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TEHRAN GEOTECHNICAL MICROZONATION PROJECT

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ABSTRACT

Megacity of Tehran with a population of more than 8 million is located in a very active region, both in terms of tectonic and seismicity. Due to socio-economic and political importance of Tehran, in 1994 IIEES has initiated a comprehensive geotechnical hazard study in Tehran. The geotechnical microzonation part of the program was composed of two parts: site effect and liquefaction potential microzonation.

Site effect microzonation was started for south of Tehran using one dimensional site response analysis and microtremor measurement. The results of these studies were compiled and presented in three microzonation maps for south of Tehran including: natural site period map, dynamic site period map and the PGA distribution map. Based on the preliminary result, comprehensive studies for south as well as for north of Tehran have been started.

Liquefaction potential study of Tehran alluvium was started in 1995. Considering that the northern part of the Tehran is located on coarse grain clayey alluvium and deep water table the liquefaction study was concentrated in the south of Tehran. The liquefaction potential was evaluated and the microzonation maps were developed. A more detailed investigation is now underway to assess more accurately the liquefaction potential for the south of Tehran.

INTRODUCTION

Tehran, the capital of Iran, one of the world megacity with a population of more than 8 million is located in one of the high seismic hazard zone of Iran. Existance of 15 active faults around Tehran with the history of the occurrence of more than 10 earthquake with magnitude greater than 7, made the Tehran an actively seismic region. Mosha and North Tehran faults are the most important faults (which lie behind the northern boundaries of the city) and have maximum desirable magnitudes of 7.9 and 7.3 respectively.

Due to socio-economic and political importance of Tehran, in 1994 IIEES has initiated a comprehensive seismotectonic, seismic hazard, geotechnical hazard, vulnerability and risk studies for Tehran. The geotechnical microzonation part of the program was composed of two parts: site effect and liquefaction potential microzonation.

Site effect microzonation was started for south of Tehran by using analytical as well as microtremor measurements studies which has resulted to the presentation of the three microzonation maps (natural site period map, dynamic site period map and the PGA distribution map) for south of Tehran. To increase the accuracy of the performed microzonation project, two projects are now underway: 1) Complementary studies on the south of Tehran for updating the existing microzonation maps with a comprehensive field and laboratory (static and dynamic testing of the collected samples) testing program; 2) Site effect study of northern part of Tehran by taking into consideration the topographic and near fields' effect. The preliminary microzonation maps for the north part of Tehran will be provided before the end of 2000.

A comprehensive study on the liquefaction potential assessment of Tehran alluvium has been initiated by IIEES in 1995. Based on historical data, geological and geomorphological maps and also the hydrogeological condition of Tehran, the liquefaction potential was studied and a preliminary microzonation map was prepared.

The northern part of the city could be considered as the most unlikely and the southeast of Tehran was found to be the most susceptible zone for liquefaction. Finally the most likely zone to liquefaction potential in the southeast of Tehran was selected and the geotechnical investigation was started.

Based on the results of this investigation and using the different appropriate methodologies, the liquefaction potential of the selected zone was accurately evaluated and the related microzonation maps were provided. Now again, the second stage of this project with a very detailed geotechnical investigation is running simultaneously with the site effect microzonation project to finalize the liquefaction potential assessment for south of Tehran.

SEISMOTECTONIC AND SEISMIC HAZARD OF TEHRAN

Seismotectonic of Tehran

The city of Tehran is located in the front of the Alborz mountain which is a tectonically active region situated between the Caspian sea and the Iran platform. The tectonic of Alborz mountain belt is controlled by the boundary condition due to the convergent motion between Arabia and Eurasia, which probably started in the Cretaceous. The folding is accompanied by the fast subsidence of the South Caspian sea where several kilometers of sediment have been accumulated. Also there is an abrupt change of about 2750m in elevation between the city and the nearest summit of the northern mountain range which is a striking topographic feature.

Several major faults run parallel to the Alborz fold-thrust mountain belt at its foothill near the Tehran as it has shown in hazard zonation map, Figure 1. The most active faults are the Musha fault, which is 400km long dipping northward and changing direction to EW. North Tehran fault striking EW at the immediate foot of the Alborz with more than 75km is smaller in dimension and might be due to the vertical movement along the major mountain-bordering. Besides, smaller faults such as North Rey, Gamsar, Kahrizak, Parchin and Ipak faults and many minor faults are widespread throughout the city and reactivation of major quaternary faults may cause some movement along the minor faults.

