Final Project Summary — PEER Lifelines Program

Project Title—**ID Number**	*Validation of 1-D Numerical Simulation Procedures*—**1C02c**		
Start/End Dates	05/01/00 – 03/31/02	Budget/ Funding Source	$50,000 / PG&E/CEC
Project Leader (boldface)	**Zeng**/ **Anderson (UNR)**		

1. Project goals and objectives

Our goal is to develop physically based broadband synthetic ground motion database using validated ground motion simulation procedure. This synthetic database will complement the existing observation on magnitude, distance, and frequency range. The objective of this project is to validate our composite source model using strong motion data from the 1999 Turkey and Taiwan earthquakes.

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.

Using the 1-D ground motion simulation procedure validated through this project, we have a synthetic ground motion database that includes 10 strike-slip scenarios earthquakes and 12 reverse-slip scenarios earthquakes with magnitude ranging from 6.5 to 8.5, distance from 0 to 200 km, and period from 0.01 to 10 seconds. The synthetic databases are currently used for the purpose of providing guidance to the selection of functional forms used in developing the next generation ground motion attenuation relations and to constrain the extrapolation of the relations outside the range of empirical data.

3. Brief description of the accomplishments of the project

We have computed a joint GPS static deformation and strong motion waveform inversion for the Kocaeli and the Chi-Chi earthquakes to obtain the composite source rupture processes of the events (Figure 1a and 2a) using the genetic algorithm procedure developed by Zeng and Anderson (1996). For both earthquakes, we used a fault model with curved fault planes based on the field surface rupture data. We found evidence of supershear rupture velocity for the Kocaeli earthquake fault rupture. For both events, the subevent of the composite sources shows significant slow rupture or long rise time comparing with other earthquakes we have previous studied. The total moment is $2.1\text{x}10^{27}$ dyne-cm for the Kocaeli earthquake and $2.9\text{x}10^{27}$ dyne-cm for the Chi-Chi earthquake.

We found that a variable rupture velocity for the subevent rupture of the composite sources provided an overall unbiased fit to the observed ground motion response spectra in the frequency range of 0.1 to 25 Hz. In general, we found that the composite source model has generated very realistic ground motion in comparison with the observations. For the Chi-Chi earthquake, there is systematic underprediction for stations to the south of the epicenter and slight overprediction for stations to the north of the epicenter. Overall, the composite source simulations agree very well with the observations over a broad frequency band for the ground motion amplitudes and duration (Figure 1b and 2b). This research has lead to the improved kinematic rupture model for scenario earthquake strong ground motion predictions.

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

Result of this project has not been used directly in industry, but the simulation procedure developed from this project has been used for other applications, i.e., the DOE Yucca Mountain ground motion simulation, PEER/SCEC/USGS NGA ground motion simulation, etc.

5. Methodology employed

We have used an improved composite source model (Zeng et al., 1994) to compute synthetic strong motion seismogram. The composite source model assumes a large earthquake is a superposition of smaller subevents that all break during the earthquake rupture processes. The number and radius of the subevents follow the Guttenberg and Richter frequency-magnitude relation given in form of a power law distribution of radii, $N(r) \sim r^{-p}$ where p is the fractal dimension. Given the source parameters of a large earthquake, we can numerically generate the subevents following the power law relation. We then place these events within the fault plane and allow them to overlap. The random nature of the heterogeneities on a complex fault is achieved by distributing the subevents randomly on the fault plane. Rupture propagates from the hypocenter, and each subevent radiates a displacement pulse of a rupture crack when the rupture front reaches the subevent. Once the source has been specified, we can propagate the motion generated at the source to the site using layered crustal model (Luco and Apsel, 1983) or 3-D inhomogeneity structure using finite difference method. The method has been successful in generating realistic strong motion seismograms. The realism is demonstrated by comparing synthetic strong motions with observations from the recent California earthquakes at Landers, Loma Prieta (Su et al., 1994a,b) and Northridge (Zeng and Anderson, 1996; Anderson and Yu, 1996; Su et al., 1998), earthquakes in the eastern US (Ni et al., 1999) and earthquakes in Guerrero, Mexico (Yu, 1994; Zeng et al., 1994; Johnson, 1999), Turkey (Anderson et al., 1997) and India (Khattri et al, 1994; Zeng et al, 1995).

