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DEVELOPMENT OF 3-DIMENSIONAL GEOTECHNICAL DATA BASE FOR LOS ANGELES SEISMIC MICROZONATION

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ABSTRACT

Past earthquakes have shown that damage patterns are often associated with local geologic and geotechnical conditions. The paper summarizes an ongoing project aimed at developing a 3-D database of geotechnical boring logs that will be integrated into a GIS for the estimation and forecasting of earthquake damage in the Los Angeles area. Geotechnical data are compared to the damage and ground motions caused by the 1994 Northridge Earthquake. Some potential applications of the data base are discussed.

KEYWORDS

Geotechnical engineering; database; GIS; microzonation; ground motions.

INTRODUCTION

Local geotechnical and geologic condition are important components in the evaluation and forecasting of earthquake damage. In 1992, a research project aimed at the development of a computer-based geotechnical data base for seismic studies of Southern California was initiated. The data from geotechnical boring logs that vary with depth are being incorporated into a three-dimensional GIS software called "Techbase" (Minesoft, Ltd.,1994), along with other relevant computer maps such as those shown in Fig. 1. The figure shows that a detailed digitized boring log will be generated for each boring log location, making the data base three-dimensional. The collection, organization, critical evaluation and subsequent digitization of the boring log data in a uniform and meaningful manner represent the primary activities of the project. The final product will be a GIS suitable for the evaluation of soil-related earthquake effects such as soil-induced amplification of seismic motion, liquefaction potential, and slope failure potential, i.e., the GIS for soil-related microzonation. The analysis and mapping of relevant geotechnical data is currently limited to the greate. Los Angeles area. The project will also encompass comparisons with the maps of the damage and strong ground motion distributions recorded during the January 17, 1994 Northridge earthquake. A few such preliminary comparisons are shown later in this paper. This paper is a continuation and update of previous publications reporting results from the same study (Doroudian et al., 1995; Vucetic and Doroudian, 1995).

SELECTION OF GEOTECHNICAL DATA RELEVANT FOR SEISMIC STUDIES

To identify the most relevant parameters and factors associated with soil-related earthquake damage that might be included in the database, the following geotechnical earthquake engineering problems were considered:

