Journal of Applied Sciences 4 (3): 364-368, 2004
ISSN 1607-8926

Evaluation of Ground Response Due to Earthquakes-Case Study

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Abstract: Two methods are usually available for designing structures subjected to seismic loads. They are equivalent static load method and dynamic analysis method. The dynamic method of analysis is not widely used, but it may be necessary for important structures. Dynamic analysis usually has three phases, defining the expected source of earthquake, evaluating ground surface response spectra taking into account local soil properties and applying response spectra to proposed structure to evaluate seismic forces. In this study, the first two phases are discussed. The recent methods in evaluating the ground response that take into account soil properties are presented. This includes sources of earthquakes in Palestine and their characteristics such as earthquake magnitude, predominant period, maximum acceleration and duration. Furthermore, this study presents a case study for evaluating ground response spectra using computer program called Shake that may be used to evaluate ground response in Palestine.

Key words: Dynamic analysis, earthquakes, ground response, Palestine, shake

INTRODUCTION

Earthquakes are one of nature's greatest hazards to life and most feared natural phenomena on this planet. Earthquakes have destroyed countless cities and villages on virtually every continent. However, the damage caused by earthquakes is almost associated with man made structures, except in the cases of landslides. Earthquakes only cause death by the damage they induced in structures such as buildings, dams, bridges and other works of man.

Past and present history indicated that Palestine and vicinity are seismically active and earthquakes may affect our region at any time in the future and may cause losses of lives and properties. This is the reason that our structures, especially important one, such as, high-rise buildings, power stations, dams, hospitals, schools, must be designed to withstand and resist earthquake forces.

There are two main methods to determine earthquake forces. The first one is the equivalent static load method, in which the earthquake forces are estimated as a lateral forces based on the dead load of the structure and the base shear coefficient. The second method is dynamic analysis method that depends on using either response spectrum or time history[1].

The dynamic method of analysis is not widely used in the country and it needs in addition to what usually use in equivalent static load method, computer software, evaluation of ground surface response spectra and specialized person. However, this method is very important for certain structures and may not be replaced by other methods. Dynamic analysis has usually three phases, the first phase defines expected source of earthquake, the second evaluates the ground surface response (motion) taking into account local soil properties and the third applies response spectra techniques (acceleration and velocity amplitudes due to earthquake) to the proposed structure to evaluate the forces, which are expected to develop. The first phase is the job of engineering geologists and/or geologists, the second phase, is the job of the geotechnical engineers and the last phase is the job of structural engineers.

In this study, the first two phases are discussed. Common methods in evaluating the ground response that take into account soil properties are presented. This study includes sources of earthquakes in Palestine and their characteristics such as earthquake magnitude, predominant period, maximum acceleration and duration. Furthermore, this paper presents a case study for evaluating ground surface response spectra using computer program called SHAKE, which may be used to evaluate ground response in Palestine.

Seismicity of Palestine: Earthquake may be defined as the vibration of the earth produced by the rapid release of energy. This energy radiates in form of waves in all direction from its source (focus). Another definition is trembling or shaking of the ground caused by the sudden

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release of energy stored in the rocks beneath the earth's surface[2].

The actual cause for earthquake occurrence is the great forces acting deep in the earth, these forces put a stress on the rock which may bend or change in volume (strain). The rock can deform until it reaches the ultimate capacity of the rock and a rupture (rock break) occurs. Hence, waves sent out through the earth that cause the ground to tremble and shake. Rock break causes one huge mass of rock to slide past another that would cause crack between the two rock masses (fault). The presence of such faults indicates that, at some time in the past, movement took place along them. Faults may be active or inactive. Most earthquakes are produced from active faults.

Earthquakes may be classified according to the main causes of the forces that put stress on the rock mass, which are tectonic movements, dilatancy in the crustal rocks, explosions, volcanic, collapse of soil and large reservoir. However, tectonic movements cause majority of earthquakes[1].

Main faults in Palestine: Major earthquakes are those of tectonic origin. The tectonic of our region is closely related to the tectonic of the Middle East and the Eastern Mediterranean region, which is considered one of the main belts and active zone of the earth. Three tectonic plates can be identified for the Middle East region[3]; they are the African, the Eurasian and the Arabian. There is movement between the African and Arabian plates occurs mainly along the Dead Sea Fault. There are about 13 major faults, in the region of Palestine, which are responsible for the seismic activity in Palestine[4]. Some faults are more active than others. The Dead Sea fault is responsible for most seismic activity in our region[5]. This fault extends from the Red Sea in the south to the Taurus Mountain (Turkey) in the north. The largest earthquake had been occurred along this fault had a magnitude of 7.8±0.5 at 748 A.C. and the largest recorded earthquake had a magnitude of about 6.25 and occurred in 1927 and was named as Nablus Earthquake.

