Ciência eNatura, Santa Maria, v. 37 Part 1 2015, p. 467–475

ISSN impressa: 0100-8307 ISSN on-line: 2179-460X

ciência e natura

A Study on the local geotechnical status of alluviums lie on the bedrock of Tabriz city

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Abstract

Tabriz is one of cities in Iran that has faced several earthquakes because it is located on a fault. Different parameters are involved related to seismic hazards of one particular region, that investing each of them is essential. One of the effective factors that has been recognized according to different earthquake experiences worldwide, is the local and geotechnical status of alluviums lie on the bedrock. In this study in order to acquire the earthquake acceleration in the region seismic bedrock, the "PSHA" probabilistic procedure has been applied. In this regard, firstly seismic parameters of the region have been acquired and then considering all the faults of the region and modeling the seismic sources and by means of "Seisrisk" software, the maximum acceleration of the bedrock (PGA) for an earthquake with return period of 475 years in the urban range has been resulted which have been presented as level curve maps of maximum acceleration of bed rock. Afterwards by means of Geotechnical data collected from exploratory bore holes excavated in the region and other sources, finally 51 representative seismic Geotechnic profiles has been prepared. in order to execute the alluvium response analyze, region bedrock seismic movement estimation is needed. Thus considering all factors, 8 appropriate entrance accelerograms opted and maximum acceleration of these accelerograms tantamounted to maximum acceleration of seismic bedrock in range of each section and each representative section for these 8 accelerograms has been analaysed. According to almost horizontal status of alluvium layers of the region, one dimensional dynamic analyze has been applied in order to calculate the dynamic response of soil layers. In addition the linear equivalent analysis procedure in mediocre strain range and hypothesis of no failure due to earthquake in alluvium, has made the use of EERA software possible in this study. The results of analysis of alluvium response for regions in the city which geotechnical specifications of alluvium layers had been collected, has been presented as maximum acceleration distribution and response acceleration spectrum maps on the ground for entrance movements and alluvium normal period distribution map. Alluvium response analyze results shows that acceleration on ground level will have amounts between 0.55g up to 0.75g for an earthquake with returning period of 475 years. Also in study range, regions with alluvium natural period more than 0.45 sec and less than 0.3 sec exist.

Keywords: *earthquake risk, alluvium, Fault, acceleration of Ground surface, acceleration response*

1- Introduction

The problem of site effect on seismic movements of ground level has been noticed by scientists and researchers since early twentieth century (Kamel Basmenj and Horton. 2012).

They evaluated site effects on changing different characteristics of earthquake waves by investigating the effects created by these waves in different spots of site and alluvium layers status in site(Horton and Chapman. 2015). These investigations has been continued till nowadays and after occurrence of new earthquakes around the world, many researches related to the quality of "site effect" on severity of these earthquakes is being done(Jafari and kamelian. 1994). From Engineering point of view, earthquake waves are being studied considering three characteristics including "maximum acceleration", "frequency content" and vibration time span", that these specifications can be derived directly from accelerograms acquired from the effect of these waves(Hough. 2012). Site condition effect is altering these characteristics in effect of existence of alluvium layers on bedrock and also in effect of topography or other geometric conditions of site(Hough. 2012). That is to say if the accelerogram of one particular earthquake is derived on the bedrock level, the existence of alluvium layers between bedrock and ground level or geometric conditions of ground level such as valleys and peaks results in altering the characteristics of accelerogram on ground level and even in different depths of alluvium layers(Jibson and Harp. 2012). Alteration is caused due to dynamic behavior of alluvium and is affected by different factors such as dynamic characteristics of layers, layers position, bedrock position or alluvium depth, geometric and topographic characteristics of site level and….

Iran, one of the most seismic countries of the world, is situated over the Himalayan-Alpied seismic belt. One of the most important features of Iran plate is young tectonic movements. Tabriz city, is one of most seismic regions of Iran. Tabriz plain Covering an area of 220 km^2 is extended approximately Along east–west. In terms of topography, it is located among three elevation levels which has surrounded the city from north, east and south. Low lying lands can only be found in western areas. With an overview of the Tabriz plain and its environs two different geology faces can determined. The bump in northern area is in red and heights along with vast area of plain is in grey. These two completely different faces indicate two different geological destiny(Jibson and Harp. 2012).