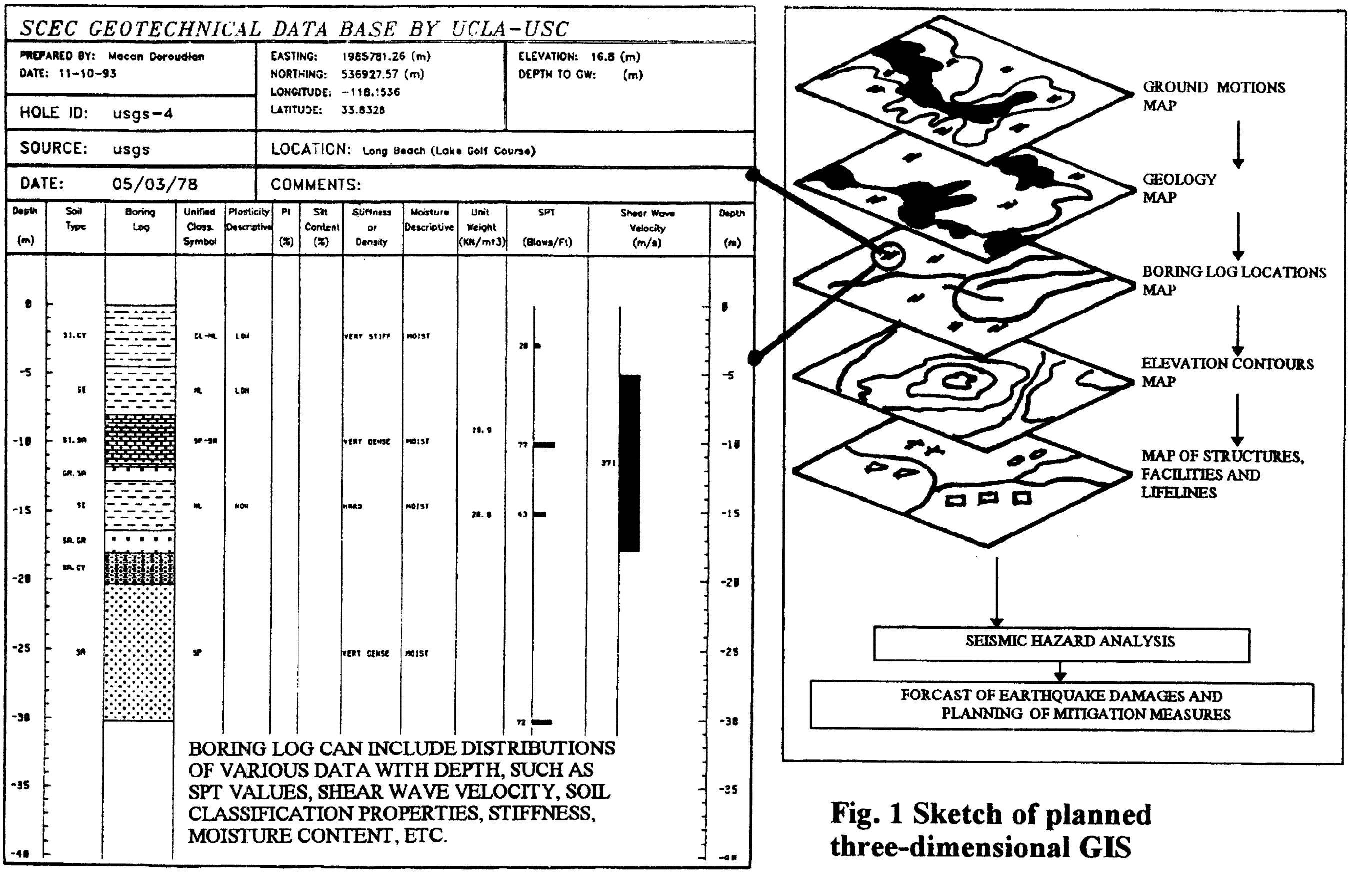

Fig. 1 Sketch of planned three-dimensional GIS

(i) amplification and attenuation of seismic motion through soil deposits, (ii) liquefaction of saturated cohesionless soils, (iii) cyclic degradation of cohesive soils, (iv) seismically induced densification and settlement, and (v) seismically induced failure of slopes. The geotechnical parameters and factors governing these phenomena were reviewed with respect to their significance, frequency of their utilization in different design procedures, availability from standard geotechnical investigation files, and role and importance in the state-of-the-art trends in geotechnical earthquake engineering. The review resulted in a list of more than 20 relevant parameters or factors. They encompass: (i) soil classification properties, (ii) stress-strain, strength, and pore water pressure characteristics, (iii) site-specific characteristics such as geometry, stratification and geology, (iv) parameters obtained by field testing, and (v) seismic loading characteristics.

During the initial phase of the data collection, two important facts became apparent. First is that many of the inspected boring logs contain just a few data of interest, and the second is that different organizations often use different soil classification systems. Given such a situation, it would be difficult to create an intelligible and useful geotechnical data base that contains a large number of parameters and information. Consequently, it was decided to incorporate into the database the 5 most important parameters and factors, with a possibility of including a few more if they are available. These factors are stratification, ground water table, classification based on Atterberg limits (including Plasticity Index, PI) and grain size distribution characteristics, silt content, moisture content, unit weight, SPT blow count and shear wave velocity. The significance of these factors is briefly discussed below.

The stratification and ground water table are essential components of any analysis of local conditions. The unit weight is essential for the dynamic response studies involving inertial forces. Another very important parameter for earthquake engineering studies is the maximum shear modulus at very small strains, G_{max}, which can be derived from shear wave velocity, V_s. Unfortunately, V_s is not usually provided in ordinary geotechnical reports. The Standard Penetration Test (SPT) is still a popular field geotechnical tests, in spite of its roughness and simplicity, and various correlations between the SPT blow count and other geotechnical engineering design properties can be found in the literature. The SPT blow count is usually available in typical geotechnical reports. Classification and the Plasticity Index of the soil (PI) are important because, during the last ten years, it became evident that PI can be correlated to some of the most important dynamic and cyclic soil properties (Dobry and Vucetic, 1987; Vucetic, 1994).