For better assessment of the fault activity, active faults are therefore observed around Tehran. However, the kinematics of the different faults is not precisely known and the relation with seismicity in not clear. Thus a comprehensive seismotectonic study of Tehran including fault-stress analysis, trenching, paleoseismology, satellite geodesy, InSar imagery, absolute gravity measurements are underway at IIEES.

Seismicity and seismic hazard of Tehran

Historical earthquakes are reported in the area of Tehran around the Musha, North- Tehran, North-Rey faults, etc. Because of the sparse population and cities, it is difficult to have a complete record of the past strong earthquakes. Despite the limited available seismic data, a short review of the historical earthquakes in Tehran indicates that the region is highly seismic and has experienced several destructive earthquakes as shown in Table 1(Gh. Ashtiany, M. et al, 1992). The occurrence of more than 10 earthquakes with magnitude around 5 during the 20th century in the Tehran region indicates activitiness of the faults.

Considering that Mosha fault has been responsible for most historical earthquakes, it is predicted that the future earthquake along this fault would have Ms magnitude of 7 or larger. Also the seismicity studies show that the return period for a strong earthquake with Ms>7 is 158 years and the last one with Ms=7.1 has occurred in 1830.

The seismic hazard assessment of Tehran shows that the average PGA for 10% probability of exceedance in 50 years is 0.40g and 10% in 100 years is 0.48g, which indicate high seismic hazard zone. Also the study shows that the occurrence probability of a strong earthquake in the Tehran region within next 10 years is approximately 69%. Figure 1 shows the seismic hazard zonation map of Tehran. It should be noted that the presented geotechnical zonation maps in this paper are based on the seismic hazard studies of Berberian et al in 1983. The present ongoing studies are based on the new hazard zonation map.

Table 1. Some of the bug historical (pre-1900) earthquakes of the Tehran region

Year	Ms	Region	Fault	MMI
300 BC	7.6	Rey-Eyvankey	Parchin, Rey	X
743	7.2	Caspian Gate	Garmasar	VIII+
855-6	7.1	Rey	Rey, Kahrizak	VIII+
958	7.7	Rey-Taleghan	Mosha, N. Tehran	X
1117	7.2	Rey-Karaj	North-Tehran	VIII+
1665	6.5	Damavand	Mosha	VIII+
1815	?	Damavand	Mosha	V+
1830	7.1	Damavand	Mosha	VIII+

SITE EFFECT MICROZONATION

The site effect seems to be more a major concern in the assessment of earthquake hazard and its consequent risk. The recent earthquake catastrophes in Mexico (Mexico city in 1985), California (Loma Prieta in 1988 and Northridge in1984), Japan (Kobe in 1995) and Turkey (Kocaeli in1999) are clear reminders of the fact that site conditions deserve much more attention and consideration. Apparently, the site response to seismic waves is the result of a complex process involving many parameters.

Analytical evaluation of site response requires detailed information on the subsurface layering, topography, seismic velocities and other geotechnical properties of the material. On

the other hand the use of microtremor measurement method in estimating site response is an attractive alternative which seems to function correctly for site natural period evaluation, but it is still controversial concerning site amplification factor. In Tehran site effect microzonation project, considered as one of the most important national projects for earthquake mitigation program in Iran, the two above-mentioned approaches have been used for Tehran south plain.

Site effect microzonation of Tehran-South

Site effect microzonation in south of Tehran started with two parallel projects in southeast and southwest of the city (Jafari K. et al , 1996, 1997, Jafari K., Pourazin Kh., 1999, Jafari K., 2000). In the first step, all the available geotechnical data including more than 400 boreholes and 50 deep well data as well as some geoelectrical profiling for the city were collected and processed. Also some geoseismic refraction investigations was performed by IIEES in about 40 locations and based on their results a SPT-V_s correlation was developed consistent with Tehran's south geological conditions.

