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SEISMIC MICROZONATION OF SOUTH EAST TEHRAN

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ABSTRACT

The experiences obtained by the past earthquakes in the world, such as Mexico City (1985), Loma Prieta (1989), and Kube (1995), demonstrated that building damage is strongly related to the ground conditions beneath the building. Tehran (Rey) is one of the most earthquake damaged zones in Iran and has been repeatedly struck by earthquakes during the previous centuries. IIEES initiated in late 1994, detailed microzonation studies of Tehran. These studies were carried out in two parallel phases: one dimensional site response analysis and microtremor measurements. Based on geoseismical investigations, among the various SPT- Vs correlations existent in the literature, one consistent with Tehran's geological conditions was selected and proposed. Preliminary microzonation maps, were developed and presented.

KEYWORDS

Earthquake; geotechnique; site effect; microtremor; site response analysis; micozonation; natural site period; dynamic site period; Iran; Tehran

INTRODUCTION

Tehran and it's surrounding in the region of central Alborz, have experienced repeated moderate to large magnitude earthquakes during the previous centuries. Only in a distance of less than 100 km. from the city, there exist about 15 active faults, which have maximum desirable earthquake magnitudes of more than 7. The most important faults are the Mosha-Fasham and North Tehran faults, which lie behind the northern boundaries of the city, and have maximum desirable magnitudes of 7.8 and 7.3 respectively.

The first phase of microzonation studies of South East Tehran was completed by IIEES in 1995. The objective area covered was about 140 square kilometers. The study included both the site response analysis and detailed microtremor measurements. Indeed, the main aim of conducting the microtremor measurements was to control the geotechnical profiling of the region. Several techniques were evaluated to estimate site effects from microtremor measurements and the best results were obtained by Nakamura's technique. Based on the site response analysis results, three preliminary microzonation maps were developed. The maps included natural site period map, dynamic site period map and PGA distribution map.

METHODOLOGY

A methodology to carry out the microzonation study was developed during this project. The general methodology was to:

1) Dividing the objective area into meshes of 1 km. squares.
2) Obtaining enough boring logs to define the soil profile throughout the region. The soil profiles should be grouped into a number of representative ones.
3) Conducting enough shear wave velocity measurements in order to get a proper correlation between the SPT numbers and Vs.
4) Conducting a detailed microtremor investigation and evaluating the natural site periods throughout the region.
5) Comparing the measured natural site periods with the corresponding calculated ones and thereafter correcting the geotechnical profiling of the region if necessary.
6) Determination of proper reference input motion consistent with the seismicity of the region.
7) Carrying out the site response analysis and interpreting the obtained results.
8) Developing the various microzonation maps.

GEOTECHNICAL ASPECTS OF SOUTH EAST TEHRAN

Surface Geology

From a geological point of view, the alluvial sediments of Tehran can be divided into two main sedimentary units. The first sedimentary unit consists of the unweathered part of the known "Hezar Darreh" or "A" formation, which is formed by conglomerates and is highly cemented. This sedimentary unit has a high shear wave velocity (more than 1000 m/s) and so can be regarded as part of the seismic bedrock. The second sedimentary unit, which is underlied by the first one, consists of the weathered part of "Hezar Darreh" formation, and above it the younger "B" & "C" & "D" formations respectively. The second sedimentary unit, is not cemented, more deformable and has much lower shear wave velocities than the first one. The second sedimentary unit itself, according to soil grain sizes, can be classified into two groups; IIA & IIB. Group IIA consists of noncohesive granular soils and covers the northern region of South East Tehran. Group IIB consists of fine grained and cohesive soils and covers the south region of the objective area. The east-west Ahang St. forms a transition zone between the two quite different deposits.

SPT-Vs Correlations

In situ shear wave velocity measurements were made at 11 stations. Among the various SPT-Vs correlations existent in the literature (see Sykora et al. 1988), the one proposed by Ishihara et al. (1982) for the Balkan region was chosen and slightly modified. Other correlations underestimated the shear wave velocities considerably. The correlation used is shown in table 1.

Table 1 : Vs-SPT Correlations for Tehran

	Cohesive Soils				Granular Soils		
	Hard	V. Stiff	Stiff	Medium	V. Dense	Dense	Medium
S.P.T.	> 30	15-30	8-15	4-8	>50	30-50	10-30
Vs (m/s)	450-720	270-450	160-270	100-160	800-1000	600-800	300-600

Seismic Bedrock

According to UBC (1984) and TC4 (1994), the seismic bedrock was defined as a layer with a shear wave velocity of more than 800 m/s. In noncohesive deposits, although the deposit's thickness was about 200 meters, but the seismic bedrock was found to lie in a depth of less than 30 meters. In cohesive deposits, the shear wave velocity at a depth of 30 meters was about 350 m/s. As the deposits thickness was less than 180 meters, the layer immediately beneath the IIB sedimentary unit was taken as the seismic bedrock.

