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EFFECT OF SITE CONDITIONS ON SEISMIC MICROZONATION OF 6Th OCTOBER CITY, EGYPT

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الملخص العربي:

في هذا البحث تم دراسة تأثير عوامل الموقع المحلية علي استجابة حركة الأرض للزلازل باستخدام طريقة التحليل الخطي المكافىء والتحليل اللاخطي بواسطة برنامج DEEPSOIL **وكذلك تم عمل تقسيم المناطق الدقيق لمدينة السادس من أكتوبر – محافظة الجيزة – مصر وذلك بالنسبة لمعامل التضخيم والزمن الدوري. وتم التصديق على 171 جسة من مدينة السادس من أكتوبر وتم إدخالهم برنامج** DEEPSOIL **لدارسة تأثير عوامل التربة المحلية علي كلا من معامل التضخم و الزمن الدوري وتسارع العجلة الطيفي وتم عمل دارسة مقارنة لمعامل التضخم و الزمن الدوري وتسارع العجلة الطيفي بالنسبة لطريقة التحليل ومقارنة اشتراطات الكود المصري الخاص بالزلازل** (ECP-201, 2011).

Abstract.

This paper presents an investigation on the effect of local site conditions on the response of ground motion to earthquakes for 6th of October city at the northwest of Giza ,Egypt. Equivalent linear and non-linear ground response analysis using DEEPSOIL software was adopted in the analysis. Microzonation map for site under consideration, was presented with respect to amplification factor and natural time period. Large number of boreholes were attested for 6th of October city to investigate the effect of local soil conditions and were simulated through the adopted DEEPSOIL software. Comparative study was conducted to investigate the effect of local site conditions on amplification factor , natural time period and pseudo-spectral acceleration for the ground surface compared to the seismic provisions of the Egyptian Code of Practice-201 (ECP-201, 2011).

Keywords.

Amplification factor, DEEPSOIL Software, Local site conditions, Microzonation, Natural time period, Pseudo-spectral acceleration, Seismic site response analysis.

Introduction.

Earthquakes are one of the natural disasters that cause a huge amount of losses in terms of economy and human life. The local site conditions such as the topographic condition and soil profile play an important role in amplifying earthquake waves that are causing severe damage at particular site compared to other site. To achieve safety against earthquakes, reduce seismic risks, seismic hazards and related consequences assessment it is necessary to construct the building considering geotechnical problems like site effects and using the seismic microzonation technique is essential [1-12].

Seismic microzonation is subdividing a region into smaller areas having different potential for hazardous earthquake effects. For microzonation studies, the local site effects need to be carried out for a scenario earthquake estimated in the seismic hazard analysis. Amplification and liquefaction are the major effects of earthquakes that it cause massive damage in the infrastructures and loss of life. In practice, the effects of local site conditions are measured with amplification factors which it describe the relationship of soil layers in terms of the seismic measure intensity parameter. The site effects are primarily based on geotechnical properties of the subsurface soil and it are combination of soil and topographical effects which it can modify the characteristics of the incoming wave field [1-9].

A comprehensive microzonation studies and site response analysis were carried out by many researchers [1-9] and in Egypt, microzonation studies and site response analysis were conducted by many researchers. EZZ El-Arab [10], presented seismic microzonation of Hurghada city by using computer finite element program. Estimation of the dynamic properties of the soil layer, evaluation of the foundation material characteristics and defining both the fundamental resonance frequency and the amplification characteristics of ground vibration at Hurghada city were done to protect the structures from damages related of earthquakes. Mohamed et al.[11], estimated the fundamental frequencies at the 6th of October club area and its extension. Horizontal to vertical spectral ratio (HVSR) analysis of surface waves were carried out in a specific area and the natural periods and amplification factor were obtained. Kamal et al. [12], presented microzonation map for El-Fayoum new city and investigated local soil response using synthetic acceleration-time based on the 1992 Dahshour earthquake. Seismic analysis was conducted using twenty boreholes and twenty seismic refraction profiles and the results were presented in microzonation of average shear wave velocity over 30 meters in the uppermost soil profile, peak ground acceleration at the ground surface and amplification factor maps. Kamal [13], conducted site response analysis for New Damietta city and site characterization was performed with 543 boreholes. An equivalent linear and the nonlinear analysis were done and peak ground acceleration at the ground surface, fundamental frequency and amplification factor for representative boreholes were obtained. Mohammed et al. [14], investigated experimental the local site effects on seismic vulnerability index using the horizontal vertical spectral ratio (HVSR) method to introduce a microzonation map of 15th

May City, Helwan, Egypt for future planning and construction purposes. 54 sites were processed and interpreted using Geopsy Software to calculate the amplification factor and fundamental resonance frequency of each observation point. Abdelrahman et al. [15] studied the local site effects on seismic response for Zafarana wind turbine farm, Egypt. 698 borings were collected and seismic analysis was conducted and the surface acceleration time history, the variation of peak ground acceleration with depth, the response spectrum at the surface, spectral acceleration ratio and the amplification spectrum between the surface layer and bedrock layers were obtained.

The main aim of present study is to investigate the effect of local site conditions on the response of ground motion to earthquakes and present microzonation map of 6th of October city, Egypt. 1-D equivalent linear and nonlinear ground response analysis for 6th of October city using DEEPSOIL software is carried out . 171 boreholes that are gathered from 6th of October city to investigate the effect of local soil conditions are used and each borehole is stimulated through DEEPSOIL software. Comparative study is conducted to investigate the effect of local site conditions on amplification factor , natural time period and pseudo-spectral acceleration for the ground surface with respect to analysis methods and seismic provisions of the Egyptian Code of Practice-201 (ECP-201, 2011) [16].

Geological and Geotechnical Features of 6th of October City.

The 6th of October city that is located in Giza governorate about 17 km from the pyramids site location and about 32 km from the centre of Cairo is selected as a case study for seismic microzonation area and the city is covered by two seismic zones which are zone 2 and zone 3 according to seismic provisions of the Egyptian code of practice-201 (ECP-201, 2011) [16]. At present, the city inhabitants have grown on an urban mass area and investments also have grown . Based on the size of the city exposure and its location from devastating earthquakes, it is essential to delineate the seismic hazard using the microzonation tool.

Fig. (1) presents geological map of the 6th of October city prepared by the Egyptian Geological Survey and Mining Authority [17] and it is depicted the geographical distribution of geological settings and their associated components for the study region . A total of 171 boreholes with depth range from 10 to 20 meters were collected as shown in Fig.(1). The types of soil at the site of boreholes are classified as following:

Sandy soils are dominated the area with 120 boreholes and a depth range of 5.0 to 20.0 meters.

Cohesive soils are covered narrow sections of the area.

Sedimentary rocks which including lime and sandstone are cover six to eight sites.

Basalt stone is found in four boreholes.

Samples collected in the field are tested in the laboratory to determine index and engineering properties of local soils. Shear wave velocity (Vs) values have been calculated using SPT-N values and three dimensional sub surface boreholes model have been generated for study area using geographical information software Rockworks 17. The logged soil property is used to produce three dimensional geographic information model for lithology (soil type), shear wave velocity (Vs) and soil density (γ) as shown in Fig. (2) , Fig. (3) and Fig. (4) respectively. Lithology (soil type), soil density (γ) and shear wave velocity (Vs) distributions indicate that the shear wave velocity (Vs) is varying from 219 to 447 m/s and soil density (γ) is varying from 17 to 18 KN/m^3 .

