The Effects of Various Filler Types and Size Classification on Early Hydration of C_3S

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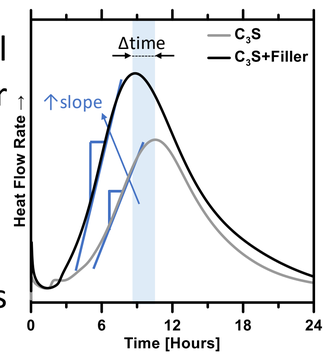
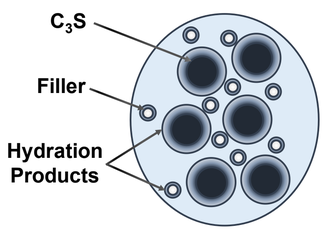
Background

- The **filler effect** describes the acceleration of early hydration rates that occur when finely ground mineral admixtures—such as quartz, limestone, rutile, and corundum—are used to dilute cement content.
- Fillers provide additional surfaces, further, sites for nucleation of the hydration products, calcium silicate hydrate (C-S-H), which accelerates reactions.[1]
- Berodier and Scrivener[2] determined that the acceleration slope is related to the nucleation slope of C-S-H.





Study Objective: to examine the changes in hydration rates as filler type and particle size class is varied.

Materials & Methods

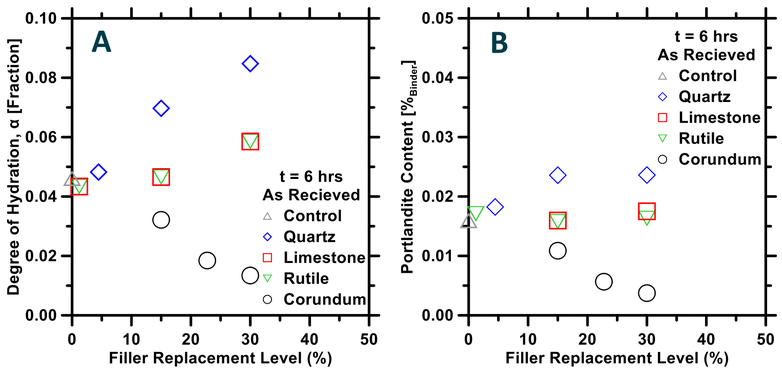
- Triclinic (T1) C_3S was confirmed using X-ray diffraction (Panalytical X'Pert Pro MPD, Spectris).
- Four size classes were created via sieve analysis from fillers (i.e., quartz, limestone, rutile, and corundum).

TAM IV Isothermal Microcalorimetry

SDT—Q600 Simultaneous DTA/ TGA

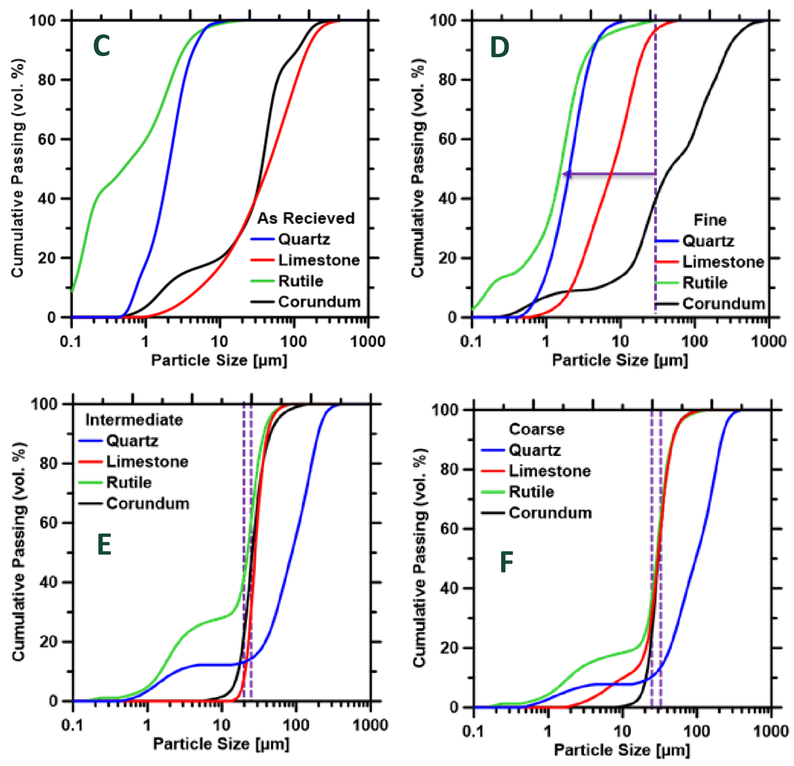
- Static light scattering was used to determine particle size distributions.
- Calorimetry was used to measure heat evolution at 20°C using a w/c of 0.45.
- Differential thermal analysis was used to determine phase evolution after hydration.

