Accepted Manuscript

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PII: S0022-5096(18)30228-X
DOI: 10.1016/j.jmps.2018.07.022
Reference: MPS 3401

To appear in: *Journal of the Mechanics and Physics of Solids*

Received date: 19 March 2018
Revised date: 24 July 2018
Accepted date: 29 July 2018

Please cite this article as: Chi-Cong Vu , Jérôme Weiss , Olivier Plé , David Amitrano , Damien Vandembroucq , Revisiting statistical size effects on compressive failure of heterogeneous materials, with a special focus on concrete, *Journal of the Mechanics and Physics of Solids* (2018), doi: 10.1016/j.jmps.2018.07.022

Revisiting statistical size effects on compressive failure of heterogeneous materials, with a special focus on concrete

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Abstract

Size effects on mechanical strength, i.e. the fact that larger structures fail under lower stresses than smaller ones, already highlighted by Leonardo da Vinci and Edmée Mariotte centuries ago, remain nowadays a crucial problem to establish structural design rules and safety regulations from an upscaling of laboratory data. These size effects are generally explained either from a deterministic energetic approach that predicts a non-vanishing asymptotic strength but, by construction, does not account for fluctuations around the mean strength and their size dependence, or from a statistical approach based on the weakest-link theory that implies a vanishing strength towards large scales. We recently proposed an alternative framework based on an interpretation of compressive failure of heterogeneous materials as a critical transition from an intact to a failed state, which releases the underlying hypotheses of the weakest-link theory, pure brittleness and the independence of damage events, while predicting a non-vanishing asymptotic mean strength but vanishing intrinsic fluctuations at large scales. Here, from an extensive series of uniaxial compression experiments (527 tests) on concrete samples with four different sizes and three different microstructures, we demonstrate (i) the failure of the weakest-link theory in this case, and instead (ii) the pertinence of our critical framework to account for size effects on compressive strength of an emblematic quasibrittle material, concrete, in terms of average strength, associated fluctuations, and probability of failure. From a detailed analysis of the microstructural disorder of