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Technical Note

Further seismic displacement PSDF results

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Abstract. The spectral content of ground displacement of the 10 largest last California earthquakes is studied. Specifically, the power spectral density function of the critical horizontal-component record of the closest-to-epicenter station is analyzed in each case. The results permit to state that horizontal ground displacement is a narrow-band process. This fact was previously noticed while trying to solve the large-base-displacement problem in isolated structures and it was fundamental in the solution of this issue; however, these preliminary results were limited in number to enable a statement like the foregoing one. Thus, the broader results presented herein were necessary.

Keywords: ground motion; displacement; spectral characterization; California earthquakes; base isolation.

1. Introduction

Ground displacement records have not drawn much attention because in conventional dynamics of fixed structures, ground acceleration signals are the significant records (Lai 1982). However, ground displacement signals are the important data in analysis of base-isolated structures (Kelly *et al.* 1987, Tadjbakhsh *et al.* 1992, Meirovitch *et al.* 1997).

Recently, a solution to the large-base-displacement (LBD) problem associated with isolated structures was proposed (Morales 2003). This solution was based on two main hypotheses, one on structural modeling and the other on seismic input modeling; the second, which is of interest here, was in turn based on a frequency-domain characterization of ground displacement. This seismic characterization was established upon the analysis of the power spectral density function (PSDF) of displacement records of the last four California events with moment magnitude (M_m) above 7.0 (Hanks 1979).

In this report, the spectral content of ground displacement of the 10 largest last California earthquakes is studied. Specifically, the PSDF of the critical horizontal-component record of the closest-to-epicenter station is analyzed for each seism, from the 71 San Fernando to the 99 Hector Mine events; of course, all the chosen stations possess an instrument at ground level. The results permit to state that *horizontal ground displacement is a narrow-band process*. This fact was previously noticed while trying to solve the LBD problem in isolated structures and it was fundamental in the solution of the problem (Morales 2003); however, those preliminary results were limited in number to enable a statement like the foregoing one. Thus, the broader results presented

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now and herein were necessary; an important fact for the generality of these results is that the site geologies of the 10 cases are very diverse.

2. Power spectral density function of ground displacements

The 10 largest inland California events since 1970 are shown in Table 1; it includes the name and code of the closest-to-epicenter station and the corresponding site geology; these stations were chosen over closest-to-fault ones simply because in public seismic databases, the epicentral (hypocentral) distance is available for all events but the distance to fault is unavailable for some; nonetheless, this last distance is included in the table. From the usual two horizontal-component records provided by each instrument, the one with the largest peak displacement is selected in the study. The PSDF of the selected displacement signals are shown in Fig. 1; it includes the corresponding components. Formally, the plots are only estimates of PSDF of samples of ground displacement after regarding the underlying stochastic process as *stationary*.

These results confirm the narrow-band characteristic first noticed in the work by Morales (2003); note that the plot range 0-10 rad/s is already a slender range, equivalent to 0-1.59 Hz. As in the previous work, and disregarding the Superstition Hills PSDF (which is justified later), the narrow band is similar in all cases. Now, the limit frequency of 0.06 Hz (0.37 rad/s) established by Morales (2003) can be corrected herein to 0.05 Hz (0.31 rad/s).

Several interesting comments on the selected samples follow. Firstly, all the signals are *corrected* records; these are available already in this form in public databases (the records herein were mostly processed by CSMIP). The epicenter of the Imperial Valley event was located in Mexico, very close to the border; although there were several (mostly Mexican) stations closer to the epicenter, the closest station from which displacement records are directly available is the Calexico Fire Station one. Regarding the Coalinga event, there are two instruments at Pleasant Valley Pumping Plant, one at the basement of a slope and the other at the top (switchyard); the switchyard instrument was selected because its records are more free-field than the basement ones (Stewart 2002).