STD & DOH: 30% Replacements



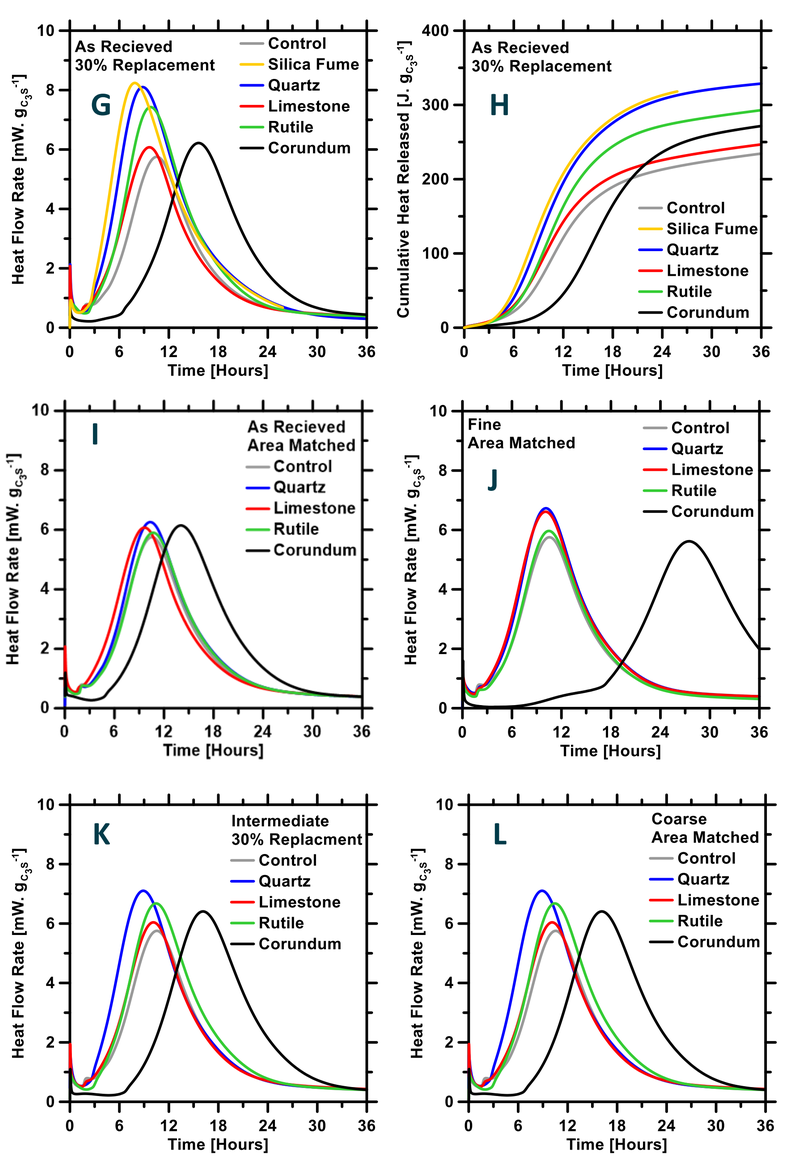
The degree of hydration (DOH) at 6 hours (**A**) and the portlandite content (**B**; $\%_{binder}$) determined from SDT and calorimetry experiments.

