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THE INTEGRATION OF GEOPHYSICAL AND GEOTECHNICAL STUDIES TO INVESTIGATE A SITE FOR A BUILDING GROUND IN WEST KOM UMBO AREA, ASWAN, EGYPT

BY

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ABSTRACT

The combination of geophysical data and geotechnical measure remints may greatly improve the quality of buildings under construction in civil engineering. The presented study here was carried out at the western Kom Ombo area. The shallow seismic refraction survey was done along a short five profiles "every profile has a length 50 meters" to delineate the type of subsurface soils in the study area and the determination of the physical parameters of the rock formations. The geotechnical properties of the ground were also investigated by continuous core sampling of nine boreholes drilled to depths of up to 10 m. The results of the geotechnical study have been aided for determine the different layers, geotechnical properties and field tests (SPT). At finally, the standard penetration test had been studied and how to desire the most important geotechnical parameters and apply them with depths to determine the degree of soil quality and their suitability for the constructions that will build on it.

Key words: Soil, Seismic refraction, Shear Waves Velocity & Poisson's Ration.

INTRODUCTION

The procedure for obtaining subsurface information in situ for civil engineering is important. An application of modern geophysical techniques for mapping subsurface structures and simple geotechnical field tests, such as the standard penetration test (SPT), they can be representing the most important methods for obtaining subsurface information.
The above methodologies were applied in our case study within the area under study, on the north west of Aswan City, Western Desert.

Five seismic refraction profiles have been carried out. The resulting measurements were combined with the available geological and geotechnical data of the study area and were used to assess the structure of the near-surface geology.
The particular data obtained through indirect geophysical and geo-technical techniques can be contributed to the decision-making process for choosing the appropriate of the design and prediction of the optimum foundations of facilities of the site.

Area of investigation: The study area is located northwest of Aswan City, in Western Desert between latitude 24° to 25° N and longitude 31° 30′ to 33° E, and comprise the El-Gallaba plain, the Western part of the Kom Ombo basin, and Wadi El-Kubanyia (Fig.1). It is characterized by is characterized by an arid climate with desert-like conditions. Although rainfall is not significant throughout the year, some rare and irregular storms take place over (area 5336 km^2). The Nile extends over a distance of 950 km long from Aswan to Cairo, but its water is limited to be used in the narrow strip of the Nile Valley where the majority of Egypt population resides since 2020, the Egyptian government has tried to reclaim the desert areas to increase the agricultural lands outside the River Nile. These researches depend on the exploitation of Soil quality and the ability to building. In this study, Seismic refraction survey was considered a suitable tool to solve engineering site problems and delineate subsurface layering and velocities.

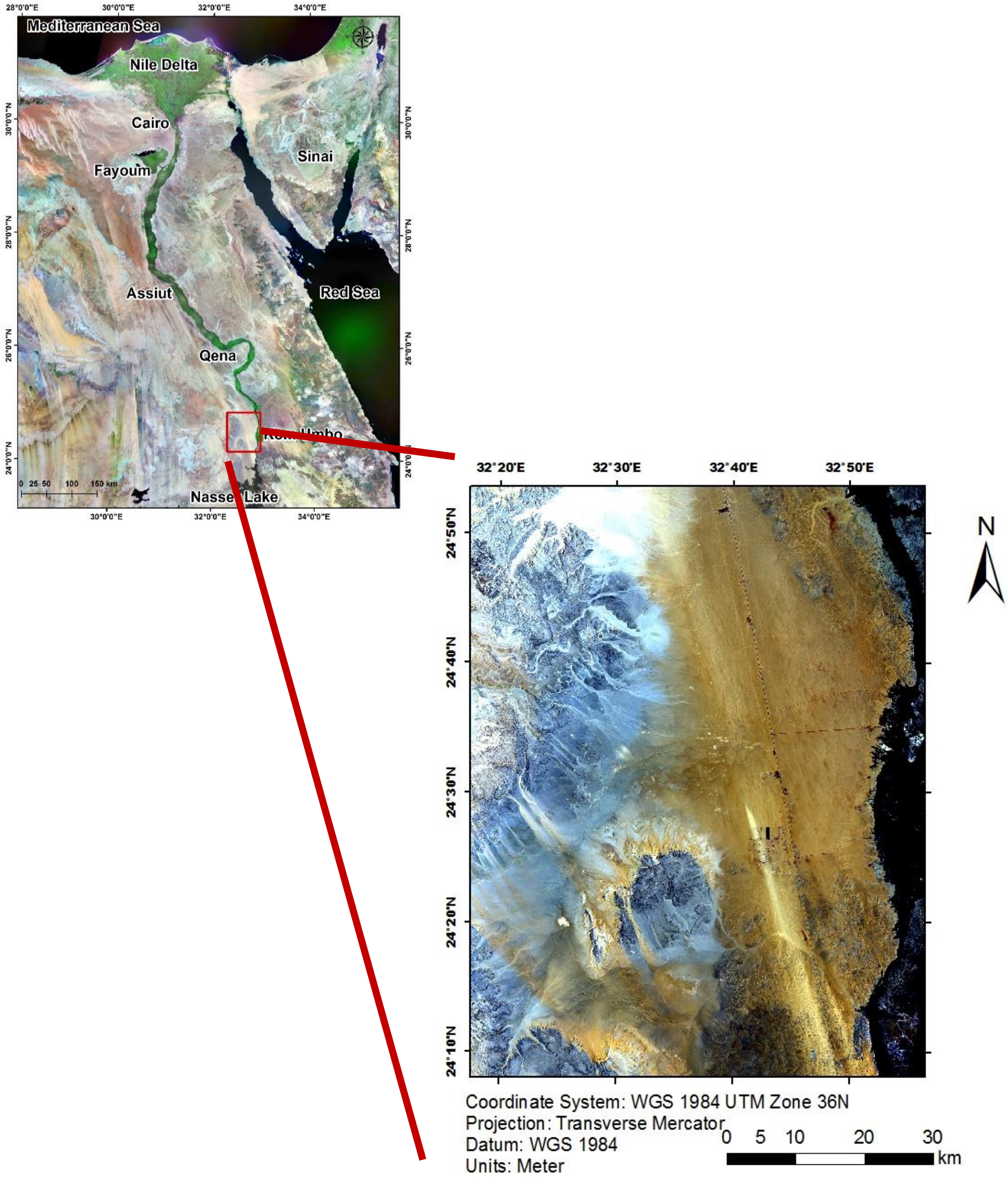


Fig (1): Location map of study area.

Geoseismic Cross sections were constructed, these sections reflect the number of shallow layers penetrated by seismic waves besides, the type of lithology of each layer was determined according to values of velocities of seismic waves through layers and geologic structures which may affect the shallow subsurface section the site response is evaluated through the geotechnical parameters (young's modulus, bearing capacity).

SCOPE OF THE PRESENT STUDY

The study focusses on investigation of soil, rock, depth to bedrock and bedrock properties on and below an area of study to determine their engineering properties including how they will interact with, on or in a proposed construction, by using shallow seismic refraction survey and geotechnical study.

