Estimation of Earthquakes Factors using geotechnical technique at Faris city, Aswan, Egypt

Hesham A. H. Ismaiel

Abstract— The present investigation interested with the assessment of earthquakes factors of solar power station project constructing at Faris city, Aswan, Egypt using a geotechnical technique. The geotechnical tests were including grain size analysis, direct shear box (frictional angle and cohesion), and standard penetration test (SPT. To fulfillment this objective, nine mechanical wash boreholes were drilled at ten meter depth. Ninety disturbed samples were collected. The results provided that the studied soils were classified as well graded sands (SW) and well graded gravels (GW) according to the unified soil classification system (USCS). The earthquakes factors like S, T_B, T_C, and T_D were 1.50, 0.10, 0.25, and 1.20 respectively. According to Egyptian code for vibration and dynamic load foundations, the studied project area was classified as low potential seismic (zone 2). According to Egyptian code for shallow foundation, the allowable bearing capacity of the studied soils was ranging from 4 to 6 kg/cm^2 at shallow foundation width must be not less than one meter. For lightly loaded building, maintenance structures and offices, conventional shallow footings with slabs on-grade were recommended. For heavy equipment pads, structural mat slabs were recommended. For heavy loads associated with the substation, a large spread footings or structural mat foundations were recommended.

Index Terms— Standard Penetration Test, Earthquakes Factors, Elasticity Modulus, Allowable Bearing Capacity

1 Introduction

The study area is located in the western desert hinterland of Faris, it is one of the most promising areas for constructing many solar power stations in Egypt because it is characterized by a high solar radiation. (Figures 1 & 2). The geological location and the shallow shear wave velocity structure of a site have an important effect on earthquake ground motion. This effect is known as the site effect and may cause amplification of earthquake ground motion in frequency ranges unfavorable for buildings and structures [1].

The seismic activity of Egypt is resulting to the relative motion between the plates of Eurasia, Africa and Arabia. Some areas in Egypt have been struck by significant earthquakes causing considerable damage [2]. The present investigation interested with the assessment of earthquakes factors of solar power station project constructing at Faris city, Aswan, Egypt using a geotechnical technique. The present work was to understand the fitting of the study area and the studied soils to construct a solar power station.

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1.1 Previous Works

There is a lack in earthquakes assessment and geological hazards researches which conducted on the investigated area, only little studies like [1], [2], [3], and [4]. The investigated area was geologically studied by many of authors. Sedimentlogical and stratigraphical investigations were conducted by [5], [6], [7], [8], [9], [10], [11], and [12]. Structural studies were conducted by [13], [14], and [15]. Geomorphological researches were done by [16], [17], and [18]. Surveying studies were carried out by [19]. Engineering geophysical investigations were achieved by [20], and [21]. Some geotechnical works were made by [22], [23], [24], and [25].

1.2 Scopes of the Present Work

The present investigation interested with the assessment of earthquakes factors of solar power station project constructing at Faris city, Aswan, Egypt using a geotechnical technique. Some geotechnical parameters of the studied soils like gradation parameters, shear parameters (ϕ & Cu), allowable bearing capacity, and elasticity modulus (Es) were measured to estimate the earthquakes factors of the studied soils and the design ground acceleration (a_g).

These geotechnical testing was to understand the fitting of the study area and the studied soils to construct a solar power station. The earthquakes factors are like soil coefficient (S), limits of constant value for elastic response spectrum (T_B and T_C), and specified value for begin of the constant displacement spectrum (T_D).