Numerical Study

To investigate the effect of local site conditions on the response of ground motion and present microzonation map for 6th of October city, Egypt. 1-D equivalent linear and non-linear ground response analysis using DEEPSOIL7 software are carried out. DEEPSOIL version 7 is implemented as seismic site response analysis software and it offers many choices for determining soil model, analysis type, and computation method [7, 9,13]. 1D site response analyses are carried out for all soil profiles which are based on the engineering properties of encountered soil layers, selection and scaling of the sufficient number of input acceleration time histories.

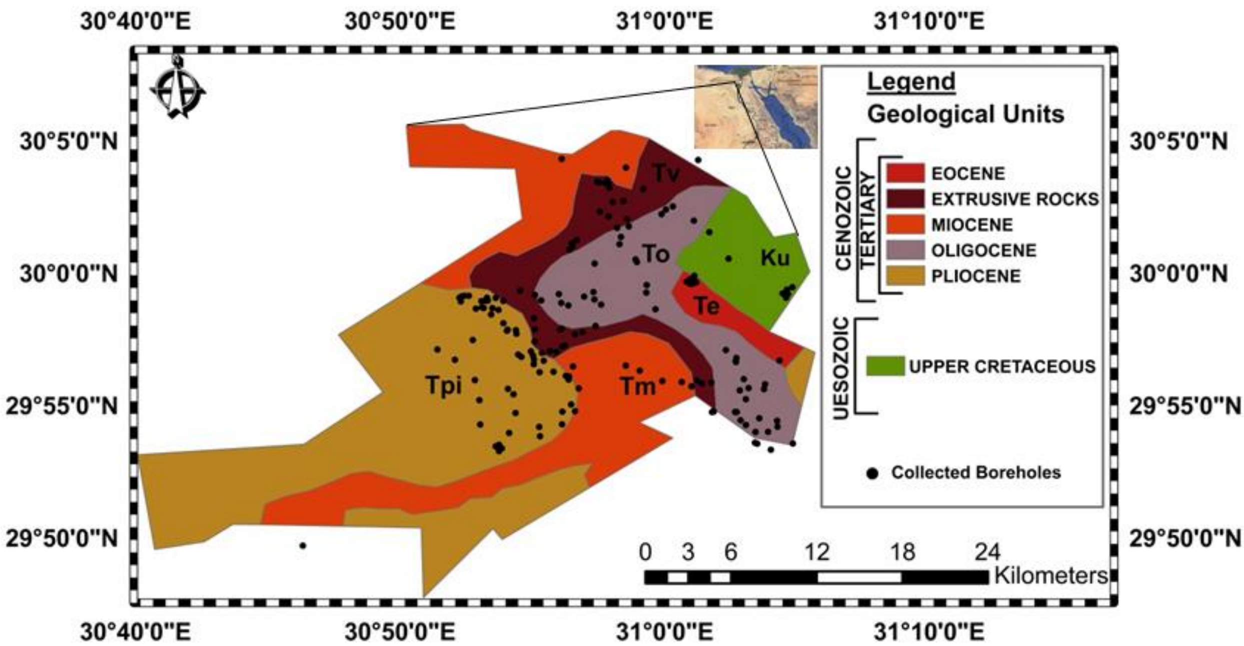

Fig. (1) Geological map of 6th of October city and location of boreholes.

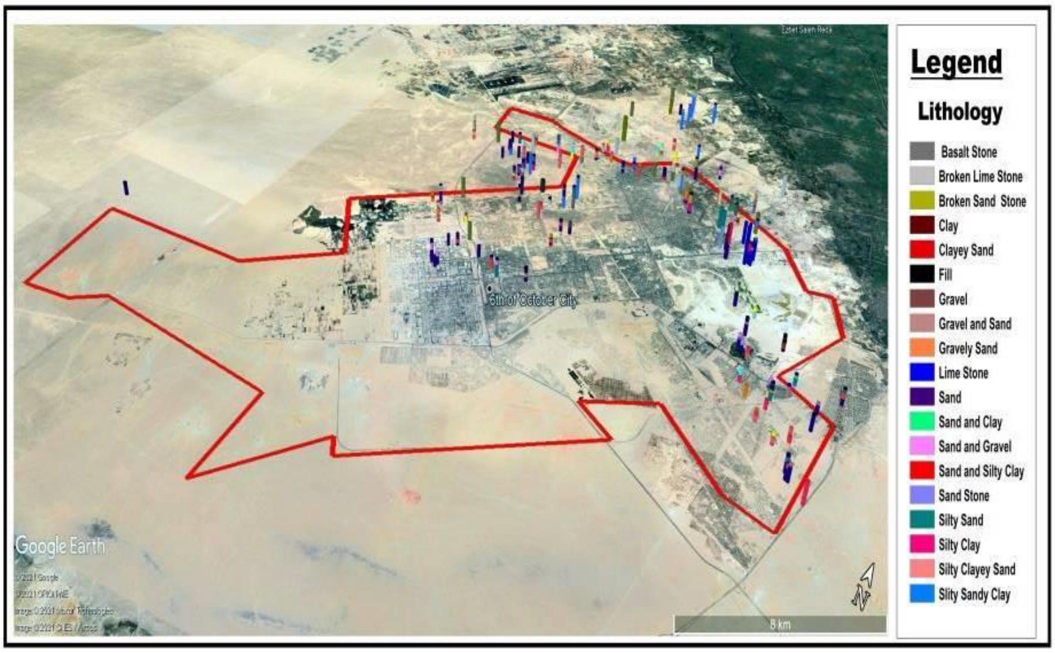

Fig. (2) 3D geographic information model for lithology (soil type) of boreholes.

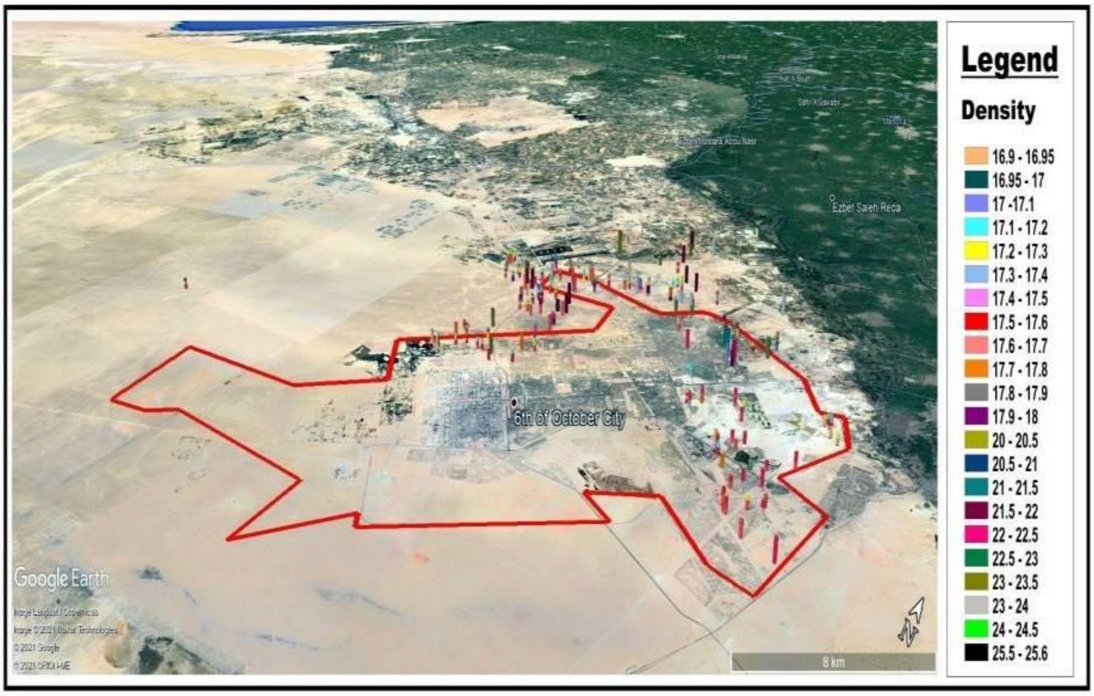

Fig. (3) 3D geographic information model for density of boreholes.

