Geotechnical properties calculated from seismic refraction velocity and borehole information for a spillway construction

Eman[1] M. Jaafar, Ali [2] Z. Almayahi and Amer [3]A. Laftah
1,2Department of Geology/ College of Science - University of Basrah
3Department of applied Geology/ College of Science - University of Babylon
*E-mail: eman.jaafar@uobasrah.edu.iq

Abstract

Seismic refraction and engineering surveys were conducted for three selected sites, Sindbad, Sehan and Albhar sites in Basra sity. The geophysical methods and bore-hole data were gathered to conducted the aim of study. The results of seismic were compared with direct method information (pore-hole) for further credibility. Thus, 24 seismic refraction profiles were acquired at three different sites in total length of (120) m. The results of P-velocity ranging from (500-517) m/s at first layers of three sites, while ranging between (397-425)m/s at second layer, and was(527-558)m/s .The results of SH-velocity in the 1st layer of three sites ranged from (290-296)m/s at depth (1-5,6)m , while in 2nd layer are between(209-237)m/s at depth (5,16)m/s, and in the 3rd was (289-3156)m/s. The bore-hole data were collected from 6 holes allocated 2 holes at each site drilled by Al-Ma'awal Company for soil investigation with depths ranging between (1- 40) m. The study shows close behavior of SPT log and S-wave with depths at the study sites. According to SPT the consistency soil in three sites divided in to several layers 1st layer is a very stiff with bearing capacity (qa) ranged between (11- 41 T/m2) in two study sites at depths (1 to 5, 6.5 m) this layer is suitable for light loads of Shallow foundation. 2nd layer is a soft to medium stiff with (qa) ranged between (2-9T/m2) at (6, 7 to 18m) depths

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

which unsubtle for foundation because of high water content (28-30%). 3rd layer is a very stiff to hard with (qa) ranged between (12-40 T/m2) at (20 to 40 m) depths because of compaction or a static load this layer is suitable for heavy loads of deep foundation such as spillway structure. The values of bearing capacity (qa) and internal friction angle(Ø) obtained from the seismic method were close to bore hole data. The results of geotechnical parameters obtained by geophysical method and borehole information are suggest Albhar site is best serve location for a spillway construction.

Keywords: S-wave, Elastic modulus, SPT, bearing cabacity.

Introduction

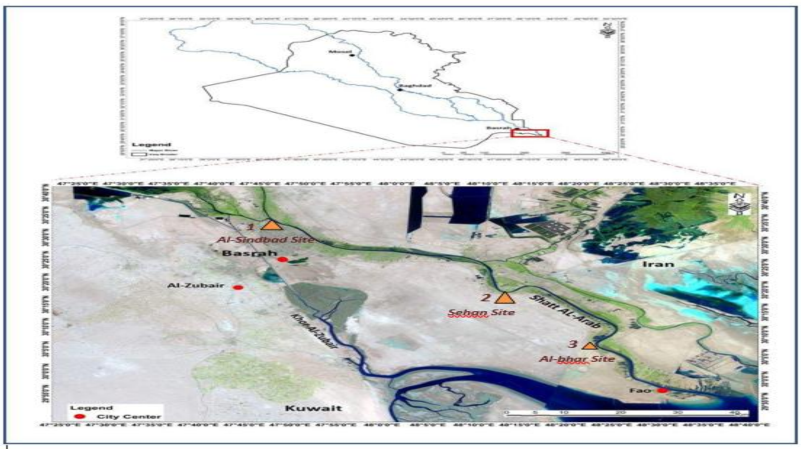
Geophysical methods are non-destructive methods that have numerous advantages in relation to geotechnical survey. They are used in underground engineering for determining geological-structural and physical-mechanical characteristics such us lithology, elastic modules, bearing capacity, porosity, water content and water conductivity of subsoil. in Seismic refraction method the energy travels through the earth and recorded on seismographs. Any medium or rock layer exposed to certain stresses, the emotions generated in that medium will be generated by flexible waves (Sjogren, 1984) There are several different types of seismic waves, and they all move in different ways. The two main types of waves are body (divided to compression P wave can move through solid rock and fluids, like water or the liquid layers of the earth and shear SH wave can only move through solid rock, and surface waves (divide to Rayleigh and Love waves) (Al-Salim, et al.,1989). The transmission of elastic waves from the source of energy (detonation, methods, etc.) to decay is subject to refraction, reflection and dispersion at the boundary between two different energies in physical properties (Yilmaz, et al., 2006). The acceleration of seismic waves is influenced by the geological factors of the medium in which it passes, such as density and elasticity properties (Khalil and Hanafy, 2008). Spillways definition as structures constructed to provide safe exit of flood waters from a dam to a

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

downstream, normally the river on which the dam has been built it. For decades Shatt Al-Arab fresh water flow into Arab Gulf salt water. In the last few years, fresh water in the river has decreased to noticeable levels due to many factors (e.g., reduced rain levels, hot weather, and construction many dams near Tigers and Euphrates rivers sources). Thus, construct a spillway which helps with regulation of fresh water to be stored in a surface reservoir on low level areas. The reserved water can be used in different aspect, irrigation, tourism, fish breeding, electrical generation, etc. Study sites are selected in three different locations adjacent to Shatt al-Arab, in province of Basra after detailed map study to Shatt Alarab course. The location of the selected sites is believed to be suitable for a proposed spillway construction. In these sites, the river course is characterized by sharp meandering features. The river flexures lead to water currents to be focused on specific pointes where the study sites are selected.

