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DEVELOPMENT OF GEOTECHNICAL DATABASE FOR PALO ALTO AND ITS UTILIZATION FOR SEISMIC MICROZONING

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ABSTRACT

A three-dimensional database of geotechnical boring logs for the area of Palo Alto, California, was developed as a component of a project on the evaluation of socio-economic consequences of large earthquakes. The database was generated with a Geographic Information System (GIS) computer software which can accommodate the distribution of information with depth. The information incorporated into the database are geographic coordinates, stratification and groundwater table, soil classification and geotechnical properties, Standard Penetration Test blowcount and shear wave velocities. The paper summarizes the development and structure of the database and includes a discussion about several potential applications. One application that is elaborated in more details is the utilization of the geotechnical data to generate input for nonlinear one-dimensional site response analyses. As an example, the nonlinear analyses for three soil profiles are briefly described. The potential application of such a link between the database and a nonlinear site response computer model for seismic microzoning is explained.

KEYWORDS

Microzonation; seismicity; soil properties; ground motion; Geographic Information System (GIS).

INTRODUCTION

The assessment of past and future damages and losses are of primary importance in the evaluation of socio-economic impacts due to earthquakes. For the last two years, researchers from several universities in California and a Japanese corporation have been conducting a project titled: "Methodologies for Evaluating the Socio-Economic Consequences of Large Earthquakes" (Kajima-CUREe, 1995). The geographic area selected in this project as a model area is the Palo Alto region near San Francisco in Califonia. When developed, the same methodologies could be applied to other similar seismically active regions.

Because past earthquakes have shown that damage patterns are often associated with local geologic and geotechnical conditions, an important component of this project is the evaluation of soil properties and their effects on ground motions. This paper describes this geotechnical component. The basis of it is a three-dimensional database of geotechnical boring logs that has been developed using a Geographic Information System (GIS) computer software called Techbase™ (Minesoft, Ltd, 1994). The geotechnical database was developed following the principles established in a similar project charged with the evaluation of ground motions in the area of Los Angeles that started earlier (Doroudian, et al, 1995). The development and utilization of the database are summarized below.

DEVELOPMENT OF THE DATABASE

A map of the Palo Alto region encompassed in the study is shown in Fig. 1. It contains coast lines, political boundaries of the city, freeway and highway system, and location of the geotechnical boring logs that were digitized into the database. A total of 73 boring logs were compiled from different agencies and digitized: 17 from Califonia Department of Transportation (Caltrans), 52 from the city of Palo Alto and 4 from the United States Geological Survey (USGS). A typical digitized boring log is presented in Fig. 2. Its structure can accomodate the following information: (i) geographic coordinates, (ii) stratification and groundwater table, (iii) soil classification and geotechnical properties, including Plasticity Index, (iv) Standard Penetration Test blowcount, and (v) shear wave velocity profile. These types of information were selected after a careful review of parameters and factors that govern many geotechnical earthquake engineering phenomena including the amplification and attenuation of seismic motion through soil deposits, liquefaction, dynamic densification and seismically induced slope failure. As shown in Fig. 2, typical boring logs do not contain all of these information. Consequently, the missing information that are necessary for the evaluation of particular earthquake effects have to be estimated.