COLLECTION AND ORGANIZATION OF GEOTECHNICAL DATA

Six sources of data have been utilized to date. They are: (i) the United State Geological Survey (USGS) reports by Fumal et al. (1980; 1981; 1982; 1984), (ii) the California Department of Transportation (CALTRANS) files, (iii) the shear wave velocity data obtained at the locations of strong ground motion stations maintained by the University of Southern California (USC) (VIC, 1993), (iv) the County of Los Angeles files, (v) the City of Long Beach files, and (vi) the files of Law/Crandall, Inc. firm.

It is important to note that the organization, critical evaluation and digitization of geotechnical data from different sources is not a straightforward operation. As already mentioned, very often, different organizations generate and/or present the same type of data in different manners. For example, the shear wave velocity profiles in USGS files are based on the downhole seismic field tests, while the velocities at the USC strong ground motion instrument locations were obtained using surface wave measurements (VIC, 1993). Furthermore, for soil identification and classification, the geotechnical firms use mainly the Unified Soil Classification System (USCS) based on the grain size distribution curve and Atterberg limits tests, while in the USGS reports the soils are usually classified according to the Department of Agriculture textural classification chart that is based on percentages of sands, silts and clays. CALTRANS has also used for many of their jobs a classification similar to that of USGS, but not exactly the same. Consequently, for this project, suitable classification and method for uniform presentation of parameters and factors obtained from different sources had to be devised. The classification and description of soils devised specifically for this project is displayed in Fig. 2. The boring log format compatible with this classification and filled in with the data digitized from a USGS file has already been shown in Fig. 1. To date around 1000 boring logs have been digitized in the same format.