Study area

The study area is represented in three different sites, Al-Sindbad Island, Sehan, and Al-Bhar which are located at Shatt Al-Arab River banks in Basra Governorate, south east of Iraq. They are lie between Latitude (29° 45´00" N- 31° 15´ 00" N) and Longitude (47° 10´ 20" E- 48° 45´ 00" E), as shown in figure (1). The Site soil comprised mainly from the cohesive deposits of Tigris, Karun and Shat Al-Arab rivers. The nature of these alluvial clayey sediments. The importance of Quaternary deposits being a base underpins a shallow and deep foundations to various buildings and engineering constructions in Basra city and a source of many Groundwater Aquifers (Mahmood &Albbadran,2002). According to Seismic hazard map derived from the global seismic hazard map after Jassim and Goff, (2006) the investigated sites lie within the no damage zone.



www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

Fig (1) Map of study sites

Methodology

1. Seismic refraction survey

Seismic survey was conducted during the dates between 9/10/2018 to 14/10/2018. Data collection by seismic refraction method was carried out in the study areas according to the ASTM D5777 procedure that is specified to investigation for engineering purposes. 24 seismic profiles approach was performed at each site. P- and SH-wave modes of total length 120 m are acquired. The geometry is fixed as shot point at end on, end off, and center shooting of 5m offset, geophones spacing 5 m, north-south direction in Al sidebad site and east-west direction in A- Siba and Al-Bhar sites .Seismic energy source that was used to generate seismic waves is a sledge hammer of (10 kg) weight. Two types of striking plates were used. The first one is H-pile shaped 25×25cm. It is appropriate for horizontal hits. Second, flat 30×30 cm rabr plate. Auto stacking mode was turned on to save each three hits at any P-and SH-wave mode. Three strikes were enough for good signal/noise ratio enhancement, figs (2).

figs (2) generate seismic waves by H-Pile and rabr plate

2. Soil investigation

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

In order to validate the results of the geophysical methods, soil investigation was performed. Thus, six boreholes were drilled by rotary drilling method according to the American Society for Testing (ASTM, 1973) specifications. A mechanical (Flight Auger) type with a diameter of (10 cm) dig into the earth. The total depths of drilling reached to (40 m) from the surface of the natural earth (NGS). Physical and engineering properties were tested at each site. Field and Laboratory work were carried out by Al-Mawal Company for soil investigation.

Engineering Properties of soils

- Standard penetration test (SPT)
- internal friction angle (Ø)
- ground water table (W.T)

Results and discussion

1. Determination of seismic waves velocities

The first step to calculate the seismic Vp or Vs is to pick the first arrival times of the signal, called first break picking. Then, time distance curve is plotted. The plot shows the arrival times against the distance between the geophones, fig (3). On the time distance curve, the expected layers are assigned to the graph.

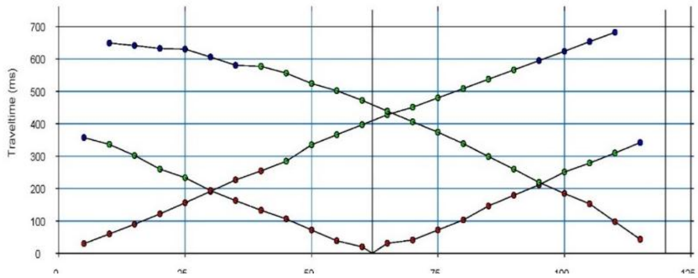


Fig (3) Seismic Refraction survey field file at Sindbad site

The time distance curves of a number of shots are appended to represent one surface seismic line and one velocity model. The seismic survey of 5 m geophone spacing showed 3 geological layers because of the wide distance between the geophones, made the penetration depth reached to the deeper layer, fig (4). The velocity of the layers at the study sites vary with depth; this may be a reflection of the variation in the composition of the subsurface materials with depth.