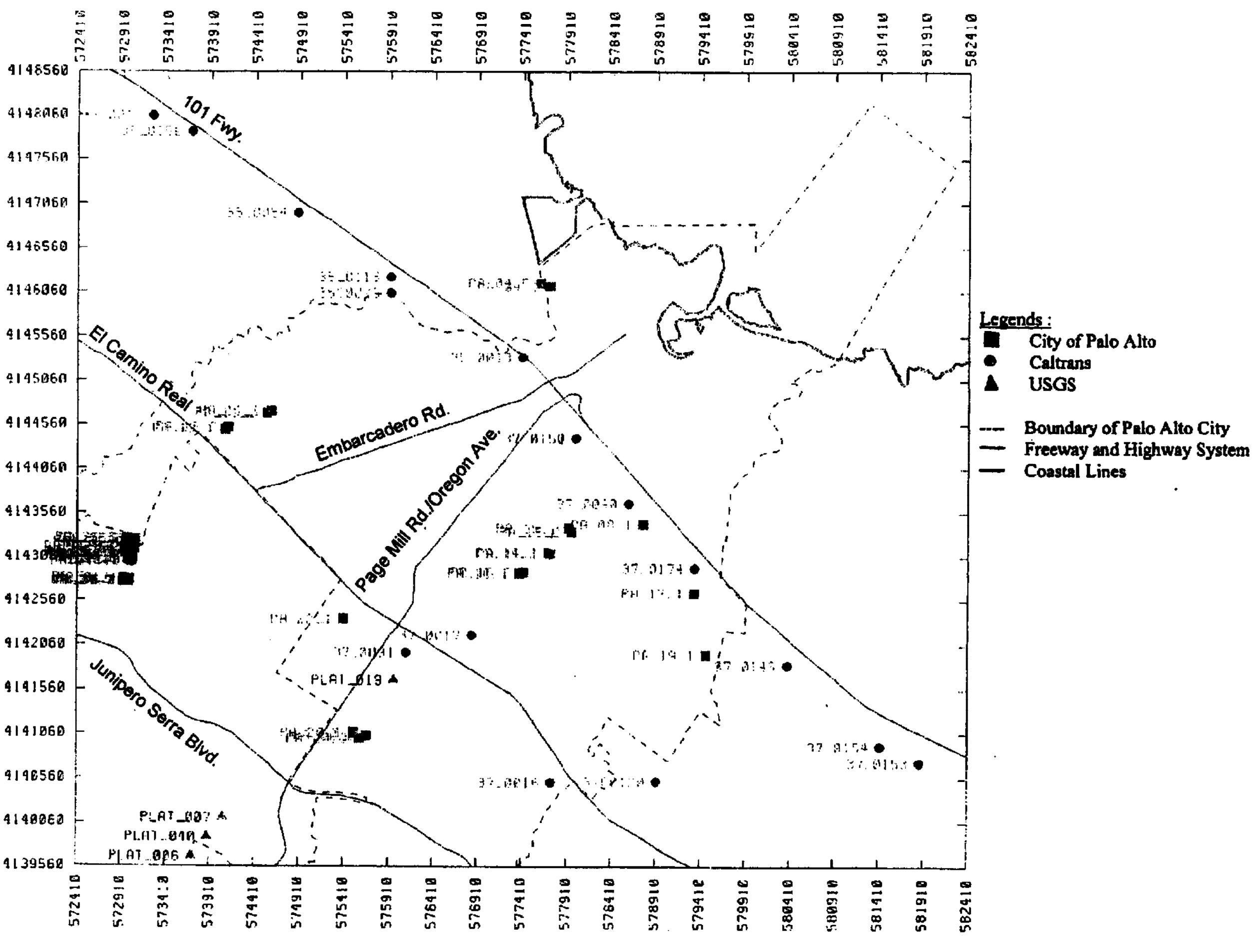
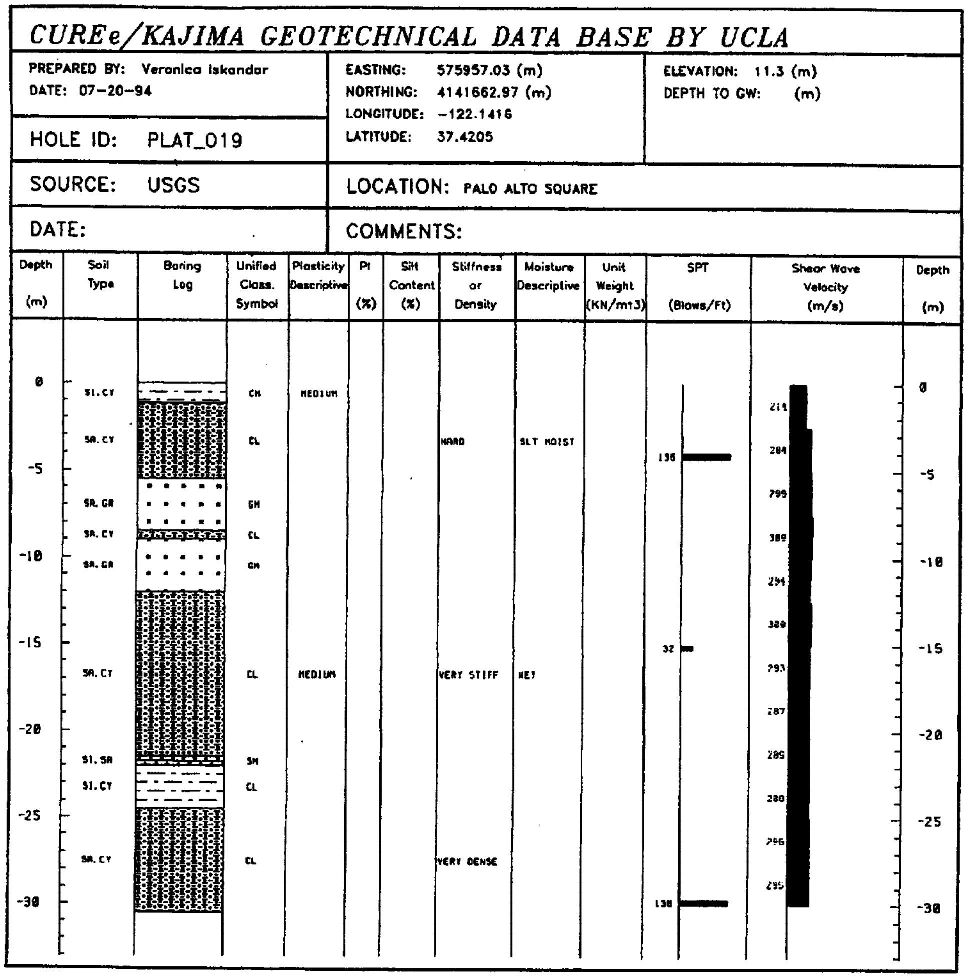


