CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Second National Earthquake Ground-Motion Mapping Workshop (20.01402.471, 20.01402.671)

DATE/PLACE: May 10–11, 2001, San Francisco, California

AUTHOR: John Stamatakos

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PERSONS PRESENT:

The workshop was attended by 112 geoscientists and engineers interested in the latest advances in earthquake hazard estimation and earthquake engineering design issues. The workshop was hosted by the Applied Technology Council (ATC) with funding from the United States Geological Survey (USGS). Co-sponsors included a host of public and private geological and engineering groups.

BACKGROUND AND PURPOSE OF TRIP:

The workshop was designed to gather input from structural engineers, geoscientists, and geotechnical engineers on key issues that affect the preparation and use of the second round of national earthquake ground-motion maps. In particular, the workshop focused on topics related to near-fault directivity, methodologies for updating design maps from the earthquake hazard maps, and potential new directions for earthquake hazard and design mapping. I attended the meeting to learn of new advances in seismic hazard assessments.

SUMMARY OF PERTINENT POINTS:

The workshop was divided into three sections. (1) Scientific issues for Probabilistic National Ground-Motion Mapping and Effects on Ground Motion Hazard; (2) Issues for Design Maps; and (3) Map Products and New Directions. Within each section there were several prepared oral presentations followed by lengthy roundtable discussions. A full copy of the workshop handout is available by request from John Stamatakos. In this trip report, I present a summary of what I found to be the most interesting presentations and discussions.

Revision of the United States Geological Survey National Seismic Hazard Maps

The USGS is in the process of revising and updating the national seismic hazard maps. The revised 2001 maps will be released by the end of 2001. The revision is based on new data and results gleaned from four regional workshops, in which the most recent scientific and technical information was presented. The effort is led by Dr. A. Frankel of the USGS, who presented a summary of the new mapping, highlighting several important results.

- The new maps will be an incremental change from the 1996 maps, avoiding drastic changes because of a need for stability by the engineering communities. New scientific findings must have sufficient maturity and acceptability by the scientific community to be incorporated into the maps.

- As in 1996, the revision of hazard maps are based on probabilistic ground motions (derived from the mean hazard curves at each map grid node). Seismic hazard curves for each node are based on a logic tree approach, greatly expanded from the 1996 version. In particular, the 2001 revision includes uncertainties in the recurrence rates for earthquakes on mapped faults and their characteristic moment magnitudes. The probabilistic ground motions are given as 2 percent probability of exceedence in 50 years which roughly corresponds to the 2,500 yr ground motion hazard.

- In addition to the base ground motion maps, the 2001 revision will include uncertainty maps expressing the variability of the input parameters used in the determination of the mean hazard as well as in the ground motion logic trees.

- The 2001 maps also included a lot of new data on fault sources and recurrence, especially for the Pacific Northwest, New Madrid, and Charleston, South Carolina. There was some discussion of using GPS-derived deformation rates to fill in areas with an incomplete inventory of active faults.

- New attenuation relationships being considered in the 2001 revision include the Atkinson and Boore (1995) attenuation relationships for the central and eastern United States and the Abrahamson and Silva (1997) and Spudich et.al. (1999) relationships for the western United States.

Directivity

Dr. Paul Somerville presented a new model for fault-rupture directivity. Directivity is the process by which the fault ruptures propagates along a fault at a velocity close to the shear-wave velocity of the rock. The effect is that much of the seismic energy arrives at a site near the fault as a single long-period pulse of ground motion. Although controversial, Dr. Somerville's previous work on directivity (Somerville et al., 1997) has been used to modify existing ground motion attenuation relationships, including the attenuation relationships used in the probabilistic seismic hazard assessments (PSHA) for Yucca Mountain and Skull Valley, Utah.

In the revised directivity model (referred to as the Narrow Band Directivity Model), Dr. Somerville notes that in many strong motion records of large earthquakes, the near fault pulse is a narrow band pulse whose period increases with earthquake magnitude. In other words, larger earthquakes produce a directivity pulse at lower frequencies of ground motion than smaller earthquakes. The physical bases for the frequency effect are that bigger earthquakes have longer rise times (time it takes for the fault to fully rupture during an earthquake) and longer earthquake durations.

Dr. Somerville recommended that the USGS incorporate directivity into its ground motion calculations, but this suggestion was not well received by the mapping team. The biggest problem to the mappers is the ability (or lack thereof) to predict a preferred directivity direction associated with fault rupture, or even to decide if fault rupture is equally likely in either direction along the fault from the epicenter. At present there is insufficient strong-motion data to be able to accurately predict if directivity for any given fault has a preferred direction. The USGS mapping team will not include directivity in the 2001 revised maps.