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

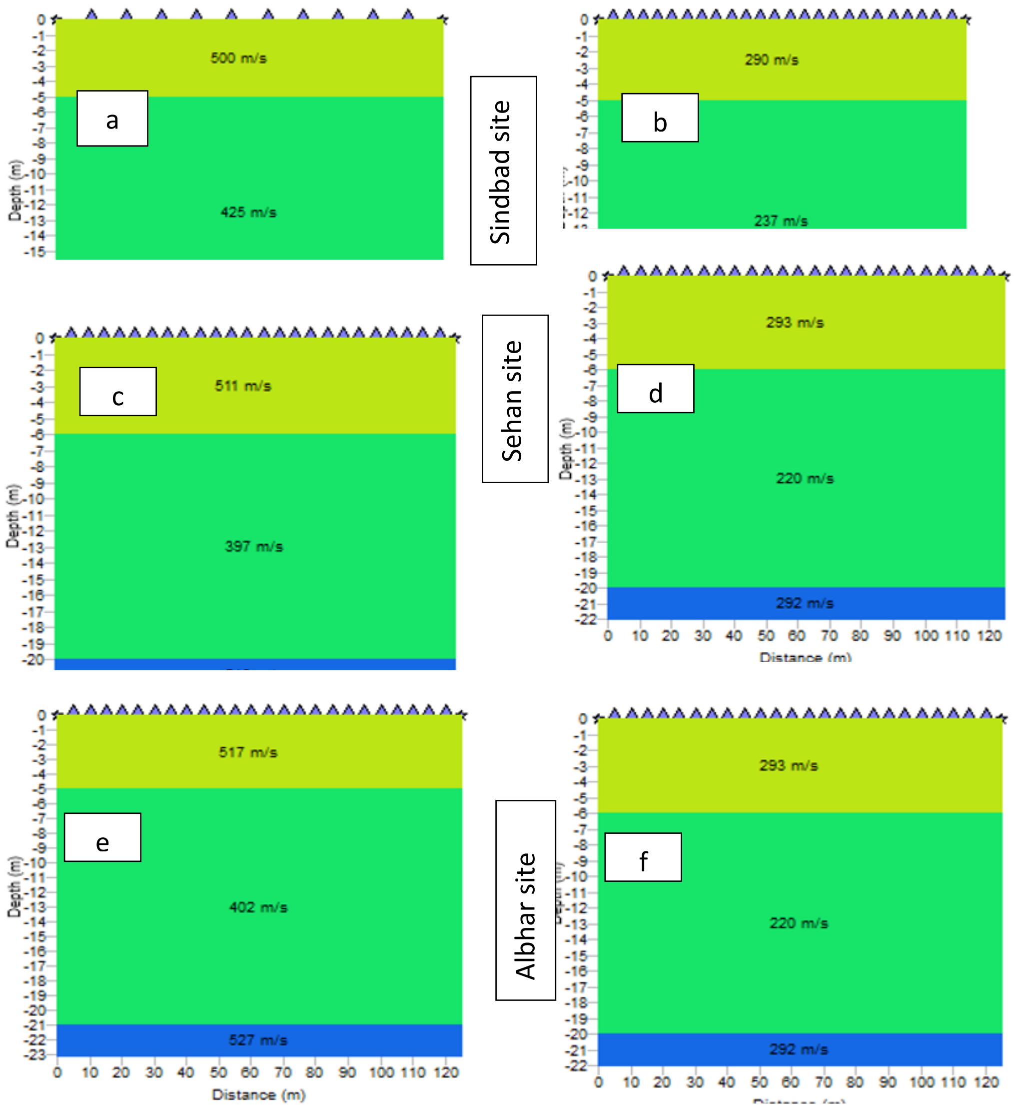


Fig (4) PW-wave and SH-wave Velocity-Depth model as a result of time-inversion Method in study sites

P and SH-w ... ated according to SiesImager software (version 2.9.1.9), while cross section model created by Refract software (version 1.0 fc 5). The results are tabulated below (Table 1)

Table (1) compression and shear waves velocities for three locations Studies

Layers No.	Al Sinbad			Sehan			Al bhar		
	Depth (m)	VP (m/s)	VS (m/s)	Depth (m)	VP (m/s)	VS (m/s)	Depth (m)	VP (m/s)	VS (m/s)
1st Layer	5	500.23	290	6	511.83	293.15	5	517.44	296.7
2nd	15	425.37	237	14	397.9	220.85	16	402.42	209.54

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

Layer									
3rd Layer	-------	558.86	316	-------	510.21	292.77	------	527.96	289.38

2. **Elastic moduli calculations**

According to the values of seismic waves velocities (VP and VS) and density (**ρ**), the elasticity moduli were calculated, table (2). The calculated values were plotted with depth in order to define the elastic characterizations variations with depth

Table (2) the calculated values of elasticity modulus at three sites

Depth (m)	**Al Sinbad**					**Sehan**					**Al bhar**				
	σ	E	G	K	M	σ	E	G	K	M	σ	E	G	K	M
		(MPa)					(MPa)					(MPa)			
1st Layer	.24	62.7	45.4	1.2	32.5	.25	90.7	55.5	3.5	74.1	.25	95.5	57.5	4.5	79.2
2nd Layer	0.27	257.6	101.1	38.7	325.1	0.27	225.5	88.2	33.4	286.5	0.31	212.3	80.7	26.3	297.9
3rd Lay	0.2٦	456.8	180.7	71.92	563.5	0.25	389.2	155.1	63.6	471.1	0.28	421.9	164.1	60.39	546.3

.

The values of poison's ratio are calculated according to its relation with

- **Poisson's Ratio σ:**

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

layers along all profiles at the study sites are illustrated in table (1) and fig(5). The difference in the Poisson's ratio **σ** relation with change the ratio between longitudinal and shear waves velocity at difference layers as shown in fig (6).

the ratio (Vs/Vp) by the following equation: -

$$\sigma = \frac{0.5(VP/VS)^2 - 1}{(VP/VS)^2 - 1} \qquad (1)$$

The ranges and mathematical mean of the Poisson's ratio for different

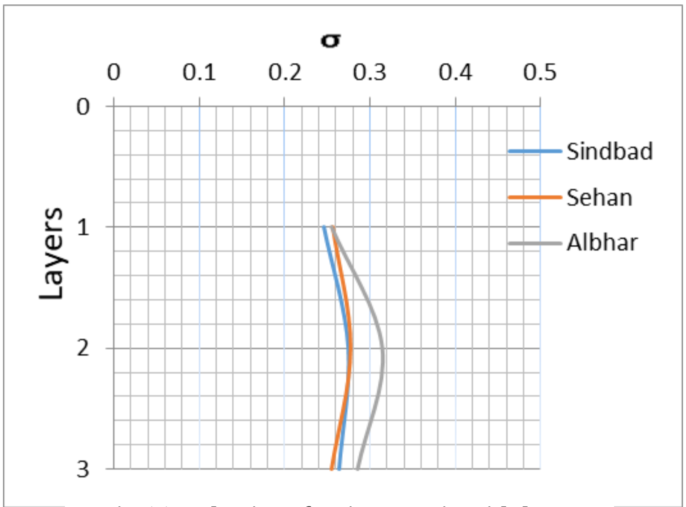


Fig (5) Behavior of Poisson ratio with layer

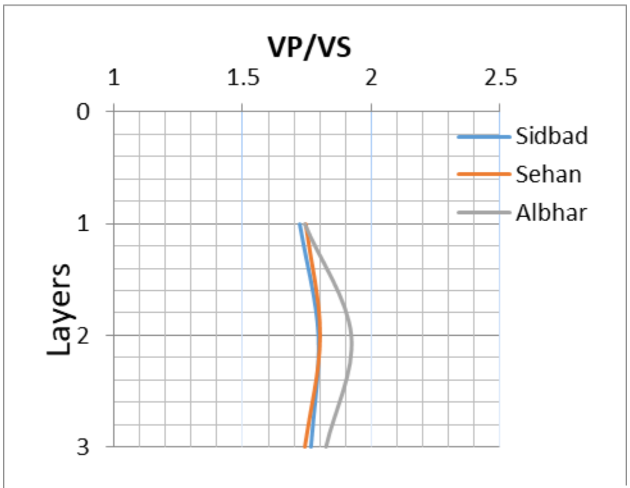


Fig (6) Vp/Vs ratio with changed layers at study sites

Poisons' ratio values at Layers lies between (0.24-0.31) because of the lithological changes, the variations in degree of consolidation, moisture content, and degree of water saturation in the soil which are consistent with engineering investigation results. The range of Poisson's ratio **σ** indicates that the sediments of these layers lies between competent to moderate competent sediments table (3). The soil of study area in three locations can be classified within ranges of clayey sand and silty sand and sand.