Geotechnical Profiling

Soil profiles from South East Tehran were ascertained from about 100 existing borings and the available geological data. The subsurface soil layers were classified as cohesive and noncohesive and each class was further classified according to it's stiffness or density respectively. Since boring data were not available in all the elements of the mesh, the elements were grouped into a number of representative soil profiles according to generic ground conditions.

MICROTREMORE MEASUREMENTS

It is over three decades since microtremors are being used to investigate the amplification characteristics of soils.There exist two main procedures for microtremor measurements in amplification studies:

In the first method, which hereafter will be called the hard rock method, microtremors are assumed to be due to white noise applied to the bedrock. The amplification of the microtremors, as is observed at the surface, is then a result of the soil characteristics. To deduce the dominant frequency of amplification, it is necessary to have simultaneous measurement of the microtremors on soil and hard rock outcrops. The dominant amplification periods (which are equivalent to natural site periods) may be obtained from the spectral ratios of such records.

In the second method, which hereafter will be called the single station method, it is assumed that only the horizontal components of microtremors are amplified and, therefore, the vertical component represents the true ground motion. The dominant amplification periods of the soil may be obtained from the spectral ratios of the horizontal to vertical components.

To evaluate the applicability of the above two methods, two simultaneous measurements were conducted in the SE part of the study area, where presence of a limestone outcrop provides a suitable location for the hardrock station. The equipment used for this purpose were two 3 channel recorder equipped with three short period velocity seismometers with one second natural period. To estimate the dominant amplified frequencies, the spectral ratios of the soil station records to the hard rock station records and horizontal components to the vertical component of the soil station records were calculated and was concluded that both methods show dominant frequency range of the amplification between 1 to 2 Hz and 2.5 to 5 Hz, (Fig. 1).

Since single station method requires less field activities, measurement of microtremors in the entire area was conducted using single station method at 30 locations. Analysis of the gathered records indicates that the dominant amplification frequencies are between 1 to 2 and 2.5 to 5 Hz.

COMPARISON OF MEASURED AND CALCULATED SITE PERIODS

Based on the geotechnical data, natural site periods were determined for each element in the mesh. The calculated site periods were compared with the corresponding ones measured through the microtremor technique. It was seen that:

1) In granular deposits, which was thought to have the seismic bedrock at a depth of 20 to 30 meters, both of the calculated and measured site periods were less than 0.2 second.
2) In cohesive deposits with a thickness of less than 150 meters, there existed a good agreement between the calculated and measured site period. In other words, this assumption, that we may have a cohesive deposit as thick as 150 meters, was confirmed.
3) On the other hand, in few elements, which was initially thought to have a deposit thickness of more than 170 meters, the calculated site period exceeded 1 second while the measured one still remained in the range of 0.5 to 1 second. This showed , that a more detailed study should be carried out in the deep cohesive deposits of South Tehran.