Figure 1. Location map of the studied area

Figure 2. Land sate image of the studied area

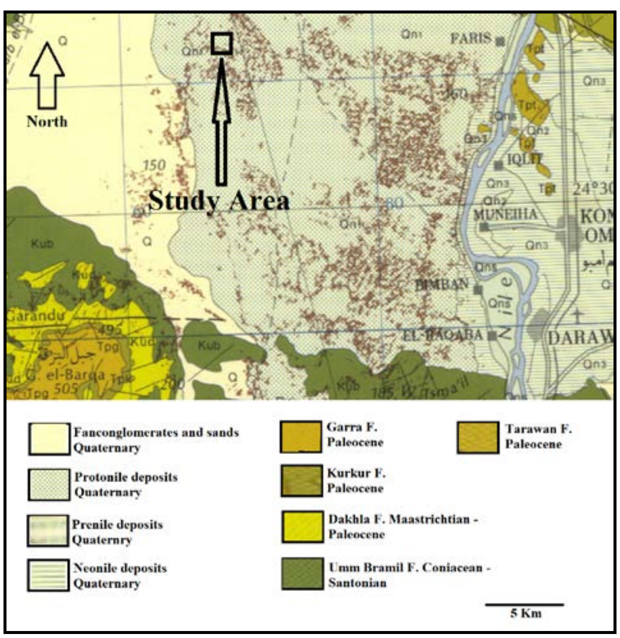

Figure 3. Geological map of the studied area modified after [26]

1.3 Geological Setting

The study area is located west of Faris city and about 8 km from Cairo-Aswan Western Road, in the Western Desert between latitude 24° 36' 6" to 24° 40' 50" N and longitude 32° 40' 43" to 32° 41' 26" E. The area has different sediments and sedimentary rocks types belonging to the Upper Cretaceous-Lower Tertiary succession and Quaternary deposits. The study area is covered by Quaternary deposits in the form of Quaternary fan conglomerates and sands, Quaternary proto-, pre-, and neo-Nile sediments. The investigated area is surrounded by Upper Cretaceous-Lower Tertiary succession at the west and south direction including Umm Bramil Formation (Coniacean–Santonian), Dakhla Formation (Masstrichtian-Paleocene), Kurkur Formation (Paleocene), Garra Formation (Paleocene), and Tarawan Formation (Paleocene). The studied soils are Quaternary deposits including mixtures of gravels and sands (Figure 3). The area under investigation has flat topography and bounded by the Cretaceous–Tertiary Succession at the west and southwest. El-Barqa Mountain is located at the southwest direction of the study area. The Cretaceous – Tertiary Succession at El-Barqa Mountain is discontinuous by two set of joints.

2 Materials and Methods

2.1 Materials

Ninety disturbed samples were collected from nine (B1 to B9) wash mechanical drilling boreholes (10 m depth); one sample was selected in each one meter depth (Figure 2 & 4). The studied soils were belonging to the Quaternary fan conglomerates and sands sediments.

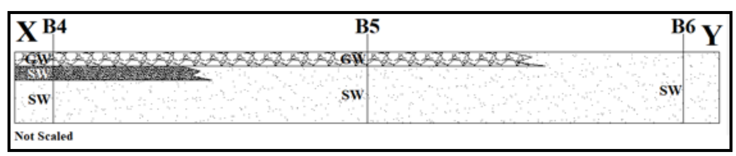

Figure 4. Cross-section in the studied area along the XY-direction

2.2 Methods

Wash mechanical drilling based on [27] was conducted to do nine (B1 to B9) boreholes (10 m depth) and to collect the studied samples. Standard penetration test (SPT) was carried out based on [27] to measure the frictional angle (ϕ), and the elasticity modulus of the studied sand samples, in the field. Grain size analysis and direct shear box [27] were done on the studied sand samples to measure the frictional angle (ϕ) and the cohesion (Cu), in the laboratory. These measured geotechnical parameters used to know the soil class [28].