Wadi Araba Fault extends from the Gulf of Aqaba up to the Dead Sea with a length of about 186 km. It is considered to have less activity than the Dead Sea Fault. Other faults are the Northern Faults, the Northern Red Sea Faults, the Wadi Sirhan Basalt Fault, Wadi Faraa-Al-Karmel-Al-Jaleel Fault, The South East Mediterranean Fault and the Cyprus Zone Fault.

Earthquake ground surface response spectra and local site effect: It has been well recognized that earthquake ground surface response spectra (motion) are affected by earthquake source conditions, source-to-site transmission path properties and site conditions[1,6,7]. The site conditions include the rock properties beneath the site, the local soil conditions at the site above the bedrock to ground surface and the topography of the site. The local soil conditions may have major effects on the ground surface response spectra. It was demonstrated by dramatic differences in ground motions in different parts of Mexico City in the 1985 Mexico earthquake[7] (Fig. 1). It was seen that there is a very significant amplification of peak ground acceleration for soil depths of 30 to 40 meters, but much smaller amplifications for soil depths exceeding about 50 m. The locations where values of peak ground accelerations are highest correspond with the parts of the city where heaviest earthquake damage occurred. Many other examples show clearly the effect of local sites[8].

This section presents the evaluation of response spectra at the ground surface for the two main faults' earthquakes that are expected to hit Nablus City, Palestine, (Latitude 32:13 North and Longitude 35:16 East), for a given soil profile in the City. The response spectra were found using computer program SHAKE[9].

Common methods use for evaluating ground surface response: The most common methods, by which the effect of site conditions on ground surface motion might be predicted, are as follows[1,8].

Accumulation of strong motion record: However, there are insufficient records of strong ground motions and the associated soil conditions available to provide a basis for detailed analysis of specific site.

Use of microtremor (synthetic small earthquake): Unfortunately, because of the nonlinear stress-strain characteristics of soils, the behavior at small strain levels during very small earthquakes can not be used as a direct basis for evaluating behavior at high strain levels during major earthquakes.

Use of analytical procedure: For deposits of horizontal boundaries either wave equation analysis may be used by considering the soil of each layer to have viscoelasitc properties or lumped mass analysis in which the characteristics of the shear springs which connect the lumped masses are determined by the stress strain relationships of the soils in the various layers. For deposits of irregular or sloping boundaries, the finite element method of analysis provides an appropriate method for response determination.

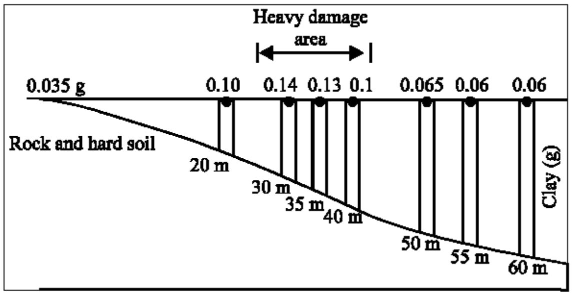

Fig. 1: Distribution of peak ground surface acceleration for typical soil profile[7]

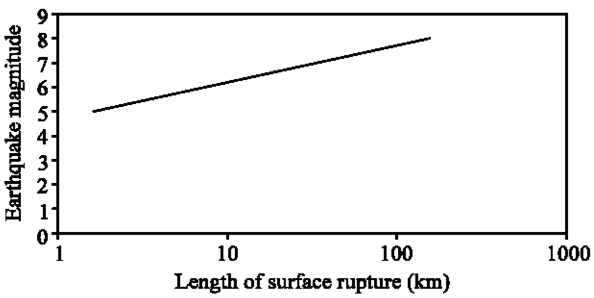

Fig. 2: Relationship between earthquake magnitude and length of surface rupture[10]

Application for evaluating ground surface response spectra: The determination of ground surface response spectra of soil deposits is generally involves three basic steps, first, selection of earthquake motions, usually corresponding to rock outcrop, i.e. selection of design earthquakes for our region. Second, idealization of stratigraphy and selection of material properties, i.e. geotechnical conditions of the proposed site. Third step is calculation and evaluation of response spectra at the ground surface. The last step will be accomplished by solving the wave equation using computer program WeShake5 (one the latest version of SHAKE[9]).

Step 1: selection and characteristics of earthquake motions at the bedrock: Characteristics of earthquake motion at the bedrock are usually consisting of maximum bedrock acceleration, predominant period of bedrock motion and duration of shaking. Investigations have developed data and techniques that allow for the estimation of these characteristics. These data include relationships between magnitude and fault rupture length[10] (Fig. 2) and relationships between the distance to the fault, bedrock acceleration and magnitude[11] (Fig. 3) or with predominant period[12] (Fig. 4).

