

A brief summary of the results of the Turkey Flat weak motion site response blind prediction

J.C. Stepp

Seismic Center, Electric Power Research Institute, Palo Alto, Calif., USA

C.H. Cramer

California Department of Conservation, Sacramento, Calif., USA

INTRODUCTION

From the earliest observations of earthquake damage it has been recognized that local geology has an important influence on the intensity of damage at any location. While today, most building codes incorporate the effects of site geology, at least in some simplified form, we lack an adequate understanding of phenomena such as the effects of site geometry and site material properties behavior under dynamic loading, needed to make confident forward quantitative predictions, for example, for microzonation as well as for building codes. Thus, well-controlled, high quality experiments that permit testing of site characterization and material properties determination as well as site response models and modeling procedures such as those being sponsored by the IASPEI/IAEE Joint Working Group on The Effects of Local Geology on Seismic Motions are critically important.

At the first workshop of the IASPEI/IAEE Joint Working Group held in August 1987, the Turkey Flat site response experiment was incorporated into the international program. The objectives of the Turkey Flat experiment are to systematically test methods for site characterization and determination of site material properties and to determine the reliability and effectiveness site response prediction methods. To accomplish these objectives, site characterization and material property determinations have been completed by multiple groups acting independently, and site response prediction models are being tested through a process of blind predictions, first using weak motions and, as data become available, with strong ground motions. Work completed to date has been reported by Real (1988), Real and Cramer (1989), and Cramer and Real (1990a, 1990b). In this paper we summarize the results of weak motion blind predictions and draw some preliminary conclusions.

INPUT MOTIONS

Turkey Flat is a small valley approximately 2 km wide and 8 km long located in central

California, about 5 km from the Parkfield segment of the San Andreas fault where a moderate-magnitude earthquake has been predicted (Bakun and McEvelly, 1984). The surface geology of the valley consists of stiff Quaternary terrace deposits which overly rock at a depth of about 20 meters. The geometry of the valley is simple, permitting one-dimensional wave propagation methods to be tested without concern about complicated site geometric effects on wave focusing and scattering. The site is subject to frequent small earthquakes and with the occurrence of the predicted magnitude 5-6 earthquake on the nearby Parkfield segment of the San Andreas fault, there is high likelihood that ground motions in the range of .3g to .5g could be recorded there in the near future. Thus the site is amenable to testing a range of wave propagation modeling methods and offers the opportunity to test nonlinear geologic effects as well.

Strong motion recording instruments have been placed at four locations in the test site area. Sensors were placed at four surface locations: rock 1 (R1), a rock outcrop on the south side of the valley; valley 1 (V1), near the center of the valley where the terrace deposit reaches its maximum thickness; valley 2 (V2), near the north edge of the valley; and rock 2 (R2), on rock outcrop at the north edge of the valley. Down-hole sensors were placed at two locations: down-hole 1 (D1) is co-located with R1 at a depth of 20m; down-hole 2 (D2) is co-located with V1 at a depth of 10m; and down-hole 3 (D3) is co-located with V1 at a depth of about 20m. Weak motion sensors were temporarily co-located with each of the strong motion sensors until an adequate set of recordings for the weak motion analyses was obtained (Real and Cramer, 1989). Weak motion recordings of 33 earthquakes ranging up to magnitude 4 were obtained at the site. The weak motion recordings selected for the low strain response prediction are from a magnitude 2 earthquake at a distance of about 34km.

GEOTECHNICAL MODEL

To address uncertainty in geotechnical properties

at the Turkey Flat site, twelve organizations independently conducted site investigations and provided their results to the Turkey Flat Site Geotechnical Characterization Committee (GCC). The results were analyzed by the GCC and a Standard Geotechnical Model was developed, including strain dependent dynamic shear modulus reduction and damping values. The Standard Geotechnical Model represents consensus of a number of experienced geotechnical engineers based on their review and evaluation of the results of the twelve independent site geotechnical characterization studies. In order to have a consistent basis for blind testing of wave propagation models, participants in the blind prediction exercise were required to provide a prediction using the standard geotechnical model, but were permitted to provide additional predictions using their preferred alternative models.