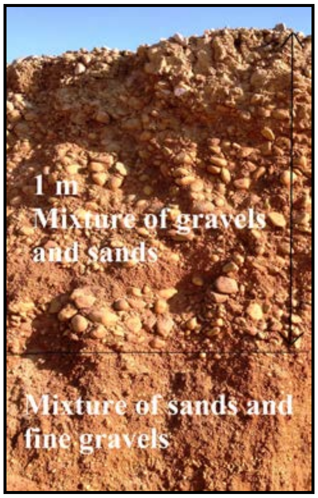

Figure 5. Photo of the studied soils in an open pit near borehole no. 5

3 Results

3.1 Wash Mechanical Drilling Results

After description of the ninety disturbed samples collected from the studied nine boreholes, the results showed that the lithology of B1, B4, and B7 was similar. The lithology of B2, B5, and B8 was the same. The lithology of B3, B6, and B9 was similar. Correlation between three boreholes data (B4, B5, and B6) was made to create a vertical cross-section of the studied area in XY-direction (Figure 2). The results illustrated that the area composed mainly of mixture of gravels and sands. From the surface to one meter depth, the soils composed of well graded friable sands at boreholes no 3, 6, and 9, and from two meter to ten meter depth composed of well graded compacted dense sands. Boreholes no. 2, 5, and 8 composed of well graded gravels (the first meter depth) and from two meter to ten meter depth composed of well graded compacted dense sands. Boreholes no. 1, 4, and 7 composed of well graded gravels (the first meter depth) and of well graded slightly compacted sands (the second meter depth) and from the third meter to the tenth meter depth composed of well graded compacted dense sands. No underground water in all the studied boreholes was detected (Figure 4 & 5).

3.2 Grain Size Analysis Results

Figure 6 illustrated the grain size distribution curves of the studied samples. Two main types of the soils were determined including well graded gravels (GW) and well graded sands (SW) according to unified soil classification system (USCS). The studied well graded sand samples composed mainly of sand size ranging from 75 to 77% and fine gravels size ranging from 20 to 23 and trace of silt size ranging from 2 to 5%. The studied well graded gravels samples composed mainly of gravel size ranging from 72 to 75% and sand size ranging from 21 to 23 and trace of silt size ranging from 2 to 4%.

3.3 Direct Shear Box Results

The direct shear box test was conducted to measure the frictional angle (ϕ) and the cohesion (Cu) of the soil samples under investigated (in the laboratory). Four representative sand samples were collected from borehole no. 4, 5, and 6 and tested based on [27]. The results were illustrated in Table 1. The results showed that the friction angle values of the studied well graded sand ranging from 33 to 43°. The frictional angels of the well graded sand at B4, B5, and B6 were 33, 36, and 43° respectively. The cohesion values (Cu) of the studied well graded sand was equal to zero.

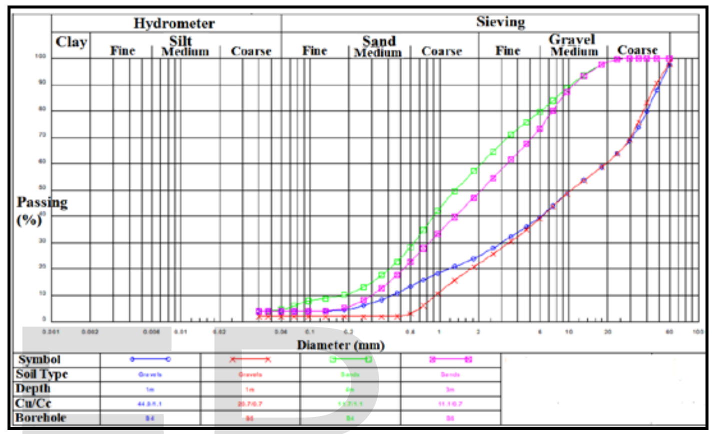

Figure 6. Grain size distribution curves of the studies samples

Table 1. Frictional angle (ϕ) and cohesion values (Cu) of the studied sand samples

Sample No.	Location	Depth (m)	Soil Type	Frictional Angel (ϕ)	Cohesion (Cu) (KN/m²)
1	B4	2	SW	33°	0.00
2	B5	3	SW	36°	0.00
3	B6	3	SW	41°	0.00
4	B6	4	SW	43°	0.00