In parallel with these investigations, the microtremor measurement was also performed in 70 locations in the south of Tehran (30 points in Southeast and 40 points in Southwest of Tehran). Two objectives were fixed for these measurements: First, comparing the measured and calculated (from 1D SHAKE site response analysis) natural site period and second, controlling the selected seismic bedrock where the sufficient geotechnical parameters were not available. In many of the measured points there were a good correlation between the value of the natural periods obtained from microtremor measurements and site response analysis. The most part of the non-conformity of results corresponds to the region where the subsurface layering is rather complex and not correctly evaluated.

Based on the PGA evaluation at the seismic bedrock made by Berberian et al (1993) the maximum peak ground acceleration of 0.27g (with a return period of 100 years) was considered for the seismic bedrock. The outcome of these studies were compiled and presented in three microzonation maps for south of Tehran including; natural site period map, dynamic site period map and the PGA distribution map (Figs. 2 to 4).

Now, in the same direction a complementary studies for south of Tehran is underway, which will help to update the existing microzonation maps with a comprehensive field and laboratory (static and dynamic) testing program. More than 700 meters boring in 27 boreholes were performed and appropriate in-situ testing as well as undisturbed and disturbed sampling were done. In addition in about 45 locations the new refraction and downhole geoseismic investigations were carried out. The defined laboratory testing program including soil physical properties determination, static and dynamic triaxial tests and also resonant column tests have also recently been finished and the site response analysis with the revised detailed geotechnical profiling for the south of Tehran have been initiated.

Site effect microzonation of Tehran-North

The site effect microzonation project for northern part of Tehran was started in 1999. In this area the topographic and near field effects should also be taken into consideration. In the first step the available geotechnical data in this area were gathered (more than 160 borings) and some refraction geoseismic investigations (30 locations) as well as microtremor studies in 30 points in north of Tehran have been performed up to now.

Based on the above mentioned data and investigation results a preliminary microzonation maps will be provided before the end of 2000. Having finalized this stage for north of Tehran, a comprehensive investigation plan will be defined for this area covering the whole part of the city with the same level of detailing and accuracy.

LIQUEFACTION MICROZONATION OF TEHRAN

Tehran liquefaction project was also started in 1995 covering all part of the city (Mirhosseini S.M. et al. 1999). Considering the geological formation of north of Tehran with coarse grain (clayey or without clay) materials and deep groundwater level in this area (More the 20 meters depth) due to the existing topography, the liquefaction potential in north of Tehran was evaluated to be impossible.

The study was concentrated in south of Tehran and was started within a pilot area in south east of Tehran, which was more susceptible for liquefaction. The available geotechnical data and the in-situ and laboratory testing results of more than 40 new boreholes of 20 meters depth were used for liquefaction potential evaluation of the adopted pilot area. The general lithology of Tehran-south is mainly fine grained and cohesive materials with interbeds or lenses of sandy and silty soils. The groundwater level influenced by the dewatering process in south of Tehran (to prevent rising its level) is less than 20 meters.

Different methodologies (Seed, Ishihara, Iwasaki,...) in Grade 3 of TC4 have been used for evaluating the liquefaction potential in the pilot area leading to the different microzonation maps from which the map for PGA=0.3g is presented in the Fig. 5. As it has been presented in this figure, some part of the adopted area could be susceptible for liquefaction in the case of strong earthquake in the Tehran region resulting from the major faults surrounding the city.

The second phase of this project with a very detailed geotechnical investigation is running simultaneously with the site effect microzonation project to finalize and bring to the end the liquefaction potential assessment for south of Tehran. This phase of the project will be implemented as joint

cooperation between IIEES, Amirkabir, Science & Technology, Sharif Technology and Tarbiat Modarres universities in Tehran.

TEHRAN GENERAL MICROZONATION PROJECT

In the third and final stage of Tehran Microzonation project a general program was defined to revise and update some part of the already performed tasks as well as to complete the remaining part of the project in the whole city. This program will start in 2001 which includes the following components:

- Revision of the existing seismic hazard map of Tehran region concerning the PGA contour maps at the seismic bedrock;
- Update the site effect microzonation of North of Tehran;
- Extend the site effect and liquefaction microzonation studies to cover the whole area defined in the general master plan of Tehran megacity;
- Perform the landslide hazard microzonation of the interested area and finally;
- Present all the results in the appropriate GIS based maps for different microzonation studies.