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

We have related projects funded by SCEC/PEER titled "1-D Rock Ground Motion Simulation to the SCEC/PEER NGA Initiative" and by USGS titled "Improving ground motion attenuation relation in the Great Basin", etc.

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

Current model is based on kinematic earthquake source model. Future improvement should include features of dynamic earthquake source rupture.

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

Final Technical Report of the project titled "Validation of 1-D Numerical Simulation Procedures of the 1999 Turkey and Taiwan earthquakes" by Yuehua Zeng on August 29, 2002.

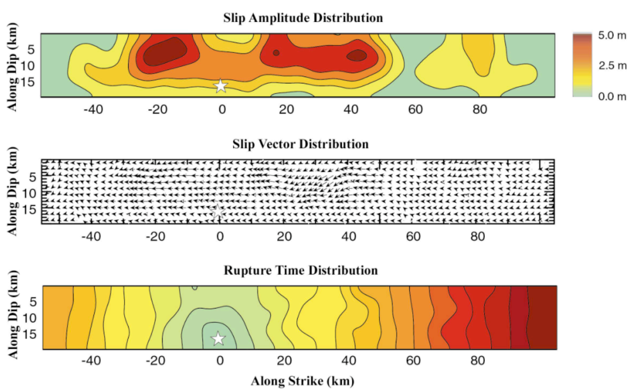

Figure 1a. The Kocaeli earthquake composite source slip amplitude, slip vector, and rupture time distributions over the fault plane.

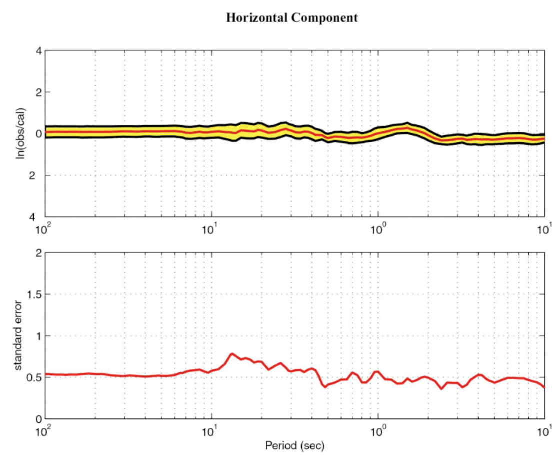

Figure 1b. The upper panel plots biases (red) and its 90% confidence limits (black) of the Kocaeli prediction for the horizontal component. The lower panel plots the standard errors.

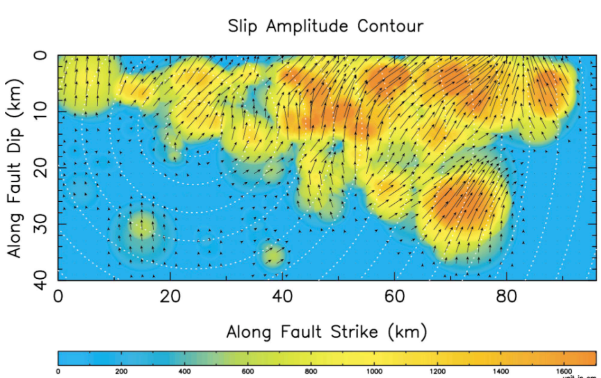

Figure 2a. The final slip amplitude and slip vector distributions of the Chi-Chi earthquake composite soruce model.

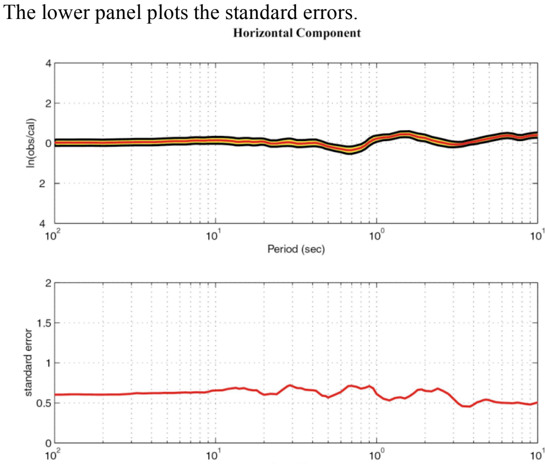

Figure 2b. The upper panel plots biases (red) and its 90% confidence limits (black) of the prediction for the horizontal component. The lower panel plots the standard errors.