3.4 Standard Penetration Test (SPT) Results

Standard penetration tests (SPT) were carried out (*in situ*), during the wash mechanical drilling only on the sands layers based on [27] applying blow weight equal to 62.5 kg and drop height equal to 76 cm, the blow numbers (N_{spt}) measured each 30 cm penetration. Generally, SPT-values were ranged from 15 to 50 blow number each 30 cm penetration. The surface well graded sands (at 1 to 2 meters depth) have the lowest values ranging from 15 to 18. SPT-values were enhanced with increase the depth and the compaction of the sands. The highest values were ranging from 40 to 50 (at 7 to 10 meters depth) and described as dense sands. Some intermediate SPT-values were ranging from 20 to 30 and described as medium dense sands (at 3 to 6 meters depth). The relationship between the

SPT-values, the relative density, and the frictional angle of the soils based on the Egyptian code showed in Table 2. According to the Egyptian cod and using the uncorrected SPT-values, elasticity modulus (Es-values) can be calculated. Where the corrected SPT-value was calculated from the following equation:

Corrected SPT-value = 1/2 (Uncorrected SPT-value plus 15)

The elasticity modulus (Es-value) was equal to the corrected SPT-value male constant (20.28). The calculation provided that Es-values of the well graded sands ranging from 304 to 659 kg/cm^2 . According to the Egyptian code for shallow foundations, Es-values of loose sand are ranging from 100 to 250 kg/cm^2.

Es-values of sand (medium density) are ranging from 250 to 750 kg/cm^2. Es-values of sand (dense) are ranging from 750 to 1500 kg/cm^2. Es-values of sand (very dense) are ranging from 1500 to 4000 kg/cm^2. In this study, Es-values of sandy layers were calculated from the SPT-values after a correction of SPT-values obtained from the STP field test. The results of calculated Es-values are summarized in Table (3).

Table 2. The relationship between the SPT-values, the relative density, and the frictional angle of the soils after [27]

Frictional Angle (ϕ)$^\circ$	Relative Density		SPT-valued (N_{spt}) Blow Number/30 cm
	Value	Description	
27 - 30	0 – 0.15	very loose	0 – 4
30 - 32	0.15 – 0.35	loose	4 – 10
32 - 36	0.35 – 0.65	medium	10 - 30
36 – 40	0.65 – 0.85	dense	30 - 50
› 40	› 0.85	very dense	› 50

Table 3. SPT-values and calculated Es-values

Soil type	Soil location	Soil depth (m)	SPT-values uncorrected	SPT-values corrected	Calculated Es-values (kg/cm^2)
SW	B1	2	15	15	304
SW	B4	2	15	15	304
SW	B7	2	15	15	304
SW	B2	2	16	15.5	314
SW	B5	2	18	16.5	334
SW	B5	5	28	21.5	436
SW	B3	1	15	15	304
SW	B6	2	17	16	324
SW	B6	6	30	22.5	456
SW	B6	9	50	32.5	659

4 Estimation of Earthquakes Factors

Earthquakes factors were assessment based on [28]. Egypt is subdivided to six activity zones arranged from the first zone to the fifth B zone. The study area at Faris near Kom Ambo city is located in the second seismic zone (zone no. 2) (Figure 7 & Table 4). The value of design ground acceleration (a_g) at seismic zone no. 2 was 0.125 g (Table 5). The geotechnical technique results illustrated that the soil layer type of the study area was class C, where the number of blow each 30 cm was ranging from 15 to 50 according [27], where the minimum drill depth of the shallow foundations must not be less than 0.8 m, (Table 6). Based on the determined soil layer type (class C), the earthquakes factors including S, T_B, T_C, and T_D were 1.50, 0.10, 0.25, and 1.20 respectively (Table 7). Based on the Egyptian code for vibration and dynamic load foundations, the studied area was classified as low potential seismic.