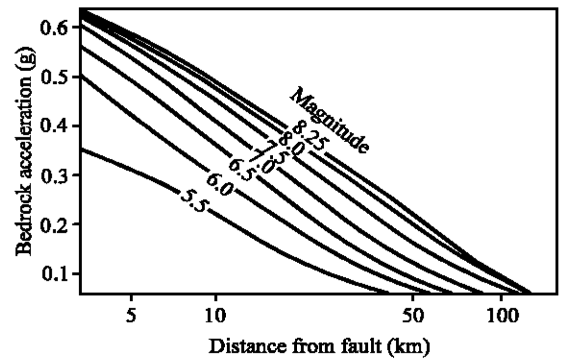

Fig. 3: Relationship between bedrock acceleration and distance from the fault[11]

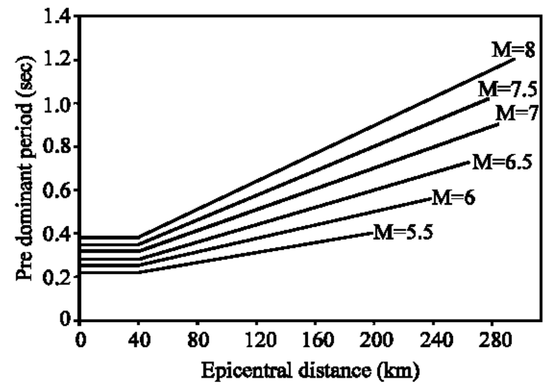

Fig. 4: Relationship between predominant period and distance from the fault[12]

Table 1: Earthquakes characteristics at the bedrock

Fault name	Earthquake magnitude	Duration (sec)	Maximum acceleration (g)	Predominant period (sec)
Dead Sea	7.4	45-00	0.16	0.37
Al-Karmel	7.2	45-50	0.30	0.33

Defining the expected source earthquake for Nablus city: The two major and most effective faults[13] to affect City of Nablus are Dead Sea Fault and Al-Karmel Fault. Hence, they were chosen to provide ground surface response spectra for the selected site. The expected length of the surface rupture for the Dead Sea fault is about 70 km and for Al-Karmel Fault is about 60 km. By using Fig. 5, the expected maximum magnitude for the Dead Sea Fault and Al-Karmel Fault are 7.4 and 7.2, respectively. The epicentral distance is taken as the closest distance from the fault to the site. The epicentral distance is approximately 54 km for the Dead Sea Fault and 27 km for Al-Karmel Fault.

The characteristics at the bedrock of the expected earthquakes from Dead Sea and Al-Karmel faults are presented in Table 1.

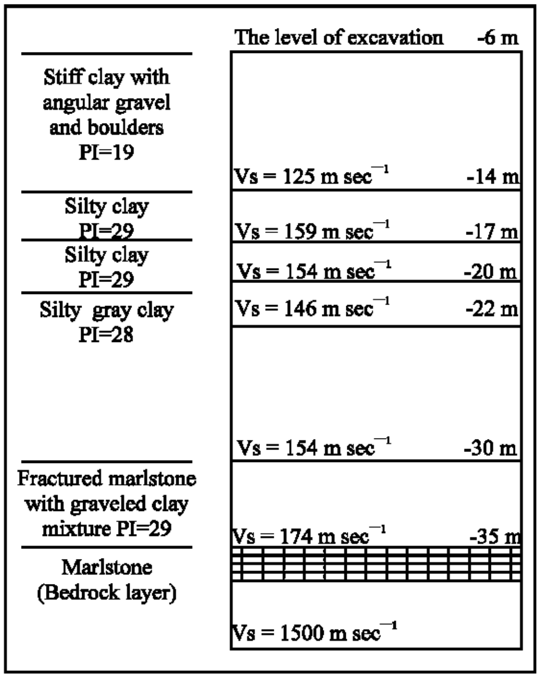

Fig. 5: Idealized soil profile

Step 2: Characteristics of site conditions: Based on the result of field and laboratory investigation programs, an idealized soil profile was developed (Fig. 5). Shear wave velocity, which is a basic dynamic soil property for layered soil (Fig. 5). The shear wave velocity (V_s m sec^{-1}) is calculated based on the modulus of elasticity of the soil (E kN m^{-2}), Poisson's ratio of the soil (v) and unit weight of the soil (y kN m^{-3}) according to the following equation:

$$V_s = \sqrt{\frac{9.81xE}{2x\gamma x(1+v)}}$$

Step 3: Development of ground surface response spectra: One dimensional ground response analysis is considered here, which is often used to modify earthquake motions in bedrock to account for the effects of a soil profile at a site. This step was accomplished by the software SKAKE. The original version of SHAKE[9] for use on a personal computer was obtained from the University of California at Berkeley in 1972. This program has been improved to reflect the numerous changes that have been made to keep pace with sate-of-art technology, to provide for needs of users and to provide a user-friendly interface. These adaptations facilitate transfer technology to and wide-spread use among interested personnel.