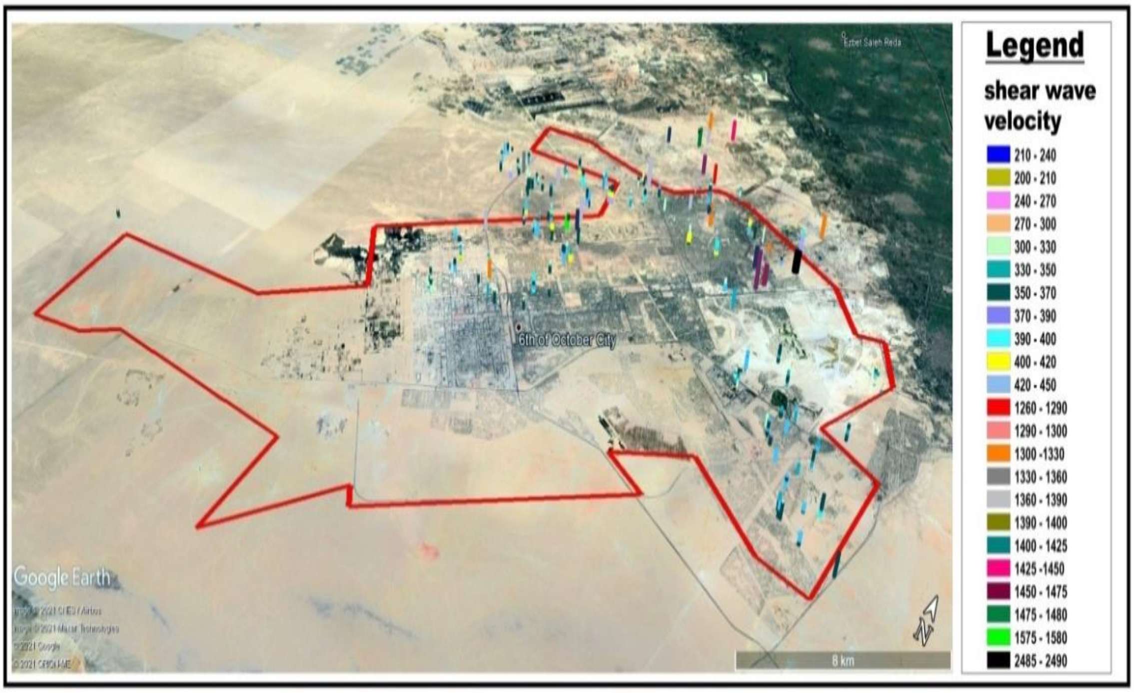

Fig. (4) 3D geographic information model for shear weave velocity of boreholes.

3-1 Soil Model.

Seismic site classification and amplification for seismic microzonation are obtained using average shear wave velocity in the top 30 m (Vs_{30}). As the depth of 171 boreholes is varying from 10 to 20 m the shear wave velocity in the top 30 m (Vs_{30}) is obtained based on topographic slope global model of the USGS [18]. A geographic information system is used to get the geographical distribution of obtained shear wave velocity in the top 30 m (Vs_{30}) within 6th of October city using surfer software (V.16) as shown in Fig. (5). According to the Egyptian code, the classification of soil depends on shear wave velocity in the top 30 m (Vs_{30}). Therefore, 171 boreholes are classified to three classes which are class A with 41 boreholes, class B with 46 boreholes and class C with 84 boreholes.

To construct the soil model through the numerical analysis, 171 boreholes are stimulated through DEEPSOIL software as shown in Fig. (6). Shear strain histories are obtained from the results and peak shear strains are evaluated for each layer. The effective of shear strains are taken as a fraction of the peak strains and it is then used to evaluate an appropriate equivalent shear modulus (G) and equivalent viscous damping ratio (β). The process is repeated until the strain-compatible properties are consistent with the properties which are used to perform the dynamic response analyses.

The linear approach assumes that shear strength (G) and damping (ξ) are constant. However, in the nonlinear approach, shear strength reduces with shear strain while damping increases with shear strain and these relationships can be tested and plotted in curves that are called shear modulus reduction curves and damping curves respectively. Then , the problem reduces to determining the equivalent values consistent with the level of strain induced in each layer by using iterative procedure as shown in Fig. (7) [3,4,5,8].

3-2 Input Ground Motion.

Performing seismic site response analysis requires defined time history which it is used as a seismic demand at the base of the soil column. Seismic scenario characteristics parameters such as magnitude, distance, focal mechanism, duration, ground-motion intensity measures, and near-fault parameters are required that it have been determined during seismic hazard assessment.

In this study, the response spectral acceleration with magnitude M = 6.7 and distance R = 13 as shown in Fig. (8) which it was presented for 6th of October city, Egypt by S. Mostafa et al. [19] is used. The time histories which are corresponding to response spectral acceleration that was presented by S. I. Mostafa et al. are presented as shown in Fig.(9).

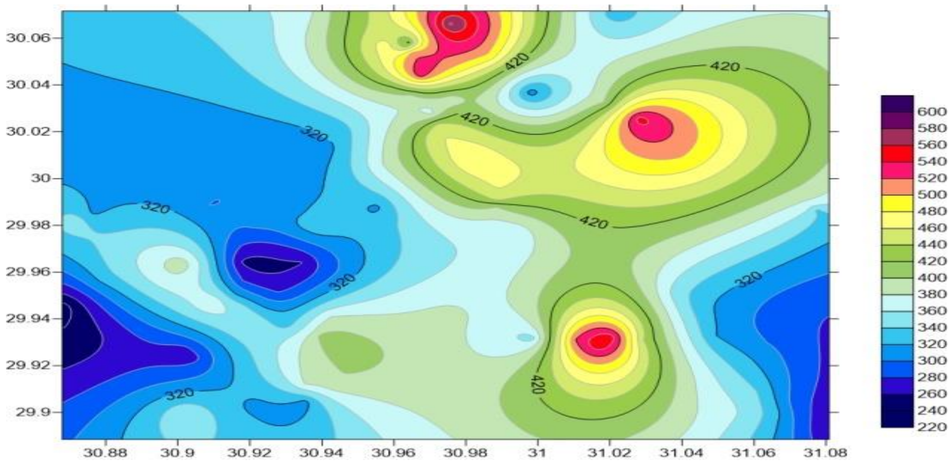

Fig.(5)Distribution of obtained shear wave velocity in the top 30 m Vs_{30} within the site.

