SEISMIC MICROZONATION OF EL-FAYOUM NEW CITY, EGYPT

Heba Kamal El Dine Moustafa [1*],
Abd El-Aziz Khairy Abd El-Aal [2] and Suzan Salem [3]
[1, 3] Staff in Housing and Building National Research Center, Egypt
[2] National Research Institute of Astronomy and Geophysics, Egypt

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ABSTRACT

Seismic micro hazard zonation for urban areas is the first step towards a seismic risk analysis and mitigation strategy. Essential here is to obtain a proper understanding of the local subsurface conditions and to evaluate ground shaking effects. In the present study, an attempt has been made to evaluate the seismic hazard considering local site effects by carrying out detailed geotechnical and geophysical site characterization in El-Fayoum New City. Seismic hazard analysis and microzonation of El-Fayoum New City are addressed in three parts: in the first part, estimation of seismic hazard is done using seismotectonic and geological information. Second part deals with site characterization using geotechnical and shallow geophysical techniques. In the last part, local site effects are assessed by carrying out one-dimensional (1-D) ground response analysis using equivalent linear method by program SHAKE 2000. Finally microzonation maps have been prepared. The detailed methodology, along with experimental details, collected data, results and maps are presented in this paper.

Keywords: Microzonation, seismic hazard, ground response analysis, El-Fayoum New City

1. Introduction

The increasing urbanization and construction of specific installations that have marked the recent decades in Egypt require heightened sensitivity towards the danger generally represented by natural phenomena, particularly earthquakes. In the framework of the Egyptian plans to extend the land used, many new cities are going to be established. The proposed El-Fayoum New City is considered as one example of them.

Earthquake damage is commonly controlled by three interacting factors – source and path characteristics, local geological and geotechnical conditions and type of structures. Obviously, all of these would require analysis and presentation of many amount of geological, seismological and geotechnical data. History of earthquakes, faults/sources in the region, attenuation relationships, site characteristics, soil physical and engineering properties are few of the important inputs required. Microzonation has generally been recognized as the most accepted tool in seismic hazard assessment and risk evaluation and it is defined as the zonation with respect to ground motion characteristics taking into account source and site conditions [3].

Evaluation of seismic hazards and microzonation of cities enable us to characterize the potential seismic areas which have similar exposures to hazards of earthquakes, and these results can be used for design new structures or retrofitting the existing ones. Study of seismic hazard and preparation of microzonation maps will provide an effective solution for city planning and earthquake resistant design of structures in an area. Seismic hazard is the study of expected earthquake ground motions at any point on the earth. Microzonation

* Corresponding author.
E- Mail address: *heba.kamal@dargroup.com*

is the process of subdivision of a region into a number of zones based on the earthquake effects in a local scale.

Seismic microzonation is the process of estimating response of soil layers under earthquake excitation and thus the variation of ground motion characteristics on the ground surface. Geotechnical site characterization and assessment of site response during earthquakes is one of the crucial phases of seismic microzonation, which includes ground shaking intensity, amplification and liquefaction susceptibility. Microzonation mapping of seismic hazards can be expressed in relative or absolute terms, on an urban block-by-block scale, based on local soil conditions (such as soil types) that affect ground shaking levels or vulnerability to soil liquefaction [1,2]. These maps would provide general guidelines for integrated planning of cities and design of new structures that are most suited to an area, along with information on the relative damage potential of the existing structures in a region.

In this study, seismic hazard analysis and microzonation of El-Fayoum New City are dscussed.

2. Geology and Geomorphology

The proposed site of El-Fayoum New City is located southeast of El-Fayoum City, between latitudes 29°12′ and 29°14′N and longitudes 30°52′ and 30°54′E as shown in Figure 1. The city is a small part of the desert which separates El-Fayoum depression from the Nile valley. The area of El-Fayoum New City is a wadi plain with a gentle relief (gradient about 1%) in the north-south direction. At the southwest of the site the elevation is more than 70 m but at the northern part of the site the elevation is less than 40 m.

The geology of the area between El-Fayoum depression and the Nile valley of south Beni Suef, where El-Fayoum New City is located, was studied by several authors [4,5,6,7] which is consisted of a complex sequence of sedimentary rocks ranging in age from Eocene to Quaternary as shown in Figure 2.

The previous geological and geophysical studies in the area under investigation indicated that the focussed area is characterized by the presence of two types of fault systems that are affecting whole the Fayoum area, 1) North Fayoum depression-Qaroun lake normal and step fault system which is extending NW-SE direction, 2) Gabal Naaloon normal fault system which is extending E-W direction.

3. Seismicity

The seismic activity in any region depends mainly on the structures present within the region including faults, trenches, subduction zone and situation of the region within the tectonic plate. As it was mentioned before the area under investigation is located in the central part of Egypt which is situated in the northeastern corner of African plate. The eastern boundary of the African plate is the Arabian Plate, and the northern boundary is the area that subjected to the internal deformation (Turkey and the Egean Plates). This area is considered as a part of the Eurasian Plate.

On 12 October 1992, a significant earthquake (Mb = 5.8) occurred southwest of Cairo in the vicinity of the Dahshour region as shown in Figure 3, about 25 km SW of direction Cairo, at the coordinates 29.77°N, 31.07°E. The event was located north of the proposed site of El-Fayoum New City at a distance of about 56 km; the focal depth of this event was 23 km. This event is the largest instrumentally recorded earthquake in Dahshour region. The October 12, 1992, earthquake is the first disastrous event to have occurred in this region since the 1847 event, after a lapse of 145 years. The source parameters of this event were estimated by El Hadidy [8, 9].

Several authors mentioned that a large number of earthquakes occurred within the area during its history as well as present times. Figure 4 shows the recent seismicity in and around the studied area from 1997 to 2009, which was recorded by the Egyptian National Seismological Network (ENSN). According to the recent seismic activity from 1997 to 2009 within 100 km around the center of the proposed site of El-Fayoum New City, the Dahshour seismic source is the nearest important seismic source that had serious effects on the studied area. The area of the epicenter of October 12, 1992, earthquake and southwest of Cairo is considered as a separate seismic zone [10, 11, and 12].