The basic assumptions used in the formulation of SHAKE are: the soil layers are horizontal and extend to infinity, the ground surface is level, each soil layer is completely defined by the shear modulus and damping as a function of strain, the thickness and unit weight. The non-linear cyclic material behavior is adequately represented by the linear visco-elasic (Voigt) constitutive model and implemented with the equivalent-linear method. The incident earthquake motions are spatially uniform, horizontally polarized shear waves and propagate vertically.

SHAKE has many real recorded earthquakes that can be modified within SHAKE to account for the earthquake expected at any region. This may be done through the program by modification factors. Hence, the two earthquakes suggested for Nablus City where exactly represented by using modified earthquakes in SHAKE.

Figures 6 and 7 showed the effect of local site conditions on the ground surface acceleration response spectra for the two earthquakes, namely, Dead Sea and Al-Karmel causes earthquakes' faults. It is clear that the

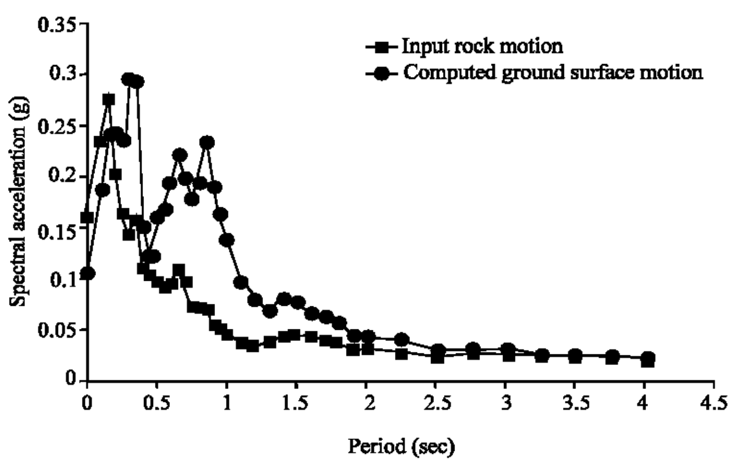

Fig. 6: Response spectral acceleration for ground surface motion compared with rock motion for Dead Sea fault

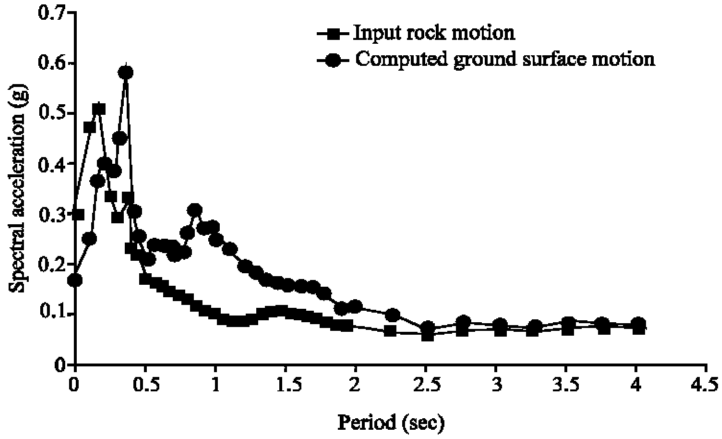

Fig. 7: Response spectral acceleration for ground surface motion compared with rock motion for Al-Karmel fault

soil profile in the site had modified the two earthquakes and worked as an amplification factor, i.e. increasing the response spectra values.

Now, it is the job of structural engineers to implement the given response spectra in their dynamic analysis, which is usually finite element analysis, to account for earthquake force in addition to other loads such as dead and live loads.

Recommendations: In order to reduce the effects of earthquake shaking, it is necessary to design bulling structures to withstand and resist earthquakes. The traditional method for specifying seismic design force is the equivalent static force method, which does not take into account the detailed characteristics and properties of the soil. To do so, dynamic analysis method should be used and response spectra at the ground surface is developed using the program SHAKE in conjunction with appropriate earthquake input motions and site specific soil information.

It is recommended to use this method for important structures as use in most developed countries. Further studies should be carried out to determine the characteristics of earthquake motion in our region, such as, maximum acceleration, predominant period and duration. In addition, it is recommended to do a future studies based on the difference between the equivalent static method and the dynamic analysis method using the response spectra that have been developed.

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