PREDICTIONS SUBMITTED

The goals of the weak motion predictions were to: 1) exercise wave propagation models using the Standard Geotechnical Model and a single input motion, 2) determine the uncertainty in predicted motions and the sources of the uncertainty, and 3) provide a data base of predicted motions at low strain for subsequent comparison with observed and predicted strong motion to investigate the effects on non-linear behavior. Predictions were conducted in two phases. For the first phase participants were given a single weak motion recording at location R1 and were required to predict motions as follows:

1. Fourier amplitude spectral ratios at locations D1, D2, D3, V1, V2, R2;
2. Acceleration time histories at location V1; and
3. 5%-damped pseudovelocity response spectra, peak acceleration, peak velocity and peak displacement at D1, D2, D3, V1, V2, R2.

For the second phase prediction participants were given the recording at location D3 and required to make each of the three required predictions at location V1. In total participants were required to make 36 specific predictions.

Twenty-six participants submitted R1-based predictions; two participants made only the D3-based prediction. The types of methods used are shown in Table 1.

DISCUSSION OF RESULTS

Most of the Fourier spectra predictions tended to group together and compared favorably with the observed amplitude and resonant frequencies response at the V2 location, but less favorable results were obtained at the V1 location. Several predictions varied widely from the observed response at both the V1 and V2 locations, perhaps due to unexplained modeling procedures. The

predicted amplitudes at location V1, the location of the deepest valley fill, generally were larger than observed. Response spectra predictions however, were significantly more consistent among participants. At the V2 location predicted response spectra amplitudes compared favorably with those observed. However, for the V1 location predicted response spectra amplitudes were generally larger than observed, consistent with the Fourier spectra results. This can be interpreted to suggest that the low strain damping taken for the Standard Geotechnical Model may be too low. The results of 1-D models and the results of 2-D and 3-D models compare favorably as expected, given the simple geometry of the test site area.

The participants predicted higher than observed values of peak acceleration, velocity and displacement at both the V1 and V2 surface locations, particularly at the V1 location. In contrast, predicted values at the three down-hole locations D1, D2, and D3 and at the valley-north surface location R2, compare very favorably with the observed values. Variability in the predicted values at the V1 and V2 surface locations large is large as compared to variability of the predicted values at the three down-hole locations and the valley-north surface location. No differences were observed with respect to whether 1-D, 2-D or 3-D wave propagation methods were used. For the V1 location predicted time histories generally compare favorably with in duration with the observed, but the amplitudes are generally larger than observed.

DISCUSSION

The submitted low strain predictions at Turkey Flat tend to group together with a few exceptions, regardless of the class of method (8 classes of methods were used) used. The middle 50% of the submitted predictions generally cluster within 10% of the median.

Predicted amplitudes tend to be larger than observed, particularly at the valley center surface location, V1. Overall shape of the predicted spectra and the location of resonant peaks tend to compare favorably with observed. These results are interpreted to indicate that the velocities and layer thicknesses in the Standard Geotechnical Model reasonably represent the Turkey Flat site condition, while the general over prediction of observed amplitude, particularly at the thickest valley fill location V1, is interpreted to indicate that the low-strain damping values of the Standard Geotechnical Model are too low.

The most significant observations of the weak motion prediction exercise at the Turkey Flat stiff soil site are: 1) 1-D models appear to give fully reliable results for sites having simple geometry, and 2) the accuracy of geotechnical site characterization and strain-dependent shear modulus and damping values are more important than the particular

modeling method used. It is likely that the latter observation will take on enhanced importance under large strain loading conditions.

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Table 1. Wave propagation models used for R1-based predictions.

1-D Methods:		#8	#17
- Equivalent linear methods:			
SIREN			
Linear Viscoelastic			
EQLM			
SHAKE-LAYSOL, DESRA2, DYNA1D			
- Spectral methods:		#3	
Boore stochastic			
Semi-analytical with plane and anti-plane wave			
Stochastic with SH-wave propagators			
- Haskell-type methods:		#3	
Haskell's method			
Discrete wavenumber boundary element method			
Sanchez-Sesma's hybrid ray path/Haskell method			
- Wave propagation methods:		#3	
Finite-difference			
Frequency-wavenumber			
Propagator matrix with source			
2-D Methods:		#5	#9
- Finite element methods:			
Non-linear hysteretic			
2-D elastic			
2-D viscoelastic			
2-D elastoplastic			
2-D (properties not given)			
- Wave propagation methods		#3	
Discrete wavenumber			
Haines' technique			
- Boundary element methods			#1
MISS2D			
3-D Methods:			#2
- Wave propagation methods		#2	
3-D viscoelastic			
Unknown:			#1