Table (3) Classification of soil's competent according to Poisson's ratio and material index values, after (Khalil &Hanafy2008

Soil description	Incompetent to slightly competent	Fairly to moderately competent	Competent material	Very high Competent material
Poisson's Ratio (σ)	0.41-0.49	0.35-0.27	0.25-0.16	0.12-0.03
Material Index(Im)	(-0.5) – (-1)	0.0) – ( )0.5(-	(0.5) –)0.0(	> 0.5

www.misan-jas.com (Arabic Impact Factor)- 1.1 ISSN (Paper)- 1994-697X (Online)-2706-722X

- **Young Modulus (E)**

The Young Modulus is the ratio of longitudinal stress to strain, consider an important parameter because of its relationship with the other elastic moduli. Domenico (1984) equation is used to calculate **E** modulus which depends on shear velocity Vs, density, and Poisson`s Ratio **σ**:

$$E=2(vs)^{2\rho}(1+\sigma) \quad \ldots\ldots\ldots \quad (2)$$

Young modulus (E) values ranged between 258 to 458 MPa at Sindbad location, and between (256 to 411) MPa at Sehan location, and ranges from 248 to 450 at Albhar location. Variations of Young modulus values with layers are represented by Figure (7). The Young modulus increase proportionally with seismic waves velocity and soil Cohesion.

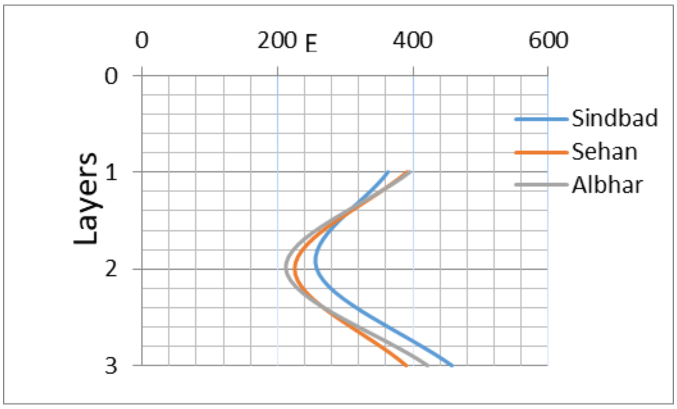


Fig (7) Variation of Young modulus with changed layers at study Locations

- **Shear or Rigidity modulus (G):**

The shear modulus refers to deformation by shearing force. Shear-wave velocity is direct proportional with shear modulus that increases the confidence in geotechnical Parameters calculations. Shear modulus is similar to Young modulus (E) increase with cohesion and stiffness of soil (Ameen, 2006). Shear-modulus is calculated by using Domenco’s (1986) equation:

$$G = (VS)\ 2\ \rho \quad \ldots\ldots\ldots \quad (3)$$

The shear modulus values ranged from (101 to 181) MPa in Sindbad location and (104 to 181) MPa in Sehan location, and between 98 MPa to 179 MPa in Albhar location, table (2). From figure (8), it can be noticed that

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

shear modulus increase in first and third layer for three locations. It reflects high values of cohesion, stiffness, and compaction for soil. However, it decreases in the second layer at those locations.

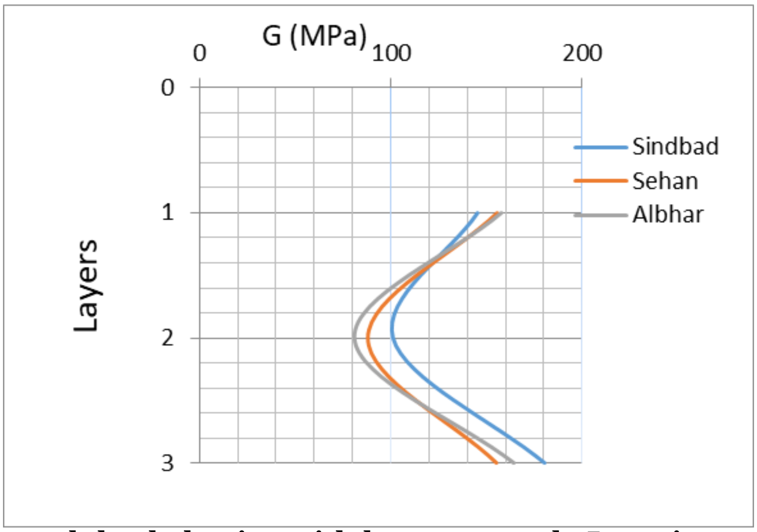


Fig (8) Shear modulus behavior with layers at study Locations

- Constrained modulus (M):

The constrained modulus is commonly used to study the settlement behavior of soils. Calculated settlement is inversely proportional with seismic longitudinal velocity and porosity, calculated by the following equation (Mark, et al, 2010):

$$M = \rho \ Vp^2 \quad \dots\dots\dots (4)$$

The constrain modulus (M) values range from 9325 to 565) MPa in Sindbad location and (292 to 504) MPa in Sehan location, and between (301 to 547) MPa in Albhar location. Figure (9) explains the relationship between the constrained modulus and depth in the three sites. It shows high values of constrained Modulus in the first and third layers. These values may because of cohesion and Stiffness Corporation with weak to moderate layer which showed lower value.