4. Methodology

Methodology for complete seismic microzonation of the study area is formulated by considering the topology, geology, geomorphology and possible hazards during the earthquakes. The earthquake damage basically depends on three groups of factors: earthquake source and path characteristics, local geological and geotechnical site conditions, structural design and construction features.

Seismic microzonation should address the assessment of the first two groups of factors. In general terms, seismic microzonation is the process of estimating the response of soil layers for earthquake excitations and thus the variation of earthquake characteristics is represented on the ground surface. For the present investigation the seismic microzonation has been subdivided into three major items:

- Evaluation of the expected input motion,
- Local site effects and ground response analysis,
- Preparation of microzonation maps.

The microzonation is graded based on the scale of the investigation and details of the study carried out. The technical committee on earthquake geotechnical engineering (TC4) of the International Society of Soil Mechanics and Foundation Engineering (TC4-ISSMGE) [13] highlighted that the first grade (Level I) map can be prepared with a scale of 1:1000,000–1:50,000 and the ground motion was assessed based on the historical earthquakes and existing information of geological and geomorphological maps. If the scale of the mapping is 1:100,000–1:10,000 and ground motion is assessed based on the microtremor and simplified geotechnical studies then it is called second grade (Level II) map. In the third grade (Level III) map ground motion has been assessed based on the complete geotechnical investigations and ground response analysis with a scale of 1:25,000–1:5000. The present investigation was carried out with a scale of 1:20,000 and ground motion is arrived based on the detailed geotechnical/ geophysical investigations and ground response analysis. Hence this work can be graded as third grade (Level III) microzonation maps for El Fayoum New City. The steps formulated for seismic hazard and microzonation of El-Fayoum new City in the present investigation is illustrated in the form of a flow chart in Figure 5.

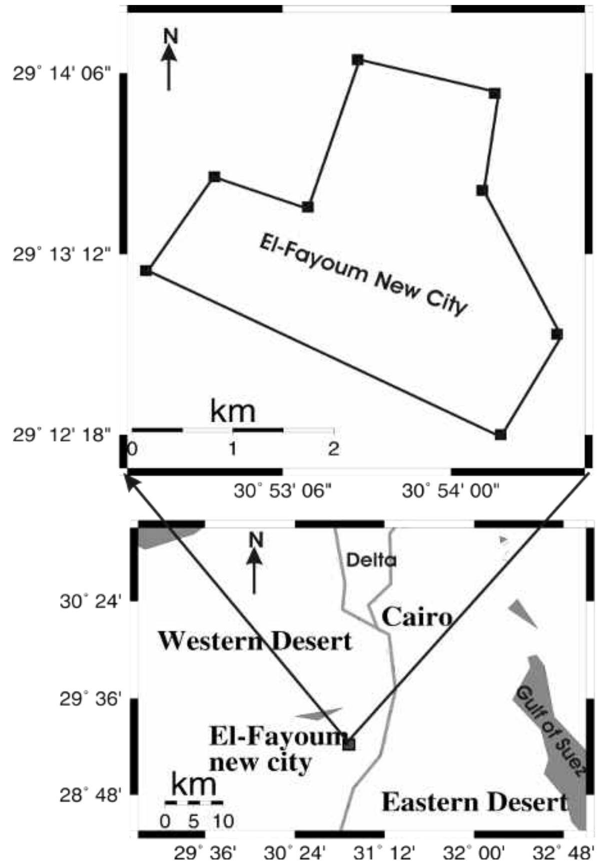

Fig. 1. Location map of El-Fayoum New City, Egypt

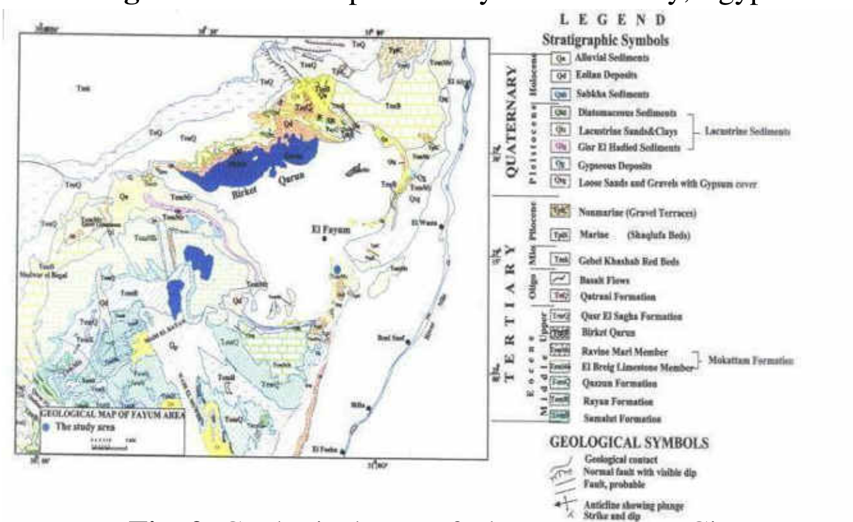

Fig. 2. Geological map of El-Fayoum New City

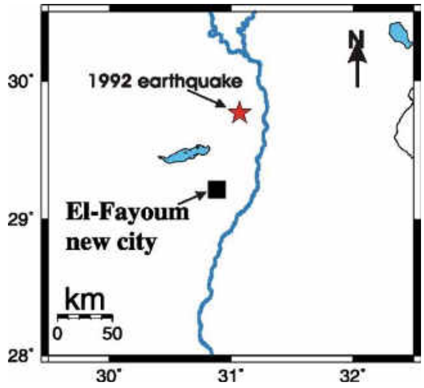

Fig. 3. The location of 1992 earthquake which had the largest effect at the proposed site of El-Fayoum New City

