Final Report Project 08028

The Source and Significance of High-Frequency Bursts Observed on Strong Motion Records from the Chi-Chi Taiwan and Parkfield California Earthquakes

Charles G. Sammis
University of Southern California

Proposal Category: Integration and Theory

Science Objectives: B5, B2, and A7

Relevant to SCEC Special Projects: ExGM and NGA-H

We investigated the source mechanics and energetics of the myriad of small high-frequency bursts revealed by band-pass filtering of strong motion records from the 1999 Mw7.6 Chi-Chi Taiwan earthquake (Fischer et al., 2007a) and the 2004 Mw6.0 earthquake in Parkfield California (Fischer et al., 2007b). The observation of bursts with dominant frequencies as high as 50 Hz at distances out to 170 km from the Chelungpu fault rules out an earlier hypothesis that they are generated at asperities on the fault plane (Chen et al., 2006). Having also ruled out obvious instrumental sources, our current hypothesis is that the bursts are generated by stick slip instabilities that are driven by the strong motion on very shallow surfaces very close to the individual stations. Our inability to correlate the signals from a given burst at stations as close together as 50 meters suggests that they occur in the upper 100 meters of the crust where Q values as low as 5 have been measured, and that their magnitudes are below 1. This magnitude limit is consistent with independent spectral estimates, which range between -1 and 0.

Two key research questions addressed by this project were: 1) given the observed spatial and temporal density of the bursts, do they convert a significant portion of the strong motion energy to higher frequencies, and 2) what is the physical mechanism by which strong motion seismic waves drive unstable slip on surfaces in the very shallow crust?

The results of this research have been published in the Bulletin of the Seismological Society of America. This was the third paper comprising the PhD thesis of Adam Fischer. The results are summarized in the following abstract.

Fischer, A. D. and C. G. Sammis (2009), Dynamic driving of small shallow events during strong motion, Bull. Seismol. Soc. Am., 99; 1720-1729; DOI: 10.1785/0120080293.

Abstract

High-pass filtering (>20 Hz) of acceleration records from the 1999 Chi-Chi Taiwan and 2004 Parkfield, California earthquakes reveal a series of bursts that occur only during strong shaking. Initially interpreted as originating from asperity failure on the Chelungpu fault, bursts observed

during the Chi-Chi earthquake were subsequently determined to be a local effect within about 1 km of the seismic stations. Similar bursts were observed at the UPSAR during the Parkfield earthquake and were constrained to originate less than 20 m from the instruments. Such small shallow events can not result from the triggered release of stored elastic energy because rate-and-state friction rules out stick-slip instability on such small, shallow patches. Our hypothesis is that the bursts are not triggered, but are driven by simultaneous shear and tensile stresses near the surface during the strong motion. At 2 Hz, SV to P wave mode conversion at the free surface produces tensile stresses to depths of 70 m. Where standard triggering releases stored elastic energy and adds to the incident wavefield, this new driving mechanism takes energy out of the 2 Hz strong motion and reradiates it at high frequencies. It is thus an attenuation mechanism which we estimate can contribute 3% to the net attenuation in the very shallow crust.