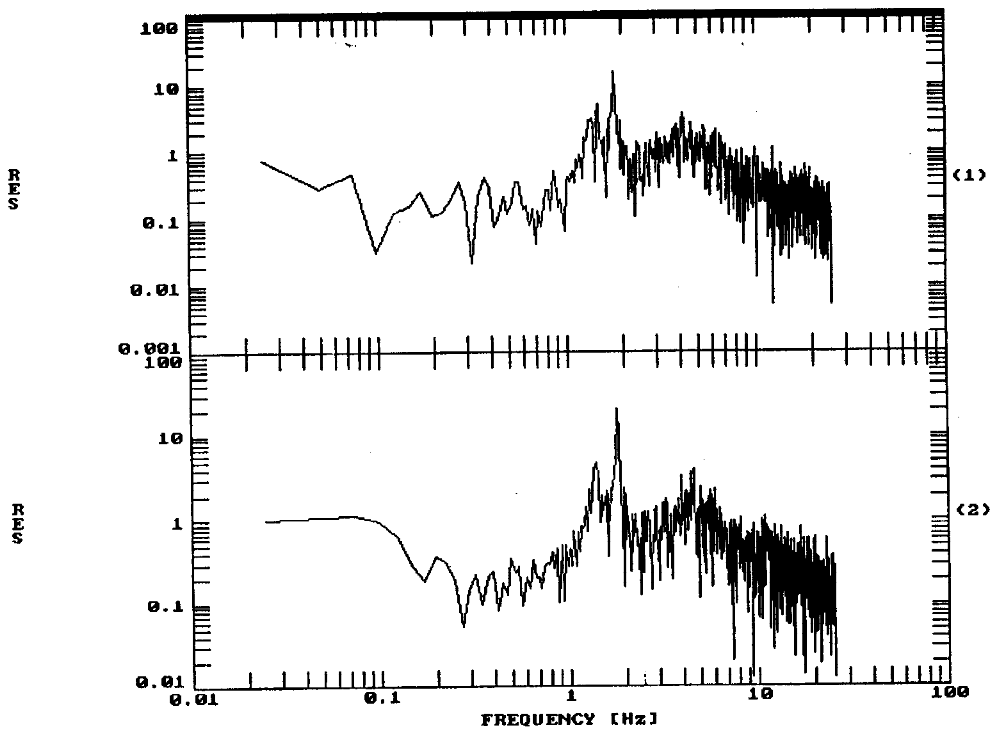

Fig. 1. Spectral ratio of the east-west component to the vertical component of the microtremor record showing dominant frequencies of 1 to 2 and 2.5 to 5 Hz.

EARTHQUAKE TIME HISTORIES

The most reliable regional seismicity investigations of Tehran was conducted by Berberian et al. (1993). According to this study, the peak rock acceleration of the design base earthquake (DBE) in the objective area is about 0.27g. The design basis earthquake was defined as an earthquake with an occurrence probability of 50 percent during a recurrence period of 100 years. The earthquake magnitude is between 7 to 7.5. If the epicentral distance is considered to be about 50 to 60 km., then according to Seed et al. (1969) attenuation curves, the predominant period of the rock motion should be between 0.3 and 0.35 second.

Since there are no strong motion time histories for Tehran earthquakes, time histories was chosen from the literature. The earthquakes were selected to model the distance, hypocentral conditions and frequency content expected in Tehran as closely as possible. Abbar & Ghazvin records of Manjil earthquake (1991), Tabas earthquake (1977) and El centro earthquake were chosen from this study. Their time histories were modified for a PGA of 0.27g and a predominant period of 0.35 second. The acceleration response spectrum for these earthquakes are shown in Fig. 2.

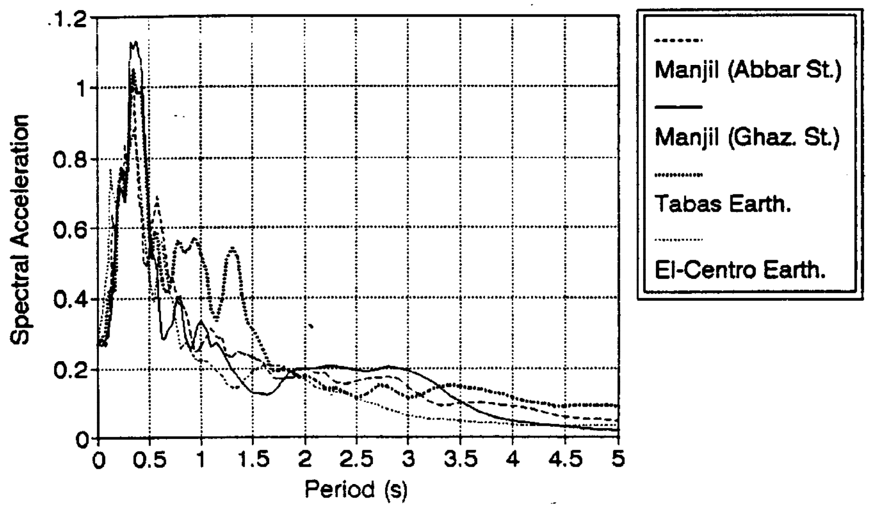

Fig. 2. Response spectra of bed rock input motions

SITE RESPONSE ANALYSIS

Method of Analysis

In this study, site responses were calculated using the SHAKE computer program. The ground conditions in South East Tehran are suited for SHAKE analysis, which is one dimensional. The flat profile of the objective area lends itself to this analysis. Each representative soil profile was analyzed using the previously mentioned normalized time histories. The required "Fc" and "Fs" coefficients were defined, according to the shear wave velocity and mean effective stress of each sublayer. Based on the calculation results and microtremore measurements, three different preliminary microzonation maps were developed which represent respectively the distribution of natural site periods (Fig. 3), dynamic site periods (Fig. 4) and PGA (Fig. 5) throughout the region.