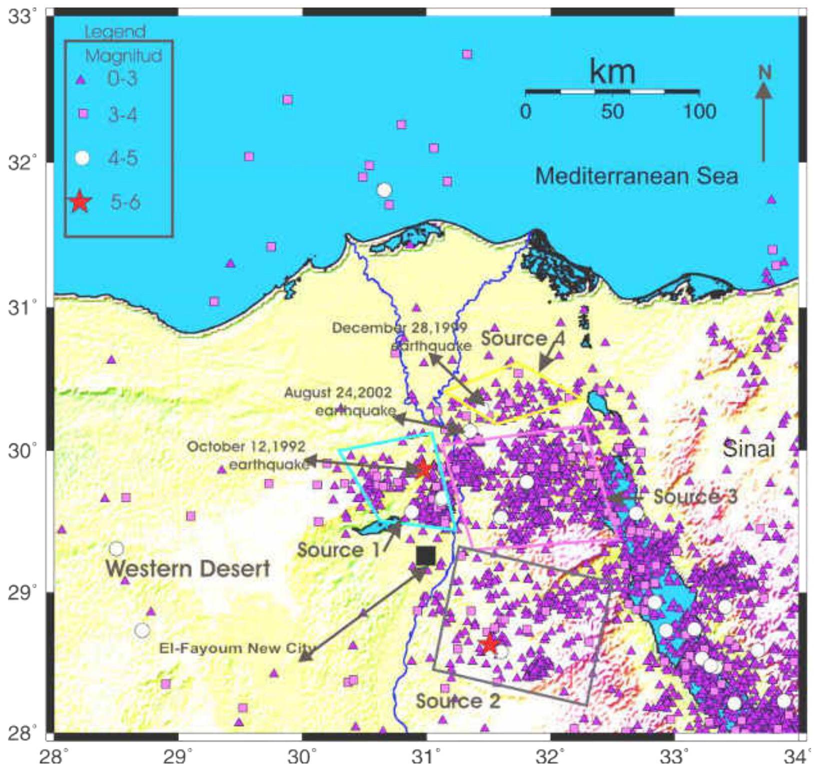

Fig. 4. Recent seismicity in and around El-Fayoum new City from 1997 to 2009

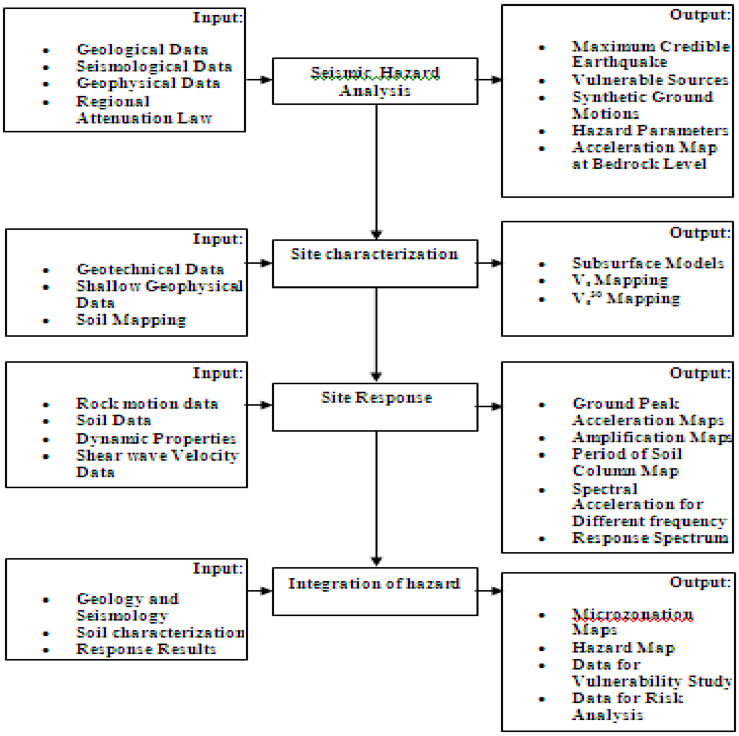

Fig. 5. Steps followed for seismic hazard and microzonation

5. Seismic Hazard Analysis

Deterministic seismic hazard analysis (DSHA) for El-Fayoum New City has been carried out by considering past earthquakes, assumed subsurface fault rupture lengths and point source synthetic ground motion model. Maximum Credible Earthquake (MCE) has been determined by considering the regional seismotectonic activity in about 100 km radius around El-Fayoum New City. Source magnitude for each source is chosen from the maximum reported past earthquake close to that source and shortest distance from each source to El-Fayoum New City as shown in Figure 4. Using these details and regional attenuation relation, the peak ground acceleration (PGA) at bedrock level has been estimated. Further seismological model developed by Boore [14, 15], SMSIM program, has been used to generate synthetic ground motions for sources resulting in higher PGA in the above using regional attenuation equation and largest earthquake close to source. The four seismic sources as shown in Figure 4 which causing considerable PGA value are studied and the most effective seismic source is further used for generating the synthetic ground motion.

5.1. Synthetic earthquake model

For microzonation, the study of local site effects needs to be carried out for a scenario earthquake estimated in the seismic hazard analysis. To study the local site effects of earthquake in the local scale level, the scenario earthquake record/ground motion in the form of time series is required. For the area having limited seismic record, synthetic ground motion models is the alternative (as the study area lacks ground motion records). Modeling of strong motion helps to estimate future hazard of the region and study the local soil effects in local scale. Seismological model by Boore [14] is used for generation of synthetic acceleration-time response [16,17]. In this study four seismic sources are studied as shown in Figure 4 and the most effective seismic source was source one which is the 1992 Dahshour earthquake. Because seismic recordings from this earthquake at the studied area are not available, the stochastic technique was used to simulate (PGA), and the acceleration time-histories at bedrock level on the proposed site of El-Fayoum New City expected from the October 12, 1992, earthquake.

5.1.1. Outlines of the method

The assessment of seismic hazard in terms of acceleration and the response spectra is the fundamental base of ground motion prediction. The radiated energy is assumed to be evenly distributed over a specified duration. Andrews [18] stated that, the shear-wave spectrum, Y (f), for source i and site j is decomposed as:

$$Y_{ij}(f) = E_i(f) \cdot P_{ij}(f) \cdot G_j(f) \quad (1)$$

where E(f) is the source spectrum, P(f) is the path spectrum, and G(f) is the site spectrum.

Equation (1) assumes that directional effects in the source are averaged out by observations at different azimuths. The path spectrum is represented by geometrical spreading and whole-path attenuation Q(f) as:

$$P(f) = r^{-y} e^{(-\pi ft)/Q(f)} \quad (2)$$

where *y* is set to 1.0 consistent with body waves in uniform medium., *t* is the travel time, and r the hypocentral distance.