Fig. 1 Plan map of boring log locations in the Palo Alto region



CUREe/KAJIMA GEOTECHNICAL DATA BASE BY UCLA

PREPARED BY: Veronica Iskandar
DATE: 07-20-94

HOLE ID: PLAT_019

EASTING: 575957.03 (m)
NORTHING: 4141662.97 (m)
LONGITUDE: -122.1416
LATITUDE: 37.4205

ELEVATION: 11.3 (m)
DEPTH TO GW: (m)

SOURCE: USGS

LOCATION: PALO ALTO SQUARE

DATE:

COMMENTS:

Fig. 2 Digitized boring log from USGS with measured shear wave velocities.

UTILIZATION OF THE DATABASE

After the database was established, the ability to manipulate the boring log data within the Techbase™ GIS environment and to utilize them for assessment of ground motions was examined. This included automatic generation of cross-sections of geotechnical properties, estimation of unavailable properties that are essential for certain seismic analyses and linking of the database to a one-dimensional nonlinear seismic site response model.

One of the primary advantages of Techbase™ GIS is its capability for generating geotechnical cross-sections from the information stored in three-dimensions. In Fig. 3 an example of such a cross-section along 101 Freeway is presented. As shown in Fig. 3a, the cross-section was generated for a strip of 1000 meters wide land along the freeway . The vertical display of boring logs encompassed by this area is presented below (Fig. 3b), while the associated profiles of the SPT blowcounts and estimated shear wave velocities are presented at the bottom (Fig. 3c). Among other applications, such cross-sections can be directly compared to soil-related damages caused by past earthquakes (Doroudian, et al, 1995) in order to improve the ability of damage forecasting. Another potential application is to divide the region of interest into small blocks, and by means of the cross-sections to assign to each block a unique soil profile. In this way, the earthquake effects could be evaluated for each block and in turn presented as GIS maps. However, for such a microzoning the distribution of digitized boring logs has to be very dense, substantially denser than in Fig. 1.