Dr. Robert Youngs (Geomatrix Consultants Inc) showed a comparison study of a sample PSHA in which the Somerville directivity effects were both included and excluded. Dr. Youngs conclusion was that the directivity effects are already included in the uncertainties associated with empirically-derived ground motion attenuation relationships and that the addition of a specific directivity factor in ground motion attenuation equations essentially double counted the effect. Dr. Youngs based his conclusion on the fact that empirical ground motion attenuation models are derived from a suite of strong ground motion records of historical earthquakes, some of which were probably from recording station optimally oriented to record the directivity pulse (the alternative is that most of the existing strong motion records unfortunately missed directivity pulses).

Time Dependent Behavior

Dr. Allin Cornell led a discussion on the possibility for time-dependent behavior. Dr. Cornell showed the end-member models: (a) earthquakes follow a Poisson process (i.e., that the time of occurrence of the next earthquake on a fault is independent of the time of the last earthquake), or (b) earthquakes are cyclical with predictable intervals between earthquakes. Earthquake cyclicity stems from the classical model for earthquake triggering—stress loading by tectonic forces until failure (fault rupture) and stress release. Because the tectonic stress is thought to be loaded at an approximate constant rate, this cyclic model predicts that earthquake recur at a uniform rate with a characteristic inter-arrival time. If the cyclic model is correct, regions near faults that have recently ruptured (and thus are in the early stages of the stress-release cycle) would be lass hazardous than areas near faults that are loaded with stress and near the end of their stress-release cycle.

Nature probably lies between the two end-member ideas. Faults often interact such that stress release on one fault could stress-load a nearby fault. Smaller intra-arrival earthquakes could modify the stress regime enough to delay or advance the arrival time of the next characteristic earthquake. Tectonic forces may not themselves be entirely constant but may vary spatially and temporally.

Nevertheless, Dr. Cornell noted that hazard calculations could incorporate some aspects of the time-since-last-earthquake in probabilistic seismic hazard calculations. He proposed a coefficient of variation (COV) parameter to capture the time dependent behavior. For purely stochastic behavior (i.e., random distribution of earthquakes), COV has a value of one. For a purely deterministic inter-arrival times, COV has a value of zero.

Introduction of the COV concept would most greatly impact areas that are prone to large earthquakes with long inter-arrival times compared to areas that experience large, relatively frequent earthquakes. For example, the Wasatch fault in Utah is known to produce magnitude 7 and larger earthquakes (last one about 10,000 yrs ago), but the inter-arrival times are on the order of 10^4 to 10^5 yr. In contrast segments of the San Andreas fault can also produce magnitude 7 and larger earthquakes, but the inter-arrival time is 100–200 yr (last one in 1989). In a probabilistic seismic hazard analysis, incorporation of a time-dependent parameter will not effect the 10^4 to 10^5 ground motion hazard of San Andreas fault segment (there will be many 100–200 yr earthquakes that contribute to the 10^5 ground motion). However, for the Wasatch fault, the COV parameter could greatly reduce the hazard because of the long inter-arrival time compared to time since the last earthquake. Similarly, introduction of the COV concept could reduce the hazards for Charleston and New. Both regions are capable of producing large albeit infrequent earthquakes. Both Charleston and New Madrid have experienced large earthquakes in the relative recent past when compared to their ca. 10^4 inter-arrival times (1811–1812 in New Madrid and 1886 in Charleston, South Carolina).

Dr. David Schwartz followed Dr. Cornell with a brief summary of the available historic and paleoseismic data for California. He showed that data support the notion of temporal regularity in earthquake occurrence. For example, of the 238 magnitude 5.5 to 8.0 earthquakes in the 20th century (compiled by Wells and Coppersmith, 1994), only four were on the same fault. For California, radiocarbon dated intervals between successive earthquakes are very similar to average recurrence rates determined from independently derived slip rates. Longer-term paleoseismic data from many faults in the Basin and Range also show regularly-spaced intervals between characteristic earthquake ruptures.

The current and planned 2001 USGS maps do not include the COV concept and assume that earthquakes are essentially a stochastic process. Dr. Mark Peterson showed sensitivity studies for incorporation of time-dependence for the Wasatch and Charleston seismic zones. Full incorporation of the effect greatly reduces the probabilistic ground motions at 2 percent probability of exceedence in 50 years. Dr. Peterson, and the rest of the USGS mapping team concluded that more research needs to be completed before time-dependence can be properly incorporated into the USGS national maps.

IMPRESSIONS/CONCLUSIONS:

The meeting was highly informative and will provide me with added insights in our work on seismic hazard issues at Yucca Mountain, Skull Valley Utah, and the MOX facility in South Carolina. I look forward to the USGS release of the new national seismic hazard maps.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None

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