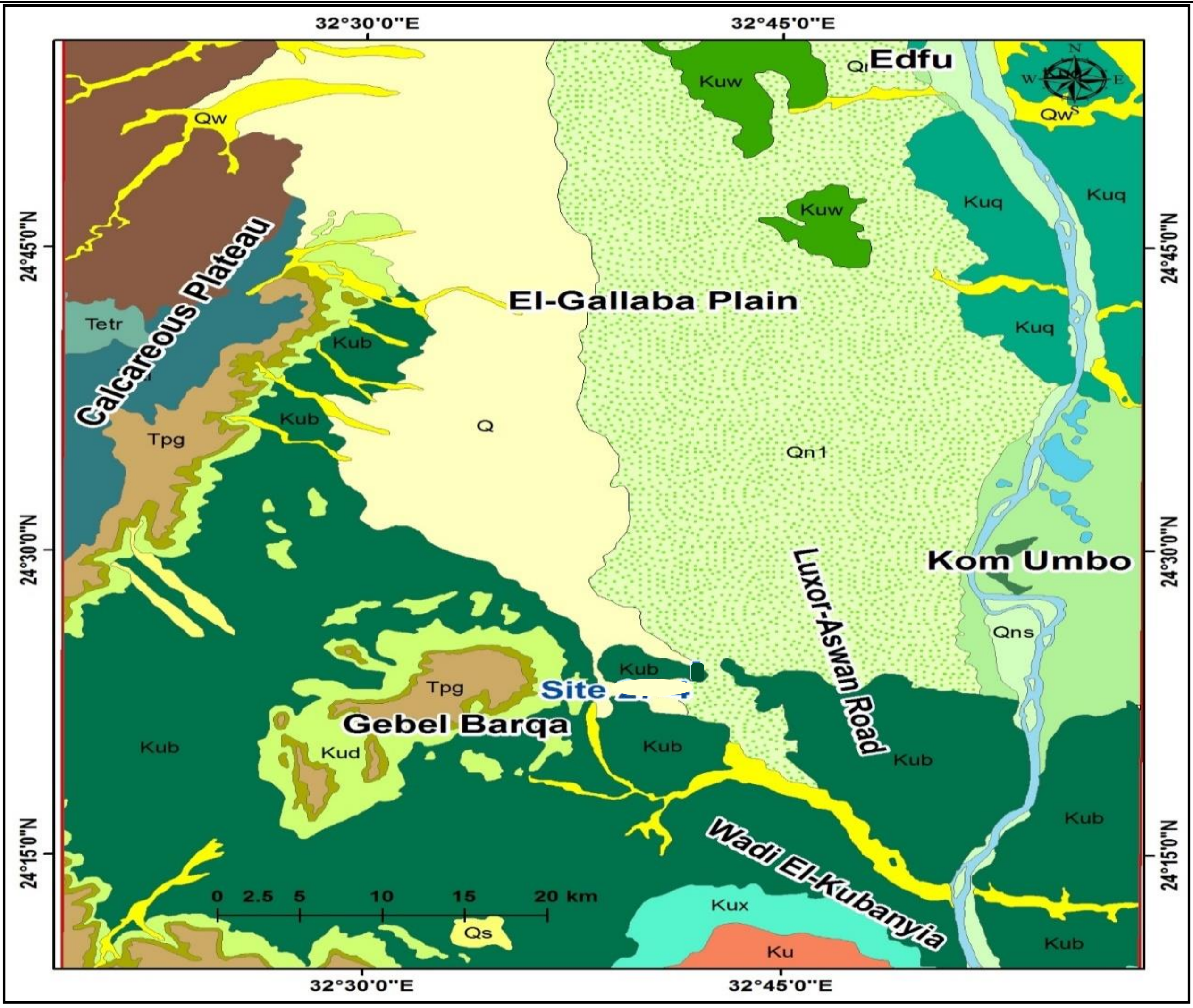
GEOLOGIC SETTING

The investigated site lies in the western extension of Kom Umbo Basin, and has most probably been affected by the geo-structure setting that shaped the basin **(Koch et al., 2013)**. Topographically, El-Gallaba Plain is relatively flat (Fig. 2), and covered by fluvial deposits (sand and gravel) brought by an old E–W striking river course (wadi), which is older in age than the present Nile River **(Koch et al, 2013)**. These sediments are known as Protonile Deposits (Qn1) on the geological map of the study area. Wadi El-Kubanyia is the western remnants of this ancient wadi system (Fig. 1).

The connection between the present-day Wadi El-Kubanyia and its delta (El-Gallaba Plain) is not known yet, because it is completely covered by an active longitudinal sand dune. This active sand dune is moving from NW–SE directions and passing through the study area, where the targeted zone of this the study locates on the western side of this dune. Hence, it has a relatively low potential of sand dunes migration risk, which should be a concern for the other project sites on the eastern side of the longitudinal sand dune. This longitudinal sand dune is well-defined landform unit in the most recent geomorphologic map of Aswan sheet and satellite images.

The top sediments in El-Gallaba Plain as described in the official geological map of Aswan, Egypt (sheet NG-36 B with scale 1:250 000) are typically characterized as sand, mix of gravel/sand and gravel sediments of fluvial and aeolian deposits (EGSMA et al., 2005) (Fig. 2). These surficial sediments originated from different sources and different directions.

The tectonic framework of El-Gallaba Plain is related to the Last African Orogenic belt (Abd El-Razik & Razavaliaev, 1972; Said, 1962). The entire Nile Valley in Egypt is controlled by wrench faults that are generally parallel either to the Gulf of Suez or the Gulf of Aqaba directions (Youssef, 1968). The stratigraphic sequence of the study area ranges in age from Pre- Cambrian to Quaternary. The Pre-Cambrian rocks consist mainly of igneous and metamorphic rocks. The sedimentary section overlying the basement complex ranges in age from Paleozoic to Recent. Thus, the study area has been affected by the same structural deformation processes that formed the Nile Valley and shaped the Kom Umbo basin.



Ku	Abu Aggag Fm. Fluviatile deposits with cross-bedded sandstone.	Qns Q	Nile silt Undifferentiated Quaternary Deposits.
Kuw	Duwi Fm. Phosphate beds	Qw	Wadi Deposits
Kub	Umm Barmil Fm. Fluviatile	Qn1	Protonile deposits
Kuq	Quseir Fm.	Qs	Sand Sheets,Serir.
Kux	Timsah Fm. Deltaic Seq.	Tetr	Thebes Group \ El-Rufuf Fm. limestone
Kud	Dakhla Fm. Shale with calcareous	Tpg	Garra Fm. shallow water limestone

Fig (2): Geological map of the study area (after geological survey of Egypt et al., 2005).

METHODOLOGY AND DATA ACQUISITION

1 - GEOPHYSICAL STUDIES

In this work, a geophysical study involving a shallow seismic refraction was conducted to provide support data for engineering site characterization. It will also elucidate the fieldwork and acquisition of the geophysical data as well as the processing of the acquired data using computer software and eventually the data interpretation, in addition to the consistency between the geophysical and geotechnical results.

It should be mentioned that every geotechnical in situ survey gives only discontinuous one-dimensional information for the subsurface conditions. In contrast, the application of engineering geophysics can provide either 2D or 3D subsurface images of the study area.

1.1 - Shallow Seismic Refraction

The seismic refraction technique used for purposes engineering now a days has increasing applications in civil projects, recognition of layer succession, blind zones, subsurface geologic structures, crushed zones, caves and fractures. The present study is a trial to evaluate the foundation rock properties in the investigated area, using shallow seismic refraction measurements by recording the seismic waves as well as their interpretation in terms of subsurface sedimentary structures, the evaluation of the elastic moduli and consequently the material competence.
As a measuring instrument, 24 channel seismograph the Mc SEIS-SX was employed during field survey Fig (3).

Fig (3): McSEIS-SX 24 channels Seismograph during the field survey at the study area

Collocated p-wave velocity data were acquired along five profiles each of length 50 m oriented in west to east direction . Geometry of the Five acquired profiles was designed to be very detailed with 5 shot points' seismic spread providing 5-time-distance curves for each profile. Each shot point yields shot record with 24-seismic traces.

The source of energy was moved from the forward offset shot point (-8 m) gradually to the forward shot point (0 m), then to the middle shot point (25 m), after that it was moved to the reverse shot at 50 m of the profile and finally to the last shot of the offset reverse at 58 m. The profile length was 50 m with a geophone interval equal only to 2 m for more details. The distance between the end-on shot point and the first geophone was also 2 m. The seismic refraction survey was carried out through applying the forward, inline, midpoint and reverse shootings to create the compressional waves (P-waves). The ground refraction field work is executed in the interested area of the five seismic refraction profiles (Fig. 4).

