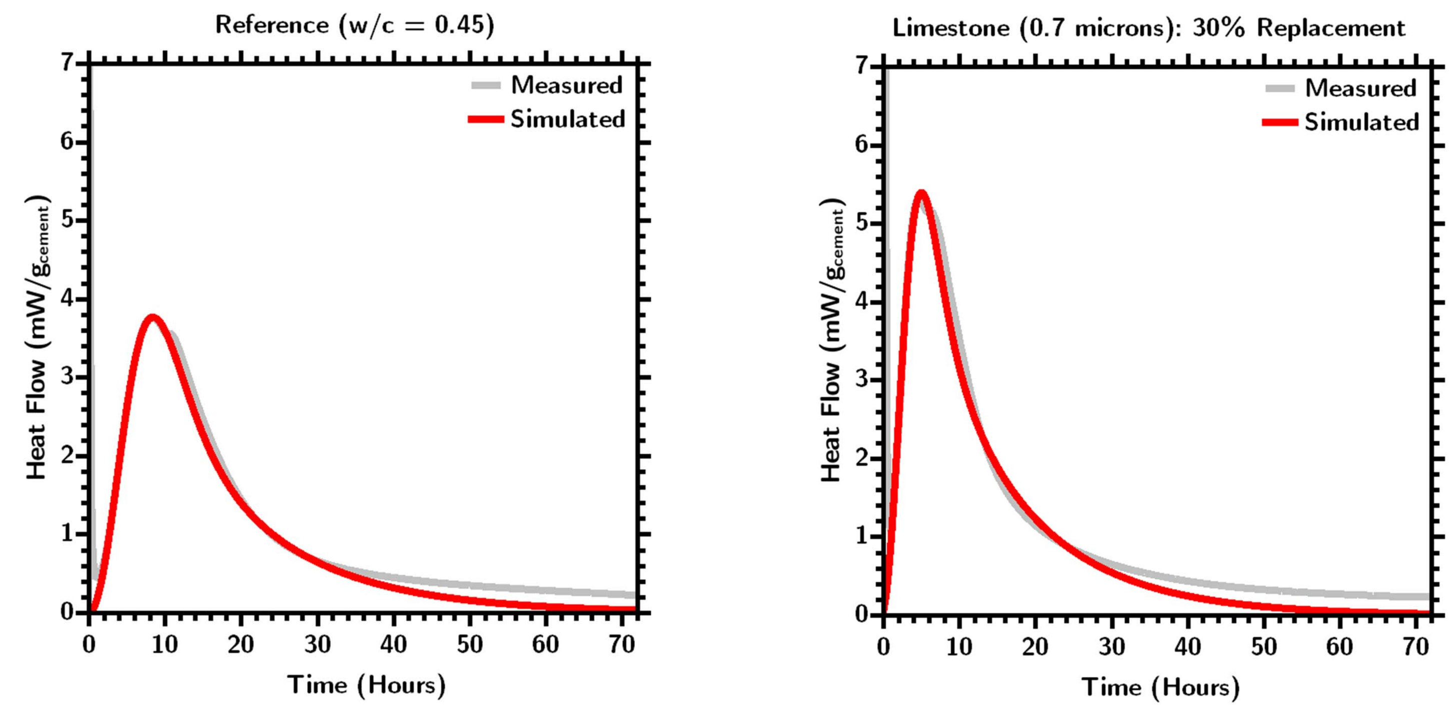
$$Area\ Multiplier\ (AM) = \frac{\left[100 + \frac{r.SSA_{filler}}{(100-r).SSA_{cement}}\right]}{100}$$