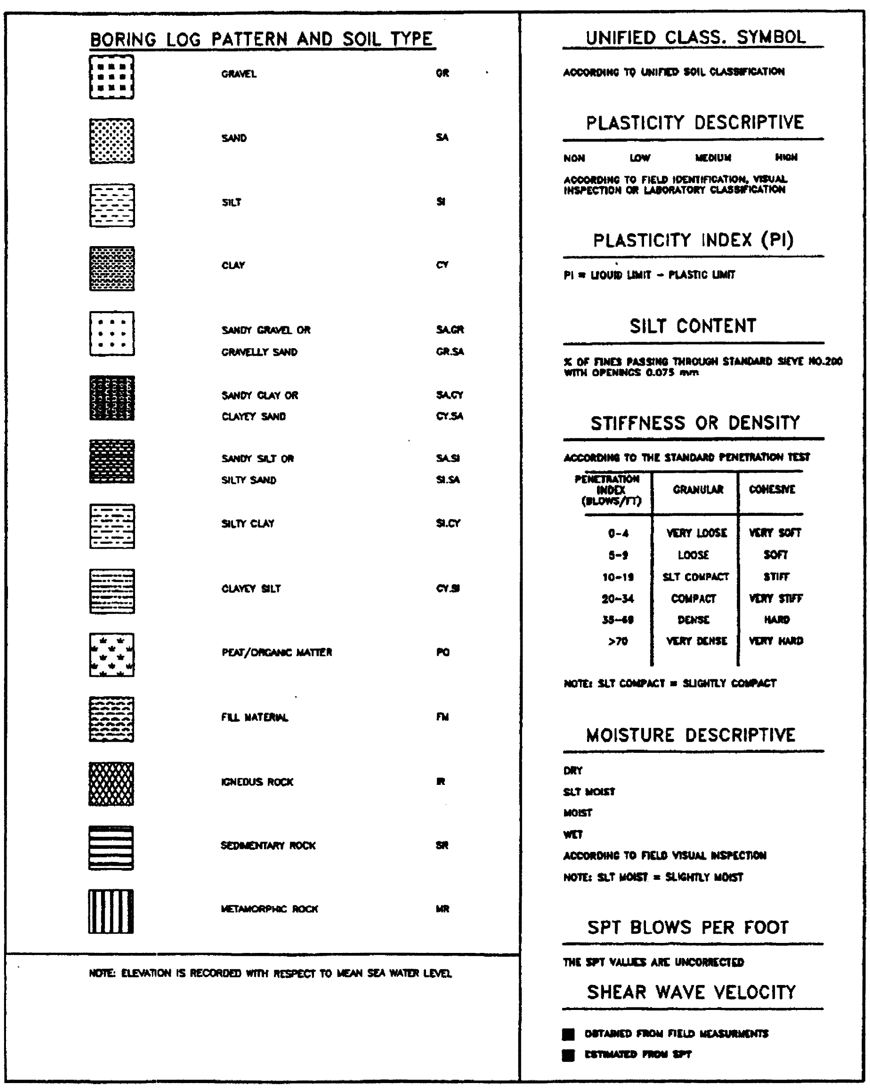

Fig. 2 Soil classification and identification used in this study

PRELIMINARY MANIPULATIONS OF BORING LOG DATA

With "Techbase", various data manipulations and presentations can be made, such as the averaging of soil properties horizontally for any depth segment, contouring of properties, and plotting of a soil profile between any two points. A distribution of digitized boring logs, most of them along major freeways in Los Angeles, is presented in Fig. 3. As an example of the capabilities of the software, some of the boring log data are used here to plot automatically a "cross-section" between two selected points over a selected width. The area is identified in Fig 3. The same area is plotted in the top section of Fig. 4, where the boring log locations identified by large dots are plotted along with the distribution of damaged buildings during the 1994 Northridge earthquake which are marked with small dots. The bottom part of Fig. 4 shows the corresponding "cross-section" with elementary soil types.