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)- 1994-697X (Online)- 2706-722X

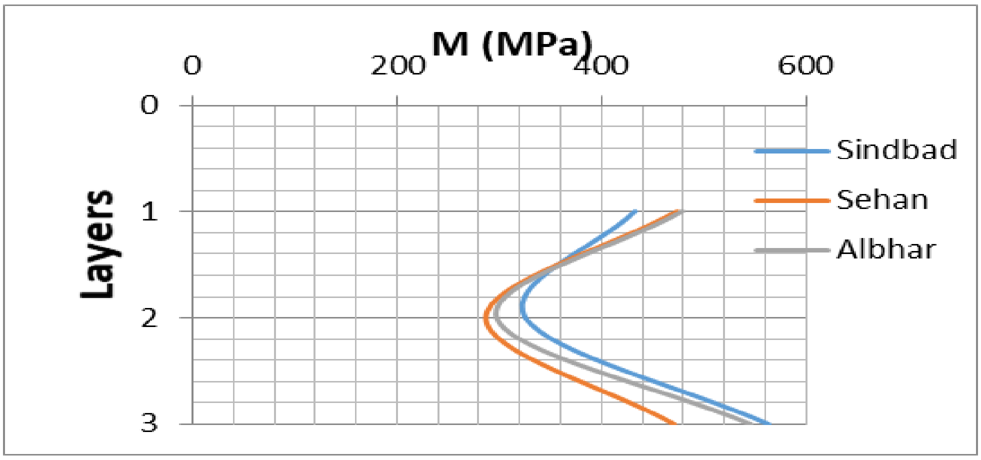


Fig (9) constrained modulus values variation with Layers at Study locations

in Albhar location. Figure (10) explain the relationship between bulk modulus and depth in the three sites. The configuration of the bulk modulus behavior is high level in the 1st layer and decrease in the 2nd layer, and then elevated back again in 3rd layer. These changes in the bulk modulus may be related to lithological and geotechnical properties (e.g., cohesion, stiffness, and water content for soil study). This values setting indicate that the ١st and 3rd layers of good geotechnical properties. In contrast, the 2nd layer shows a poor geotechnical property.

- **Bulk modulus (K)**

Bulk (incompressibility) modulus is an important modulus that is compatible with VP velocity. It can be calculated from Equation () that relates Young modulus (E) and Poisson`s Ratio (**σ**) with Bulk modules, (Obert and Duvall 1967):

$$K= E / 3 (1-2\sigma) \quad .... (5)$$

The bulk modulus (K) values ranged from (39 to 72) MPa in Sindbad location and (47 to 65) MPa in Sehan location, and between (40 to 73) MPa

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

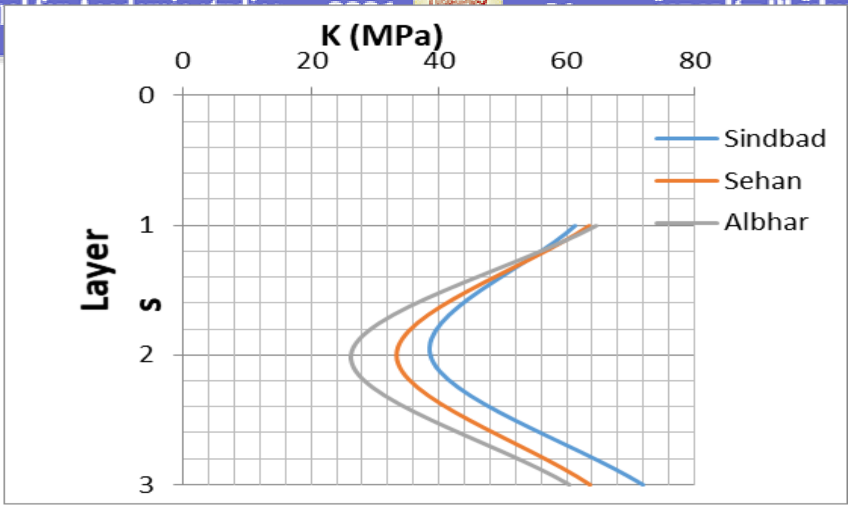


Fig (10) bulk modulus values variation with layers at study locations

3. GeotechnicalProperties

In order to assess the suitability of the subsurface conditions for engineering buildings, the engineering parameters of shallow soil were computed from the values of P-wave velocity (VP), S wave velocity (VS), density (ρ). Poisson's Ratio (σ), Young's Modulus (E), and the Shear Modulus (μ) are required. From the acquired seismic refraction profiles both of P- and S wave velocities were obtained. The density values are extract from laboratorial analysis of soil samples collected from the available boreholes; the elastic moduli values are calculated from the equations listed in table (2). Six geotechnical parameter were computed: The material index (IM), Coefficient of Lateral Earth Pressure at Rest (KO), Concentration Index (Ic), Effective Angle of internal Friction (Ø), Ultimate Bearing Capacity (qult), and Safety Factor (SF). The tables (4,5 and 6) explain the values of the calculated geotechnical properties.

Table (4) values of geotechnical properties for soil in Sindbad Site.

Depth (M)	(IM)	(Ic)	(KO)	(Ø)	(qult) T/M^2	SF
1st layer	-0.32	0.98	0.32	33	20.0	2.5

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)- 1994-697X (Online)- 2706-722X

2nd layer	-0.37	1.13	0.37	20	17.0	2.5
3rd layer	-0.35	1.07	0.35	37	30.1	2.5

Table (5) values of geotechnical properties for soil in Sehan site.

Depth (M)	(IM)	(Ic)	(KO)	(Ø)	(qult) T/M^2	SF
1st layer	-0.34	1.03	0.34	32	21.2	2.5
2nd layer	-0.38	1.15	0.38	22	15.9	2.5
3rd layer	-0.40	1.22	0.40	36	22.0	2.5

Table (6) values of geotechnical properties for soil in Albhar Site.

Depth (M)	(IM)	(Ic)	(KO)	(Ø)	(qult) T/M^2	SF
1st layer	-0.34	1.02	0.34	32	21.2	2.5
2nd layer	-0.45	1.37	0.45	24	15.4	2.5
3rd layer	-0.39	1.19	0.39	35	22.6	2.5

- **Material Index (IM)**

Material index (IM) is an important geotechnical index because it represents competence of soil as a foundation materials, and it is derived from to the ratios of (μ/ K) and (λ / K) . The material index calculated by using to the following equation (Yasig, 2011):

$$IM = \frac{3\,(VS / VP)^2 - 1}{1 - (VS / VP)^2} \quad \ldots\ldots\ldots\ldots (6)$$

The ranges of material index for different layers along all profiles are illustrated in table (4, 5 and 6). The tabulated values are ranged from (-0.32 to -0.37) in Al Sinbad

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)- 1994-697X (Online)-2706-722X

site and from (-0.28 to- 0.4) in Sehan site, and from (-0.33 to -0.34) in Albhar site. The resulted values indicate that study sites are fairly to moderately competent soil because the clay is mixed with silt and sand. Figure (11) shows the behavior of material index with depth at three locations.