Particle Size Analysis



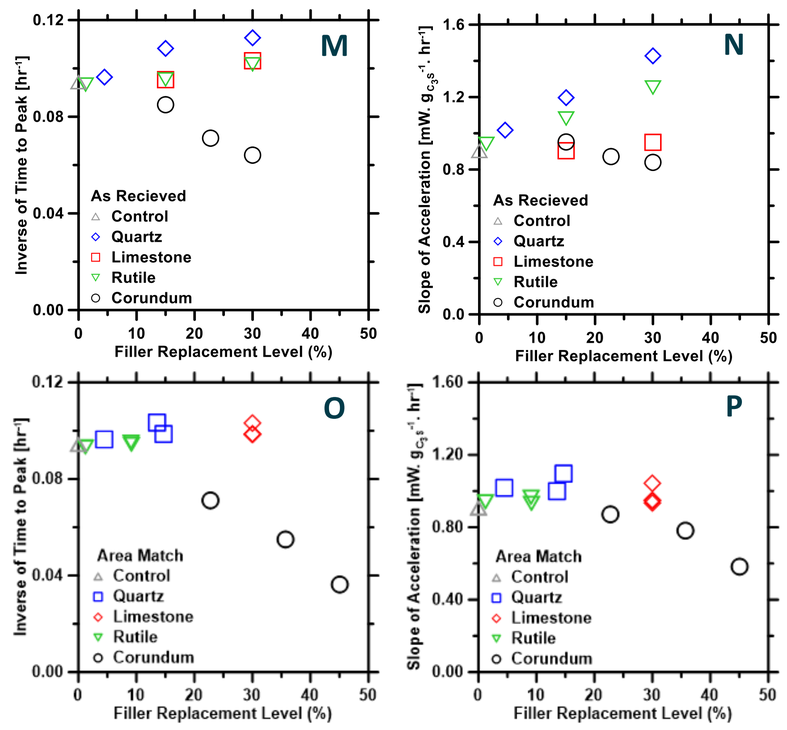
Particle size distributions of as received (**C**), fine (**D**; >20µm), intermediate (**E**; 20-25µm), and course (**F**; 25-32µm) size classes. The d_{50} of C_3S was determined to be 7.73 µm.

