The Effects of Dynamic Damage on Earthquake Ruptures and on the Seismic Coupling of Underground Explosions: An Experimental and Theoretical Study

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Abstract

High-speed photography is used to study the effects of off-fault damage on the propagation of ruptures on fault planes in photoelastic polymer plates. Interaction between the rupture tip and fracture damage is observed to significantly slow the rupture velocity and can produce asymmetric propagation which is much stronger than that produced by the mismatch in elastic velocities alone. Similar high-speed photographic studies were also used to explore the evolution of fracture damage and seismic radiation generated by point explosions in plates of “candy glass” (the extremely brittle material used to simulate glass in movie stunts). The seismic waves were also recorded using laser velocimeters. We find that the generation of fracture damage has a strong effect on the resultant seismic radiation, even in the absence of asymmetry caused by pre-stress or fracture anisotropy. These earthquake and explosion simulations were modeled using a dynamic micromechanical damage mechanics that was incorporated as a user prescribed rheology in the ABAQUS dynamic finite element code. The damage mechanics is an extension of a quasistatic formulation that includes a natural rate-dependence based on established high-speed crack nucleation and growth dynamics. It is shown to give a good description of observed nonlinearities in the triaxial failure envelope and stress-strain curves of Westerly granite, as well as the observed dependence of strength on loading rate, and it accurately predicts the observed strength of marble over a 10 order of magnitude range in loading rate.