According to seismic studies in recent years, the maximum congestion of Earthquake focuses is observable in the study area of North west- South east from Khoy city to Sarab related to Tabriz northern Fault, and also in north-south direction in north of Tabriz toward Iran-Russia border and up to kilometers from Caucasia, Whereas in other areas this congestion is less and tiny shakes in time units, are features of this region and during twentieth century and passed centuries, devastating earthquakes has occurred in this region several times causing widespread human loss and destruction(Hesami and Tabasi. 2003). Dispersal of earthquakes occurred in twentieth century within a radius of 150 kilometers from Tabriz city is illustrated in figure 1.

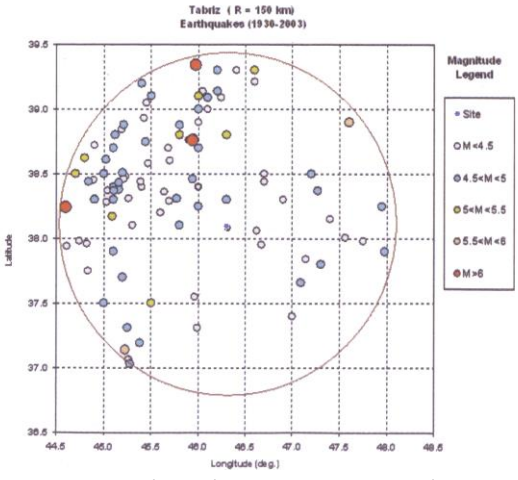

Figure 1- Earthquake Focus Dispersal occurring after 1900 within a radius of 150 km from study area

Most prominent tectonic phenomenon in Azerbayjan region is North of Tabriz young Fault. The general trend in this Fault is N 115° and its slope in most of sections is vertical and it has slip protraction rupture mechanism which is right turn type and starts from Misho mountains near Marand city and extends to the near of Miyaneh after crossing Tabriz and Bostan Abad (Jafari and Kamelian. 1994). It's length is more than 150 km and from tectonics point of view this fault has been considered as tailing of Anatoli fault system which is extended through entire north of Turkey. Tabriz north fault has not shown any specific activity in present century but according to historically intense earthquake occurrences in Tabriz specially the 1721 earthquake with 7.6 Richter magnitude, in addition to considerable seismic activity that it has shown in past centuries and congestion of earthquake focuses on it indicates its active condition in present era, That is to say its renewal movement is possible. Four main and important faults which their position is in 100km radius from study region and have been used as seismic sources in the analyze of seismic risk in study region are: Tabriz north fault, Mishow north fault, Tasuj fault, and Azarshahr-Tabriz fault. in this study earthquake risk analyze is done for different regions in Tabriz city and then alluvium layers condition effect on seismic movements of bedrock is evaluated by analyzing alluvium response (Mc Namara and Gee. 2014).

2- Methodology:

In this research in order to do the probabilistic Analyze of risk and evaluation of maximum acceleration of Bedrock "Seisrisk III" software is applied. By means of this software by modeling seismic sources of the region and by means of Seismic parameters (derived from "kijko" software) and assigning the lowering formula, maximum horizontal acceleration of bedrock for an earthquake with returning period of 475 years for each spot from studying range has been acquired and by interpolation as same level curve maps of maximum acceleration of seismic bedrock (horizontal component) is presented in figure 2. Lowering formula is a formula which relates lowering and rate of lowering of ground seismic parameters to parameters such as the distance of region from seismic source, earthquake magnitude, tectonic and geological status and …, which in this study in order to evaluate the maximum acceleration of ground PGA (bedrock) of the region "Campbell" and "Bozorginia" (2003) lowering formula has been used which is the newest and most complete formula and also seems appropriate for Iran. This formula has many parameters which among them, fault mechanism, soil type, distance from Fault rupture point, depth of fault rupture, and standard deviation can be mentioned. In This formula the near fault effects are also included, so it is very suitable for region near to fault and estimates the acceleration pretty well.