The result of this program, which will finish at the end of 2003, will be very valuable technical documents for researchers, engineers and decision-makers of the country and the city.

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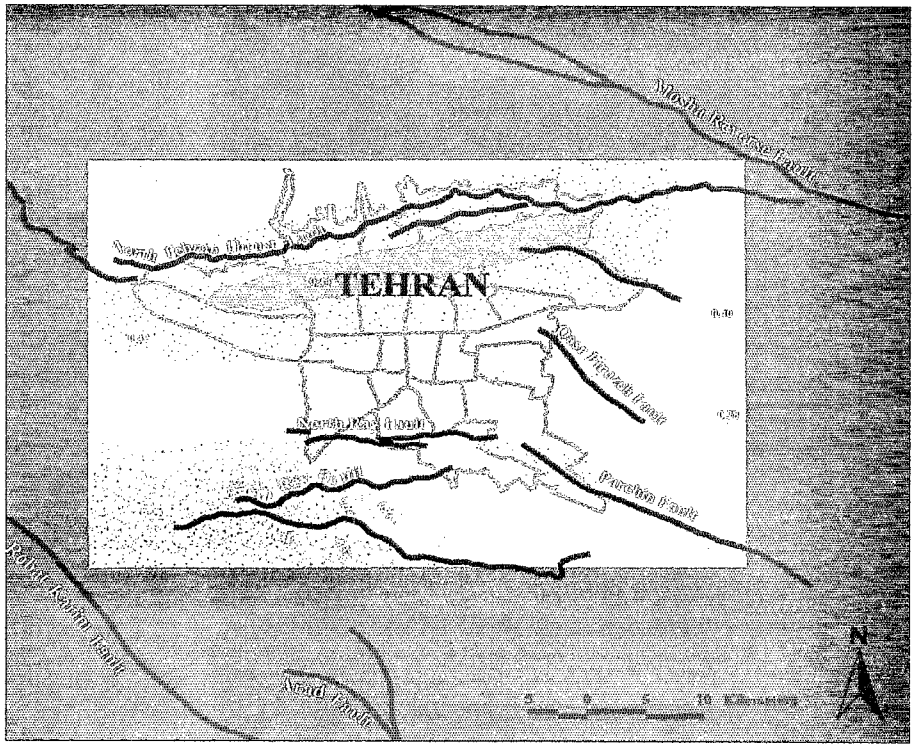