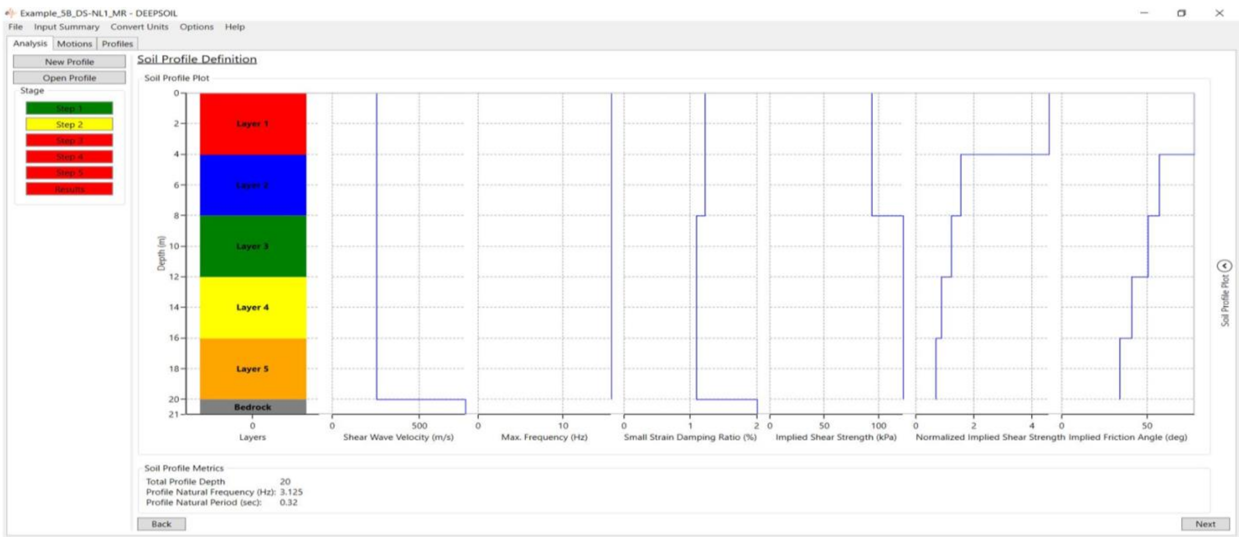

Fig.(6) Boreholes stimulation through DEEPSOIL software.

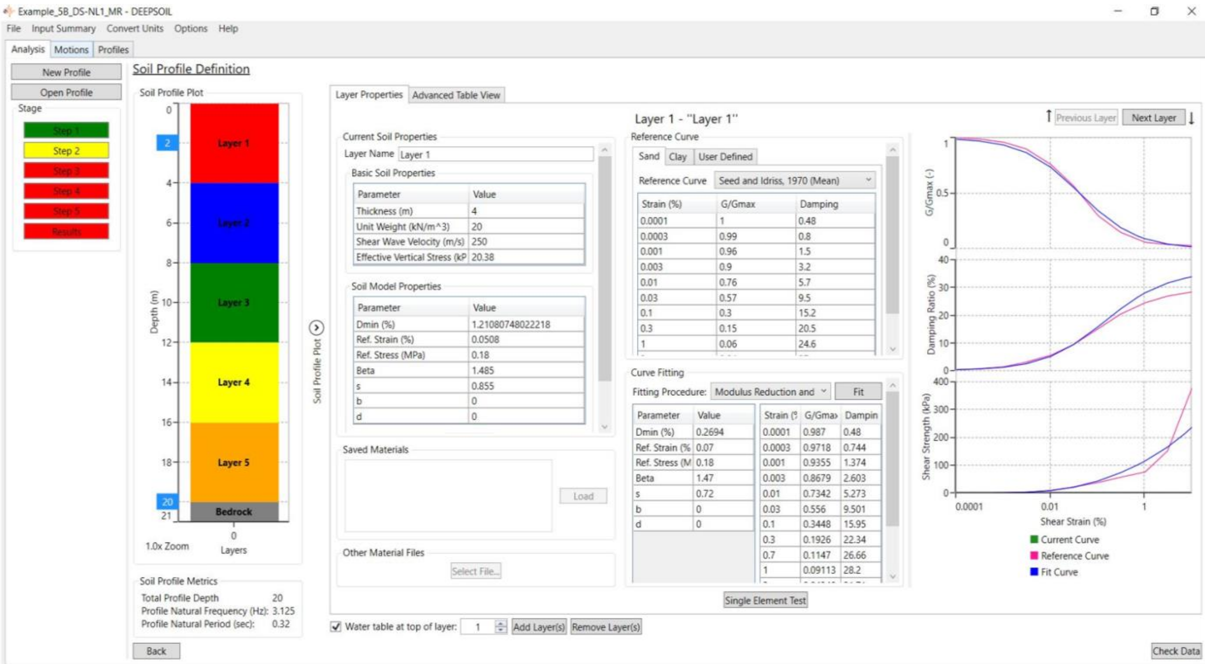

Fig. (7) Shear modulus reduction curves and damping curves through DEEPSOIL software.

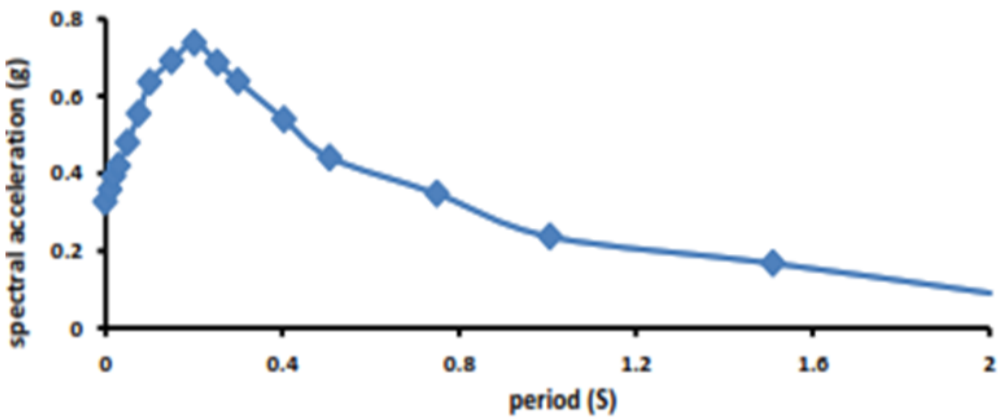

Fig.(8) Response spectral acceleration with M = 6.7 and R = 13 presented By S. Mostafa et al. [19] for 6th of October city.

