U.C. BERKELEY SEISMIC GUIDELINES

APPENDIX II

GROUND MOTION TIME HISTORIES FOR THE UC BERKELEY CAMPUS

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Introduction

Three sets of ten time histories each were developed to represent the ground motions for each of the three return periods. All of the time histories are provided as pairs of fault-normal and fault-parallel components. The ground motion time histories are provided in two forms: unmodified, and spectrally modified to match the probabilistic response spectra. The unmodified time histories can be scaled to match the probabilistic response spectra at a specified period, such as the first mode period of the structure being analyzed, while leaving the shape of the response spectrum unmodified. This approach preserves the particular characteristics of the individual time history, together with the peaks and troughs of its response spectrum. These individual characteristics are modified in the spectrally matched time histories, resulting in a suite of ten time histories (for a given return period) that all have the same response spectrum for a given component (fault normal or fault parallel) that follows the smooth shape of the probabilistic response spectrum.

Magnitude and Distance Combinations for Time Histories

The magnitude and distance combinations for use in the selection of time histories were derived from the deaggregation of the seismic hazard. These values at a period of 0.3 seconds are given in Table 1. At all three hazard levels, the hazard is dominated by earthquakes on the Hayward fault, which is located about 1 km east of the site. The Hayward fault is a strike-slip fault that has the potential to generate earthquakes having magnitudes as large as 7.

Table 1. Uniform Hazard Spectra, 5% damping, Sa at 0.3 seconds, at the UC Berkeley Main Campus

Hazard Level	Sa at 0.3 sec	M mode	R mode
50% in 50 years	0.7	6.5 – 7.0	1 km
10% in 50 years	1.9	6.5 – 7.0	1 km
5% in 50 years	2.4	6.5 – 7.0	1 km

For all three hazard levels, the largest contributions come from magnitudes in the range of 6.5 to 7.0. The successively higher ground motions for the lower probability levels reflect not larger magnitudes (the maximum magnitude earthquake on the Hayward fault is 7.0), but higher ground motion levels for the same magnitude (larger number of standard deviations above the median ground motion level).

Process of Selecting Ground Motion Recordings

The recordings listed in Tables 2 and 3 were selected to satisfy to the extent possible the magnitude and distance combinations listed in Table 1 for strike-slip earthquakes on S_C sites. In general, it was not easy to satisfy these requirements, and none of the sets of time histories is larger than the minimum requirement of ten. It was not possible to satisfy the distance requirement exactly, but all of the selected recordings are within about 10 km of the fault. In all but a few cases, the recordings are from sites that are classified as S_C, but in general these site classifications are not based on shear wave velocity measurements. If there were a much larger set of recordings to choose from, it is likely that the sets of selected recordings would have less variability than the sets that are provided.

Time Histories for 50% in 50 years

The time histories used to represent the 50% in 50 year ground motions are listed in Table 2. Three of the recordings are from sites that are classified as S_D. No attempt was made to adjust these recordings for S_C site conditions. Two of the recordings are from the abutment of the Coyote Lake dam.

Table 2. Time histories representing 50% in 50 year hazard level at UC Berkeley Main Campus

Earthquake	Mw	Station	Distance	Site	Reference
Coyote Lake, 1979/6/8	5.7	Coyote Lake Dam abutment	4.0	C	Liu & Helmberger, 1983
		Gilroy #6	1.2	C	
Parkfield, 1966/6/27	6.0	Temblor	4.4	C	Cloud & Perez, 1967
		Array #5	3.7	D	
		Array #8	8.0	D	
Livermore, 1980/1/27	5.5	Fagundes Ranch	4.1	D	Boatwright & Boore, 1983.
		Morgan Territory Park	8.1	C	
Morgan Hill, 1984/4/24	6.2	Coyote Lake Dam abutment	0.1	C	Hartzell & Heaton, 1986
		Anderson Dam Downstream	4.5	C	
		Halls Valley	2.5	C	

Time Histories for 10% in 50 years and 5% in 50 years

The time histories used to represent the 10% in 50 year and 5% in 50 year ground motions are listed in Table 2. The same set of time histories is used to generate the two sets. This is justified in part by the fact that the magnitude – distance combinations that dominate the hazard in each case are the same (Table 1). However, this ignores the fact that the 5% in 50 year time histories should be drawn from larger ground motion recordings than the 10% in 50 year time histories. The use of different scaling factors largely but not completely obviates this shortcoming.

There is a remarkable sparsity of appropriate recordings on rock from strike-slip California earthquakes in the magnitude range of 6.5 to 7. The recording that would nominally appear to be the best representations of a Hayward fault earthquake is the recording of the Kobe earthquake. However, the rheology of the faults that produced the Kobe earthquake may be quite different from that of the Hayward fault, which has been described by Bergmann et al., 2000.