Taking the natural logarithm, equation (1) becomes:

$$\ln Y_{ij}(f) = \ln E_i(f) + \ln P_{ij}(f) + \ln G_j(f) \quad (3)$$

This linear expression often forms the basis of attempts to separate the source, the path, and site effects.

Aki [19] derived an expression for the spectrum of seismic waves radiated from complex faulting and for the first time determined the seismic moment of an earthquake. Hanks and McGuire [20] presented a simple theoretical model that accurately predicted the peak acceleration (a_{max}) for California earthquakes and corroborated the scaling of motions with magnitude that had been derived empirically. The model treats ground motion as band limited finite-duration Gaussian white noise, with an amplitude spectrum given by Brune's model [21, 22] for shear radiation. The source spectra are described by a single corner frequency that depends on earthquake size. Boore [14] and McGuire et al. [23] extended the model to predict the peak velocity (v_{max}) and the pseudo relative velocity spectra (PSV). Boore [15] employed a stochastic time-domain simulation method and also used general equations from random process theory. He broke the total spectrum of the motion at a site into contributions from earthquake source, path, site, and instrument. By separating the spectrum into these components, the models based on the stochastic method can be easily modified to account for specific situations or to account for improved information about particular aspects of the model.

5.1.2. Input parameters

The input parameters involve all the terms in the following equation:

$$Y\ (Mo, R, f) = E(Mo, f)\ P(R, f)\ G(f)\ I(f) \tag{4}$$

The method begins with the specification of the Fourier amplitude spectrum of ground acceleration as a function of seismic moment and distance, Y (Mo, R, and f). The term E (Mo, f) is the earthquake source spectrum for a specific seismic moment (i.e., Fourier spectrum of the ground acceleration at a distance of 1 km) and P(R, f) is the path effect that models the geometric spreading and the anelastic attenuation of the spectrum as a function of hypocentral distance, R and frequency, f. The term G(f) is the site effect and the term I(f) is the instrument effect or a filter used to shape the spectrum to correspond to the particular ground motion measure of interest. Below, a detailed discussion of the input parameters required for simulation of ground motion at the area of interest is presented.

5.1.2.1. Source parameters

The earthquake source spectrum E (Mo, f) for the horizontal component of ground motion is given by the following functional form:

$$E\ (Mo, f) = CMoS(Mo,f) \tag{5}$$

where S(Mo, f) is the displacement source spectrum and C is a constant. $C = RsVF/\ (4\pi\rho\beta^3R)$, with R = 1km. The source parameters in the stochastic model involve the following items: 1) Rs = average shear wave radiation pattern (= 0.55) for the S-wave [15], 2) the free surface amplification F=2, 3) the reduction factor that accounts for the partitioning of energy into two horizontal components, V= 0.71, 4) the density, and the shear wave velocity, for average crustal properties in the vicinity of the Dahshour region are equal to 2.7 gm/cm³ and 3.7 km/s, respectively. The seismic moment and the stress drop of effective earthquake were estimated by El-Hadidy [8] and are presented in Table 1.

Table 1.
Source parameters of the 1992 Dahshour Earthquake

Moment	Stress Drop	Raduis	Area	Dislocation
6.99×10^{17} N.m	2.30MPa	4.5km	63.64km2	0.22m

5.1.2.2. Path parameters

The second component of the process that affects the spectrum of motion at a particular site is the path effect. The simplified path effect *P* is given by the multiplication of the geometrical spreading and *Q* functions.

$$P(R, f) = Z_r \exp\ [-\pi\ fR/Q(f)c_Q] \tag{6}$$

where c_Q is the seismic velocity used in the determination of Q(*f*), and Z_r is the geometrical spreading function, and r is usually taken as the closest distance to the rupture surface, rather than the hypocentral distance, R. The geometrical spreading and the attenuation are the parameters that affect the most the spectrum of motion at a particular site. In the current study, the geometrical spreading relationship of Atkinson and Boore [16] and the attenuation model of Moustafa [24]

$$Q(f) = 86\ f^{0.79} \tag{7}$$

are used. Empirical observations and theoretical simulations suggest that the path-dependent part of the duration can be represented by a connected series of straight-line segments with different slopes. The function of Atkinson and Boore [16] is used here. In this function the path duration is modeled as trilinear, using the transition distances 70 and 130 km for consistency with the attenuation model. The slope is 0.16 for the distance ranges between 10 and 70 km, -0.03 for the distance ranges between 70 and 130 km and 0.04 for the distance ranges from 130 to 1000 km. The slope is assumed to zero for distances less than 10 km.

5.1.2.3. Site parameters

The site effect G (f) is split into amplification vector A (f), and diminuation operator D (f).

$$G(f) = A(f) + D(f) \tag{8}$$

The diminution operator D (f) accounts for the path independent loss of high frequency in the ground motion. For this high-cut filter the equation of Boore, [14] is used:

$$D(f) = [1 + (f / f_{max})^{8}]^{-0.5} \tag{9}$$

where f_{max} is the high-frequency cutoff proposed by Hanks [25]. Based on Hanks [25] review for a limited data set, a value of f_{max} = 20 Hz is assumed. This value is chosen due to absence of strong motion records in Egypt suitable for its empirical determination and to avoid frequencies vital from an engineering point of view (up to 10 Hz). According to Hanks [25], maximum frequency is equal to 15 Hz for soft surface layers and 25 Hz for bedrock.

5.1.3. Output parameters and results

Table 2 illustrates the predicted peak ground accelerations (PGA) from the 1992 Dahshour earthquake at bedrock level and it was calculated at the location of boreholes. The simulation was done also by computer program SMSIM [26]. Peak ground acceleration map at bedrock level was produced using geographical information system program (Arc GIS) as shown in Figure 6.

Table 2.

