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**Jamming in Granular Systems**[1]

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Granular materials exist all around us, from the formation of sand dunes and collapse of seemingly stable grain silos, to the mixing of pharmaceuticals and other industrial materials. The behavior of these "fluids" though poorly understood. Their flow can be characterized by the continuous forming and breaking of a strong force network resisting flow. This jamming/unjamming behavior is typical of a variety of systems, including granular flows, and is influenced by factors such as grain packing fraction, applied shear stress, and the random kinetic energy of the particles. We present experiments on quasi-static shear and free-surface granular flows under the influence of external vibrations. By using photoelastic grains, we are able to measure particle trajectories and the local force network in these 2D flows. We find that during shear, sufficient shaking weakens the strong force network and reduces the amount of flow driven by sidewalls. We vibrate either the driving wall (sidewall forcing) or the entire shearing zone (bulk forcing). For sidewall forcing, flow behavior is controlled by vibration amplitude in particular and slipping of force chains at the boundary. In a rotating drum geometry, we find that small vibration leads to strengthening of the pile while larger vibrations induce failure as might be expected. This behavior is strongly history dependent and sufficient vibration erases the memory of the pile.

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