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Jammed particulate systems are inherently nonharmonic[1]

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Normal mode analysis in the harmonic approximation underlies most of solid-state physics and applies well to both ordered and dis- ordered systems. Naturally, researches apply this analysis to jammed particulate systems, such as granular media, colloids, and foams, that interact via one-sided interactions, which are nonzero only when particles overlap. However, we find that systems with one-sided repulsive interactions possess no linear, harmonic response regime for large systems ($N \to \infty$) at finite pressures P, and for all N near jamming onset $P \to 0$. We perform simulations on 2D frictionless bidisperse mechanically stable disk packings over a range of packing fractions $\Delta\phi = \phi - \phi_J$ above jamming onset ϕ_J. We apply perturbations with amplitude δ to the packings along each eigen-direction from the dynamical matrix and determine whether the response of the system evolving at constant energy remains in the original eigenmode of the perturbation. For $\delta > \delta_c$, a single contact breaks and fluctuations abruptly spread to all discrete harmonic modes. As δ increases further all harmonic modes disappear into a continuous frequency band. We find that $\delta_c \sim \Delta\phi/N$, and thus jammed particulate systems are inherently nonharmonic with no linear vibrational response regime as $N \to \infty$ over the full range of $\Delta\phi$, and as $\Delta\phi \to 0$ at any N. This breakdown of harmonic behavior dramatically affects all aspects of system response including heat capacity, density of states, elastic moduli, and energy propagation.

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