The peak ground acceleration (PGA) predicted at bedrock level from the 1992 Dahshour Earthquake at locations of boreholes

Boring No	**Latitude**	**Longitude**	**PGA (gal) (cm/sec^2)**
1	29.2340347	30.8997421	11.66
2	29.2305182	30.8986470	9.94
3	29.2333513	30.8966035	12.35
4	29.2293640	30.8944509	10.57
5	29.2303556	30.9030500	15.11
6	29.2260147	30.9011357	13.89
7	29.2286090	30.8969991	9.37

Boring No	Latitude	Longitude	PGA (gal) (cm/sec^2)
8	29.2252185	30.8980980	18.16
9	29.2253560	30.8931935	15.94
10	29.2232856	30.9056020	17.54
11	29.2196277	30.9001827	13.97
12	29.2226845	30.8976352	11.64
13	29.2203504	30.8949782	16.74
14	29.2174400	30.9035700	15.14
15	29.2156100	30.9016100	15.99
16	29.2176490	30.8967264	16.78
17	29.2245131	30.8842045	16.33
18	29.2200952	30.8842994	17.72
19	29.2124400	30.9029439	14.70
20	29.2138792	30.8949618	17.20

6. Geotechnical and Geophysical Investigation

For the complete microzonation and site response study of the area, the subsurface soil characterization was carried out. This section presents the subsurface soil characterizations of El-Fayoum New City using geotechnical and geophysical investigation.

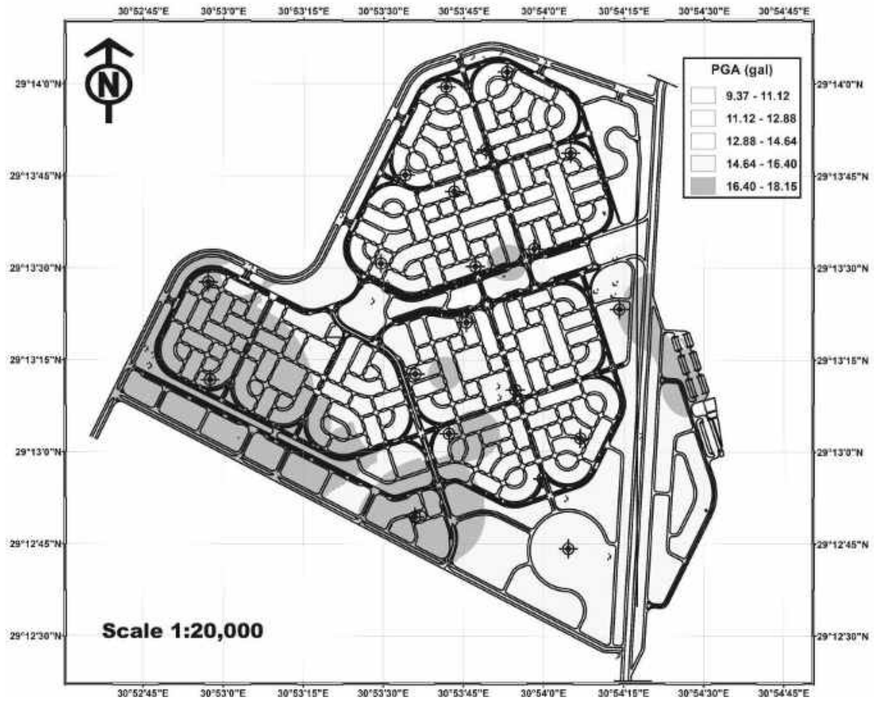

Fig. 6. Distribution of peak ground acceleration (PGA) at bedrock level

For geotechnical investigation 20 boreholes were done in the city as shown in Figure 7. The depth of these boreholes ranging from 15 m to 18 m with total length 340 m. Several tests were done on samples from these boreholes to identify the physical, mechanical and chemical properties such as:

- Percentage extraction (Recovery)
- Coefficient of rock quality (RQD) of rock layers
- Natural density of rock and soil samples
- Atterberg limits for clay, clayeystone and siltystone samples.
- Sieve analysis for cohesionless soil
- Free swelling for clay samples
- Swelling pressure for silty clay with liquid limit greater that 104%
- Unconfined compression test for limestone and clayey limestone before and after soaking
- Chemical analysis for clayeystone samples
- Mineral composition test on different types of rock samples using X-ray

From visual classification and laboratory test results the distribution of soil and rock layers at the site were nonhomogeneous in the vertical direction as well as in the horizontal direction and most of site configurations are calcareous siltystone which contain clay and limestone with low to medium strength in some locations and thin layers of gypsum crystals are appeared also in a few locations clayey and silty clay with high plastic limit and swelling potential are appeared. Ground water does not appear until the end of perforation in all boreholes.

Base map has been generated in the scale of 1:20,000 with several layers of information (such as outer and administrative boundaries, contours, highways, major roads, minor roads, streets, landmarks and borehole locations) using Geographical Information System program (Arc GIS). The GIS model developed currently consists of 20 borehole locations marked on the digitized El-Fayoum New City map as shown in Figure 7. Figure 8 and Figure 9 show geotechnical section (I-I) from north to south and geotechnical section (II-II) from east to west respectively.

In order to obtain the distribution of shear-wave velocity in the uppermost 30 m layer in the proposed area of El-Fayoum New City, shallow seismic refraction survey was carried out by Abd El-Aal [27]. Twenty seismic refraction profiles were conducted covering the whole area of the investigated site as shown in Figure 10. Table 3 shows the shear wave velocity and fundamental frequency of subsurface layers obtained from the seismic investigation. The ground model consists of two layers; the uppermost layer is soil layer (gravelly sand) with thickness on average from 1 m to 4 m and S-wave velocity range from 220 m/s to 357 m/s. The second layer (limestone) has S-wave velocity range from 1132 m/s to 1395 m/s.

The seismic site characterization for calculating seismic hazard is usually carried out based on the near-surface shear wave velocity values. The average shear wave velocity for the depth '*d*' of soil, referred as V_H, is computed as follows:

$$V_H = \frac{\sum d_i}{\sum (d_i / v_i)} \tag{10}$$

Where:

di = the thickness (in meters) of the *i*th formation or layer

vi = shear-wave velocity in m/s of the *i*th formation or layer

H = ∑*di* = cumulative depth in m.