Table 3. Time histories representing 10% in 50 year and 5% in 50 year hazard levels at UC Berkeley Main Campus

Earthquake	Mw	Station	Distance	Site	Reference
Loma Prieta, 1989/10/17	7.0	Los Gatos Presentation Center	3.5	C	Wald et al., 1991
		Saratoga Aloha Ave	8.3	C	
		Corralitos	3.4	C	
		Gavilan College	9.5	C	
		Gilroy historic		C	
		Lexington Dam abutment	6.3	C	
Kobe, Japan, 1995/1/17	6.9	Kobe JMA	0.5	C	Wald, 1996
Tottori, Japan, 2000/10/6	6.6	Kofu	10.0	C	K-net
		Hino	1.0	C	Kik-net
Erzincan, Turkey, 1992/3/13	6.7	Erzincan	1.8	C*	EERI, 1993

Discussion of the Selected Records

Many of the recordings have response spectral amplitudes that are larger than the uniform hazard spectrum at periods longer than 0.45 seconds. In many cases, these may be attributable to forward rupture directivity effects.

The shallow stiff soil conditions at the site have the potential of causing strong resonances in the ground motions. Some of the recordings contain resonances at periods shorter than 0.45 seconds that may be attributable to such effects.

The Kofu recording of the Tottori earthquake was obtained at a K-net site whose soil and seismic wave velocity profiles are known to bedrock at a depth of 10 km. The Hino recording of the Tottori earthquake was obtained at a Kik-net site whose soil and seismic wave velocity profiles are known to a depth of 100 meters. The Hino site consists of 10 meters of sand and gravel overlying weathered granite. The spectral peak at a period of about 0.7 second is interpreted as indicating strong non-linear effects. The ground motion level at the Kofu site was apparently not high enough to cause similar nonlinear effects at Kofu, whose soil also has higher shear wave velocity.

The Erzincan recording of the Erzincan earthquake was recorded on deep alluvium (EERI, 1993). It was spectrally modified to represent a rock site recording. The target spectrum for the spectral matching was obtained by scaling the recorded spectrum by the ratio of rock to soil in the Abrahamson and Silva (1997) ground motion relations. The resulting response spectrum is very compatible with the uniform hazard spectrum. The rheology of the Anatolia fault on which the Erzincan earthquake occurred is considered to be potentially quite compatible with that of the Hayward fault.

The Lexington Dam record was obtained on the rock abutment of Lexington Dam. Using this recording as a representation of the input ground motions at the base of the dam, several investigators have successfully modeled the recordings from the crest of the dam (Mejia et al., 1992; Makdisi et al., 1994), implying that the abutment recording is not severely contaminated by dam interaction effects.

Representation of Near Fault Rupture Directivity Effects in the Ground Motion Recordings

The selected ground motion time histories were all recorded sufficiently close to the fault to contain rupture directivity effects, although not all of the recordings are as close as the UC Berkeley Main Campus is to the Hayward fault. In strike-slip earthquakes, forward rupture directivity (propagation of rupture horizontally towards the recording station) produces a pulse of intermediate or long period ground motion whose particle motion is orientated in the direction normal to the strike of the fault (Somerville et al., 1997; Somerville, 1998; Somerville et al., 2000). This pulse is manifested by a response spectrum that is larger on the fault normal component than on the fault parallel component at periods longer than about 0.5 seconds. There are indications that the period of the pulse may increase with magnitude (Somerville, 2003). If the earthquake ruptures away from the recording station, then rupture directivity effects are less pronounced. Some of the selected recordings contain strong forward rupture directivity pulses, and others do not.

In the vicinity of the UC Berkeley main campus, the Hayward fault has a strike of N 34 degrees west. All of the recorded time histories were rotated to the strike normal and strike parallel directions. Generally, if the recording contains forward rupture directivity effects, its transverse component is expected to be larger than its longitudinal component for peak velocity and peak displacement, and for spectral accelerations having periods longer than about 0.5 seconds. This expectation is generally borne out in the recordings.

Scaling of the Ground Motion Recordings

Each set of recordings was spectrally matched to the corresponding probabilistic response spectra. The fault normal component of the recorded time history was matched to the fault normal component of the probabilistic response spectrum, and the fault parallel component was matched to the fault parallel component of the probabilistic response spectrum. We used the time domain spectral matching procedure of Abrahamson (personal communication) to match the spectra in the period range of 0.01 to 4.0 seconds. Unlike spectral domain procedures, this time domain procedure aims to preserve the phasing of the original recording, but it still introduces considerable distortion into the waveform of the recorded motion at long periods.

Display of the Time Histories and Response Spectra

The attached sets of figures show the following information for each set of ten time histories:

1. Unmodified time histories – acceleration, velocity, and displacement
2. Spectrally modified time histories – acceleration, velocity, and displacement
3. Response spectra, before and after spectral matching, compared with the probabilistic response spectra

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