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Trampoline effect under extreme ground motions

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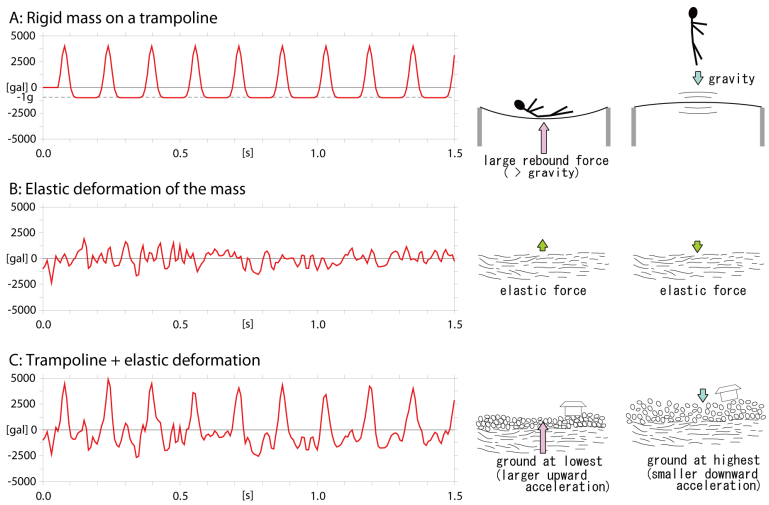
In earthquake hazard assessment studies, the focus is usually on horizontal ground motion. However, records from the 14 June 2008 Iwate-Miyagi earthquake in Japan, a crustal event with a moment magnitude (Mw) of 6.9, revealed an unprecedented vertical surface acceleration of nearly four times gravity, more than twice its horizontal counterpart.

The deployment of high-density seismograph networks has contributed to recent discoveries concerning ground shaking and complex wave propagation. As more and more near-source data have become available, the stockpile of extreme ground motion observations has become ever larger, with potentially rich implications for earthquake engineering and building design.

The motion in question was recorded at the IWTH25 (West Ichinoseki) station, located on the hanging-wall side of the fault, 3 km southwest of the epicenter. The vertical acceleration was distinctly asymmetric - the waveform envelope was ca. 1.6 times larger in the upward direction than in the downward direction, which is not explained by existing models of the soil response.

We present a simple model of a mass bouncing on a trampoline to account for this asymmetry and the large vertical amplitude (Figure). Our trampoline model can well explain the characters of observed asymmetric acceleration both for the amplitude (S+/S-) and the period (T-/T+) and the tendency for the downgoing accelerations to be bounded near -1×g is also reproduced. The finding of a hitherto-unknown mode of strong ground motion may prompt major progress in near-source shaking assessments.



(A) Simplified model of the motion of an undeformable mass bouncing on a trampoline. (B) Elastic deformation of a deformable mass, represented by a selected part of a downhole seismic record. (C) Simulated motion of a deformable mass bouncing on a trampoline, obtained as the sum of (A) and (B).