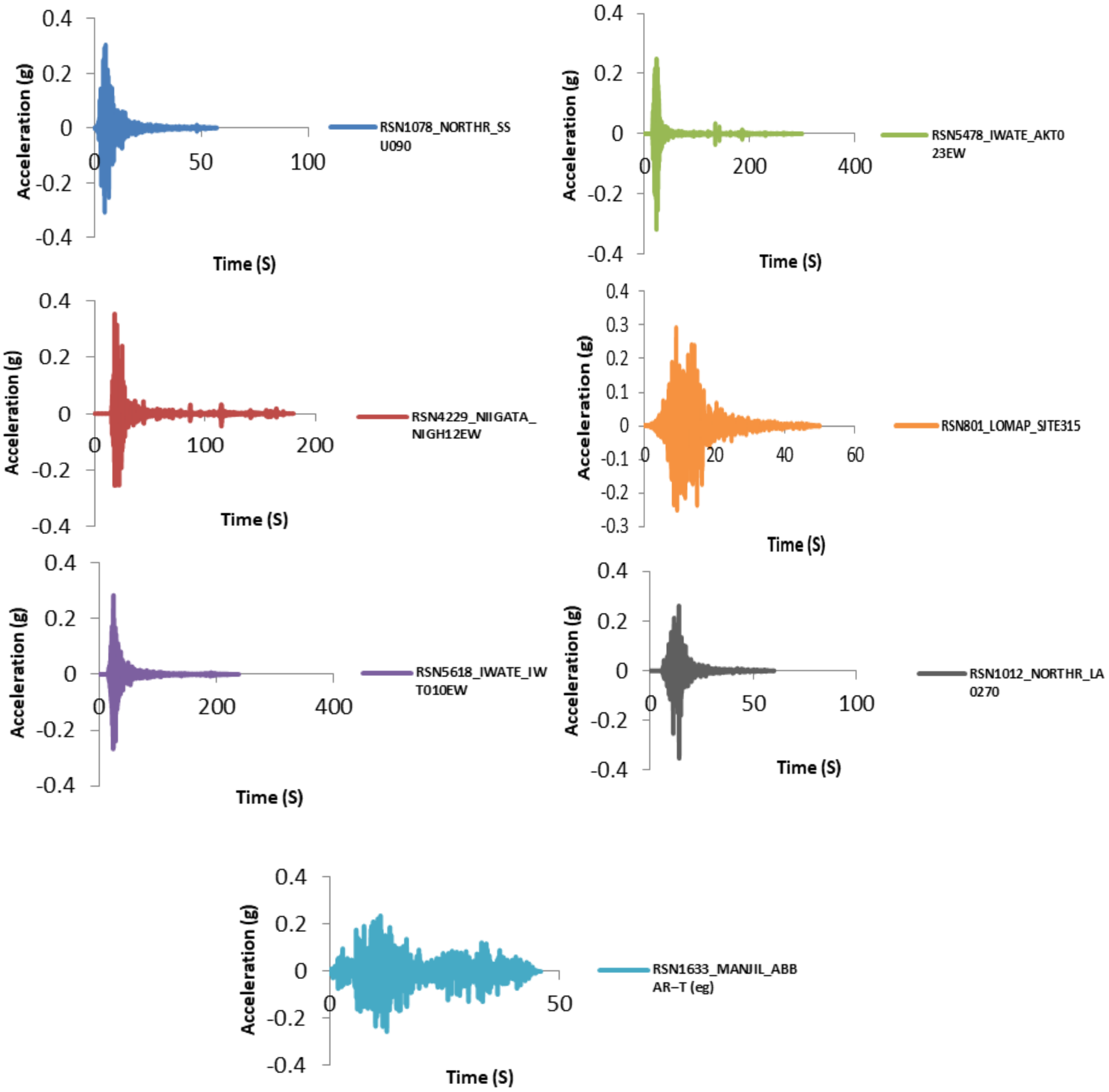

Fig. (9) Time histories corresponding to response spectral acceleration presented by S. Mostafa et al. [22].

3-3 Method of Analysis.

Site response analysis is conducted with two analysis methods which are equivalent linear (EL) and nonlinear (NL) of analysis. Equivalent Linear ground response modeling is widely used in practice to simulate true nonlinear soil behavior and the advantages of equivalent linear modeling are including small computational effort and few input parameters. Equivalent linear modeling is based on a total stress representation of soil behavior and the nonlinear stress strain loop is approximated by a single equivalent linear secant shear modulus that it is a function of the amount of shear strain.

Nonlinear ground response modeling has more potential to simulate soil behavior accurately and it is more realistic. Nonlinear approach is performed using the established soil model for assembling stiffness and damping matrix. For accounting viscous/small-

Strain, damping is accomplished using the frequency independent option and numerical computation is done in the integration scheme using the Newmark Beta method with unconditionally stable values.

Results and Discussion.

The seismic site response analysis using DEEPSOIL has been carried out and amplification factor, natural time period, and pseudo-spectral acceleration for the ground surface are obtained. To present microzonation map and investigate the effect of local site conditions on the response of ground motion for 6th of October city, Egypt., the results obtained are analyzed. For simplicity, the results are presented by charts as follows:

4-1 Spectral Amplification Factors.

Fig.(10) presents amplification factors map for equivalent linear analysis within 6 October city.

Fig.(11) presents amplification factors map for nonlinear analysis within 6 October city.

Fig.(12) presents comparison of max amplification factors for soil class B with equivalent linear analysis, nonlinear analysis and Egyptian code.

Fig.(13) presents comparison of max amplification factors for soil class C with equivalent linear analysis, nonlinear analysis and Egyptian code.

From the previous figures, it is noticed that:

In generally, there is no much variation in amplification factors with equivalent linear and nonlinear analysis for all boreholes. The values of amplification factors for 6th of October city are ranging from 0.96 to 1.52 for equivalent linear and nonlinear analysis. The biggest values of amplification factors are laying in western regions of 6th of October city and the lowest values of amplification factors are laying in eastern and northing regions of 6th of October city for equivalent linear and nonlinear analysis as shown in Figures (10) and (11).

The maximum amplification factor with equivalent linear and nonlinear analysis is higher than that value in Egyptian code for soil class B and the maximum amplification factor with equivalent linear and nonlinear analysis is smaller than that value in Egyptian code for soil class C in Figures (12) and (13).

4-2 Time Period.

Fig.(14) presents time period map for equivalent linear analysis within 6 October city.

Fig.(15) presents time period map for nonlinear analysis within 6 October city.

From the previous figures, it is noticed that:

In generally, there is no much variation in time period with equivalent linear and nonlinear analysis for all boreholes. The values of time period for 6th of October city are ranging from 0.1 to 0.29 sec. for equivalent linear and nonlinear analysis. The biggest values of time period are laying in western regions of 6th of October city and the lowest values of time period are laying in eastern western and northing regions of 6th of October city for equivalent linear and nonlinear analysis as shown in Figures (14) and (15).

4-3 Pseudo-Spectral Acceleration.

Fig.(16) presents average pseudo–spectral acceleration for soil class B with equivalent linear and nonlinear analysis and Egyptian code.

Fig.(17) presents average pseudo–spectral acceleration for soil class C with equivalent linear and nonlinear analysis and Egyptian code.

Fig.(18) presents comparison of average pseudo–spectral acceleration at time period 0.11 sec. for soil class B with equivalent linear analysis, nonlinear analysis and Egyptian code.

Fig.(19) presents comparison of average pseudo–spectral acceleration at time period 0.11 sec. for soil class C with equivalent linear analysis, nonlinear analysis and Egyptian code.

From the previous figures, it is noticed that:

In generally, there is no much variation in average pseudo–spectral acceleration with equivalent linear and nonlinear analysis for all boreholes. The average pseudo–spectral acceleration with equivalent linear and nonlinear analysis is higher than that with Egyptian code for soil class B and class C as shown in Figures (16) and (17). There is difference in average pseudo–spectral acceleration with all time period for equivalent linear and nonlinear analysis compared with Egyptian code. The maximum value of average pseudo–spectral acceleration for soil class B is 1.62g at time period 0.11 sec as shown in Fig. (18) and the maximum value of average pseudo–spectral acceleration for soil class C is 1.57g at time period 0.11 sec as shown in Fig. (19).