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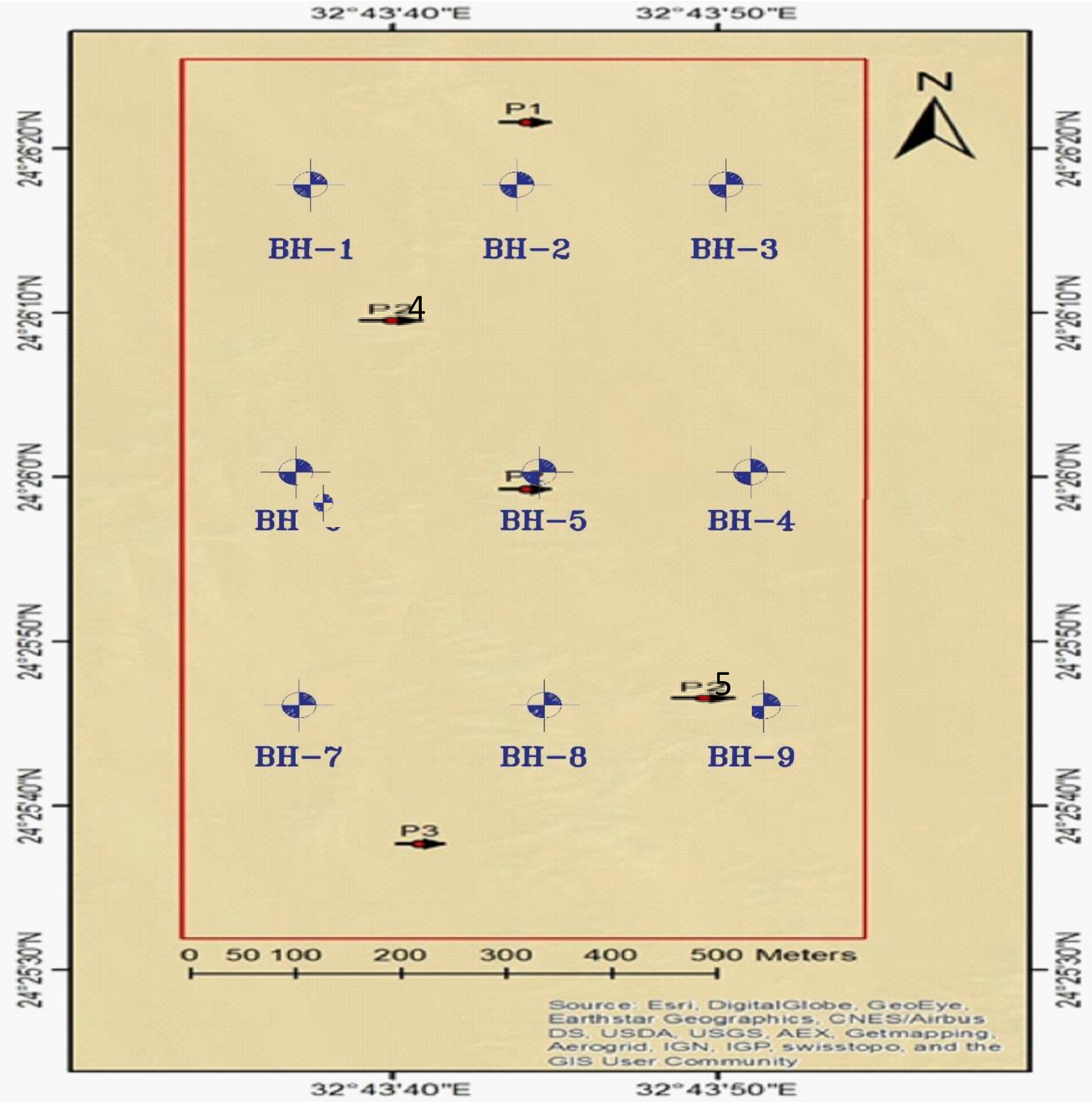


Fig (4): Location map of profile sections and boreholes.

The relationship between compressional wave velocity and shear wave velocity suggested by **(Grant and West, 1965)** and **(Sherif and Geldart, 1986)**, as follow:

$$Vs = V_p/1.7=0.58*V_p$$

The seismic refraction survey was carried out through applying the forward, inline, midpoint and reverse shootings to create the compressional waves (P-waves). The ground refraction field work is executed in the interested area of the five seismic refraction profiles (Fig. 4).

Where: V_p is the velocity of the P-waves and V_s is the velocity of the S-waves. These formulas are useful for predicting reasonable velocities for the shear waves, when only compressional wave velocity is known. Table (1) shows the seismic velocities of the earth's materials.

Gardner et al., 1974, showed that, the compressional wave velocity can be used in the evaluation of the material densities. This empirical relationship is valid for the sedimentary rocks and shows the increase in P-wave velocity (V_p) with density (ρ),

$$\rho = 1.62+0.00021\ V_p$$

Where: ρ is given in g/m^3 and V_p in m/s, and Table (2) shows the density variations of the earth's materials.

Table (1): Seismic velocities of various earth materials.

Material	P-wave velocity (m/s)	S-wave velocity (m/s)
Air	332	
Water	1400 - 1500	
Petroleum	1300 - 1400	
Steel	6100	3500
Concrete	3600	2000
Granite	5500 - 5900	2800 - 3000
Basalt	6400	3200
Sandstone	1400 - 4300	700 - 2800
Limestone	5900 - 6100	2800 - 3000
Sand(Unsaturated)	200 - 1000	80 - 400
Sand (Saturated)	800 - 2200	320 - 880
Clay	1000 - 2500	400 - 1000

Table (2): Densities of various earth materials.

Material	Density (gm/cm^3)
Air	~0
Water	1
Sediments	1.7 - 2.3
Sandstone	2.0 - 2.6
Shale	2.0 - 2.7
Limestone	2.5 - 2.8
Granite	2.5 - 2.8
Basalts	2.7 - 3.1
Metamorphic Rocks	2.6 - 3.0

The geotechnical value (N), which is a measure of the material resistance to penetration by normalized cylindrical pointed bars under standard load, was geophysically evaluated using shear wave velocity. Tables (3 and 4) classified the N-values with the types of soil (Bowels, 1984). The empirical relationship between the geotechnical value (N) and the shear wave velocity (V_s) was formulated by (Imai, 1975) and later confirmed by (Stumpel et al, 1984) as follows:

$$V_s = 89.9\ N^{0.341}$$

Table (3): N-values classification for cohesive soil, (Bowels, 1984).

N-value	0-10	11-30	31-50	>50
Status	Loose	Medium	Dense	Very dense

Table 4: N-values classification for cohesiveless soil, (Bowels, 1984).

N-value	<4	4-6	6-15	>5025
Status	Very soft	Soft	Medium	Hard

1.1.1 - **Poisson′s Ratio (δ)**

is the ratio of the lateral to the longitudinal strain elastic body. It is always positive, and varies from 0.0 to 0.5, and about 0.25 for most rock materials. The range of (σ) from 0.2 to 0.3 is for highly-consolidated un weathered rocks, while its range from 0.05 to 0.02 is for most elastic sedimentary rocks, depending on porosity and weathering. This ratio becomes 0.5, when there is no volume change, through which a unidirectional stress is applied, as in the case of fluids.
However, Gutenberg, 1951, expressed this relation in terms of P- and S-wave velocities, as follows:

$$\sigma = \frac{1}{2}\left[1 - \frac{1}{\left(V_P / V_S\right)^2 - 1}\right]$$

1.1.2- Kinetic Rigidity Modulus (μ)

The shear modulus, usually abbreviated μ, plays the same role in describing shear as Young's modulus does in describing longitudinal strain. It is represented by μ, which is the ratio between shear stress and shear strain. Shear stress cannot be applied to ideal liquids and gases. For these substances μ = 0. Only solids possess the physical properties described by the shear modulus.
It is given in terms of shear waves (V_s), density (ρ) and gravity acceleration (g) of the area (Gardener et al., 1974):
$\mu = V_s^2 / \rho . g$ and $\rho = 1.62 + 0.00021\ V_p$

1.1.3 Kinetic Young's Modulus (E)

The conventional terminology of the modulus of elasticity is the kinetic deformation coefficient and formulated as a function of rigidity modulus and Poisson's ratio by **(Imai et al., 1976)** as follows:

$$\mathbf{E = 2\ \mu\ (1+\delta)\ or\ E = \rho Vp^2}\ \frac{2[1+\delta][1-2\delta]}{1-\delta}$$

1.1.4 - Bulk Modulus (K)

It is the measure of the volumetric change due to the applied force given by (**Imai et al.1976)** as follows:

$$K = \frac{2m[1+\delta]}{3[1-2\delta]} = \frac{E}{3[1-2\delta]}$$

1.1.5 - Ultimate Bearing Capacity (Qult)

The shear strength is the controlling factor of the ultimate bearing capacity of the soil. can be evaluated using the formula by **(Parry 1977)**:
$Q_{ult} = 10^{2.932}$ (log V_s-1.45).