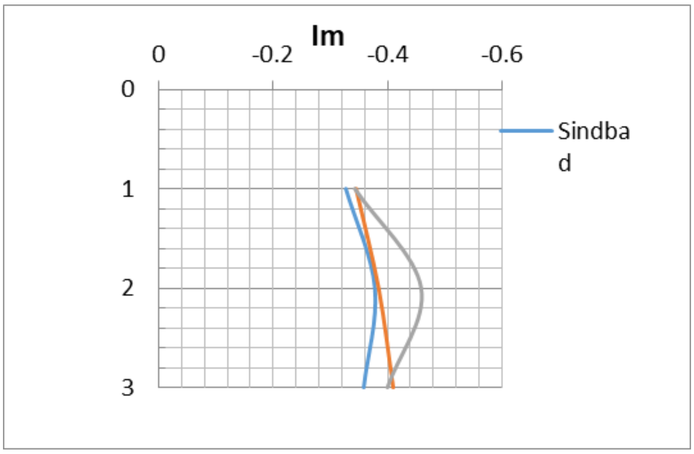


Fig (11) Material Index IM variation with depth at study locations

- **Concentration Index (Ic)**

Concentration index utilize to measure the qualification of foundation and other engineering targets. The computed values determined through the relationship between Vp and VS values equation (Al-Khafaji, 2004)

$$I_c = \frac{3- 4\,(vs/vp)^2}{1-2\,(vs/vp)^2} \quad \text{.........} \quad (7)$$

Concentration index Ic ranges from (0.97 to 1.12) at Al Sindbad site and between (0.84 to 1.22) at Sehan site and between (0.99 to 1.03) at Albhar site. These natural values of soil study site refer to the normal density, stiffness and naturally cohesion of soil, fig (12).

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)- 1994-697X (Online)- 2706-722X

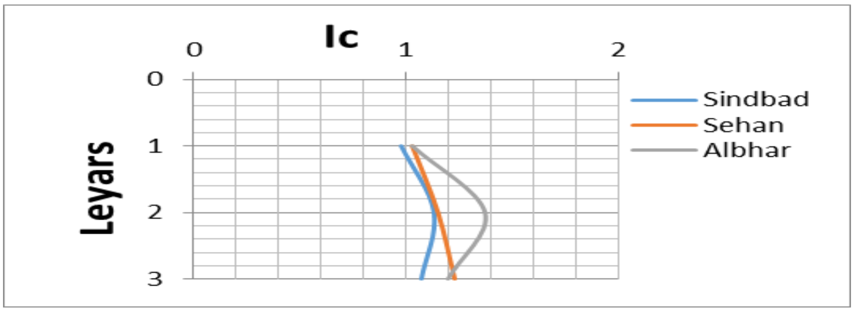


Fig (12) Relation between concentration index and depth for three

- Coefficient of Lateral Earth Pressure at Rest (Ko)

This geotechnical parameter is derived from (Vs/Vp) ratio by equation :((Bishop 1968)

$$K_O=1-2[VS\ VP]^2 \ldots\ldots\ldots (8)$$

Calculated values of Lateral Earth Pressure at Rest are shown in the tables (4, 5 and 6). The tabulated values are ranged from (0.32 to 0.37) in Al Sinbad site and from (0.28 to 0.4) in Sehan site and from 0.33 to 0.34 in Al bhar site. Thus, the soil type at the three sites are classified as over–consolidated clay to dense sand. Figure (13) shows relationship of Ko values variation with depth.

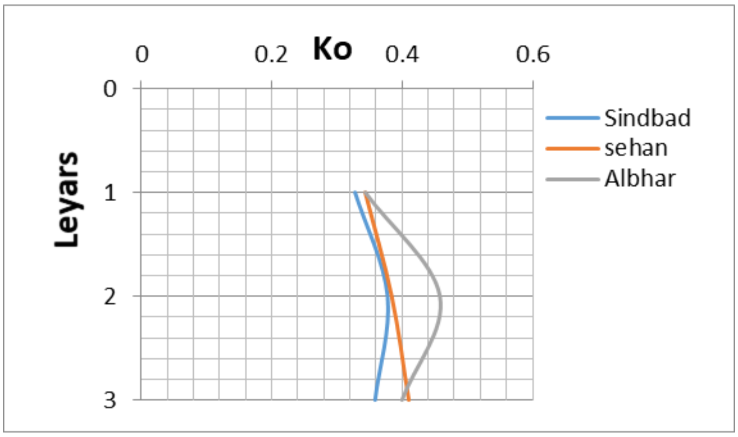


Fig (13) Relationship between coefficients of lateral earth pressure at rest (Ko) and depth in study locations

- Effective angle of internal friction (Ø)

Important factors are effect on friction angle: density, water content, shape of grain and mineral

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

composition. The internal friction angle (Ø) can be calculated by using P- and S-wave velocities by the equation: **SinØ = 2 [VS VP] ^{2}……… (9)** (Al-khafaji, 2010)

The values of Ø in Tables (4, 5 and 6) ranged from (20^o to 37^o) in Sinbad site, and from (22 to 36$^{o)}$ in Sehan site, and from (24^o to 35 ^{o}). These values vary with depth as shown in Figure (14).