5 Estimation of Allowable Bearing Capacity of the Study Soils

Based on the Egyptian code of shallow foundations, where the soil under investigation is dry and the pore water pressure equal to zero, the allowable bearing capacity of the studied medium compacted sands at the suitable drill depth of the shallow foundations (not less than 0.8 m depth) was ranging from 4 to 6 kg/cm^2 (in case of shallow foundation wide must not be less than 1 m). Table 8 showed the allowable bearing capacity based on [29] in the dry conditions.

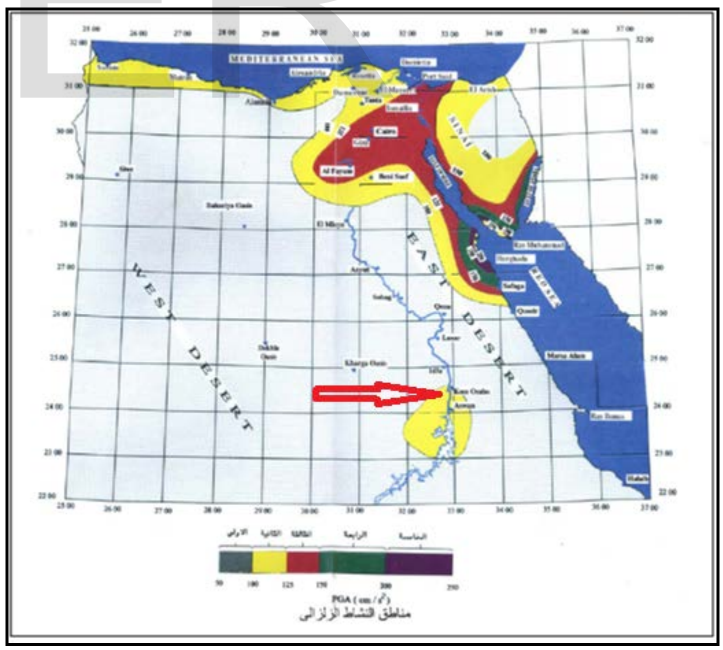

Figure 7. Seismic activity zones in Egypt, after [28]

Table 4. Seismic effect zones for cities in Egypt [28]

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Governorate	City	Zone	Governorate	City	Zone
Aswan	Edfo	1	Cairo		3
	Kom Ambo	**2**			
	Aswan	3			
Assuit		1	Alkaliobia	Kafr shoukr	2
				The Rest	3
Alexandria	Alexandria	2	Almonoufia		2
Ismailia		3	Minia		1
Luxor		1	Alwadi algadeed		1
Red Sea	Quseir, Halaib & shalateen	3	Bani Suif	Alwasta	3
	Ras Gharib-Safaga	4			
	Hurghada	5A		The Rest	2
	Shedwan Illand	5B			
Albehaira		2	Port said		3
Giza		2&3	South Sinai	Abu Redis-Ras Sedr	3
				Dahab-altor	4
				Sharm alshikh-Noibaa	5A
				Taba	5B
Aldakahlia		2	Domiatt		2
Suez	Suez	3	Sohag		1
Alsharqia	Belbis-Abu Hamad, 10th of Ramadan	2	North Sinai		2,3
	The Rest	3			
Algharbia		2	Qena		1
Fayoum		3	Kafr		2
			Alshikh		
			Marsa Matrouh	Marsa Matrouh	2
				Saloum	2

Table 5. Values of design ground acceleration (a_g) and seismic zones [28]

Zone	Value of design ground acceleration (a_g)
Frist	0.100
Second	**0.125**
Third	0.150
Forth	0.200
Fifth A	0.250
Fifth B	0.300

Table 6. Soil layers classification under foundations [28]