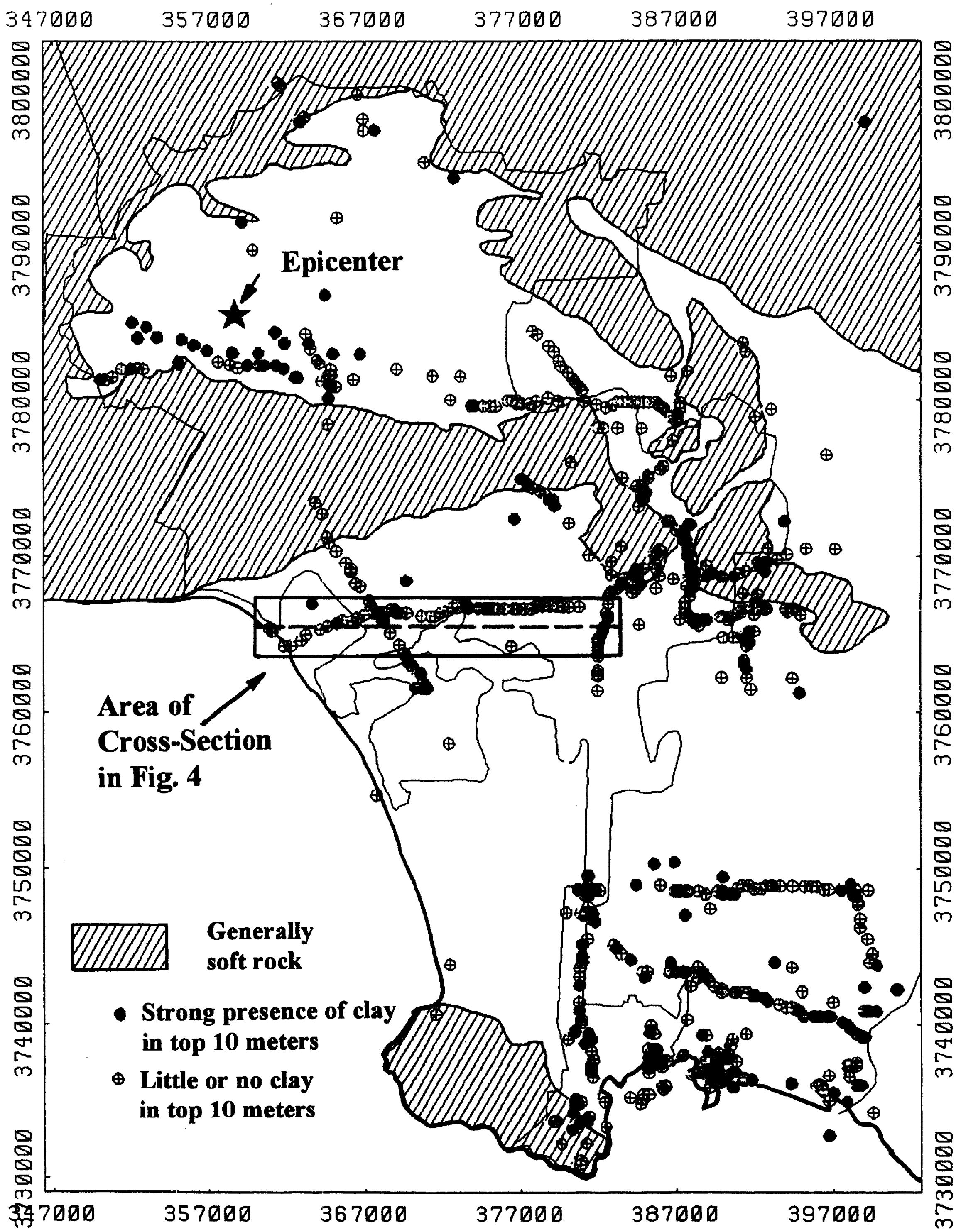

Fig. 3 Locations of digitized boring logs in Los Angeles

It is believed that variation in ground response from site to site depends on several factors. Some of these factors are the distance of the site from the fault, orientation of the site relative to the fault and direction of rupture, size of the rupture and the type of fault , topography of the nearby areas and sites, the variations in geology, and local soil conditions. In some cases it has been observed that the ground shaking can vary by a factor of two within a city block distance. Differences in the intensity of ground shaking within a small city block area may be influenced by the variation in soil types.

In the area encompassed by Fig. 4 the water table is mostly at larger depth, in which case the partially saturated sandy and silty soils should represent stiffer deposits, while the clayey soils are usually softer. This is roughly in agreement with the distribution of damage in Fig. 4. There is less damage along the boring log lines in the areas A, C, and E where the top soil is silty and sandy alluvial soil, while more damage can be noticed along area D where the surface deposit is mostly clayey soils. A certain exception to that pattern is area B where clayey soils are not spread right on the ground surface but at some depth. However, area B is known to have experienced at several locations quite high accelerations during the Northridge earthquake. In any case, considering that the damage distribution also depends strongly on the density and type of structures and lifelines, valley or topographic effects, etc., the GIS-based comparison in Fig. 4 could be of significance.

The distribution of damaged buildings recorded after the Northridge earthquake over a large area is shown in Fig. 5. It can be seen that, at equal distance from the epicenter the density of damaged buildings varies greatly from place to place. The appreciable differences in the values of the peak ground horizontal accelerations in Fig. 6, which are recorded by California Division of Mines and Geology's Strong Motion Instrumentation Program (CSMIP), the University of Southern California's Los Angeles Strong Motion Accelerograph Network (USC), and the United States Geological Survey's National Strong Motion Program (NSMP), are in agreement with such variations of damage. For example, from one station to another at an almost equal epicentral distance of about 22 kilometers, indicated in Fig.6 by a solid circle, peak acceleration varies between 0.17g to 0.93g. Such differences in damage density and peak ground accelerations at equal distance from the epicenter are believed to have been caused in part by the variations in soil types and depth of soil deposits.