For 30m average depth, shear wave velocity is written as:

$$V_s^{30} = \frac{30}{\sum_{i=1}^{N} (d_i/v_i)} \tag{11}$$

Where:

di = the thickness (in meters) of the *i*th formation or layer

vi = shear-wave velocity in m/s (at a shear strain l evel of 10−5 or less) of the *i*th formation or layer

N= total number of layers, existing in the top 30m.

$V\ s_{30}$ is accepted for site classification as per NEHRP classification and also UBC classification (Uniform Building Code in 1997) [28, 29]. In order to figure out the average shear-wave velocity distribution in El-Fayoum New City, the average velocity has been calculated using the equation (10) for the each borehole location. The *Vs* average has been calculated up to a depth of 30m. Usually, for amplification and site response study the 30m average *Vs* is considered. However, if the rock is found within a depth of about 30m, average shear-wave velocity of soil thickness (overburden thickness) needs to be considered. Otherwise, $Vs_{\ 30}$ obtained will be higher due to the velocity of the hard rock mass. The average shear-wave velocities calculated above are mapped for the area of study and Arc GIS has been used for mapping average *Vs* in the area. Figure 11 shows the typical average velocity (for depth of 30m) in El-Fayoum New City. Most of the study area is having a velocity range of 729 m/sec to 1208 m/sec.

7. Site Response Studies

The proposed area of El-Fayoum New City is characterized by low to moderate seismic activity and was affected by some felt and damaging historical and instrumental earthquakes and highly altered soil structure needs a detailed study to assess the local site effects for an earthquake.

In the present study, an attempt has been made to assess the site response using geotechnical, geophysical data. The subsurface profiles of the study area was represented by 20 geotechnical boreholes and 20 shear wave velocity profiles obtained by seismic refraction survey. These soil properties and synthetic ground motions for each borehole location are further used to study the local site effects by conducting one dimensional ground response analysis using the program SHAKE2000 [30]. A typical synthetic ground motion used for the ground response study having a PGA of 11.66 (ga) is given in Figure 12. The response and amplification spectrum have been evaluated for each location. The natural period of the soil column, peak spectral acceleration, spectral acceleration at different frequencies and frequency at peak spectral acceleration of each location (using borehole data as well as shear wave velocity data) has been evaluated and presented as maps.

7.1. 1-D Ground response analysis using equivalent linear approach

A ground response analysis consists of studying the behaviour of a soil deposit subjected to an acceleration time history applied to a layer of the soil profile. Ground response analysis is used to predict the ground surface motions for evaluating the amplification potential and for developing the design response spectrum. In the present study, one-dimensional ground response analysis using equivalent linear model has been carried out using SHAKE2000 software [30] in which motion of the object can be given in any one layer in the system and motions can be computed in any other layer.

In equivalent linear approach, the non-linearity of the shear modulus and damping is accounted for the use of equivalent linear soil properties using an iterative procedure to obtain values for modulus and damping compatible with the effective strains in each layer [31]. In this approach, first, a known time history of bedrock motion is represented as a Fourier series, usually using the Fast Fourier Transform (FFT) [32,33]. Second, the transfer functions for the different layers are determined using the current properties of the soil profile. The transfer functions give the amplification factor in terms of frequency for a given profile. In the third step, the Fourier spectrum is multiplied by the soil profile transfer function to obtain an amplification spectrum transferred to the specified layer. Then, the acceleration time history is determined for that layer by the Inverse Fourier transformation in step four. With the peak acceleration from the acceleration time history obtained and with the properties of the soil layer, the shear stress and strain time histories are determined in step five. In step six, new values of soil damping and shear modulus are obtained from the damping ratio and shear modulus degradation curves corresponding to the effective strain from the strain time history. With these new soil properties, new transfer functions are obtained and the process is repeated until the difference between the old and new properties fit in a specified range. The basic approach of one dimensional site response study is the vertical propagation of shear waves through soil layers lying on an elastic layer of the rock which extends to infinite depth. The degradation curves used for sand and rock used for the present work are those proposed by Seed and Idriss [34] and Schnabel [33] respectively.

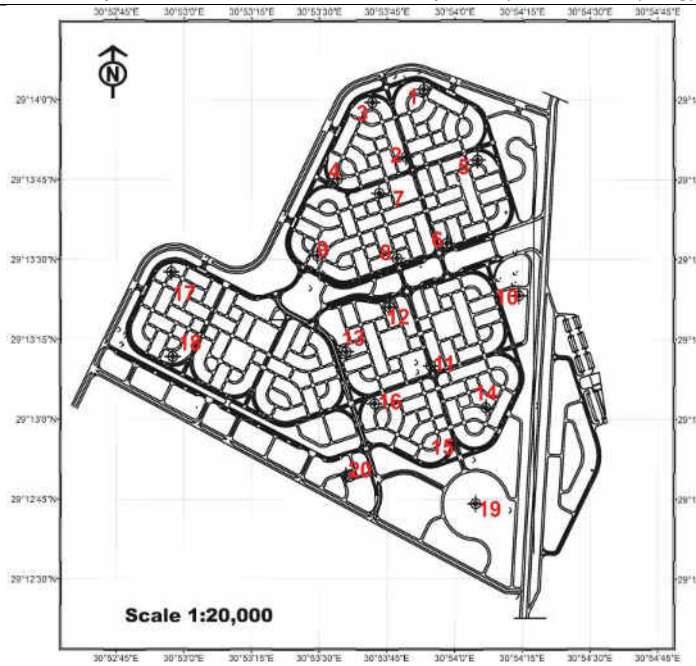

Fig. 7. El-Fayoum New City map shows the location of boreholes and geotechnical sections