GEOTECHNICAL STUDY

These Studies are concerned with the study of the physical and engineering properties of the soils encountered in the West Kom Umpo, as well as their effects on the construction stability. It aims also at providing alternative solutions for the excepted concerned problems of this rocks and soils. This target will be companied with the previous obtained geologic information.

By using the different methods of geology (sample collection and Geophysics technique). The result was the foundation bedrock at West Kom Umpo composed of two layers besides. The surface layer is the layer consists of that covers the area with a mixture of graded sand and gravel some site. The second layer compacted of graded sand some silt and gravel. (Fig. 5) shows a geotechnical section.

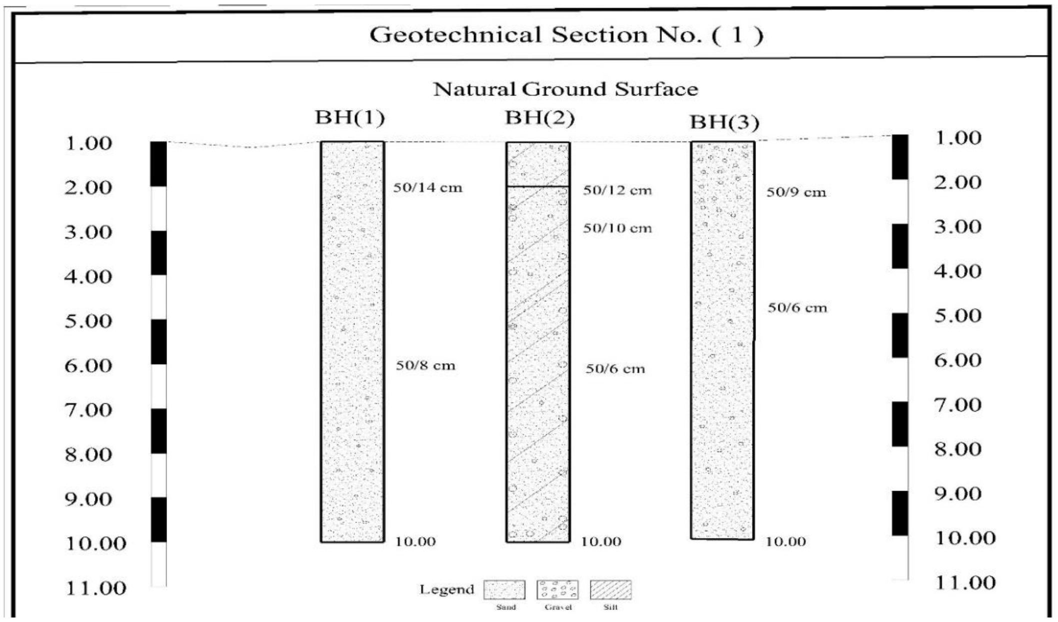


Fig. (5): Geological /Geotechnical profile of the study site based on boreholes 1,2 and 3 data.

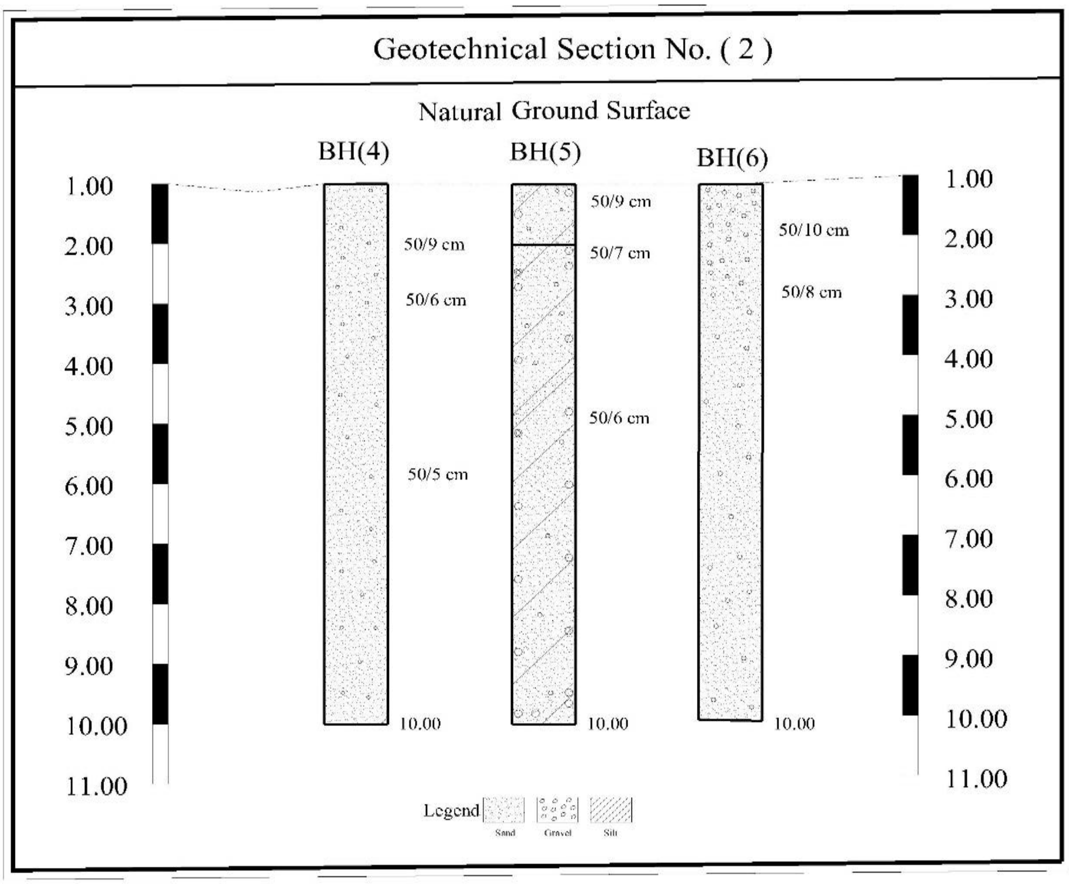


Fig. (6): Geological /Geotechnical profile of the study site based on boreholes 4,5 and 6 data.