Soil classification	Description of soil	N_{spt} Number of blow/30 cm	C_u (KN/m²)	Vs (m/s)
A	Rock or rock fragments resembling contain a week surface layer have a thickness of at most 5 m.	-	-	More than 800
B	Deposits extends for tens of meters thick composed of (sand + gravel) dense or clay with heavy resistance cohesion C_u shown in the table, with the increasing values of mechanical properties gradually with depth.	More than 50	More than 250	360-800
C	**Deep soil deposits of non-cohesive (sand+gravel) medium to heavy or clay with resistance cohesion C_u shown in the table, thickness ranges from tens to hundreds of meters.**	**15-50**	**70-250**	**180-360**
D	Soil is non-cohesive (sand, gravel) loose to medium density (may be present by cohesive	Less than 15	Less than 70	Less than 180

	layers such clay, loam or the prevailing coherent soil with cohesion resistance C_u shown in the table.			
E	Soil section consists of the surface layer of river sediment Vs, such C or D with with variable thickness from 5-20m and the material underneath are strongest Vs more than 800m/s	-	-	-

Table 7. Earthquakes factors based on subsoil class [28]

Subsoil Class	S	T_B	T_C	T_D
A	1.00	0.05	0.25	1.20
B	1.35	0.05	0.25	1.20
C	**1.50**	**0.10**	**0.25**	**1.20**
D	1.80	0.10	0.30	1.20

Table 8. Allowable bearing capacity values according to [29]

6 Conclusions and Recommendations

6.1 Conclusions

Soil type	Description	Allowable bearing capacity (Kg/cm^2)	Notes
Gravel or mixtures of gravel and sand	High compacted	5 – 7	Foundation wide must be not less than 1 m
	Medium compacted	**4 – 6**	
	Loose	2 – 4	
Coarse to medium sand or mixture of sand with little gravel	Very dense	3 – 5	
	Medium to Dense	1.5 – 3	
	Loose	1 – 2	
Fine to medium sand or clayey or silty sand	Very dense	2 – 4	
	Medium to Dense	1.5 – 2.5	
	Loose	1 – 1.5	

The studied soils were belonging to the Quaternary fan conglomerates and sands sediments. The present investigation interested with the assessment of earthquakes factors of solar power station project constructing at Faris city, Aswan, Egypt using a geotechnical technique. This geotechnical technique was to understand the fitting of the study area and the studied soils to construct a solar power station. The earthquakes factors are soil coefficient (S), limits of constant value for elastic response spectrum (T_B and T_C), and specified value for begin of the constant displacement spectrum (T_D). To fulfillment this objective, nine mechanical wash boreholes were drilled at ten meter depth. Ninety disturbed samples were collected. Two main types of the soils were determined including well graded gravels (GW) and well graded sands (SW) according to unified soil classification system (USCS). The results of shear box test showed that the friction angle values of the studied well graded sand ranging from 33 to 43°. The surface well graded sands (at 1 to 2 meters depth) have the lowest values ranging from 15 to 18. SPT-values were enhanced with increase the depth and the compaction of the sands. The highest values were ranging from 40 to 50 (at 7 to 10 meters depth) and described as dense sands. Some intermediate SPT-values were ranging from 20 to 30 and described as medium dense sands (at 3 to 6 meters depth). The value of design ground acceleration (a_g) at seismic zone no. 2 was 0.125 g and the earthquakes factors including S, T_B, T_C, and T_D were 1.50, 0.10, 0.25, and 1.20 respectively. Based on the Egyptian code for vibration and dynamic load foundations, the studied area was classified as low potential seismic, so that the potential for liquefaction of the studied sands is negligible during seismic shaking (if happened). Based on the Egyptian code of shallow foundations, (in case of dry condition) the allowable bearing capacity of the tested sand at drill depth of the shallow foundations (not less than 0.8 m depth) was ranging from 4 to 6 kg/cm^2.

6.2 Recommendations

For lightly loaded building, maintenance structures and offices, conventional shallow footings with slabs on-grade were recommended. For heavy equipment pads, structural mat slabs were recommended. For heavy loads associated with the substation, a large spread footings or structural mat foundations were recommended.

Correlation between global positioning system (GPS) investigation and earthquake factor assessment was recommended to deep understand of the local geological conditions and the site effect on the earthquake ground motion.

Acknowledgment

Greatly thanks to the contractor of the solar power station project at Faris city for valuable data and cooperation.

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