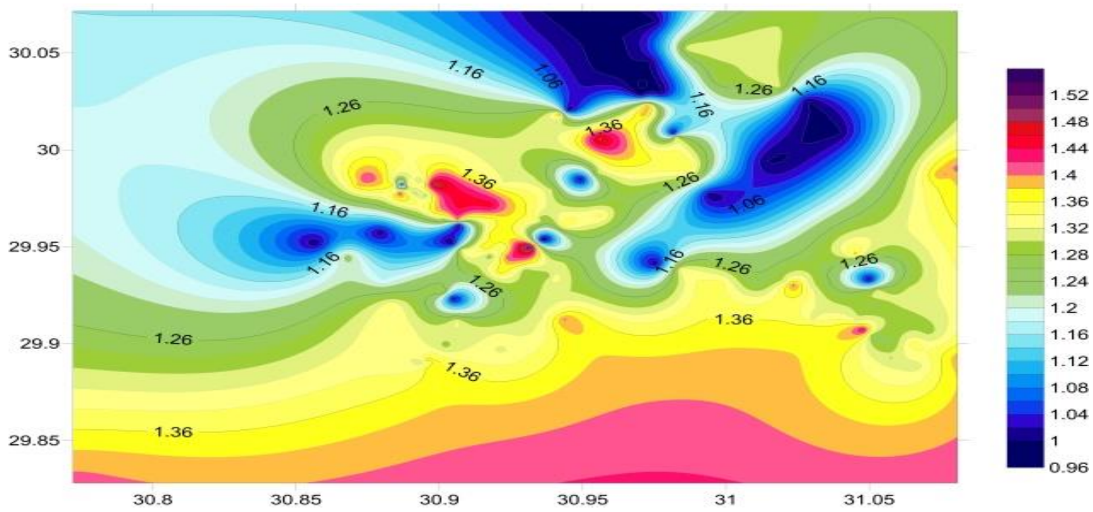

Fig. (10) Amplification factors map for equivalent linear analysis within 6 October city.

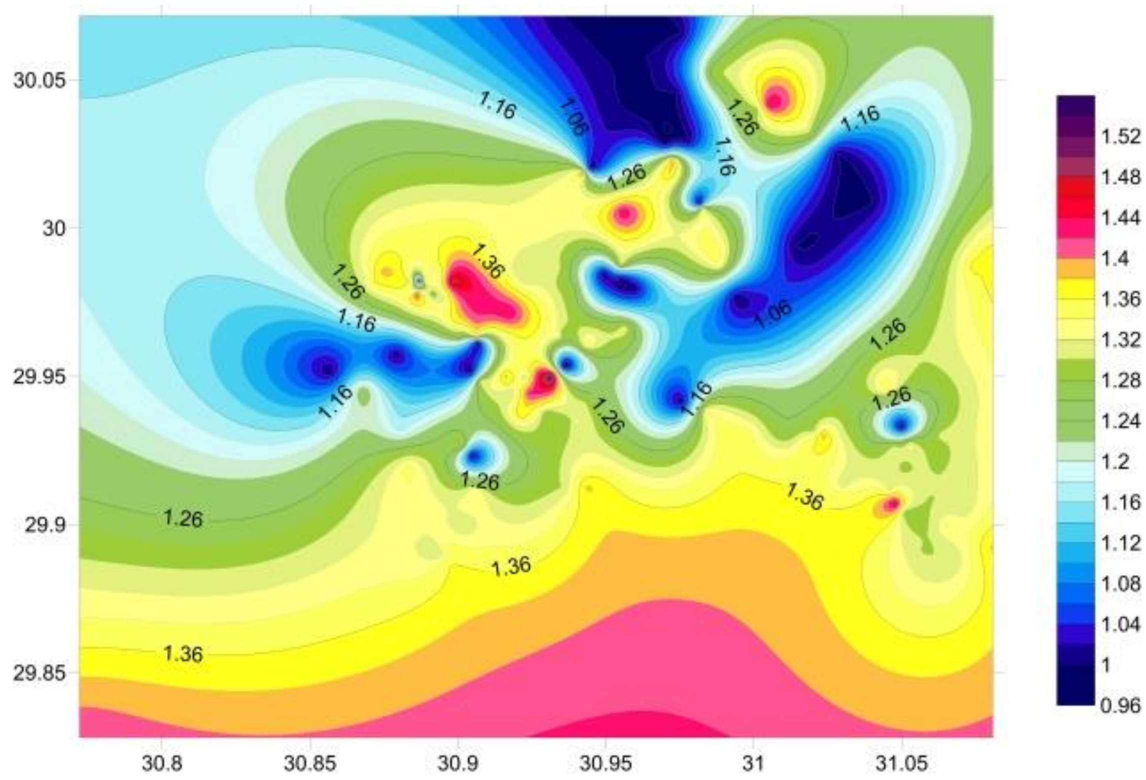

Fig. (11) Amplification factors map for nonlinear analysis within 6 October city.

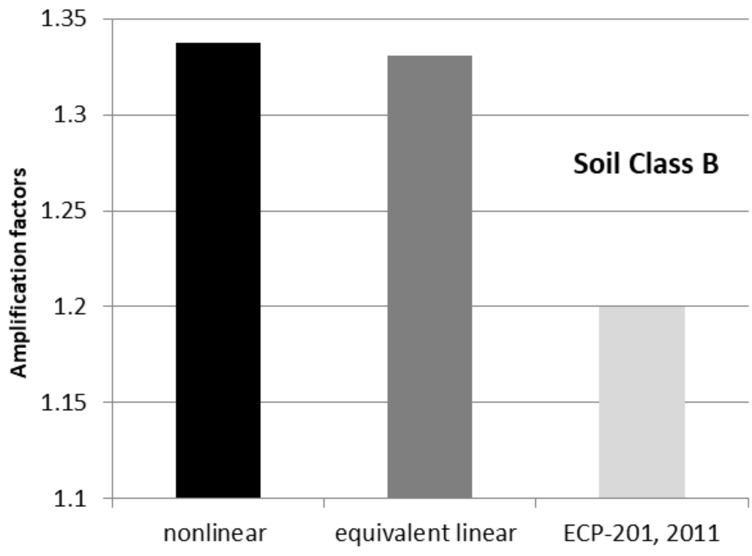

Fig.(12) Comparison of max amplification factors for soil class B with equivalent linear analysis, nonlinear analysis and Egyptian Code.

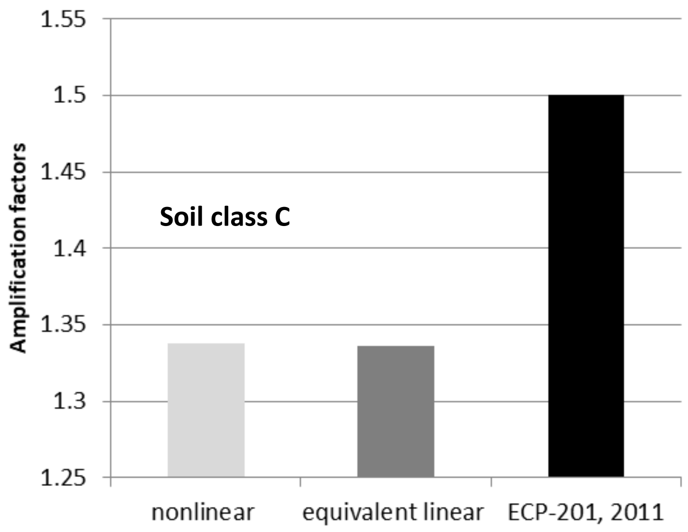

Fig.(13) Comparison of max amplification factors for soil class C with equivalent linear analysis, nonlinear analysis and Egyptian Code.