The shear wave velocity profiles in Fig. 3c are estimations obtained from the SPT blowcount profiles. Such a manipulation of SPT data to obtain the shear wave velocity distribution is extremely crude and is not generally recommended. However, in this study, this crude approximation seemed to be the only alternative. It was done because the SPT data are abundant, correlations between SPT blowcount and shear wave velocity are available and the shear wave velocities are essential for the site response analyses that had to be conducted in this study. These site response analyses are summarized below in a separate chapter.

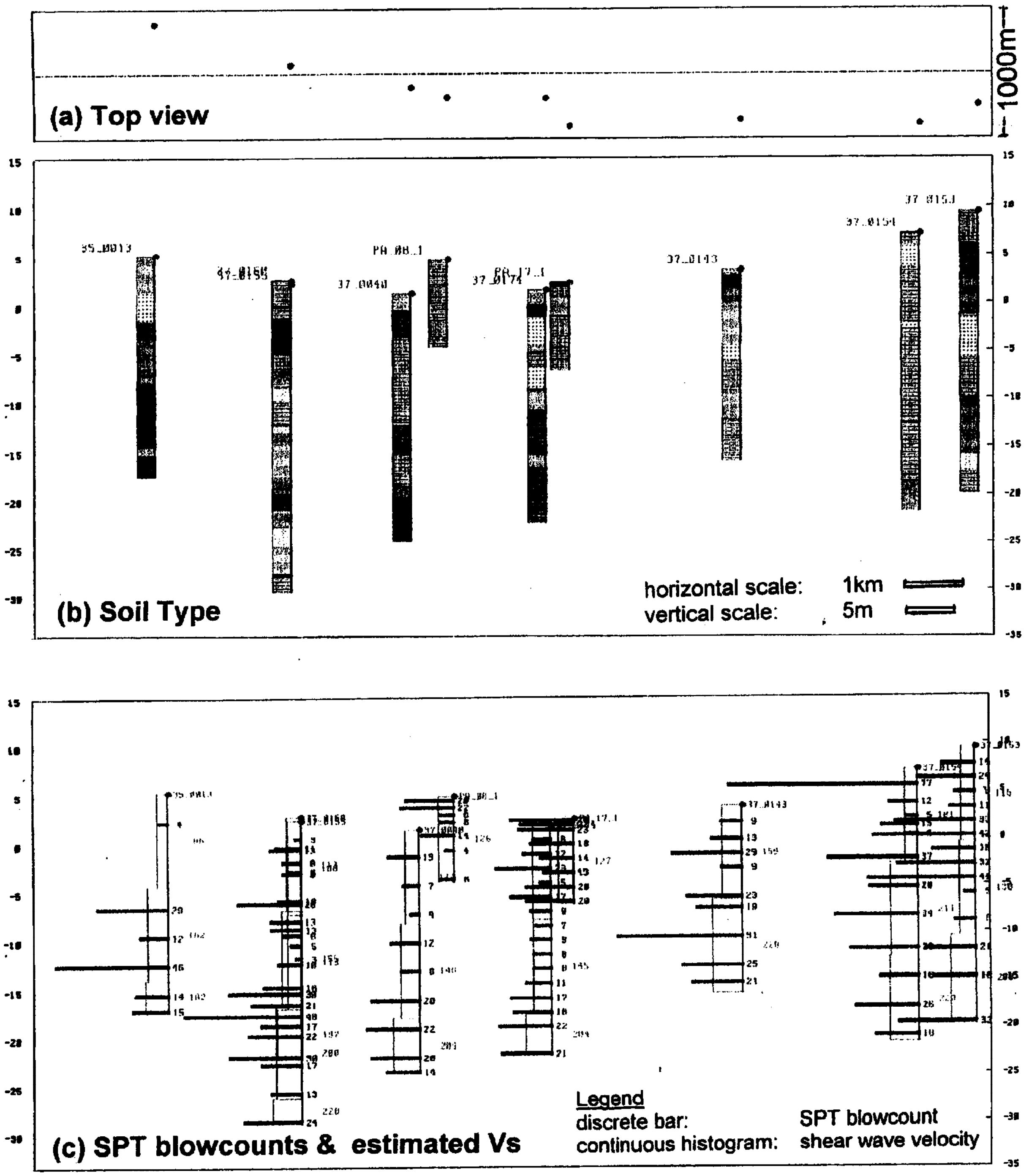


Fig. 3 Cross-sections of various geotechnical properties along a portion of 101 Fwy.