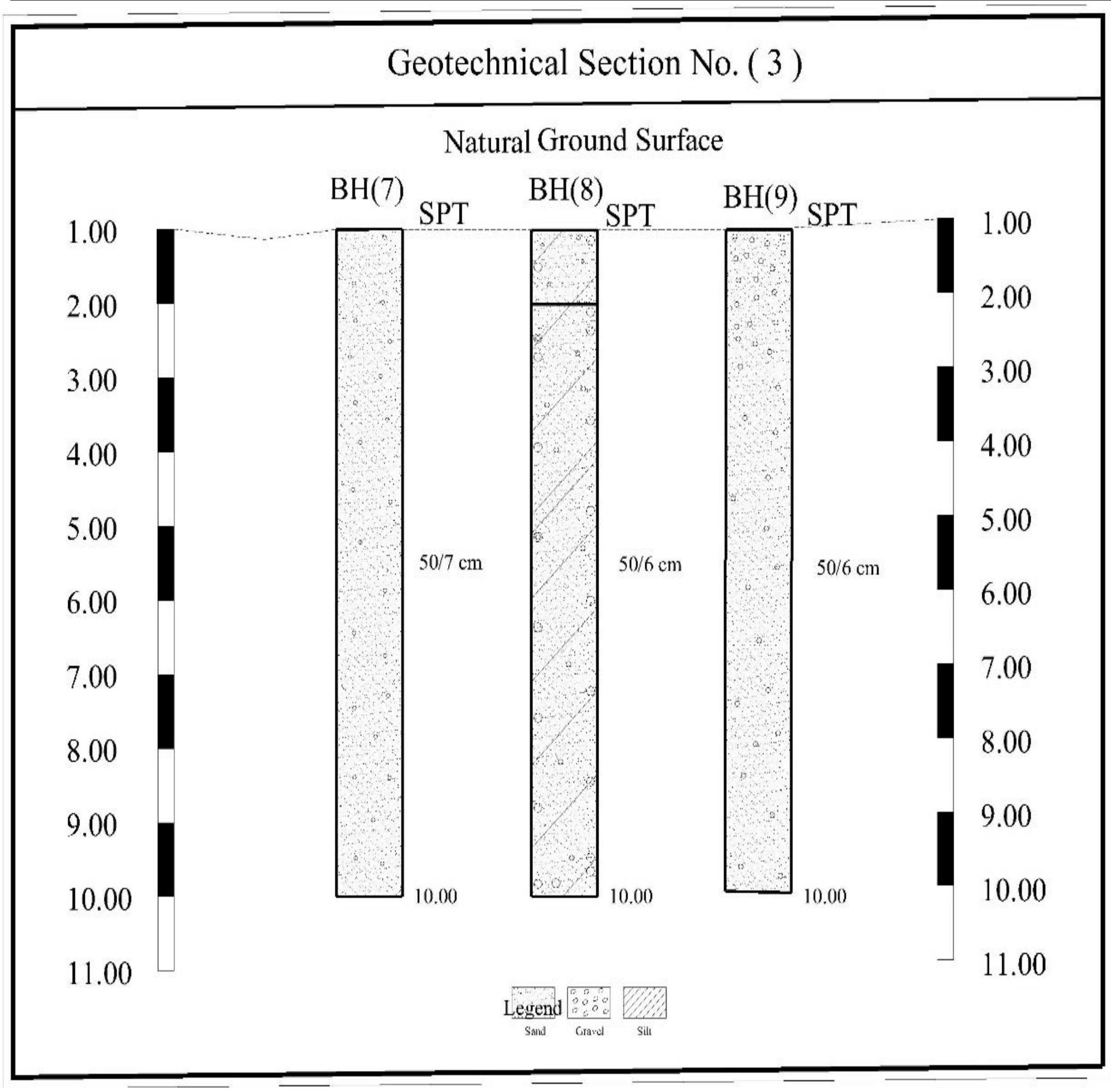


Fig. (7): Geological /Geotechnical profile of the study site based on boreholes 7,8 and 9 data.

Geotechnical parameters from SPT after Correction

1 - Effective Friction Angle, ϕ′:

There are many correlations between effective friction angle, ϕ′ and the number of blow counts, N from SPT. In **Peck et al, (1974)** introduced the following equation to determine the effective friction angle, ϕ'_{tc} from the SPT values. This correlation is function of stress level.

$$\phi'_{tc} = \tan^{-1}\left[\frac{N}{12.2 + 20.3\frac{\sigma'_{vo}}{Pa}}\right]^{0.34}$$

Where,

ϕ'_{tc}: Triaxial compression effective stress friction angle (degree),

N: Corrected number of blow counts from SPT,

σ'_{vo}: Effective overburden pressure (kPa), and

P_a: Atmospheric pressure (≈ 100 kPa)

2 - Bearing Capacity:

After estimation the angle of internal friction as shown above, the bearing capacity of soil can be directly calculated. In (Terzaghi and Peck, 1967) published an accumulation of field observations for different bearing capacity failures. Based on the basis of the empirical data derived from these field observations, Terzaghi and Peck estimated the following bearing capacity equation:

$$q_{ult} = cN_c\lambda_c + \gamma_a D_f N_q \lambda_q + 0.5\,\gamma_b B N_\gamma \lambda_\gamma$$

$$q_{all} = q_{ult}/FS$$

Where,

q_{ult}: Ultimate bearing capacity of soil (kPa),

c: Cohesion of soil (≈ zero) (kPa),

N_c, N_q and N_γ: Bearing capacity factors,

$$N_q = e^{\pi\tan\varphi} \cdot \tan^2\left(45 + \frac{\varphi}{2}\right)$$

$$N_c = (N_q - 1)\cot\phi$$

$$N_\gamma = (N_q - 1)\tan\phi$$

λ_c, λ_q and λ_γ: Shape factors,

γ_a: Effective unit weight of soil above foundation level (kN/m^3),

D_f: Depth of foundation (m),

γ_b: Effective unit weight of soil below foundation level (kN/m^3),

B: Foundation width (m),

q_{all}: Allowable soil bearing capacity (kPa), and

FS: Factor of safety (3.0)

3 - Modulus of Elasticity, E_s:

The soil deformations should be estimated with a great care to expect the settlements of the structures. To calculate the deformations of soil under static loads, the modulus of elasticity, or Young's modulus, E_s should be estimated.

There are many correlations in the literature related the modulus of elasticity of cohesionless soils and the number of blow counts, N from SPT. The following equations show direct relationship between E_s and N (Kulhawy and Mayne, 1990):

$E_s = 4\,N$ For silt or sandy silt soils

$E_s = 7\,N$ For fine to medium sand soils

$E_s = 10\,N$ For coarse sand or sand with some gravel soils

$E_s = 12\,N$ For gravelly or sandy gravel soils

Where,

E_s: Modulus of elasticity (kg/cm^2), and

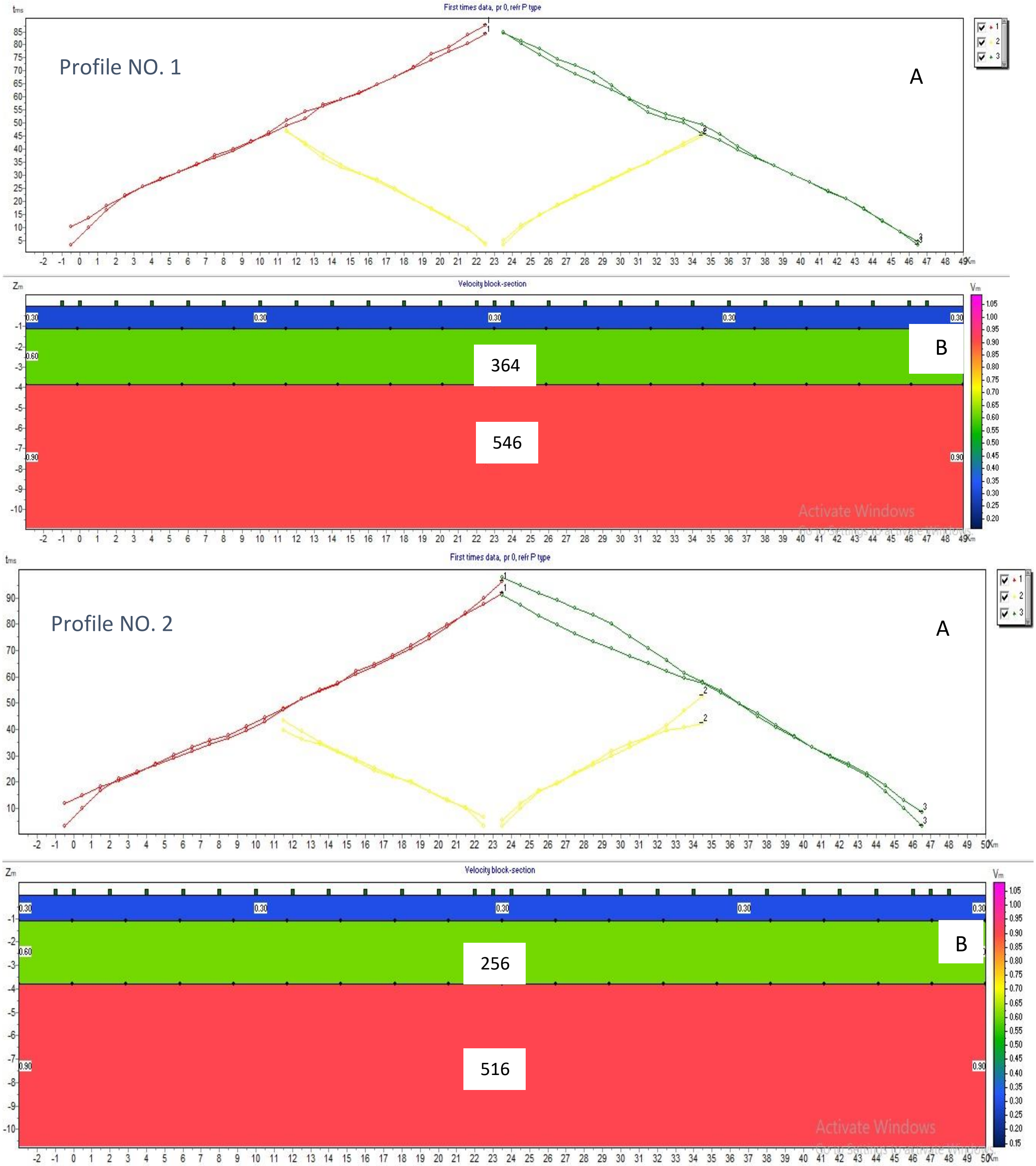
N: Corrected number of blow counts from SPT