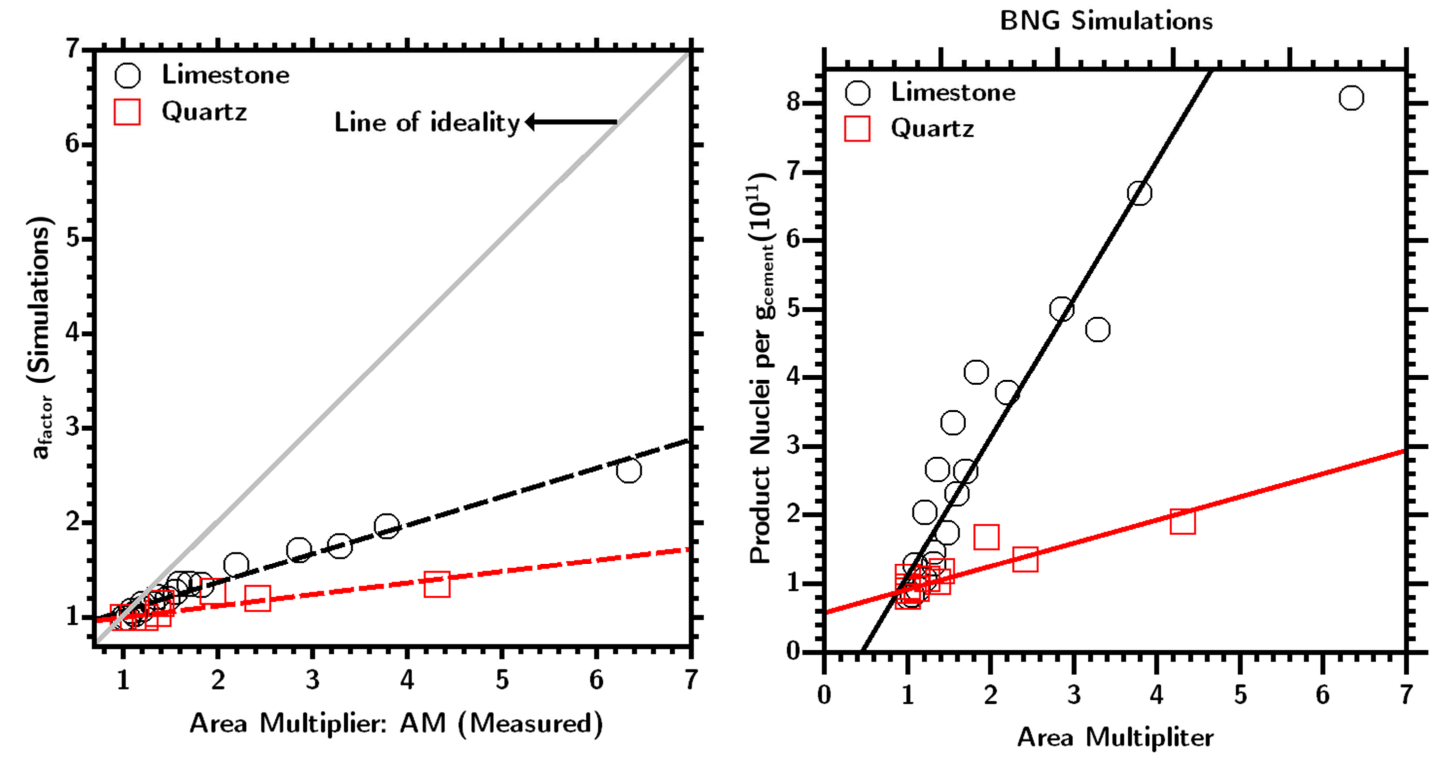
Experimental Results

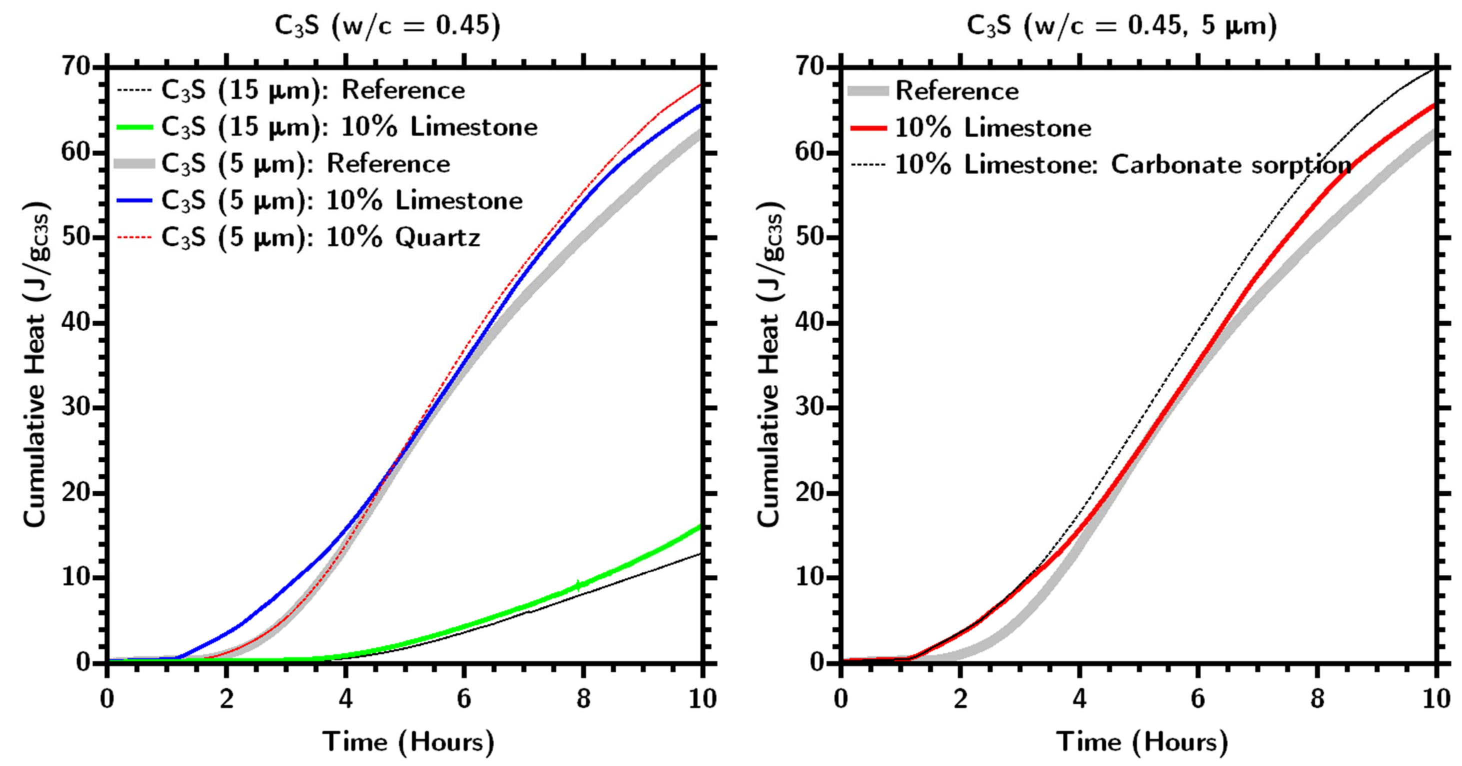




Simulation Results







$$\Delta G_{HET} = \Delta G_{HOM}.\phi(\theta) = \left(\frac{16\pi\Upsilon_{PL}^3 V_M^2}{3\Delta\mu^2}\right).\left[\frac{(2+cos\theta)(1-cos\theta)^2}{4}\right]^n$$

$$cos\theta = \frac{\Upsilon_{SL} - \Upsilon_{PS}}{\Upsilon_{PL}}$$

Summary and Conclusions

This work describes the generalized influence of mineral fillers on accelerating the rate of hydration reactions in cementitious materials. New simulation results are used to quantitatively interpret the role of dilution and the filler’s characteristics on the rates of reactions. Aspects of surface area, interfacial properties and ion exchange (i.e., sorption) reactions are distinguished and analyzed separately in terms of their influence on hydration rates. The results suggest that limestone is superior to quartz (and certain other fillers) as an accelerant due to its favored interfacial properties and its ability to participate in ion exchange reactions. Overall, the results shed new light on the filler effect and point the way to improved methods to better analyze, quantify, and screen minerals in terms of their ability to serve as filler agents.