SEISMIC SITE RESPONSE ANALYSES

In addition to various manipulations that can be performed within the Techbase™ GIS environment, such as those summarized above, the geotechnical database can be utilized to perform a regional site response study taking into account the nonlinear nature of soil. Such study can be performed by dividing the region of interest into blocks, as mentioned above, and conducting analysis for each block. Another approach is to conduct a nonlinear analysis for each individual boring log. The latter approach is taken in this study, one of the reasons being that the distribution of digitized boring logs for Palo Alto is not very dense. In both approaches, however, the outcomes of the analyses can be plotted in the form of GIS microzonation maps for the entire region of interest.

To present the essence of the study of the Palo Alto region, the nonlinear site response analyses of three digitized boring logs have been selected. The corresponding soil profiles are shown in Fig. 4. The analyses were conducted using a computer program called DESRAMOD (Vucetic, 1986) enhanced with the model for cyclic behavior of sand by Matasovic and Vucetic (1993). DESRAMOD is a modified version of the computer code DESRA-2 originally developed by Lee and Finn (1978) for nonlinear analyses of horizontally layered soil deposits. The modification of DESRA-2 included the replacement of the original pore pressure model with the pore pressure model by Dobry (Dobry, et al, 1985). The earthquake excitation is provided in DESRA-2, and thus in DESRAMOD, by appropriate acceleration-time history input assigned at the base of the soil column, which is usually bedrock (identified in Fig. 4 for all three profiles). The Stanford linear accelerator time history from the Loma Prieta Earthquake presented in Fig. 5 was used as the bedrock input in this study .

Depth (ft)	Thickness (ft)	Layer No.	Soil Type and gw table
	6.6	1	sandy-SILT
GW = 9.9 ▽	3.3	2	
═	1.8	3	gravelly-SAND
23.0	5.0	4	
29.0	26.0	5	CLAY
	7.0	6	silty-SAND
44.0	8.0	7	
	12.0	8	CLAY
66.0	10.0	9	
69.0	3.0	10	SAND
75.0	6.0	11	CLAY
	85.0	12	clayey-SAND
	85.0	13	
	85.0	14	
	85.0	15	
500.0	85.0	16	
Bedrock at ~500 feet			

(a) Boring log no. 35_0013

Depth (ft)	Thickness (ft)	Layer No.	Soil Type and gw table
	9.0	1	sandy-CLAY
18.0	9.0	2	
GW = 24.0 ▽	6.0	3	gravelly-SAND
28.0 ═	4.0	4	
29.5	1.5	5	sandy-CLAY
39.0	9.5	6	gravelly-SAND
	11.0	7	sandy-CLAY
	11.0	8	
72.0	11.0	9	
75.0	3.0	10	silty-SAND
	13.5	11	silty-CLAY
102.0	13.5	12	
	24.0	13	silty-SAND (Qoa)
150.0	24.0	14	
Bedrock at ~150 feet			

(c) Boring log no. PLAT_019

Depth (ft)	Thickness (ft)	Layer No.	Soil Type and gw table
	4.4	1	silty-SAND
	4.4	2	
13.2	4.4	3	
	6.7	4	silty-CLAY
26.6	6.7	5	
32.8	6.2	6	SILTY
GW = 39.4 ▽	6.6	7	silty-CLAY
45.6 ═	6.2	8	
	5.0	9	SANDY soils
	5.0	10	
	5.0	11	
	5.0	12	
	5.0	13	
75.6	5.0	14	
	91.5	15	silty-SAND (Qoa)
	91.5	16	
350.1	91.5	17	
Bedrock at ~350 feet			

(b) Boring log no. PA_13_1

Fig. 4 Soil profiles analyzed by 1-D nonlinear computer model.

