Minimizing cement usage in concrete

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Manufacture of cement is responsible for about 5% of anthropogenic emissions of CO_2, and the rate of concrete consumption is rising rapidly, owing to the economic development of China and other populous contries. In fact, the carbon footprint of concrete is far lower than that of other building materials, but it could be reduced further if the volume fraction of cement in concrete could be reduced. The goal of this project is to increase the proportion of aggregate (*i.e.*, sand and stone) in concrete by applying recent theoretical developments by Torquato and Hopkins on the optimal packing of particles. They predicted that exceptionally dense packings could be obtained at certain size ratios and concentrations of spheres. We have experimentally confirmed the high densities predicted by their computer simulations, and have initiated simulations of the flow behavior of such mixtures, in collaboration with Nick Martys at NIST. For practical application of these ideas, it will be necessary to use aggregate with a wide range of particle sizes, and with imperfect shapes. In this talk, we will explain the insight obtained from the theoretical work on particle packing, and the potential for optimization of concrete.