There are different methods and models for analyzing alluvium seismic response. In a general grouping, models are divided into simple one dimensional and two or three dimensional models. In one dimensional models, alluvium is divided into horizontal layers and it is assumed that shear waves due to vibration of seismic bedrock disperse vertically bottom-up. In two or three dimensional models, real status such as ground level topography, limit and border of different alluvium layers and … are considered also and alluvium is analyzed in a more realistic model. According to almost horizontal position of the alluvium layers and little topographic inclination in Tabriz city range and as regards in this study ground level topographic effect and limit and border situation of different layers are not are not required, single dimensional model is applied for modeling the alluvium layers. Also the equivalent linear analyze method in mediocre strain range and the hypothesis of no rupture due to earthquake in alluvium, has made the application of "EERA" software possible in this study. The basic of analyze in this software is the equivalent linear method. "EERA" calculates

the response in a stone-soil system with horizontal stratification under transient and vertical shear waves. In order to consider the effect of non-linear behavior, the methods proposed by "Seed" and "Idriss" (1970) has been applied[*]. In this method the real nonlinear hysteresis stress- strain behavior of cyclic loaded soil can be determined by considering equivalent linear properties of soil. Equivalent shear module (G) generally considered as secant shear module and equivalent linear damping factor (ξ) also is considered generally as a damping factor with same energy dissipation as what hysteresis curve dependent to one real cycle causes. For analyzing ground response by "EERA" the soil profile properties must be defined to the software.

These properties are: material type (clay, sand, stone or other materials which are defined by user), thickness of the layers, specific weight, shear wave speed, groundwater level (is used merely for effective stress in layers). In this study the correlation between SPT number and speed of shear wave V_s which is based on "Ohta" ans "Goto" (1978) has been applied for acquiring shear wave speed in different geotechnical profiles and also determining seismic bedrock in profiles. This formula Considers parameters such as layer age and its type (clay, fine sand and …) and is very suitable for region under survey which is consisted of sand and clay layers. In EERA software both mixed shear modules (G^*) independent from frequency and dependent to frequency are defined which alluvium response analyze can be done with each of these modules. Introducing the shear module G curves and damping factor ξ in this software by defining coordinates some points from these curves. The user can increase define points to as many as needed. For defining most of shear module and damping curves entering 10 to 15 points of their coordinates suffice. Geotechnical properties of 51 representative profiles in entered for analyze in EERA software and stratification and defining the seismic bedrock in each of profiles are determined by means of speed of shear waves.

In this study by considering seismic features of region, accelerograms for analyzing alluvium response which could cover expected frequency features in Tabriz city range were opted and used. For this purpose, acceleration response spectrum content (Target) were opted by means of lowering formulas and accelerograms with frequency content similar to target spectrum. By means of Bozorginia and Campbell lowering formula (2003) target spectrum for studying region was provided and eventually calculated considering factors such as region topography, earthquake magnitude, fault mechanism and …, and by searching in "Peer" data base (belonged to University of California, Berkeley), 8 accelerograms were opted. alluvium response Analyze has been executed in each of representative geotechnical profiles which were scaled to maximum acceleration of bedrock for 8 entrance accelerograms in each of profiles in study range. Figure 4, illustaretes maximum acceleration distribution map in study region which is derived based on average acceleration amount resulted from analayzes for entrance accelerograms for each one of provided representative profiles.

The study area is selected as follow: Longitude of 38 degrees and 3 minutes to 38 degrees and 10 minutes east, Latidude of 46 degrees and 10 minutes to 46 degrees and 25 minutes North.