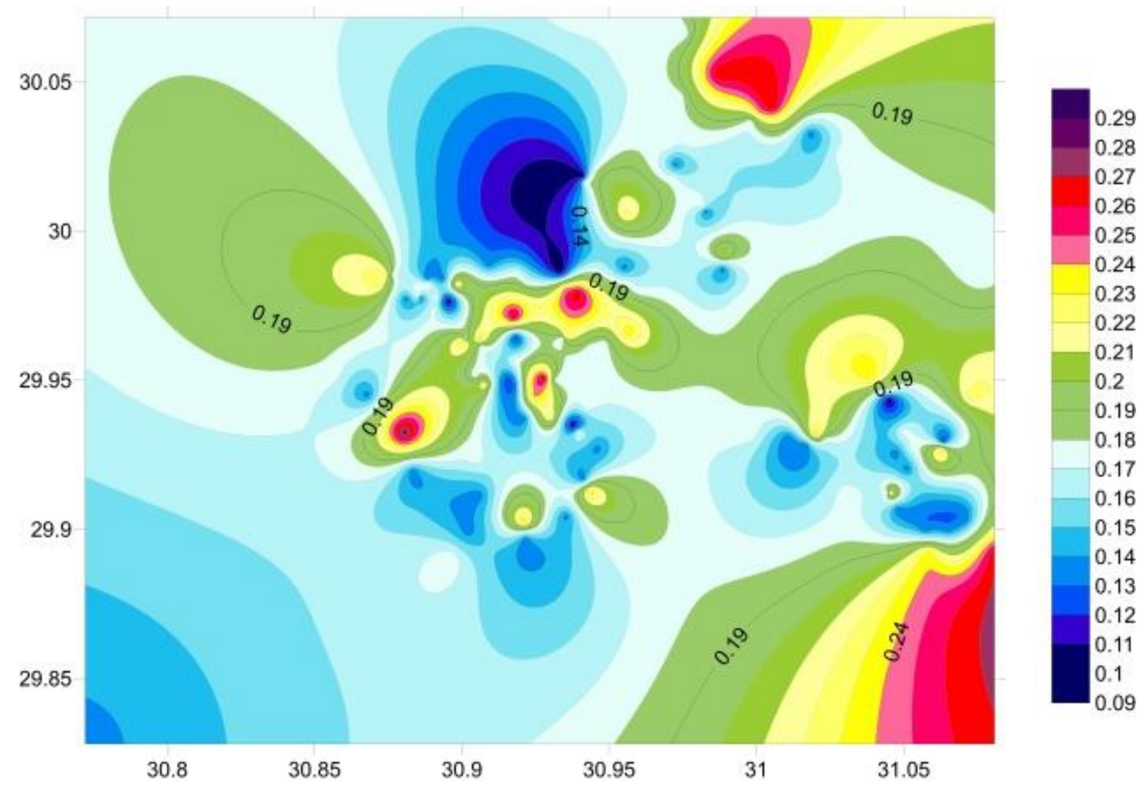

Fig.(14) Time period map for equivalent linear analysis within 6 October city.

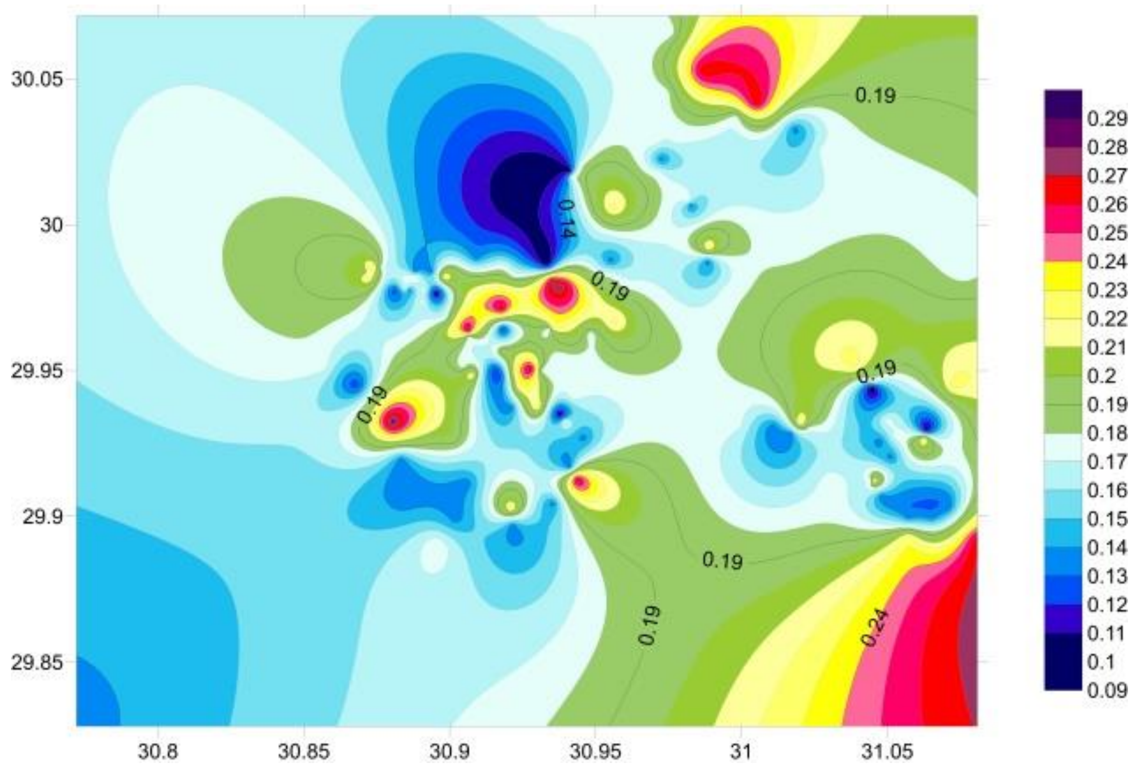

Fig.(15) Time period map for nonlinear analysis within 6 October city.