Results

Natural Site Periods. Examination of Fig. 3 reveals several trends:
1) The central and southwest portions of south east Tehran, covered by the cohesive soil deposits, have natural site periods in the 0.50 to 1.00 second range.
2) The northern and west portions of the objective area, covered by the noncohesive soil deposits, have natural site periods of less than 0.20 second.
3) The geological transition zone between cohesive and granular deposits has natural site periods in the 0.20 to 0.50 second range.
4) The highest natural site periods, i.e. the range of 1.00 to 1.50 second, occur in few elements in the central part of the area. This elements have cohesive deposits with a thickness of more than 170 meters.

Dynamic Site Periods. Examination of Fig. 4 reveals that:

1) The distribution of dynamic site periods is very similar to the natural site periods.
2) The southwest portion of south east Tehran, covered by cohesive soil deposits with a thickness between 70 to 120 meters , generally has dynamic site periods in the 1.50 to 2.00 second range.
3) The central portion of the objective area, covered by cohesive soil deposits with a thickness of more than 120 meters , generally has dynamic site periods more than 2.50 second.
4) The northern and west portions of the objective area, covered by noncohesive soil deposits, have dynamic site periods of less than 0.20 second.

Peak Ground Accelerations. Examination of Fig. 5 reveals that:

1) The northern part of southeast Tehran , where the shear wave velocity of surface layers are more than 800 m/s, has peak ground accelerations in the range of 0.25g to 0.30g. In other words, there are no amplifications in this region.
2) The central and southwest portions of south east Tehran, generally have peak ground accelerations in the 0.30g to 0.35g range.
3) The following regions have the highest PGA (more than 0.35g)
   a) The west portion of the objective area, which lies entirely in the granular region.
   b) The east-west 15 Khordad St. in the transition zone.