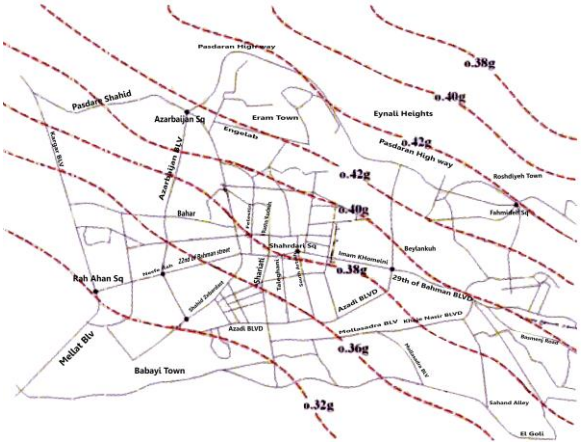

Figure 2- the map of same level curves of maximum acceleration of bedrock in Tabriz city range (Returning period of 475 years)

3- Results:

As can be interpreted from figure 2, results show that in Bed rock of study range the amount of acceleration bigger than 0.42g and smaller than 0.32g exist. Maximum amounts are those related to spots located in the north of city which are near Tabriz north Fault or on it. By moving from north east to south west and keeping out from main fault, acceleration amount decreases and in ranges of Kasayi highway reaches to its minimum value. Also this figure illustrates that the determinative fault and seismic source in Tabriz city range is Tabriz north fault and other seismic sources doesn't have much effect in results and acceleration amounts.

The results acquired from seismic risk analyze are applicable only in solid rocky terrain. These results can differ significantly in terrain with weak layers depending on material, Density and soil layer depth. Different analytical methods are available for studying site effect due to site soil status on seismic response of ground level. Most of these methods are based on vertical dispersion of waves from bedrock upwards. Results acquired by nonlinear analytical methods which are based on this hypothesis have good conformity with site observations and application these methods in earthquake engineering for estimating the seismic response of soil layers have had dramatic increase. Determining dynamic properties of soil layers and opting appropriate internal movement for bedrock are of great important in dynamic analyze.

Geotechnical properties and dynamic parameters are considered the most important in creation of site effect of earthquake. Material, thickness, stratification, density and stiffness, natural density and groundwater level are among those geotechnical parameters that exact evaluation of each of them does have an important impact on accuracy of the results acquired from dynamic analyze of alluvium. Also the speed of shear waves in soil layers is very important in evaluating seismic response of the site. Evaluating each of geotechnical and dynamical parameters which were mentioned above requires enough information on sub ground soil layers status in different regions. Boring geotechnical boreholes and executing laboratory and field tests and also geotechnical surveys are considered required tools for accurate evaluation of these parameters. In this study information from boreholes excavated for civil projects in the city. For each region a borehole is opted as representing geotechnical profile. In fact the specifications of boreholes in each region are summed in representing profile of that region. In this case representing profile reflects geotechnical specifications and stratification of that particular region.

Finally 51 seismic geotechnical profiles were provided. Tabriz map and location of these profiles are shown in figure 3. When analyzing alluvium response, Bedrock is an environment which stiffness and density and shear wave speed in that environment is less than real bedrock but yet is that much which it can be assumed that waves would not be strengthened. Real bedrock is normally located in much lower depths than seismic bedrock and it can be assumed that seismic movement of these two environments would be similar. Therefore The point which is important in studying risk analyze for region is finding seismic bedrock and not natural bedrock. In this study the layer which the speed of shear wave in it is more than 800 m/s is defined as natural bedrock.

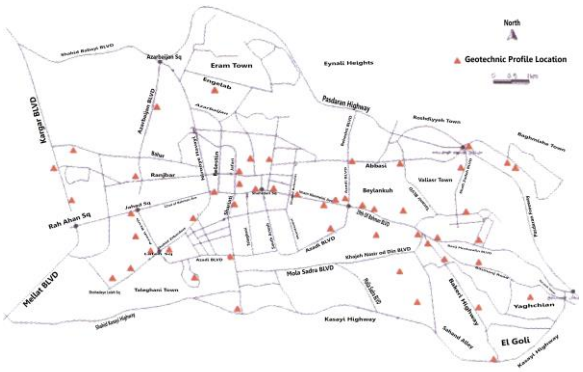

Figure 3- Tabriz distribution map and location of geotechnical seismic representative profiles in Tabriz city range.