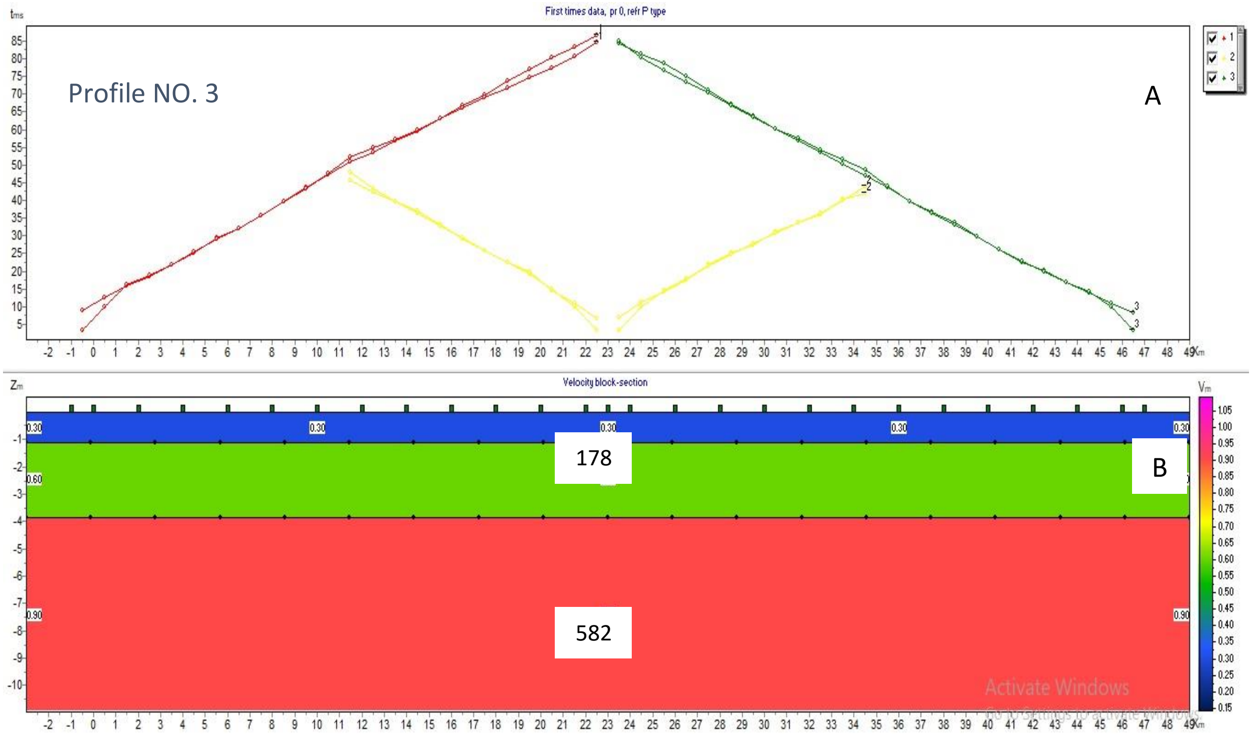
DISCUSSION AND INTERPRETATION:

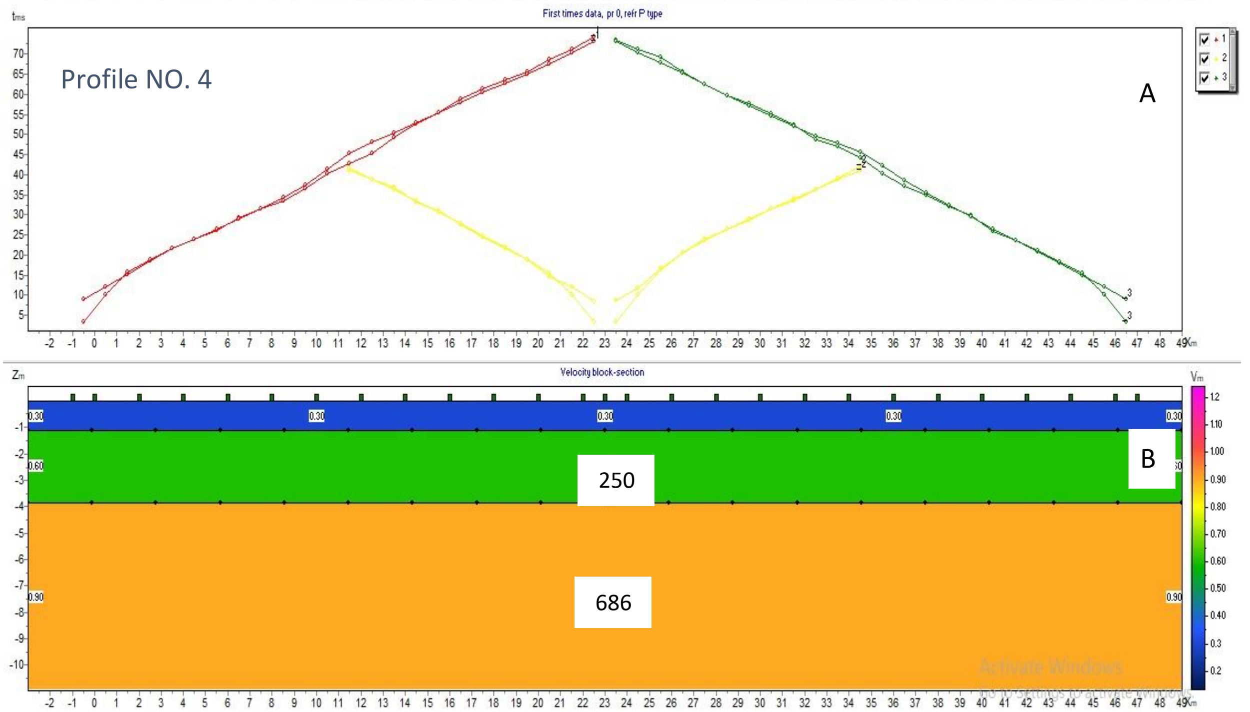
1. Seismic refraction:

1.1 - seismic wave velocities

Five Cross Sections reflecting the nature and continuity of the geo-seismic layers in the shallow section underneath the studied area Fig (8).