Calorimetry Results



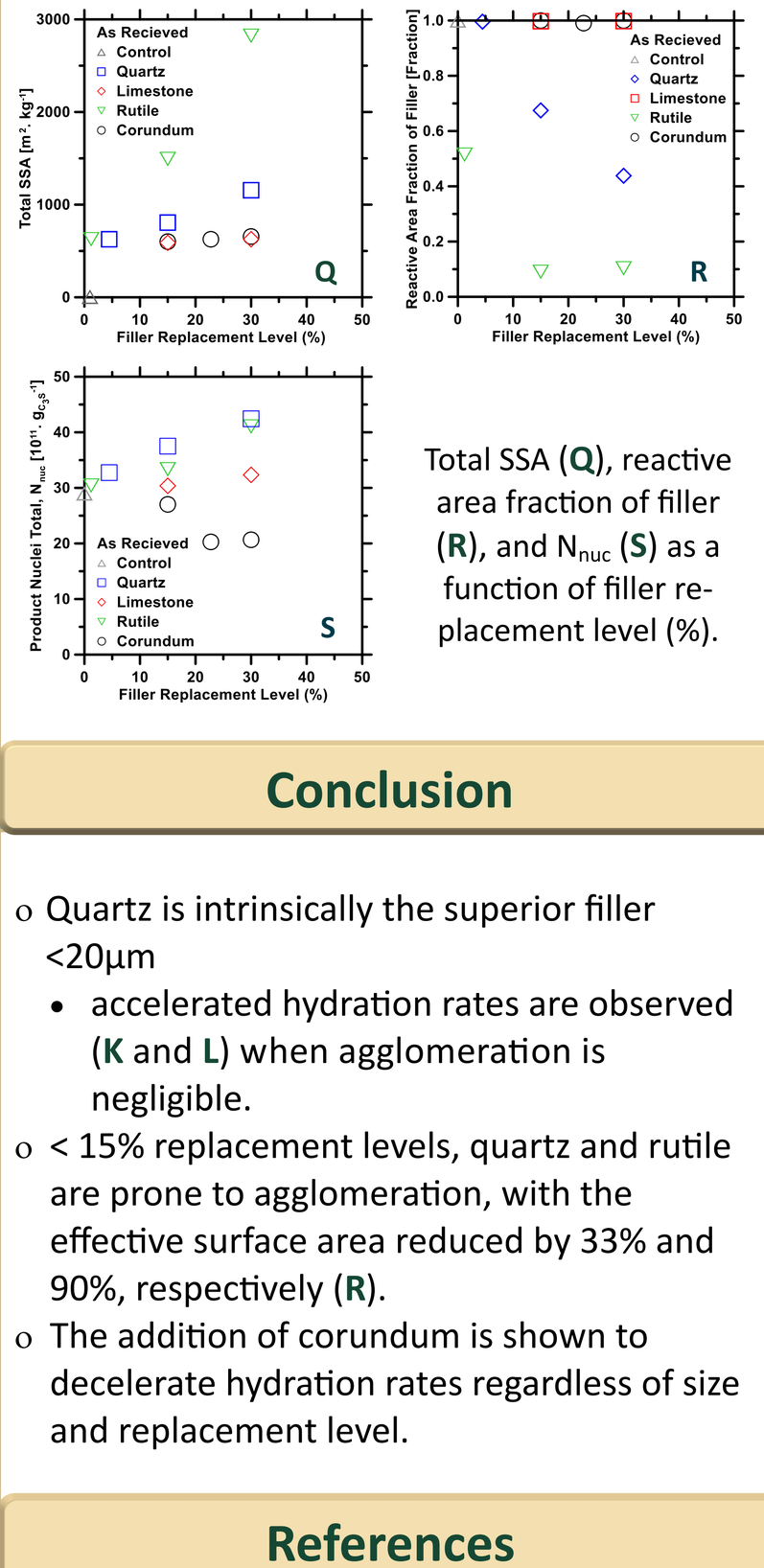
Calorimetry results for as received 30% replacement systems (**G** and **H**), and the four size classes: as received (**I**), fine (**J**; >20µm), intermediate (**K**; 20-25µm), and coarse (**L**; 25-32µm). Areas were matched to specific surface area (SSA) corresponding to limestone for respective size classes.

Calorimetry Parameters



Calorimetry parameters: inverse of time to peak and slope of acceleration as a function of filler replacement level for all as received (**M** and **N**) and all area matched pastes (**O** and **P**), respectively.

Filler Performance



Total SSA (**Q**), reactive area fraction of filler (**R**), and N_{nuc} (**S**) as a function of filler replacement level (%).

Conclusion

- Quartz is intrinsically the superior filler <20µm
  - accelerated hydration rates are observed (**K** and **L**) when agglomeration is negligible.
- < 15% replacement levels, quartz and rutile are prone to agglomeration, with the effective surface area reduced by 33% and 90%, respectively (**R**).
- The addition of corundum is shown to decelerate hydration rates regardless of size and replacement level.

Acknowledgments

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References

1. The Filler Effect: The Influence of Filler Content and Surface Area on Cementitious Reaction Rates.
2. Understanding the Filler Effect on the Nucleation and Growth of C-S-H.