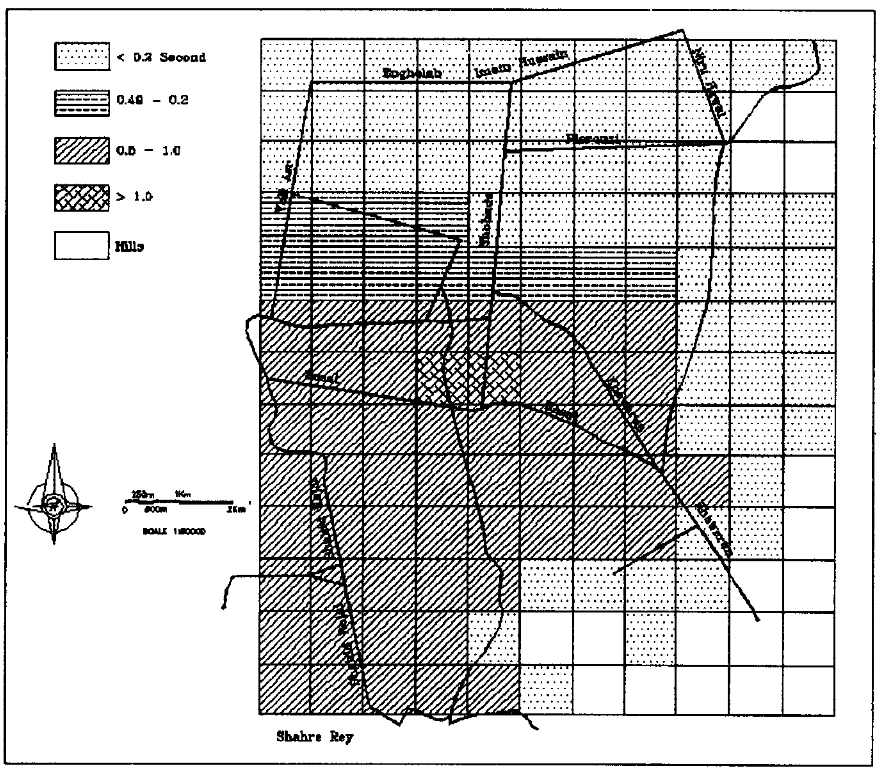

Fig. 3. Natural site period map for south east Tehran

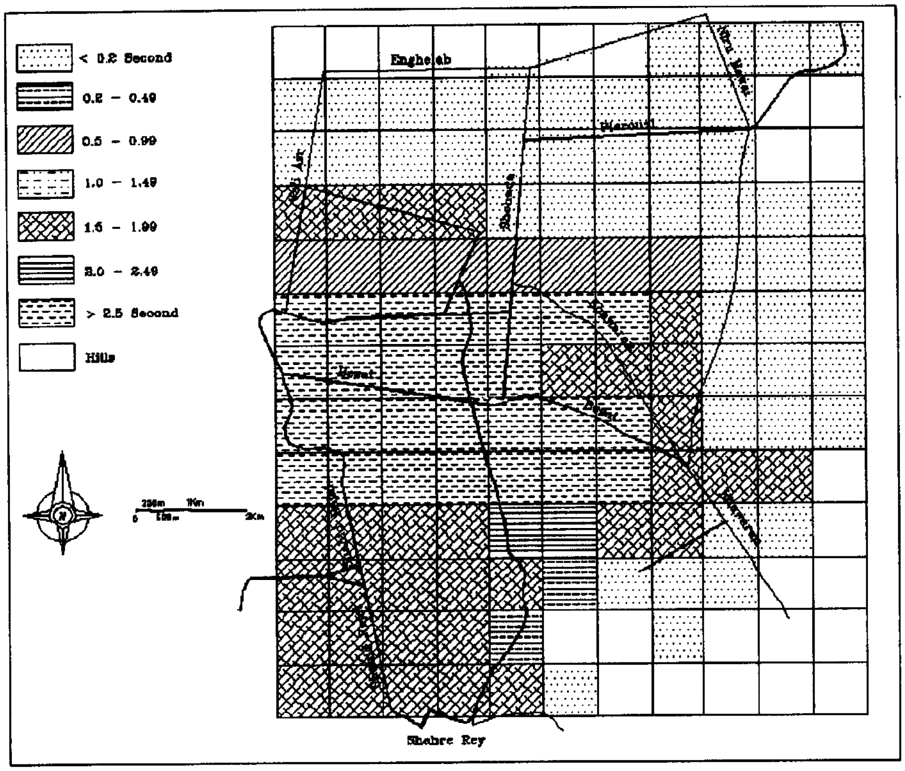

Fig. 4. Dynamic site period map for south east Tehran

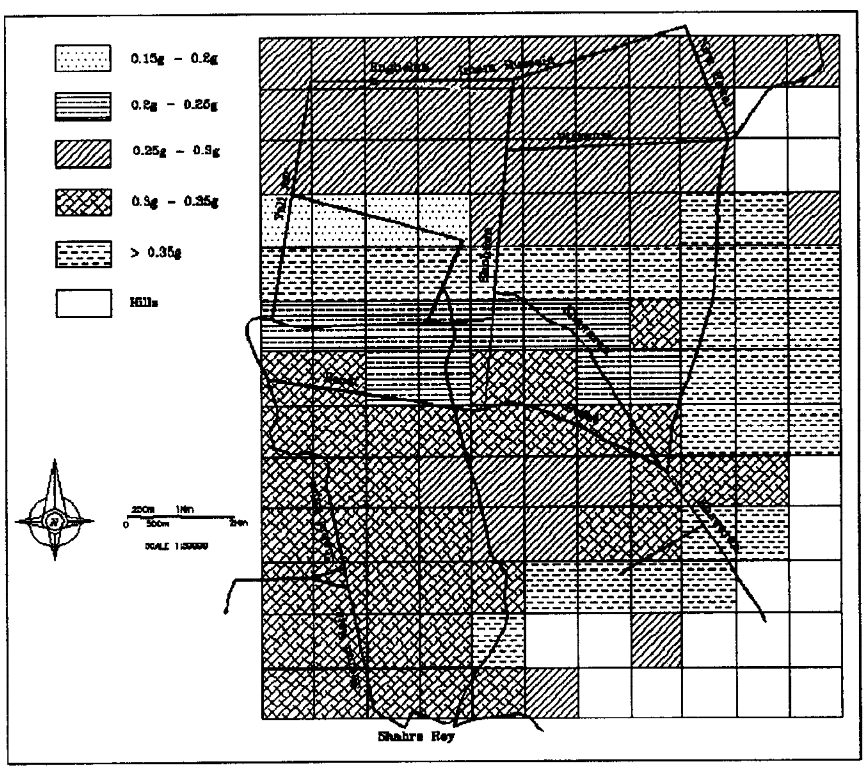

Fig. 5. PGA distriibution map for south east Tehran

CONCLUSIONS

Three conclusions can be drawn from this study:

1) Microtremore study is a useful tool, in order to control the geotechnical profiling of a region. In special, in deep deposits, if we have not enough data to locate precisely the seismic bedrock layer, microtremore measurements can be a great help to have a better judgment about the baserock stratum.

2) It is important to note, that natural site periods will increase during an earthquake. In this study, based on the calculation results, the natural site periods increased by a factor of 3 to 4. Obviously great damage can occur, if the structure has a natural period nearly the same as the dynamic periods of the site on which the building rests.

3) More detailed investigations should be conducted, in order to define precisely the seismic bedrock in the deep cohesive deposits of south Tehran.

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