The DESRAMOD input parameters describing the dynamic and other soil characteristics were derived directly or estimated from the database. The most uncertain part of that phase was the estimation of input soil parameters between the bottom of the boring log and bedrock. A map showing thickness of alluvium in Palo Alto indicated an estimated depth to bedrock that is much deeper than the bottom of boring logs (Kajima-CUREe, 1995). Therefore, the distributions of input soil properties between the bottom of boring logs and the bedrock was estimated with the help of geologic maps. In addition, the corresponding unknown distributions of shear wave velocities with depth were estimated using the information published by Idriss (1990).

The outcomes of DESRA-2 and DESRAMOD analyses include the time histories of acceleration, velocities, displacements and excess pore water pressures for each horizontal layer of the soil column. The limited space does not allow a presentation of all of these time histories. Therefore, as an example, only the time histories of calculated ground surface accelerations are presented in Fig. 6. Also, the calculated maximum excess pore water pressures normalized to the geostatic effective overburden pressures, u^*, that correspond to the end of the main shock at about 14 seconds are shown in the table below:

Boring Log No.	**Normalized excess pore water pressure, u^* at 14 seconds**	Layer no. (Layer depth)
35_0013	**0.31**	6 (29-36 ft.)
PA_13_1	**0.41**	11 (56-61 ft.)
PLAT_019	**0.50**	10 (72-75 ft.)

The above values of u^* indicate that during the main baserock excitation shock, between 6 and 14 seconds, significant degradation of soil stiffness took place in all three profiles. Consequently, the calculated ground surface accelerograms show attenuation of motion starting between approximately 6 and 8seconds (compare the acceleration magnitudes in Figs. 5 and 6). Before the arrival of the main shock between 0 and 6 seconds, the calculated ground surface accelerations in Fig.6 are noticeably larger than the corresponding small input accelerations in Fig. 5. Such amplification of the motion in the beginning of shaking occurred because small input accelerations at the base generated the response which is close to a linear. Once the input accelerations increased, the soil response became highly nonlinear and soil started degrading due to the pore water pressure build-up, thereby causing the attenuation of ground surface motion.

For the forecasting of ground response of the Palo Alto region, the DESRAMOD outputs are planned to be presented in the form of GIS maps such the map of peak ground surface accelerations, spectral ordinates and maximum excess pore water pressures.

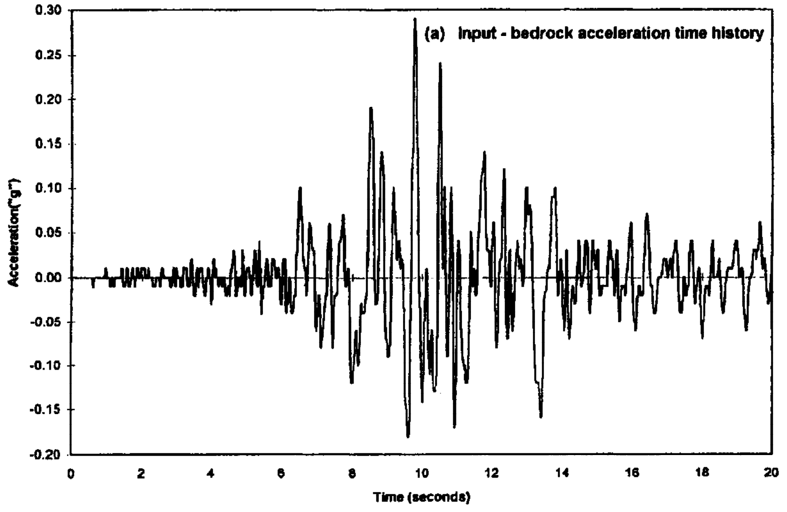


Fig. 5 Acceleration-time history used as the base excitation input.

