Clinker Grindability: Microstructure Matters

Problem

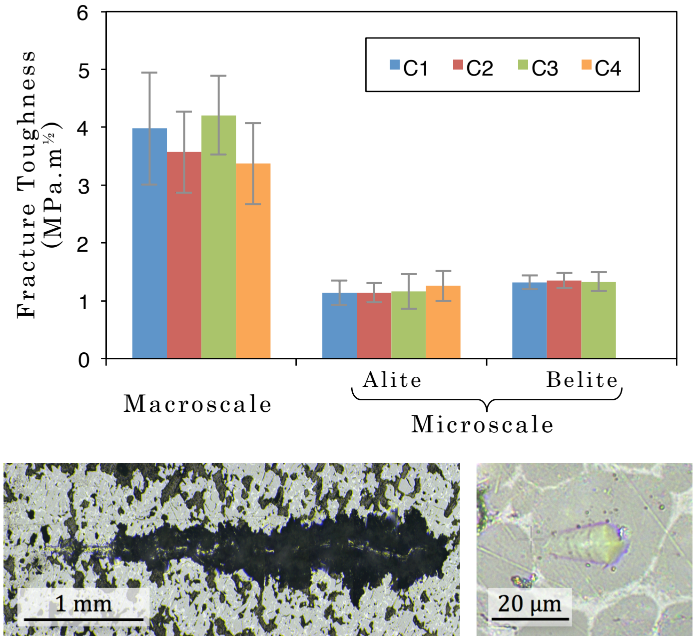
The production of cement contributes to global anthropogenic emission of CO_2, and the cement industry has been engaged in an effort to reduce its environmental impact. In this context, studies on the mechanics of clinker fracture are of interest, as grinding processes require considerable energy input at cement plants. Research on grinding of clinker is not new, but the latest developments in experimental and theoretical fracture mechanics open new venues for a better understanding of this phenomenon at different length scales, from micro-to-macro.

Approach

In this research, we focus on the fracture properties of four industrial clinkers. The microscratch test technique, previously developed by researchers of the CSHub[1], is applied to measure the fracture toughness at the macro and micro scales. The macroscale measurements relate to a clinker's microstructure, as each scratch of 3 mm in length covers number of grains, pores and interfaces. We also downscale the method to investigate the intrinsic fracture toughness of single alite and belite crystals at the microscale with scratches of 20 μm length. This extension of the technique is validated with reference glass materials.

Findings

For these four clinkers, we find that belite crystals exhibit higher toughness than alite crystals, which is in line with other independent observations[2]. Larger differences in toughness at the macroscale than at the microscale suggest that the grindability of clinkers relates to the microtexture and the abundance of the clinker phases, rather than to variations in intrinsic toughness of each phase. Toughening also occurs from the microscale to the macroscale, similarly as observed in polycrystalline ceramics. This can be explained with the microstructure of clinkers and a combination of toughening mechanisms such as crack tip deflection, shielding by microcracks, or crack trapping and pinning[3].



Top: Multi-scale fracture toughness measured with the microscratch test on four industrial clinkers (Belite crystals of clinker C4 were too small for microscratch testing) Bottom left: Imprint of a scratch test performed on a clinker surface to evaluate the effect of microstructure. Bottom right: Imprint of a scratch test on a single belite crystal.

Impact

This multi-scale investigation of fracture properties with the microscratch test highlights the importance of microstructure in clinker grindability. This original approach also provides a means for investigating the effects of microstructural characteristics (e.g. crystal size, porosity, belite clustering) on the grindability of clinkers.

More

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1 Akono *et al.* (2012) *Journal of Materials Research*, 27(2), 485-493
2 Hornain and Regourd (1980) *7th Int. Concr. Chem. Cem.*, I276-I281
3 Wiederhorn (1984) *Ann Rev Mater Sci*, 14(10), 373-403

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