First times data, pr 0, refr P type
Profile NO. 1
A
Velocity block-section
B
364
546
First times data, pr 0, refr P type
Profile NO. 2
A
Velocity block-section
B
256
516


First times data, pr 0, refr P type
Profile NO. 3
A
Velocity block-section
178
B
582


First times data, pr 0, refr P type
Profile NO. 4
A
Velocity block-section
250
B
686

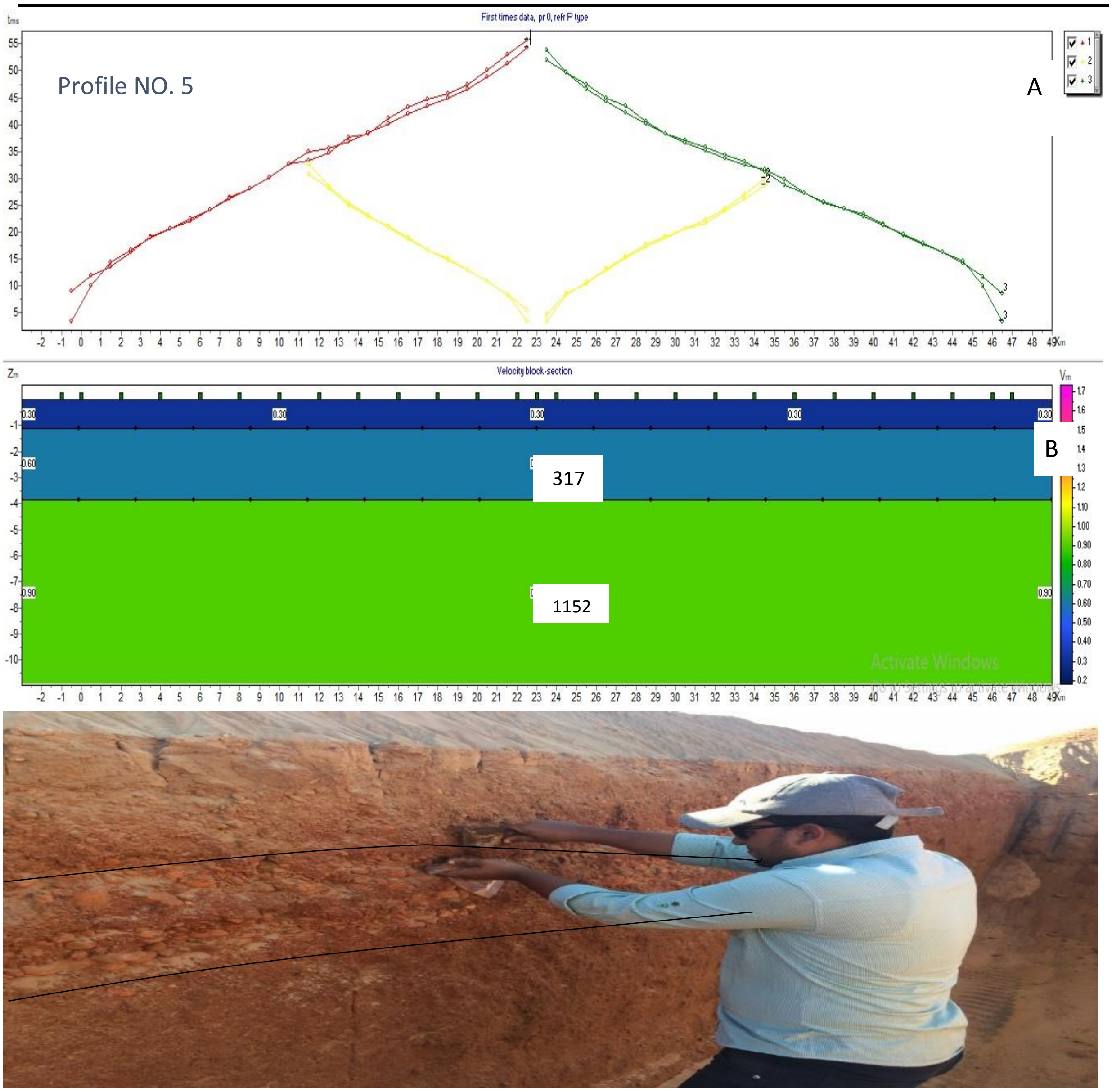


Fig. (8): Results along the seismic profile No.5 through that study area. (A) Time-distance graphs of shots along profile and (B) 2D velocity model of the underground beneath the profile, it shows the p-wave velocities and corresponding thicknesses.

The shallow section could be divided into two geo-seismic layers with S-wave velocities are ranging from 104 m/sec to 214 m/sec and P-wave velocities from 178 m/sec to 364 m/sec for the first layer. The first layer is interpreted to be the top soil of sand and gravel with thickness up to a maximum of 3.85 meters. Also, seismic wave velocities have been calculated for the second layer to range from 303 m/sec to 677 m/sec for the S-wave and P-wave velocities from 516 m/sec to 1152 m/sec (Table. 5), It is also composed significally of sand and gravel and it has thickness that varies considerably (between 3.85m to 10m).

Table (5): Distribution of seismic wave velocities along the profiles at West Kom Umpo Aswan.

Profile No.	Velocity (m/sec) for 1st layer		Velocity (m/sec) for 2nd layer		Expected type of Lithology
	P-wave	S-wave	P-wave	S-wave	
1	364	214	546	321	Sand and Gravel
2	256	150	516	303	Sand and Gravel
3	178	104	582	342	Sand and Gravel
4	250	147	686	403	Sand and Gravel
5	317	186	1152	677	Sand and Gravel

1.2- Geotechnical parameters for the investigated area:

The seismic method has emerged as a powerful tool for computing the elastic moduli allowing elastic deformation to be estimated **(**Stuempel et al 1984, Davis and Taylor 1979 and others). The soundness of rock or soil materials used for any foundation purpose is a qualitative term. The average line method (Sjogren and Sangberg 1979, Mohamed 1994) can estimate soundness and weak zones. The complete categorization of the rocks or soils in a given area, on the basis of degree of competence, has been established using both geotechnical and geophysical tools.

1.2.1- Poisson′s Ratio (δ)

The first layer is characterized by the value 0.241, while the Poisson's ratio in the second layer is characterized by the value 0.237 indicating competent materials

1.2.2 Kinetic Rigidity Modulus (μ)

The kinetic rigidity modulus in the first layer is ranged between 152.96 and 647.52, while it in the second layer is ranged between 1468.39 and 7627.48 Kg /cm2

1.2.3 - Kinetic Young's Modulus (E)

The kinetic young's modulus in the first layer is ranges between 379.33 and 1600.95 Kg /cm2. While in the second layer it ranges between 3619.99 and 18864.75 Kg /cm2

1.2.4 - Bulk Modulus (K)

The Bulk modulus of the first layer ranges between 243.71 Kg /cm2 and 1008.49 Kg /cm2 while that of the second layer ranges between 2294.36 Kg /cm2 and 11930.68 Kg /cm2

1.2.5- Ultimate Bearing Capacity (Qult)

The ultimate bearing capacity in the first layer is characterized by the minimum value (3.81 kpa) and maximum value (252.82 kpa). In the second layer the ultimate bearing capacity has values ranging between (1057.28 kpa) and (11165.70 kpa).

Table (6): shows the values of the different mechanical properties of the first layer which calculated from the different relations.

Layer	Prof No.	Vp (m/s)	Vs (m/s)	Poisson's ratio	Rigidity modulus (kg/cm^2)	Young's modulus (kg/cm^2)	Bulk's modulus (kg/cm^2)	Material index	Concentration index	Stress ratio SI	Ultimate bearing capacity (Qu) (Kpa)	Allowable bearing capacity (Qa) (kpa), F_s=3
Layer 1	1	364	214	0.236	647.523	1600.95	1008.49	0.056	5.239	0.309	3.81	1.27
	2	256	150	0.239	339.565	841.26	536.37	0.046	5.191	0.313	134.55	44.85
	3	178	104	0.241	152.957	379.33	243.71	0.037	5.152	0.317	45.98	15.33
	4	250	147	0.236	316.112	782.12	492.52	0.057	5.241	0.309	126.82	42.27
	5	317	186	0.237	489.463	1213.46	767.85	0.050	5.211	0.311	252.82	84.27
Layer 2	1	546	321	0.236	1488.79	3691.37	2324.95	0.056	5.239	0.309	1252.20	417.40
	2	516	303	0.237	1468.39	3619.99	2294.36	0.053	5.222	0.310	1057.28	352.43
	3	582	342	0.236	1692.73	4191.03	2641.06	0.055	5.232	0.309	1507.87	502.62
	4	686	403	0.237	2294.36	5679.82	3589.40	0.054	5.228	0.310	2439.80	813.27
	5	1152	677	0.236	7627.48	18864.75	11930.68	0.055	5.233	0.309	11165.70	3721.90

Geotechnical parameters from SPT after Correction

1 - Effective Friction Angle, ϕ′:

The following figure shows the profile of the effective friction angle, ϕ′ values estimated from SPT with depth for the soil layers in the West Kom Umpo site.