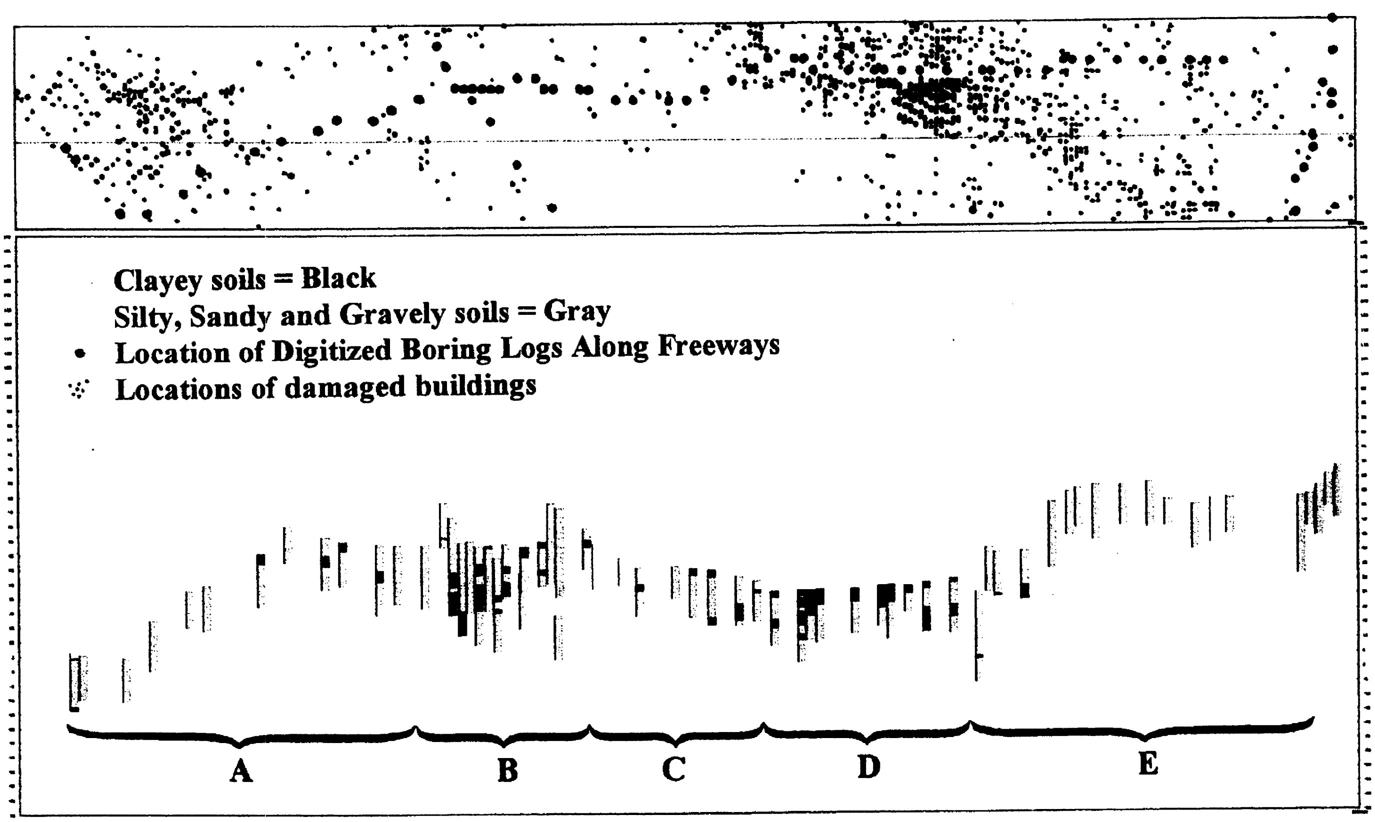

Fig. 4 Cross-section displaying soil types and comparison with damage distribution

It is also interesting to note in Fig. 5, that the damages near the valley edges in some areas are substantially greater than in the middle of the valleys. This is the manifestation of the well recognized basin edge effect which is, among other factors, also related to the type and thickness of the soil deposit.

