

Final Project Summary — PEER Lifelines Program

Project Title—ID Number	<i>Interim Spectral Attenuation Relations—1C01</i>		
Start/End Dates	05/01/00 – 04/31/02	Budget/ Funding Source	\$56,750 / PG&E/CEC
Project Leader (boldface) and Other Team Members	Chiou (Geomatrix)		

1. Project goals and objectives

There are two goals: 1. To update the Sadigh and others (SAO) attenuation model, which has been a major tool used for seismic design in California. 2. To conduct a preliminary evaluation of the potential impacts of three major 1999 earthquakes on the attenuation models used in current practice for seismic design in California.

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.

The outcome of this project improves our understanding of the characteristics of shaking due to large magnitude earthquakes, which have a high probability to occur in California in the next 50 years. This is particularly important given that California hasn't experienced large earthquake ($M > 7.5$) since strong-motion observatory system was established in the 1930s.

3. Brief description of the accomplishments of the project

We completed several major improvements to the Sadigh attenuation models, including the use of mixed-effects statistical model for regression analysis, overhaul of the modeling of soil effects to better capture the soil non-linear behavior and its effect on spectral shape (Figure 1), period-dependence of the style-of-faulting effect (Figure 2).

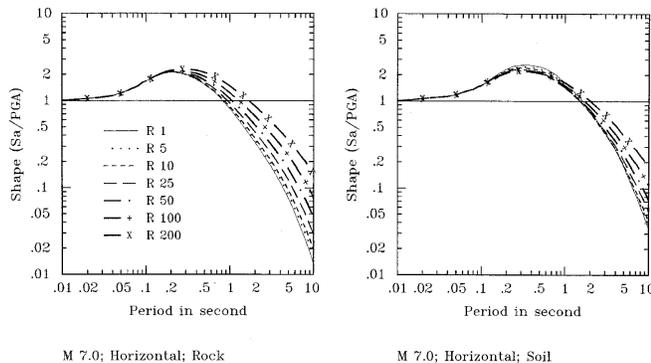


Figure 1

Comparison of Style-of-Faulting Factor

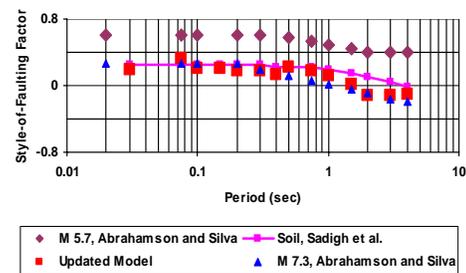


Figure 2

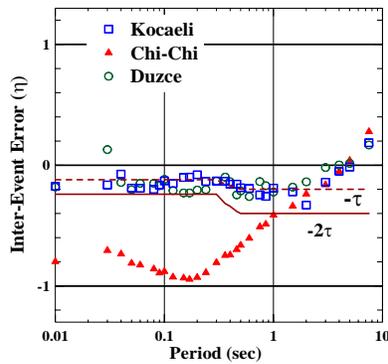


Figure 3

We evaluated the 400+ recordings from the 1999 Kocaeli (M7.4) and Duzce (M7.2) earthquakes from Turkey and the 1999 ChiChi Taiwan earthquake (M7.6). The objective is to explore their potential impacts on the predictive relationship of ground shaking in terms of both the median and the standard deviation. The main results are summarized in Figures 3 and 4. All three earthquakes generated lower-than-average shaking (Figure 3), but ChiChi is clearly an outlier in the context of SAO. Our attempt to model the 1999 data set leads to the results shown in Figure 4. The inclusion of these 1999 data increase the total standard error by about 20% due to the reduced magnitude-dependence of earthquake-to-earthquake variation stemming from the unusually low shaking of ChiChi earthquake. On the other hand, the median value (Figure 4) of high frequency motion decreases by also about 20% at distances less than 50 km. It is noted that, even with this reduction, ChiChi is still, on average, two standard errors below the median predicted for typical M7.6 earthquake. The same can be anticipated when other attenuation models are considered.

Updated Model:
Median, Rock

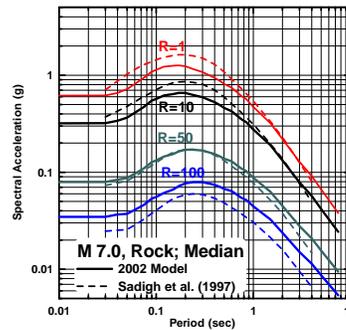
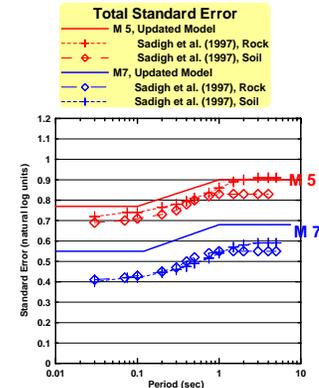


Figure 4

Updated Model
Total Standard Error



It is concluded that the attenuation models used in current practice cannot satisfactorily explain ChiChi data. The observed low level of shaking may be explained by new explanatory source parameters and/or regional differences in source/path/site effects between California and other seismically active regions.

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

The data and supporting information collected during this project has been incorporated into the PEER strong-motion database, which has been an important resource for both industry and academy.

5. Methodology employed

(See section 3)

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

This project sets the stage for the major research initiative of Next Generation of Attenuation Model (NGA), which is a national, multi-agencies collaboration aimed to dramatically improve our ability to predict ground-motion hazard of future major earthquake in California.

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

This study concludes that the attenuation models used in current practice cannot satisfactorily explain the lower-than-average shaking of the recent large earthquakes, particularly the ChiChi earthquake. Better understandings of the behavior of these recent large earthquakes would greatly benefit California in the area of earthquake hazard mitigation. Search for new explanatory source parameters and understanding of regional variation in source/path/site effects are thus highly recommended for the future work to be conducted under the NGA project.

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

“Update of the attenuation relationships of Sadigh and others for shallow crustal earthquakes”, Brian Chiou & Robert Youngs.