# Final Project Summary — PEER Lifelines Program

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| *Project Title*—**ID Number** | *Utilization of Physical Model Data to Validate Numerical Procedures for Near-Field Motions*—**1D02** | | |
| **Start/End Dates** | 9/1/01 – 10/31/03 | Budget/ Funding Source | $120,000 / PG&E/CEC |
| **Project Leader (boldface)** and Other Team Members | **S. M. Day,** R. Graves, A. Pitarka, Y. Zeng, W. Silva | | |

### 1. Project goals and objectives

The objective of Project 1D02 was to determine whether numerical procedures for simulating ground motions are capable of capturing the near-field effects of an earthquake. Ground-motion time histories generated from the rupture of a foam rubber model were used as the "data" against which several widely used simulation procedures were tested.

### 2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

Earthquake modeling using a foam rubber model automatically accounts for the source and wave propagation effects in a controlled environment. Data obtained from the foam rubber modeling not only directly provides important insights into the near-field effects, but also provides a set of time histories against which numerical procedures can be validated.

### 3. Brief description of the accomplishments of the project

The analysis and numerical modeling of the data led to an improved understanding of the foam rubber experiments. Two types of experimental events were identified, for which the directivity effects were very different: those events that ruptured mainly along strike, and those with highly oblique incidence, respectively (Fig 1). Model rupture velocities were determined and found consistent with predictions from numerical modeling with dynamic rupture code DFM. Measured directivity effects (as quantified by the slope of a spectral-ordinate-versus-Xcos(theta) regression) on response spectra are comparable to predictions from earthquake regression models at periods comparable to and greater than the S transit time across the fault (Fig 2). However, the foam data have higher directivity slopes than real earthquakes at shorter periods. The latter suggests that, in real earthquakes, disordering effects such as frictional and elastic heterogeneity reduce short-period directivity relative to simple models. In addition, comparison of DFM simulations and recorded waveforms aided in the identification and correction of reported model parameters (S and P velocities). Simulation of recorded waveforms by kinematic modeling techniques, after a numerical model calibration using a subset of the recorded data, had good predictive capability for the remainder of the data. A calibration error (factor of two amplitude scale factor) in the data was reported to us after completion of the technical work, limiting our ability to draw firm quantitative conclusions from the numerical simulations at present.

### 4. Describe any instances where you are aware that your results have been used in industry

### 5. Methodology employed

The scale-model earthquakes were done under separate support and are described elsewhere. Project 1D02 used an explicit, 3D finite difference code, DFM, to model the dynamics of the foam experiments. The kinematic simulation component of the project used 4 different methods: 2 kinematic models based upon different frequency-wavenumber transform methods, a kinematic-source finite difference method (explicit, fourth-order in space, second-order in time) and a primary-only ray-theory approach. The former 3 include elastic waves of all types (in the context of isotropic elasticity), while the latter includes only far-field terms, and only those associated with primary body-wave arrivals.

### 6. Other related work conducted within and/or outside PEER

The foam rubber experiments were performed by University of Nevada, Reno, under separate PEER support. The kinematic simulation methods were calibrated to earthquake data under separate PEER Lifelines projects.

### 7. Recommendations for the future work: what do you think should be done next?

Subsequent to the completion of the technical work for this project, the foam rubber data supplied to the project were determined to be mis-calibrated by a factor of two. The numerical simulations done for this project therefore needs to be updated, using new kinematic and dynamic simulations appropriate to the correctly calibrated foam rubber data. Further numerical modeling of data from foam rubber experiments has great potential for testing dynamic rupture models and proposed finite-source inversion methods, both of which are important to ground motion simulation methods in use or under development.

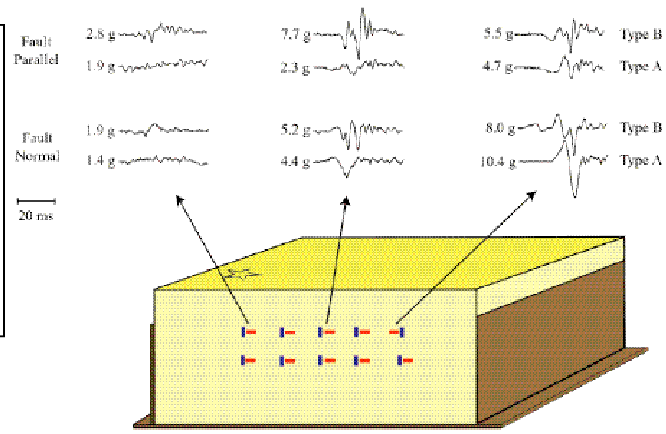
### 8. Author(s), Title, and Date for the final report for this project

**Authors**: Steven M. Day, Robert Graves, Arben Pitarka, Walter Silva, Yuehua Zeng, Rasool Anooshehpoor, and James N. Brune

**Title**: Utilization of Physical Model Data to Validate Numerical Procedures for Simulating Near-Field Motions

**Date**: Pending

Fig 1. Comparison of fault parallel and fault normal acceleration records for sensors located 25 cm from fault trace (fault plane in dark yellow; sensors are on free surface plane, shown in light yellow). Events labeled "Type A" were found to have predominantly along-strike rupture direction. "Type B" events had highly oblique rupture direction. Note very different waveforms and directivity patterns for the 2 types of events.



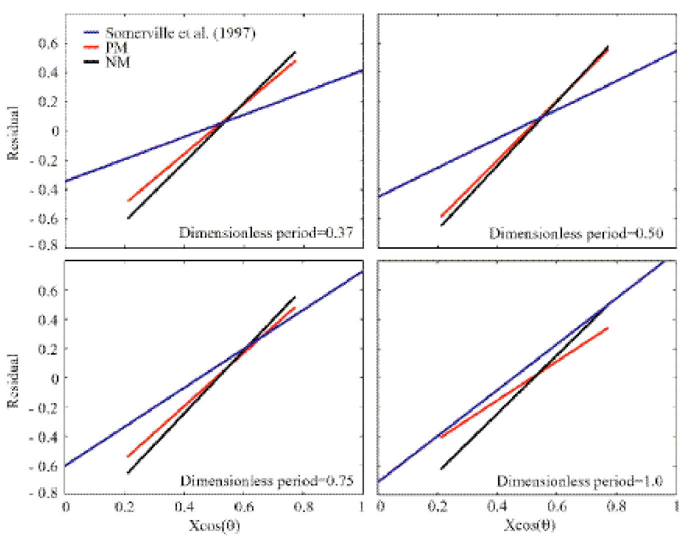




Fig 2. Regression lines for residuals as function of directivity variable Xcos(θ), for DFM numerical model (black), foam model (red), and empirical earthquake model (blue—from Somerville et al, 1997, *Seism. Res. Letters*). A dimensionless period is used as basis of comparison between scale-model and real earthquake data, where a dimensionless period of 1 corresponds to S wave transit time across fault width.