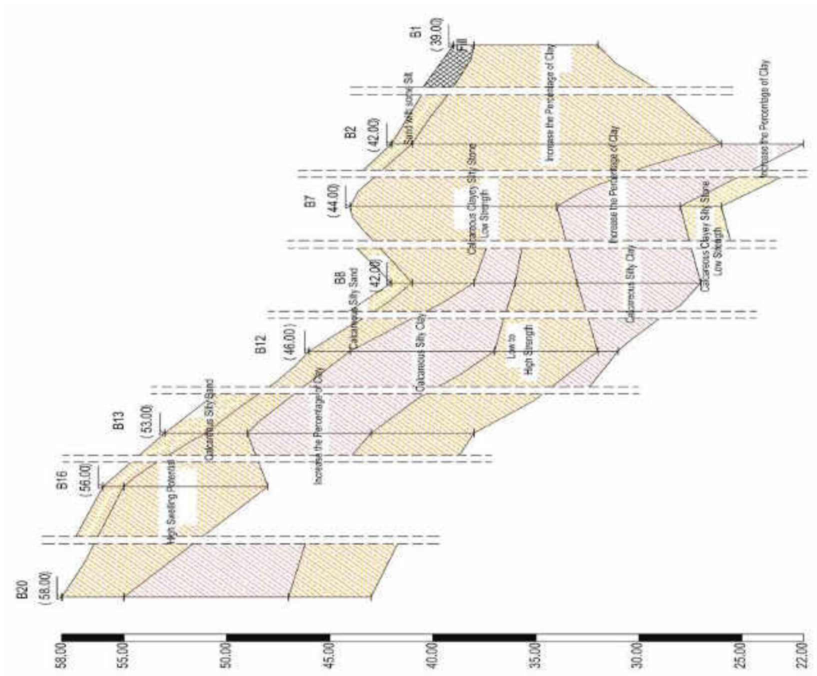

Fig. 8. Geotechnical section (I-I) across El-Fayoum New City from north to south

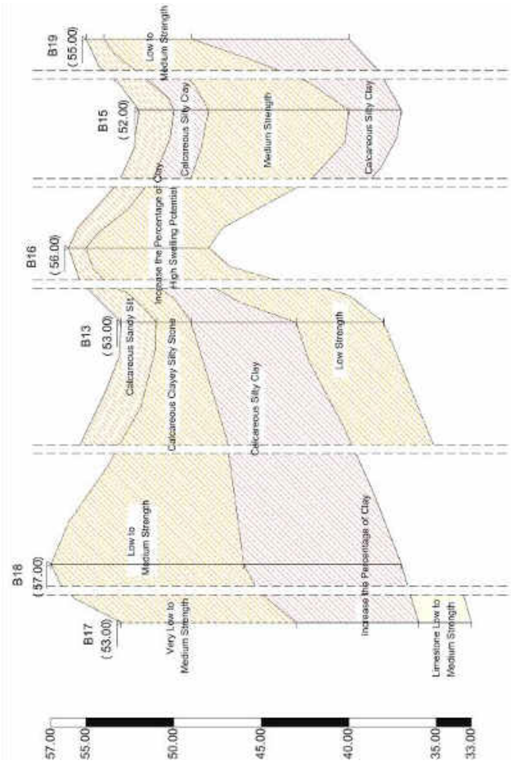

Fig. 9. Geotechnical section (II-II) across El-Fayoum New City from east to west

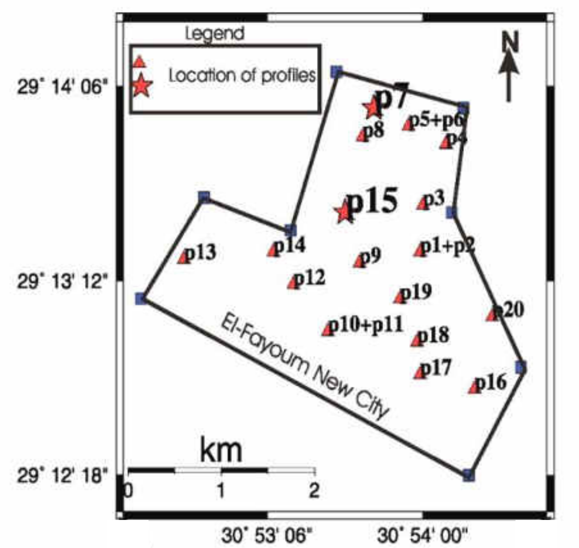

Fig. 10. Location map of seismic profiles at the proposed site of El-Fayoum New City

Table 3.
Shear wave velocity and fundamental frequency of subsurface layers obtained from conducted seismic profiles at the proposed area of El-Fayoum New City (Abd El-Aal [27]).

Seismic profile	Density of surface layer (gm/cm3)	S-wave velocity of surface layer (m/s)	S-wave velocity of second layer (m/s)	Thickens of surface layer (m)	fundamental frequency Fo (Hz)
P1+P2	1.62	329	1385	1.6	50.0
P3	1.59	308	1360	1.5	51.3
P4	1.62	254	1235	1.9	33.3
P5+P6	1.64	328	1350	1.7	48.2
P7	1.67	357	1395	1.6	55.7
P8	1.71	357	1390	2.1	42.4
P9	1.62	294	1292	2.0	36.7
P10+P11	1.43	208	1189	1.4	37.1
P12	1.55	292	1285	1.2	62.5
P13	1.52	256	1240	1.9	33.7
P14	1.68	324	1339	1.8	45.0
P15	1.54	220	1132	4.0	13.8
P16	1.50	239	1223	2.2	27.1
P17	1.45	220	1211	2.0	27.9
P18	1.53	303	1350	1.7	44.5
P19	1.64	340	1375	2.2	38.6
P20	1.46	223	1214	2.1	26.5

Fig. 11. The average shear wave velocity distribution in El-Fayoum New City

7.2. Site response analysis based on shear velocity data

From the wave propagation theory, it is clear that the ground motion amplitude depends on the density and shear wave velocity of subsurface material [35,36]. Usually in situ density has relatively smaller variation with depth and thus the shear wave velocity is the logical choice for representing site conditions. An attempt has been made to study the site response of study area using measured shear wave velocity obtained from previous shallow seismic refraction survey by Abd El-Aal [27].