Fig. 1. Seismotectonic and Seismic hazard map of Tehran region

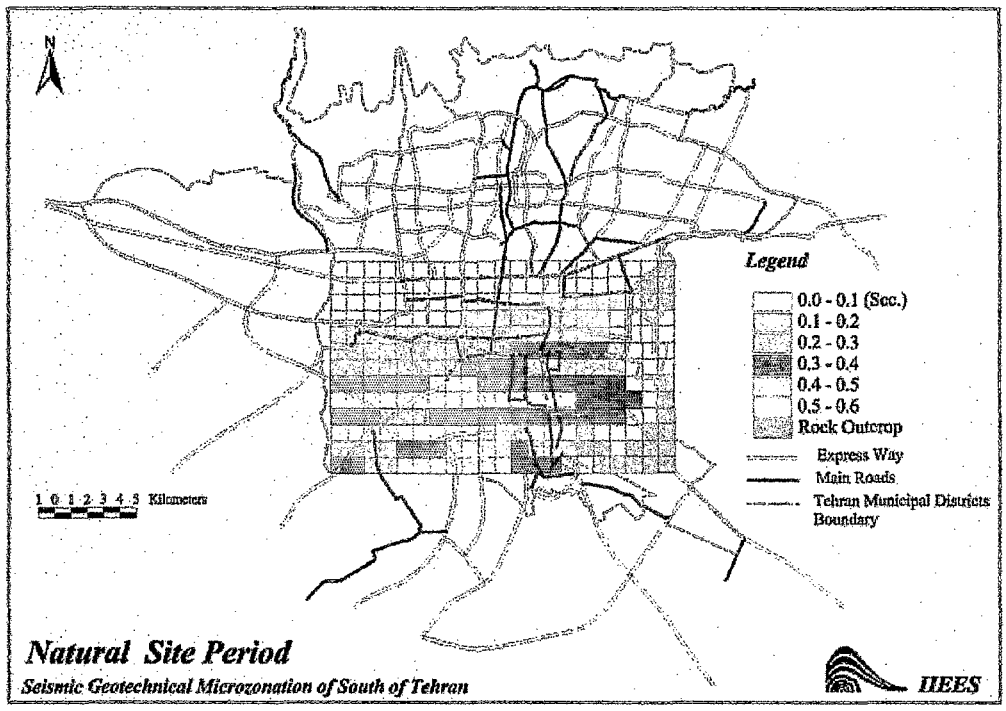

Fig. 2. Natural site period microzonation of Tehran south

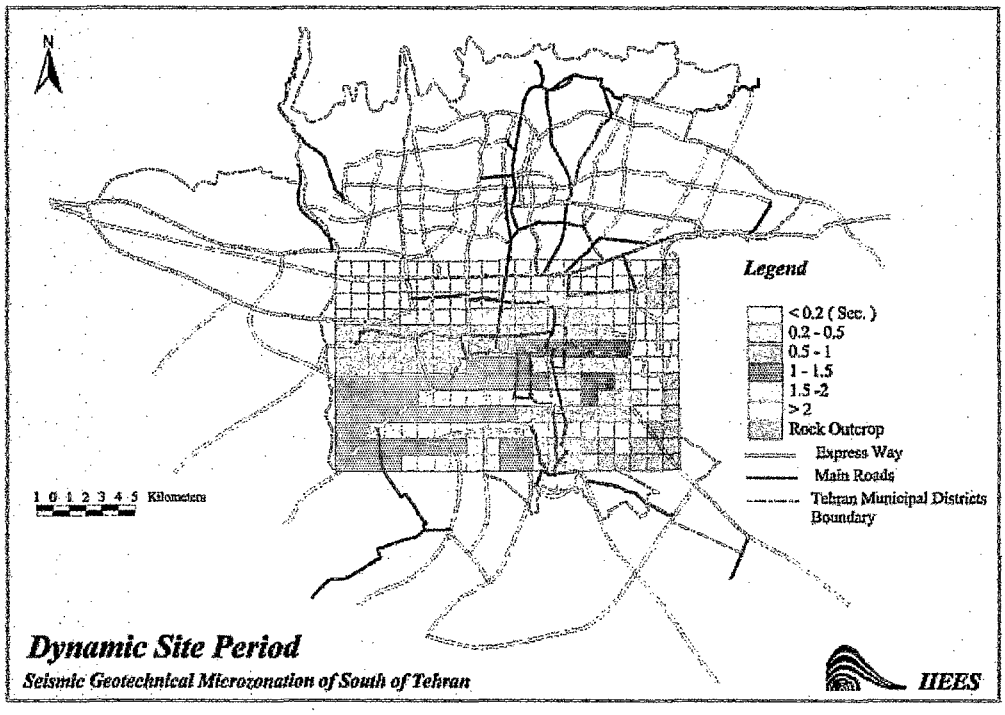