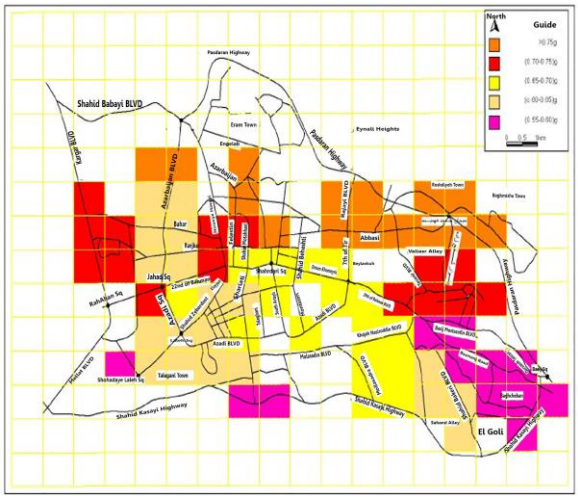

Figure 4- maximum acceleration distribution map in Tabriz city range (returning period of 475 years) By analyzing the representative profiles in EERA software, natural period values related to each region is determined and eventually alluvium natural period zoning map is provided which is illustrated in figure 5

As it is shown in the figure, in the study area, regions with periods less than 0.3 sec and more than 0.45 sec are observed. Regions with less natural period are related to tose profiles which alluvium layer thickness on bedrock is less and alluvium is consisted from dense layers. In regions with higher natural period, alluvium layer thickness on bedrock is moe and soil layers have less density.

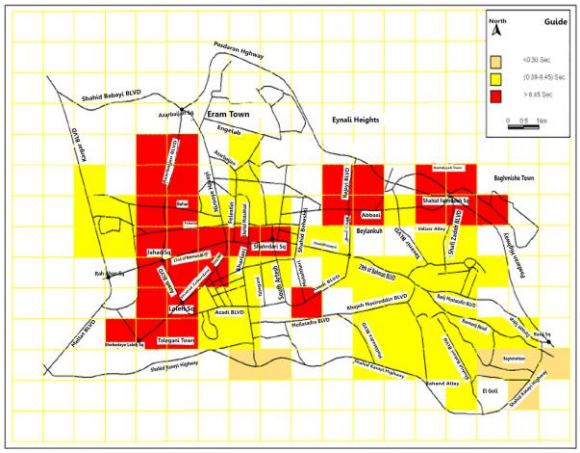

Figure 5- alluvium natural period distribution map in Tabriz city range

As previously mentioned, in this study 51 seismic geotechnical profiles for Tabriz city has been selected and alluvium response analyze for each of profiles and for each one 8 enternal accelerograms. Results from these analysis gave 408 accelerograms and response spectrum on alluvium geotechnical profile level. In this study in order to compare results from dynamic analysis of representative geotechnical profiles and Iranian 2800 code proposed spectrum, first response spectrum average value in each profile for 8 accelerograms is acquired and then the amount of these spectrums are divided into spectrum values in zero period (Maximum acceleration on ground level) to normalize the spectrum. These spectrums are illustrated in figure 6, and Iranian 2800 code proposal spectrum for regions with seismic risk of "almost high" and "very high" for different soil types are presented in figure 7. Comparing these two figures it becomes clear that code proposal spectrum does not cover response spectrum for some representative profiles.

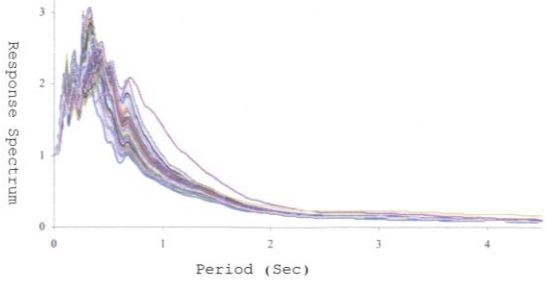

Figure 6- Averege values of normalaized response spectrum in each of representative profiles for entrance seismic movements.