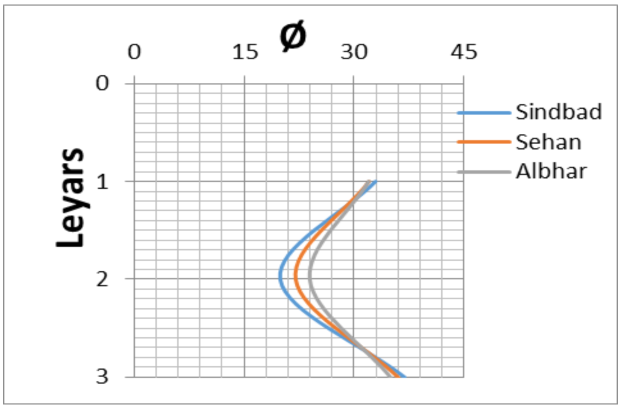


Fig (14) Relationship between Depth and Ø in the both locations

From the figure (14) above it can be noticed instability values. this is due to the difference in moisture content, density and shape of grain-mineral composition. The resulted values according to table (7) articulate that the first layer type at three locations is dense (silty and clayey sand). The second layer is considered loose (clayey and silty sand) , The third layer is dense silty sand with . Also, it is clear that values instability may be a result of the difference in moisture content, density and shape of grain-mineral composition.

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

Table (7) true angle′s typical range of internal frictions Ø values for several soil types (Bowles, 1988).

Soil type Loose	Ø		Soil type Dense	Ø	
	Dense	Loose		Loose	Dense
Gravel	32 – 36	35 – 50	Fine sand	27 – 33	33 – 39
Coarse sand	32 – 38	35 – 48	Sandy gravel	30 – 38	36 – 45
Clayey sand	28 – 32	35 - 40	Gravely sand	30 – 38	36 – 50
Silty sand	28 – 32	32 - 38	Silt	20 – 30	25 – 32
Gravel	32 – 36	35 – 50	Fine sand	27 – 33	33 – 39

- **Ultimate Bearing Capacity (qult)**

The Ultimate Bearing Capacity are considered as the main object of geotechnical properties because it indicates the soil ability to accommodate the applied loads. Thus, it gives the limits that should not be reached to avoid a structure failure. The (qult) was calculated by using the equation below :

$$qa = \frac{\gamma Vs\ (0.1)}{Fs} \quad KN/m^2 \qquad \dots\dots\dots\dots(10)$$

which explain the relationship between (Vs) and depth. The (qult) in Sindbad site is (20.1 T/m^{2}) at 1st layer while in Sehan site is (20.3 T/m^2) and (21.2 T/m^2) in Albhar site. At 2nd layer of three sites the (qult) ranging between (17.1, 17.4 and 17.0) respectively. At 3rd layer the (qult) reached to (30.1, 22.6 and 23.7) respectively. Figure (15) shows the close relationship between the qult extract from VS and SPT through layers.

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)- 1994-697X (Online)- 2706-722X

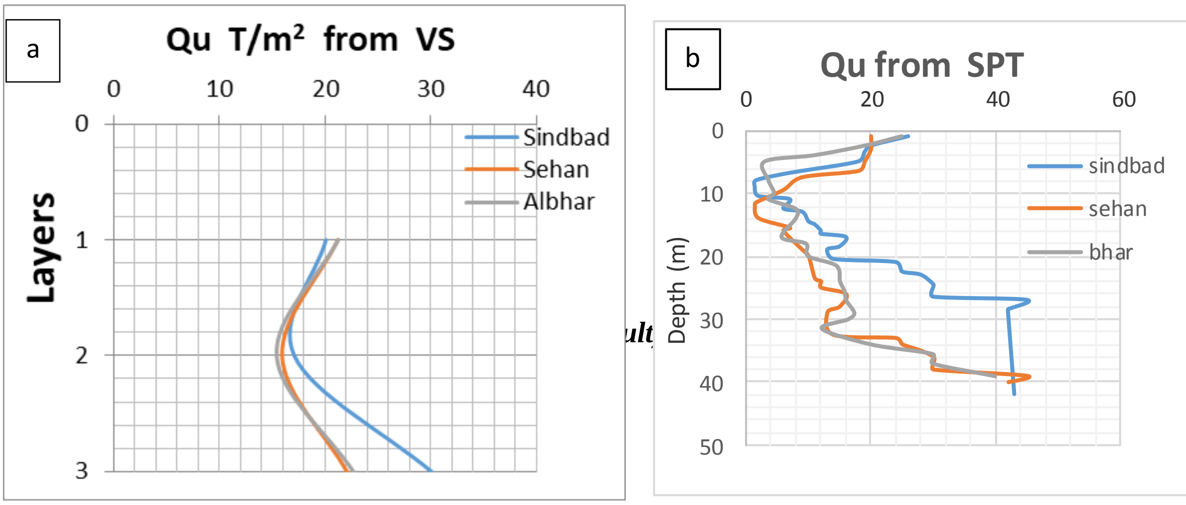


Figure above shows the variation of (qult) value with depth because of heterogeneity of soil and different in compaction and water content. The values of bearing capacity achieved results close with the results measured from borehole data.

- Safety Factor (SF)

Safety factor is the ability of structure capacity system to be applicable beyond its expected or real loads. Thus, to avoid the engineering problems that may occur in future. The safety factor (SF) is calculated based on seismic wave velocity and VP/VS ratio. The SF about is 92.5) in the studied sites. Fig (16) shows the elastic modulus and geotechnical properties of study sites.

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)- 1994-697X (Online)- 2706-722X

Depth	Sehan site
1 2 3 ٤ 5 6	Sandy silty clay soil E = 390.7 MPa -High G =155.5 MPa – High K = 63.5 MPa - High M = 474.1 MPa - High σ = 0.25 competent Im = -0.34 Competent Ic = 1.03 Ko = 0.34 Ø= 32 Silty Sand Qu=21.2 T/M^2 V.Stiff SF = 2.5
٧ ٨ ٩ ١٠ ١١ ١٢ ١٣ ١٤	Silty sandy clay Soil E =225.5 MPa -Medium G =88.2 MPa Med. K = 33.4 MPa Med. M = 286.5 MPa Med. σ =0.27 M.Competent Im =-0.38 M.competent Ic = 1.15 Ko = 0.38 Ø = 22 Silt Qu = 15.9 T/M^2 Stiff SF = 2.5
١٥ ١٦ ١٧ ١٨ ١٩ ٢٠ ٢١ ٢٢ ٢٣ ٢٤ ٢٥ ٢٦ ٢٧ ٢٨ ٢٩ 30	Silty sand clay , silty sand soil E = 389.2 MPa High G =155.1 MPa High K = 63.6 MPa High M = 471.1 MPa High σ = 0.25 Competent Im = -0.40 competent Ic = 1.22 Ko = 0.40 Ø = 36 Silty Sand Qu = 22 T/M^2 V.Stiff SF = 2.5

