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Failure modes of complex materials with spatially-correlated mechanical properties - the critical role of internal damage

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The study reports a systematic evaluation of the role of spatially correlated mechanical elements on failure behavior of heterogeneous materials represented by fiber bundle models (FBM) with different load redistribution rules.

Results indicate that FBM failure mode varies dramatically with increasing correlation length and localized load sharing rules. Systems with similar composition of mechanical elements exhibit a dramatic transition from ductile and diffuse damage for global load sharing to brittle single failure for correlated and local load sharing. These changes in mechanical responses also affect the statistical properties of fiber failure avalanches (micro-cracks) activity preceding rupture and sought after in various early warning scenarios. While diffuse damage behavior exhibits clear precursory signals (such as increased seismic activity prior to global failure), brittle failure occurs abruptly with only few precursors.

Although increasing spatial correlations of mechanical properties promotes abrupt ruptures at lower external load, this study identified an "universal" global failure criterion based on macroscopic properties which is independent of the rupture mode, load redistribution rules, or the spatial organization of mechanical properties. This metric that considers the combined role of external load and cumulative damage provides a means for evaluating imminence of failure of heterogeneous materials without resolving details of the heterogeneity.

This study also provides new insights that are potentially useful for understanding landslide (but also snow avalanche or rockfall) triggering and points out the importance of spatial organization of heterogeneities on the failure behavior of complex geomaterials.