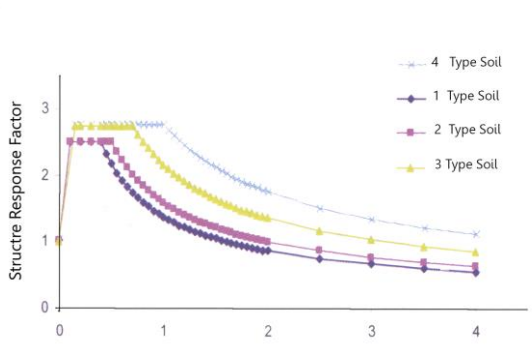

Figure 7- coefficient of reflection values for different types of soil for regions with high and very high seismic hazard according to Iranian 2800 code

4- Conclusion:

Faults existing in Tabriz city range, can cause an earthquake with maximum acceleration of 0.46g with returning period of 475 years in seismic bedrock in northern area of the city in areas which have the least distance from Tabriz north fault. Also in southern areas of which do have the maximum distance from Tabriz north fault, these amounts reaches to less than 0.32g, while Iranian 2800 code has determinded an acceleration of 0.35g for entire Tabriz city.

Alluvium response analyze results shows that acceleration on ground level will have amounts between 0.55g up to 0.75g for an earthquake with returning period of 475 years. Also in study range, regions with alluvium natural period more than 0.45 sec and less than 0.3 sec exist. Checking results indicates that response spectrum proposed by Iranian 2800 code for Tabriz city (region with very high seismic hazard) has not been satisfying for some profiles. Response spectrum form is very affected by from type and intensively of internal movement and mechanical and geomatic specifications of soil profile.

In order to complete the studying in this survey the followings are proposed:

One dimensional models provides reasonable answers for locations which does not have abnormal topographical and stratificational situation. Otherwise these results would be with errors. In this study the places of some representative geotechnical profiles does have abnormal topographic ups and downs. It is proposed that in these places and in each region which does have topographic and terrain abnormality, the effect of topographic factor be evaluated by different methods including two or three dimensional method.

5- Suggestions:

Some of the applied bore holes does not have sufficient accuracy and sometimes are with errors and also dispersion of these bore holes in the city does not have a homogenous state and in some areas does have more congestion and in some other areas there were no boreholes. As a result firstly correct results must be seperated from incorrect and inaccurate data and correct data become the basis of calculations, and secondly available data must be used by engineering judgment. These restrictions must be considered in usage of the results of this study. It is proposed that for feature researches bore holes excavated for all city areas and for determining the specifications of alluvium layers such as shear wave speed in soil and seismic bedrock location site, geophysical methods such as seismic refraction and laboratory along with experimental formulas applied.

It is proposed that for better conception of areas exposed to feature earthquakes, more records for analyze be applied. Since Iranian 2800 code is not appropriate for some geotechnical profiles in the study area, It is proposed that for special and with high importance structures, more accurate analyze and special site spectrum be applied.

In recent decades according to spread of accelerogram networks worldwide, some records in near distances with earthquake has been registered. These records are vary valuable from earthquake engineering point of view, because they have started a new era in seismic researches. For a range that is located in a 10 to 15 kilometers range from earthquake source, the amplitude and frequency of waves and resulting energy is different with what is about earthquake in far area. This sate is called "near source". Records registered in near source do have one or more big pulse in speed-time or displacement-time record. This pulse shows big accumulation and discharge amounts of energy in a very short time span. Structures which are located besides big earthquake focuses, face a very big displacement during earthquake. When it is discusse about areas near to fault in Tabriz city range, it is normally limited to Baghmishe alley, while with this definition of near-source many areas in Tabriz city are not included in this definition. It is proposed that in later researches seismic hazard analyze is done by considering more accurate near-source situation for Tabriz city range.

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