The Superstition Hills at Imperial Wildlife PSDF is distinct because liquefaction occurred at the

Table 1 Ten largest last california events and analyzed station

Event	Date	M_m	Station and Code	Geology	Fault dist.
San Fernando	2/9/71	6.6	Pacoima dam, CSMIP24207	Diorite gneiss	3.5 km
Imperial Valley	10/15/79	6.5	Calexico, USGS5053	Alluvium	10.4
Coalinga	5/2/83	6.5	Pleasant Valley, USBR1162	Deep alluvium	
Superstition Hills	11/24/87	6.6	Imperial Wildlife, USGS5210	Silt	21.9
Loma Prieta	10/18/89	7.0	Corralitos, CSMIP57007	Landslide deposits	2.8
Cape Mendocino	4/25/92	7.0	Cape Mendocino, CSMIP89005	Cretaceous rock	
Landers	6/28/92	7.3	Joshua Tree, CSMIP22170	Shallow alluvium	10.0
Northridge	1/17/94	6.7	Northridge church, USC5303	Alluvium	12.9
Eureka	9/1/94	7.2	Cape Mendocino, CSMIP89005	Cretaceous rock	
Hector Mine	10/16/99	7.1	Amboy, CSMIP21081	Alluvium	

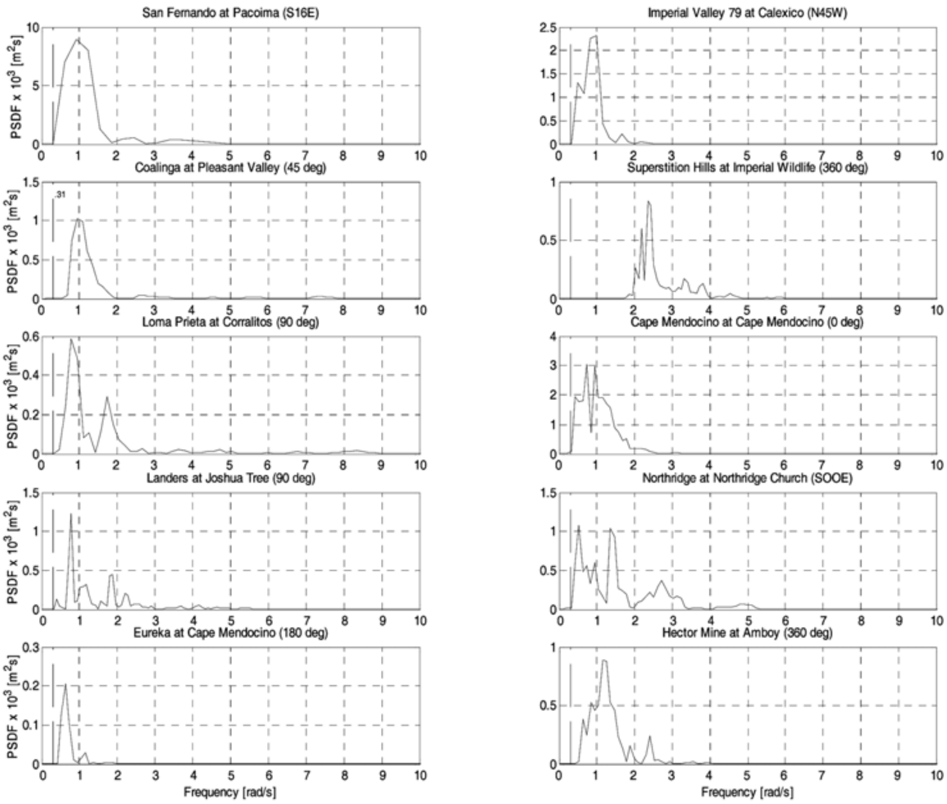

Fig. 1 Power spectral density function of ground displacement of the 10 last largest California events

site; in fact, the objective of the station was to study this phenomenon. Its complete name is Imperial Wildlife Liquefaction Array; of course, the ground-level instrument was selected (there was another in a 7-meter downhole). The epicenter of the Eureka event was not located inland; it is included because of its intensity. On the other hand, Hector Mine at Amboy is an example of records in which the component with the largest peak acceleration (90 deg) is not the same as the one with the largest peak displacement (360 deg). Finally, Pacoima Dam and Corralitos are the closest to both, the epicenter and the fault; this is of course for the San Fernando and Loma Prieta seisms.

Based on the diversity (geological) of the analyzed set, similar results are expected with other California strong-motion records, or with any intense seismic-displacement signal for that matter, although spectral characterization in other critical regions of the world may be necessary as well as interesting.

3. Conclusions

Strong-motion records have been analyzed; it can be concluded that horizontal ground displacement is practically a narrow-band process. A lower frequency of the band can be established as 0.05 Hz for the analyzed California set. These results corroborate previous ones, and that the LBD problem in isolated structures can be solved.

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