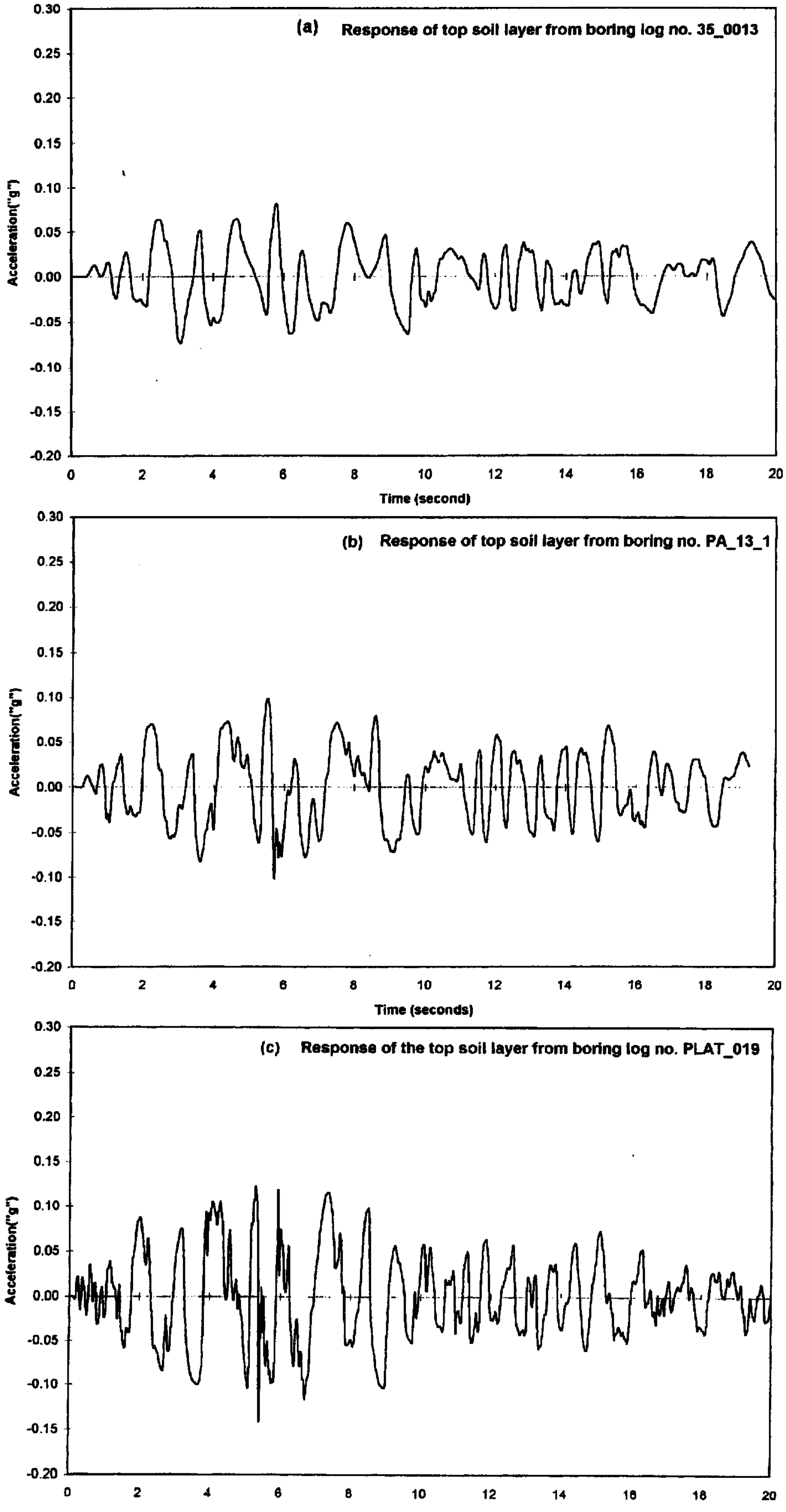


Fig. 6 Calculated ground surface acceleration-time histories.

CONCLUSIONS

The study summarized in this paper shows that three-dimensional databases such as that presented have a significant potential for seismic microzonation. It also indicates the unique capability of GIS approach in displaying spatial distribution of regional geotechnical and geologic conditions and in utilizing the stored data for complex nonlinear site response analyses. The effort to make an automatic link between the database and the nonlinear response program DESRAMOD is underway. Such a link will enable presentation of the site response characteristic in the form of geographic maps for the entire region that will be suitable for the evaluation of soil-related structural damage.

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