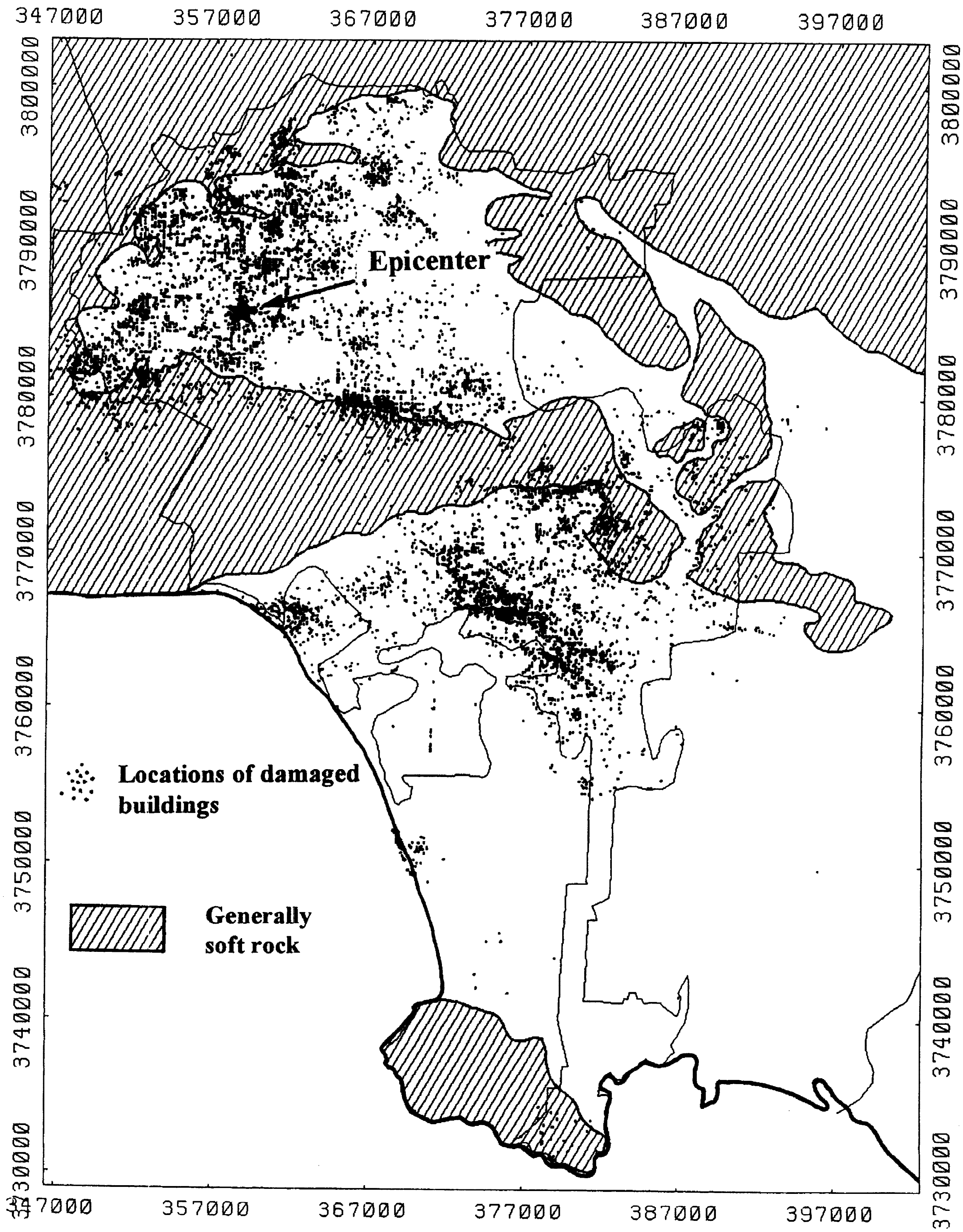

Fig. 5 Distribution of damaged buildings after the, 1994 Northridge earthquake

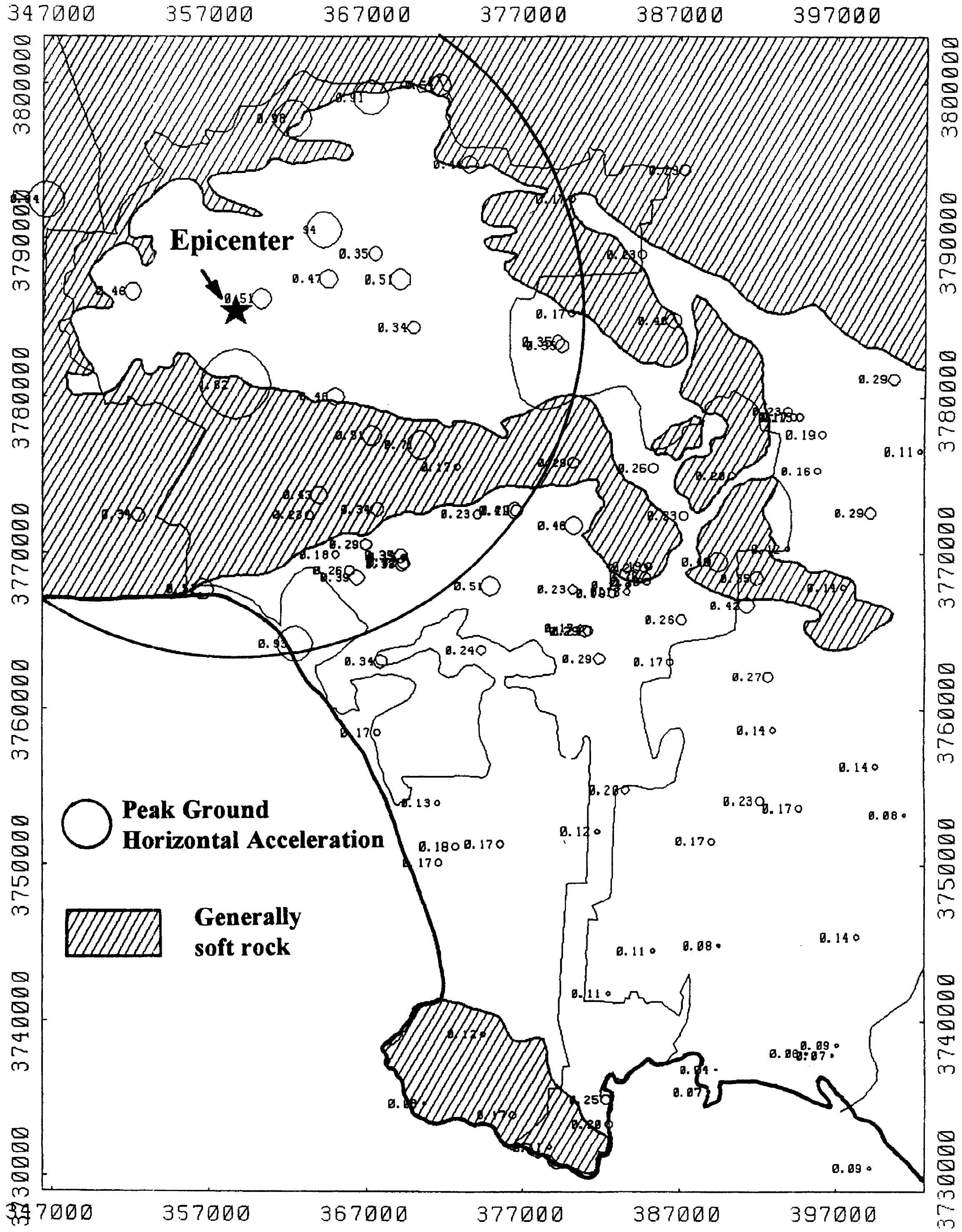

Fig. 6 Peak ground horizontal accelerations recorded during the 1994 Northridge earthquake, expressed as a fraction of acceleration of gravity

FUTURE STUDIES AND DATA BASE POTENTIAL

The collection, organization and digitization of the boring logs will continue until a high-density geotechnical data base is obtained. In addition, some of the following tasks are being conducted or will be conducted in the near future: (i) acquisition of digitized open channel maps, elevation contour maps, geologic maps, and water table data, and their incorporation into the GIS, (ii) manipulation of the existing boring log data to derive important missing information (for example, if the shear wave velocity profile is missing, it may be roughly estimated by using automatically within the "Techbase" one of the existing correlations between SPT and V_s), (iii) generation of a microzoning map of site classes according to the site classification for seismic site response proposed recently in the USA (Martin and Dobry, 1994).

The availability of the planned geotechnical data base is also expected to stimulate development of numerous innovative procedures for the evaluation of the effects of local soil conditions on earthquake damages. For example, the integration of the 3-dimensional geotechnical data base of the Los Angeles area with a 1-dimensional non-linear site response model and the damage distribution maps of the 1994 Northridge earthquake is under way. With such an integrated GIS, the calculated site response and soil amplification characteristics will be compared to the recorded damages of the structures of different natural periods. This will enable critical evaluation and improvement of the site response concepts and analyses techniques in use today.

CONCLUSIONS

The main format and methodology of the planned 3-dimensional geotechnical data base of Los Angeles area have been developed. As its density increases, it is evident that the data base will become a useful source of geotechnical and geologic information. As an integral part of earthquake-related GIS, the data base will also enable the development of innovative techniques for evaluation and forecasting of earthquake damage.

ACKNOWLEDGMENTS

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