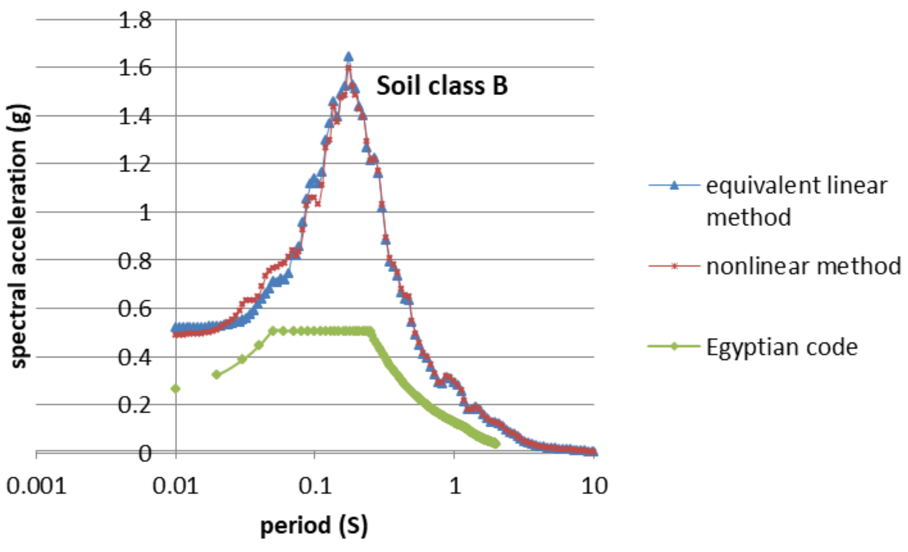

Fig.(16) Average pseudo–spectral acceleration for soil class B with equivalent linear and nonlinear analysis and Egyptian code.

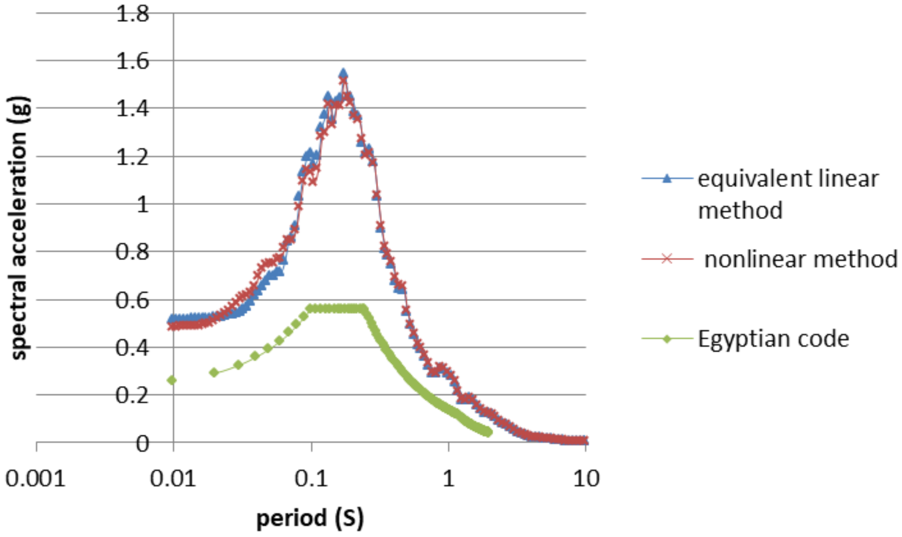

Fig.(17) Average pseudo–spectral acceleration for soil class C with equivalent linear and nonlinear analysis and Egyptian code.

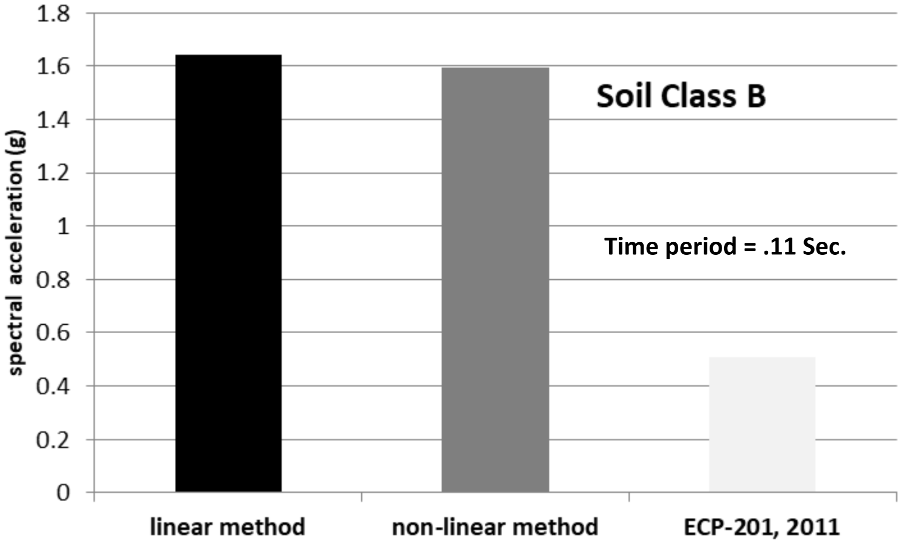

Fig. (18) Comparison of average pseudo–spectral acceleration at time period 0.11 sec. for soil class B with equivalent linear analysis, nonlinear analysis and Egyptian code.

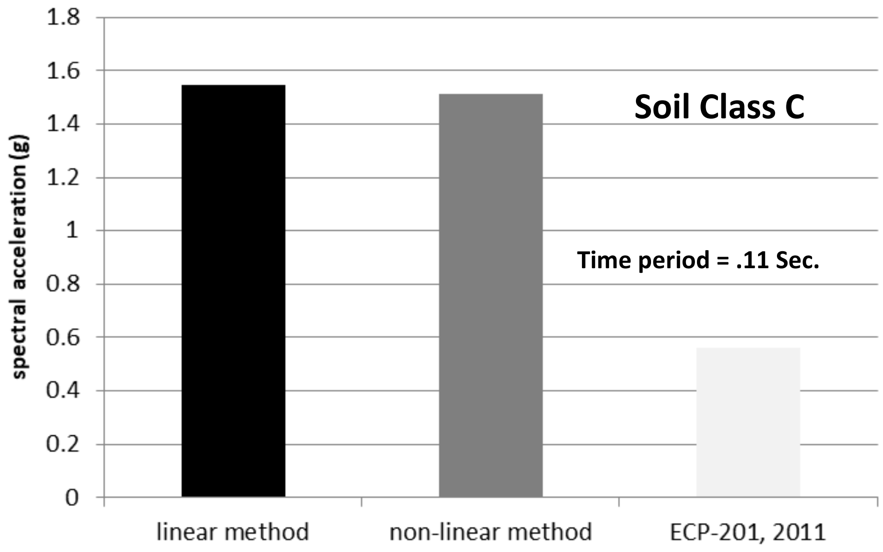

Fig. (19) Comparison of average pseudo–spectral acceleration at time period 0.11 sec. for soil class C with equivalent linear analysis, nonlinear analysis and Egyptian code.

Conclusions.

In this paper, equivalent linear and non-linear ground response analysis for 6th of October city Egypt, has been done to present microzonation map and study the effect of local site conditions on the response of ground motion. From the results reported herein, the following conclusions are obtained:

The biggest values of amplification factors are laying in western regions of 6th of October city and the lowest values of amplification factors are laying in eastern and northing regions of 6th of October city for equivalent linear and nonlinear analysis.

The maximum amplification factor with equivalent linear and nonlinear analysis is higher than that it is in Egyptian code for soil class B and the maximum amplification factor with equivalent linear and nonlinear analysis is smaller than that it is in Egyptian code for soil class C.

The biggest values of time period are laying in western regions of 6th of October city and the lowest values of time period are laying in eastern western and northing regions of 6th of October city for equivalent linear and nonlinear analysis.

The average pseudo–spectral acceleration with equivalent linear and nonlinear analysis is higher than that it is in Egyptian code for soil class B and class C.

There is difference in average pseudo–spectral acceleration with all time period for equivalent linear and nonlinear analysis compared with Egyptian code.

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