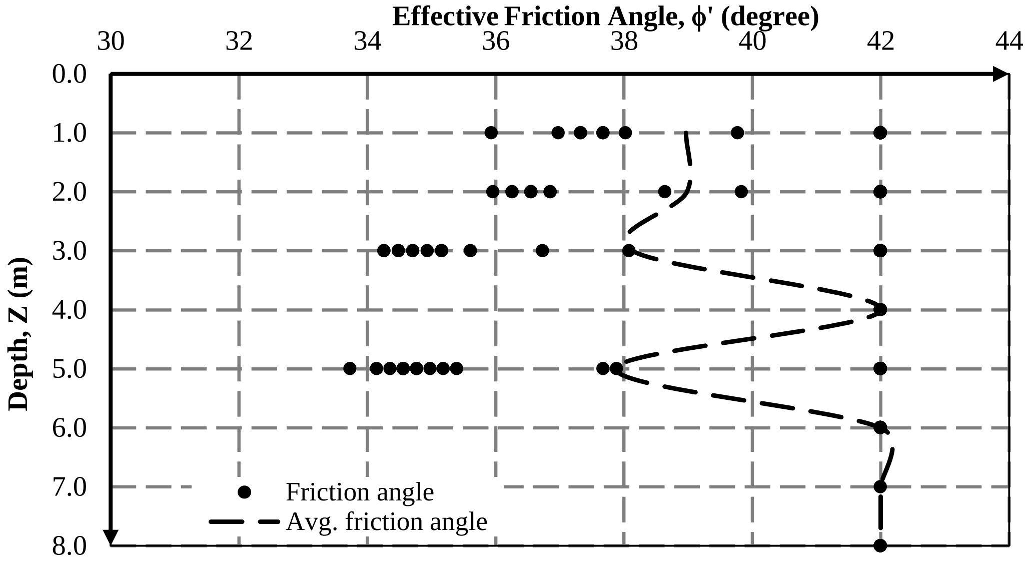


Fig. (9): Profile of effective friction angle, ϕ' with depth of the West Kom Umpo site

2 - Bearing Capacity:

The following figure shows the profile of the allowable bearing capacity obtained from SPT with depth for the soil layers in the West Kom Umpo site.

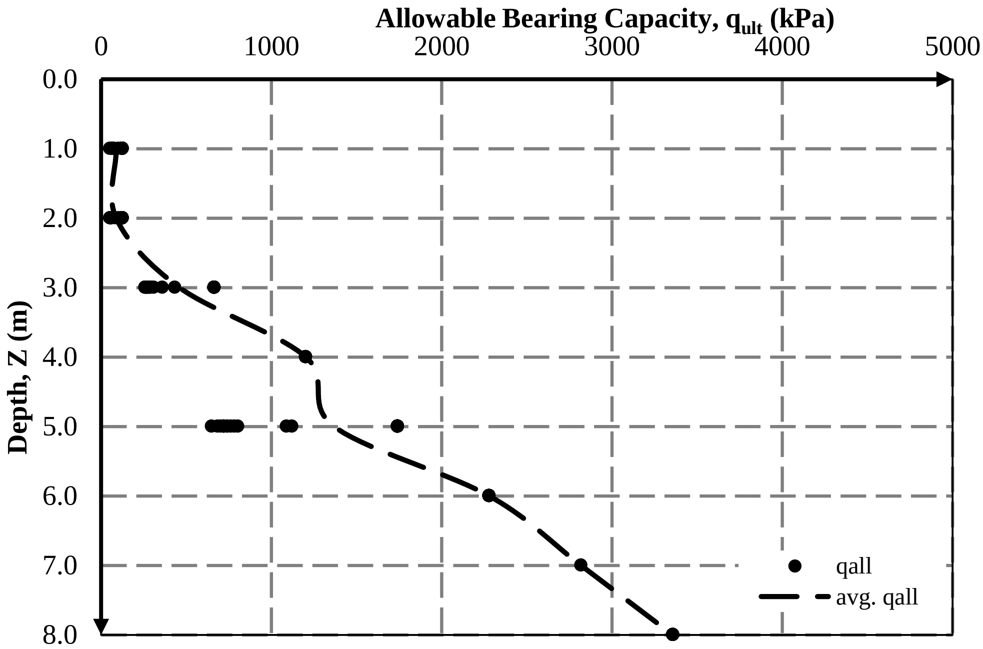


Fig. (10): Profile of allowable bearing capacity with depth of West Kom Umpo soil

3 - Modulus of Elasticity, E_s:

Fig. (11) shows the profile of the modulus of elasticity that obtained from SPT with depth for the soil layers in the West Kom Umpo.

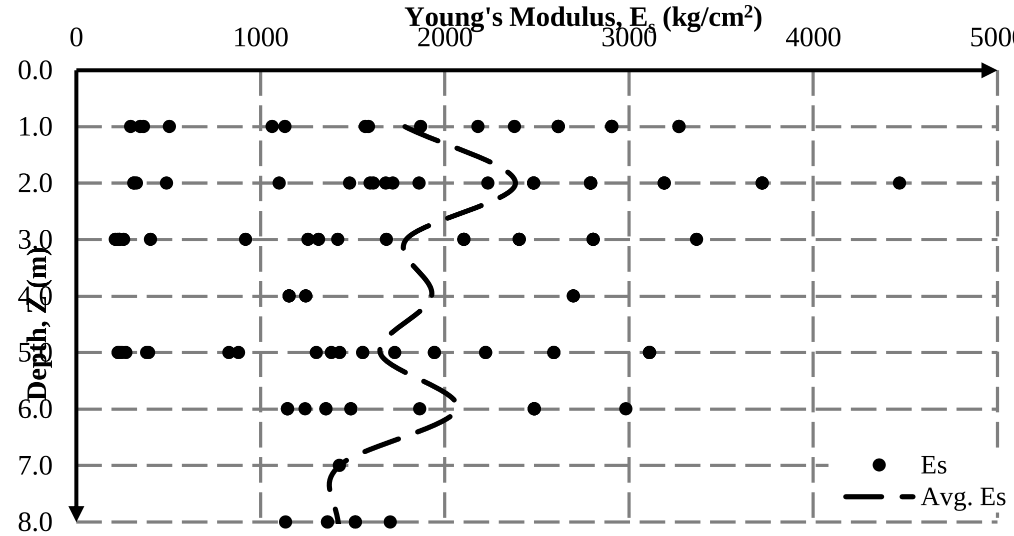


Fig. (11): Profile of modulus of elasticity, E_s with depth of West Kom Umpo soil

CONCLUSION

The present works have been carried out to study the geophysical and engineering properties about the bed soil foundations in the area of West Kom Umpo.

First: Geophysical Studies witch include Shallow Seismic Refraction, results they're as the following:

The results of seismic refraction survey at west Kom Umpo area indicate a subsurface structure that consists of two acoustic layers. The calculation of foundation material referring that the ultimate bearing capacity of the first layer is ranging between 3.81 and 252.82 kpa and in the second layer the ultimate bearing capacity is ranging between 1057.28 and 11165.70 kpa .

Second: The geotechnical properties of the ground were investigated by continuous core sampling of nine boreholes drilled to depths of up to 10m. Engineering studies on samples which collected throughout the entire length of the holes in the study area reveal that, the results of Geotechnical parameters From SPT after Correction, 1.Young's Modulus (Es) is ranging between 370 and 870 kg/cm2 and Estimation of Bearing Capacity from SPT is ranging between 24 and 35 kg/cm2 and Friction Angle, ϕ (Degree)is ranging between 37.2° and 40°

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