In this study the input rock motions at bed rock were generated for each borehole location based on the hypocentral distance calculated for each borehole to the 1992 Dahshour Earthquake and used as input for the corresponding borehole to study the site response. Out of 20 borelogs were carefully evaluated, for the engineering bed rock depth in each borelog from the rock characterization tests, and selected for the site response study. The rock motion obtained from synthetic ground motion model is assigned at the bedrock level as input in SHAKE2000 and evaluated peak acceleration values and acceleration time histories at the top of each sublayer. Response spectra at the top of the bedrock and at ground surface and amplification spectrum between the first and last layers at a frequency step of 0.125 are obtained. Similarly, stress-strain time history and Fourier amplitude spectrum have been obtained for all the borehole locations. These are compiled and presented in the form of maps depicting variation of different parameters. The peak horizontal acceleration (PGA) values at bedrock level are amplified based on the soil profile at various locations. The peak acceleration value at the ground surface obtained from SHAKE2000 is used to prepare the PGA map at ground surface of El-Fayoum New City , which is shown in Figure 12. The PGA value ranges from 15.29 to 45.98 (gal).

7.3. Amplification factor map

The term Amplification Factor is used here to refer to the ratio of the peak horizontal acceleration at the ground surface to the peak horizontal acceleration at the bedrock. This factor is evaluated for all the boreholes using the PGA at bedrock obtained from the synthetic acceleration time history for each borehole and the peak ground surface acceleration obtained as a result of ground response analysis using SHAKE2000. The amplification factor thus calculated ranged from 1.25 to 3.75. The amplification factors obtained are used to prepare the amplification map of El-Fayoum New City. The city can be divided into four zones based on the range of amplification factors assigned to each zone as shown in Figure 13. Lower amplification values indicate lesser amplification potential and hence lesser seismic hazard. It can be observed that the amplification factor for most of El-Fayoum New City is in the range of 1.25–2.50. A very small part of the city comes under high amplification potential with the amplification factor ranging from 2.50 to 3.75. Comparison of the variation of overburden thickness map and the amplification factor map shows that the regions having higher amplification zone has an overburden thickness in the range of 5 to 8m. The high amplification potential in these regions can be attributed to factors other than the overburden thickness.

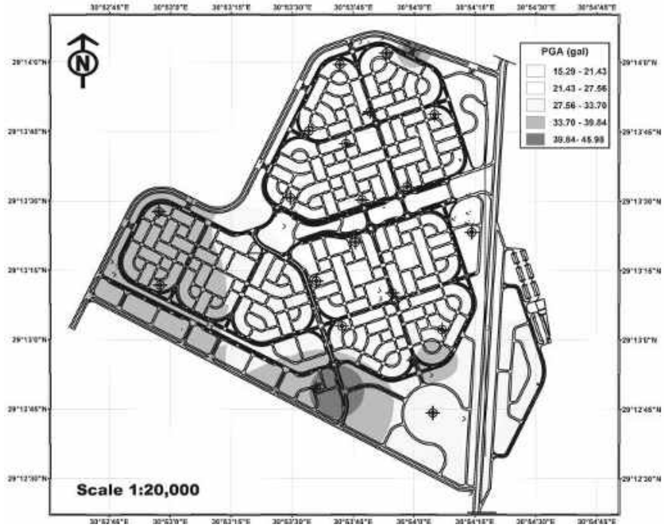

Fig. 12. Distribution of peak ground acceleration (PGA) at ground surface

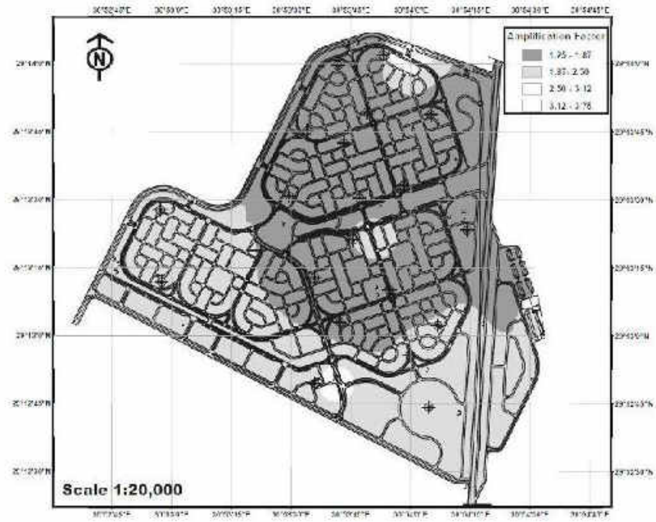

Fig. 13. Amplification factor map of El-Fayoum New City

8. Conclusions

The proposed area of El-Fayoum New City is characterized by low to moderate seismic activity and was affected by some felt and damaging historical and instrumental earthquakes. This study shows that, expected peak ground acceleration (PGA) at rock level using DSHA for El-Fayoum New City is range from 9.37 to 18.15 gal. Based on 20 borehole data geotechnical borehole model has been generated using GIS. Average shear wave velocity up to a depth of 30m was evaluated and presented and it is range from 927 to 1208 m/sec. Theoretical 1-D site response study shows that the amplification factor is in the range from 1.25 to 3.75 .This may be attributed to the fact that this region has a filled up soil of about 4m depth which considerably increases the amplification potential.

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تقسيم مدينة الفيوم الجديدة طبقا لى شدتها الزلزالية

الملخص العربى:

تقسيم المناطق الحضرية طبقا لشدتها الزلزالية يعد الخطوة الأولى نحو تقييم المخاطر الزلزالية و الحد من خطورتها. ومن الضرورى دراسة خواص التربة فى المناطق الحضرية تحت تأثير الزلازل. وتهدف هذه الدراسة إلى تقييم المخاطر الزلزالية فى مدينة الفيوم الجديدة مع الأخذ فى الاعتبار الخواص الجيوتكنيكية والجيوفزيقية للمدينة. وتم تقسيم تحليل المخاطر الزلزالية فى هذه الدراسة إلى ثلاث أجزاء. الجزء الأول يشمل تقدير المخاطر الزلزالية باستخدام المعلومات السيزموتكتونية والجيولوجية. الجزء الثاني يشمل توصيف الموقع باستخدام المعلومات الجيوتكنيكية والجيوفزيقية. الجزء الثالث تقيم تأثير الموقع من خلال إجراء تحليل خطى معادل أحادى البعد لاستجابة الأرض باستخدام برنامج SHAKE2000. وقد تم استعراض منهجية الدراسة ونتائج الاختبارات الحقلية والمعملية وخرائط الشدة الزلزالية عند السطح وعند صخور الأساس ومعامل التكبير بالتفصيل فى هذا البحث.