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A Seismic Site-Amplification Map for Memphis, Shelby County, Tennessee From Geophysical, Geotechnical, and Geological Measurements

C. Cramer
U.S. Geological Survey, Memphis, TN

R. Williams
U. S. Geological Survey, Denver, CO

K. Tucker
CERI, Memphis, TN

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C. Cramer
U.S. Geological Survey
3876 Central Ave Ste 2
Memphis, TN 38152-3050

R. Williams
U.S. Geological Survey
P.O. Box 25046, MS 966
Denver, CO 80225

K. Tucker
CERI
3876 Central Ave Ste 1
Memphis, TN 38152-3050

ABSTRACT

As a part of the U.S. Geological Survey's (USGS) Memphis, Shelby County Seismic Hazard Mapping project, geophysical and geotechnical subsurface data are being collected into a subsurface database for Shelby County, Tennessee. Memphis is a major urban area near the New Madrid Seismic Zone in the central U.S. and has a building stock that is largely vulnerable to even moderate ground shaking from earthquakes. The subsurface geological, geotechnical, and geophysical information gathered will be used to construct a three-dimensional model of the geology and seismic velocity structure of the area down to Paleozoic bedrock (up to 1 km deep) for the purpose of determining site amplifications. The resulting characteristic seismic velocity profiles will include variability in S-wave velocity with depth and will be used to provide the uncertainty estimates in site amplification measurements. The mean site amplification map for Shelby County will serve as an amplification potential map for use in the seismic hazard assessment portion of the project.

INTRODUCTION

Central United States (CUS) earthquakes often are classified as low probability, high impact events. The impact of even a moderate CUS earthquake could be high, causing widespread damage because seismic waves lose energy very slowly in the CUS and because most of the building stock is not designed to withstand strong earthquake ground shaking. Memphis and the other areas of Shelby County, Tennessee would be especially hard hit because it is a densely populated urban area near the seismically active New Madrid seismic zone (NMSZ).

The U.S. Geological Survey's (USGS) Memphis - Shelby County Seismic Hazard Mapping project is producing a series of state-of-the-art geologic hazard products, including a subsurface geologic and geophysical database, and a seismic site amplification map at a scale of 1:24,000. Other products include surface geology maps (Broughton et al., 2000), liquefaction susceptibility maps (Broughton et al., 2000), and probabilistic seismic hazard maps that will include site conditions (Cramer et al., 2000). This presentation will focus on the development of a subsurface database of available geological, geophysical, and geotechnical data and the site amplification map derived from that database of information.

DATABASE

The surface geology within Shelby Co. varies from recent fluvial deposits near the Mississippi River to loess-capped bluffs overlooking the river, with the loess thinning to the east and overlying older fluvial deposits. These deposits overlie poorly consolidated Mississippi embayment sediments of Cretaceous to Eocene age up to 1 km thick that rest on hard, dense Paleozoic limestones.

Subsurface information is being compiled into a database for the generation of site amplifications. This includes surface and downhole measurements of shear-wave velocity (Vs), lithology, geotechnical parameters, and ground response to weak seismic motions. Data are being contributed by the USGS, the Center for Earthquake Research and Information (CERI), Memphis Light, Water, and Gas (MLWG), the Ground Water Institute of the University of Memphis, the University of Kentucky, Georgia Tech, and other engineering sources. Geophysical data being gathered included borehole, seismic cone penetrometer, shallow seismic refraction/reflection, and shallow surface-wave data (Liu et al., 1997; Schneider, 1999; Liao et al., 2000; Williams et al., 2000; Street, 1999). The spatially sparse Vs data are being supplemented with lithologic (downhole and CPT) and

geotechnical subsurface data (Liu et al., 1997; Schneider, 1999; Liao et al., 2000; Hwang et al., 1999). Within Shelby County seismic S-wave velocity is being correlated with geology and lithology to determine spatial consistency and variability of seismic velocity and hence site response. Site amplification estimates will be validated using Nakamura's method (microtremors) and earthquake recordings (weak ground motion) (Bodin et al., 2000).

SITE AMPLIFICATION FACTORS

Amplification factors based on site geology will be derived from shear wave velocity (Vs) and geotechnical measurements throughout the county. Previous amplification factors have been based on regionally generalized geology and geotechnical profiles (Mueller, 2000). Characteristic seismic velocity profiles will include variability in velocity with depth and will be used to generate amplification factors and provide uncertainty in these estimates following the method of Silva et al., (1999). Several approaches to deriving amplification factors (quarter wave length, linear, equivalent linear, and non-linear) will be examined and incorporated into the final amplification factors used to generate the final seismic hazard maps.

Probabilistic seismic ground motion maps with site conditions specific to Shelby Co. will also require a probabilistic seismic hazard model. The probabilistic seismic hazard model will be the latest USGS National Seismic Hazard Mapping project model for the CUS (update of Frankel et al., 1996) and will include a logic tree to incorporate the latest scientific knowledge about the NMSZ (Cramer and Frankel, 2000; Cramer, 2000). This seismic hazard model will be used to generate seismic hazard maps for PGA and 0.2 & 1.0 s spectral acceleration (Sa) for bedrock conditions beneath Shelby Co. The site amplification factors generated from the subsurface database will then be used to bring ground motions to the surface and to generate site specific seismic hazard maps for Memphis and Shelby County.

DISCUSSION

Alternative amplification factors and their uncertainty estimaties for Shelby Co, Tennessee, will be presented and compared at the meeting. Linear and non-linear assumptions will be tested and methodology uncertainties explored. Published reports on the shallow Vs data from the subsurface database suggest a good correlation of Vs with the geology and lithology of Shelby County (Romero and Rix, 2000; Romero et al., 2000; and Cramer et al., 2000). Initial results based on NEHRP site classifications and FEMA 302 (1998) suggest small amplification factors (20% or less) for PGA and 0.2s Sa, and larger amplification factors (~50%) for 1.0s Sa in the Memphis area (Cramer et al., 2000).

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