Fig. 3. Dynamic site period microzonation of Tehran south

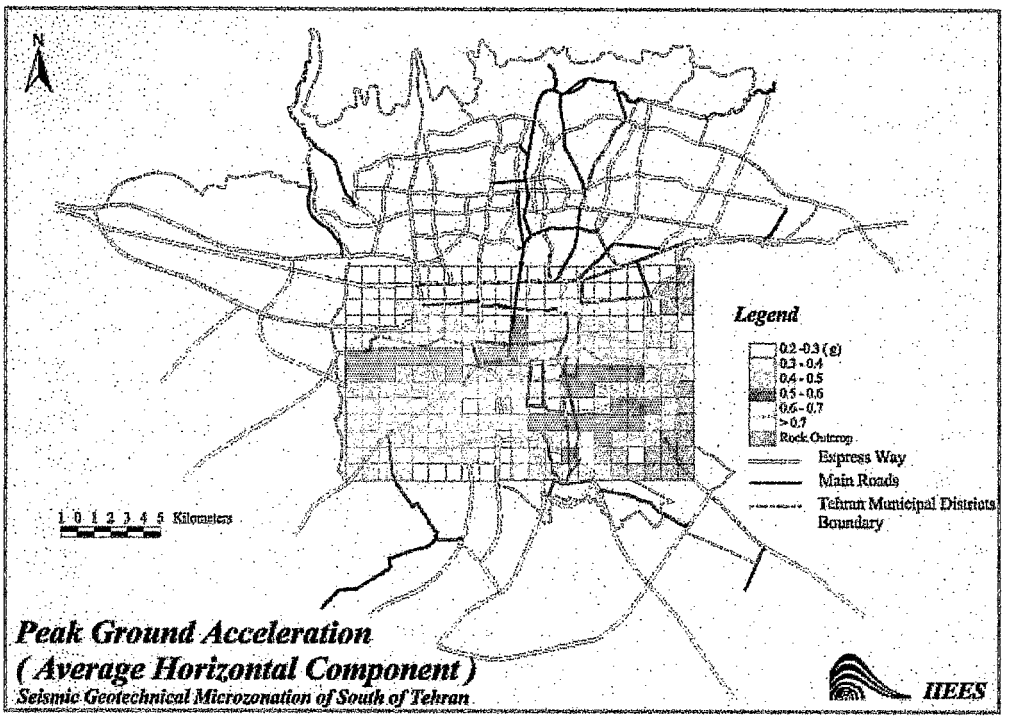

Fig. 4. Horizontal PGA microzonation of Tehran south

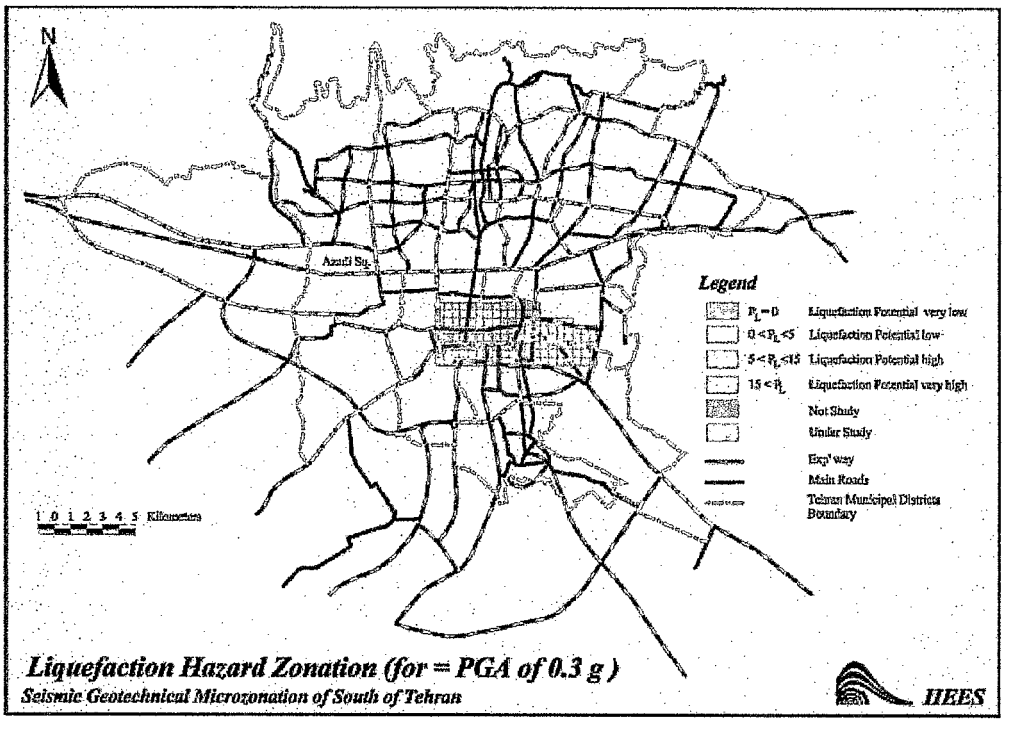

Fig. 5. Liquefaction hazard zonation map of Tehran south pilot area