Depth	Sindba site
1 2 3 ٤ ٥	Silty Sand Soil with Clay E = 362.7 MPa - High G = 145.4 MPa - High K = 61.2 MPa - High M = 432 MPa - High σ = 0.24 competent Im= - 0.34 competent Ic = 0.98 Ko = 0.32 Ø= 33 Silty Sand Qu= 20 T/M^2 V.Stiff SF= 2.5
٦ ٧ ٨ ٩ ١٠ ١١ ١٢ ١٣ ١٤ ١٥	Clayey Silt and loose silty sand Soil E =257.6 MPa Medium G =101.1 MPa Med. K = 38.7 MPa Med. M = 325.1 MPa Med. σ = 0.27 M.competent Im=-0.45 M. competent Ic= 1.13 Ko=0.37 Ø= 20 Silt Qu= 17 T/M^2 Stiff SF=2.5
١٦ ١٧ ١٨ ١٩ ٢٠ ٢١ ٢٢ ٢٣ ٢٤ ٢٥ ٢٦ ٢٧ ٢٨ ٢٩ ٣٠	Clayey silt, silty clay, Silty Sand soil E = 456.8 MPa High G = 180.7 MPa High K = 71.92 MPa High M = 563.5 MPa High σ = 0.26 =Competent Im=-0.39 competent Ic = 1.07 Ko = 0.35 Ø =37 Slity Sand Qu = 30 T/M^2 V.Stiff SF=2.5

Depth	Al-bhar site
1 2 3 ٤ ٥	Sandy silty clay soil E = 395.5 MPa - High G = 157.5 MPa –High K = 64.5 MPa-High M = 479.2 MPa-High σ = 0.25 Competent Im = -0.34 Competent Ic = 1.02 Ko = 0.34 Ø = 32 Silty Sand Qu = 21.2 T/M^2 V.Stiff SF = 2.5
٦ ٧ ٨ ٩ ١٠ ١١ ١٢ ١٣ ١٤ ١٥	Silty sandy clay soil E =212.3 MPa-Medium G =80.7 MPa Med. K = 26.3 MPa Med. M = 297.9 MPa Med. σ = 0.31 M. competent Im = -0.45 M.competent Ic = 1.37 Ko = 0.45 Ø = 24 Silt Qu = 15.4 T/M^2 Stiff SF = 2.5
١٦ ١٧ ١٨ ١٩ ٢٠ ٢١ ٢٢ ٢٣ ٢٤ ٢٥ ٢٦ ٢٧ ٢٨ ٢٩ ٣٠	Silty sand clay , silty sand soil E = 421.9 MPa High G =164.1 MPa High K = 60.39 MPa High M = 546.3 MPa High σ = 0.28 M.Competent Im = -0.39 competent Ic = 1.19 Ko = 0.39 Ø = 35 Clayey Sand Qu = 22.6 T/M^2 V.Stiff SF = 2.5

- **Borehole information**

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)- 1994-697X (Online)- 2706-722X

For the purpose to consider multi-layer of evidence, borehole information was considered and gathered with seismic data. The borehole information was collected at the study sites and the nearby borehole test. Thus, we considered data mating for particular parameters that are traditionally collected boreholes test. The comparable factors were Ø and qa. The compared values are tabulated in Table (8).

Table (8) the calculated Ø values from seismic and borehole data

Depth (m)	Ø (borehole data) Sindbad site		Ø (borehole data) Sehan site		Ø (borehole data) Albhar site	
	seismic	Borehole	seismic	Borehole	seismic	Borehole
3-3.5	--	19^{o}	--	16	--	5
4.5-5	33	21^{o}	32	7	32	6
19-20.5	20	22^{o}	22	27^{o}	24	29^{o}
23-23.5	37	25^{o}	36	31^{o}	35	33^{o}
34-34.5	--	37	--	36^{o}	--	37^{o}

S

tandard penetration test (SPT)

It is usually used in geotechnical field test on land it indicates to soil consistency and soil characteristics. The results of standard penetration test in study locations shown in tables (10, 1, and 12). The equation that is used for N values correction as the below:

Nc = 15+ 0.5 (N-15) ……. (11)

The results in (Table 9,10,11) shows N values ranged (9-30) in (2-6m) depth, and between (1.4-9) in (7-20 m) depth, While range d (14-50) in (20-40m). Fig (17) show close behavior of SPT log and S-wave with depths at the study sites.

- **Bearing capacity (qa)**

Bearing capacity values ranged between (11-41 T/m^2) in (2-6 m) depth and between (2-9 T/m^2) in (7-20 m), while ranged (12-50 T/m^2) in (20-40 m) depth. This results approach the values of bearing capacity which resulted from seismic velocity. The layers of soil in the study sites depending on bearing capacity (Table 9) divided into three layers: The first layer is a stiff to very stiff in three study sites and ranged between (2 to 6

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

m) depths because of compaction and high contain of sand, silt with clay. The second layer is a soft to medium stiff which ranged between (7 to 18m) because of water content and high range of clay. The third layer is very stiff to hard and ranged between (20to 40 m) depths due to increase the bulk density with depth as a result of compaction or load of the layers with appears dense silty sand strata.

Table (9) approximate correlation between standard penetration test (SPT), consistency and of clay and silt. [8] Ultimate bearing capacity and

Consistency	Standard Penetration Test N-value	qu	
		Ton/m^2	kN/m^2
Very Soft	<2	<2.5	<25
Soft	2 – 4	2.5 – 5	25 – 50
Medium stiff	4 – 8	5 – 10	50 – 100
Stiff	8 – 15	10 – 20	100 – 200
Very Stiff	16 – 30	20 – 40	200 – 400
Hard	>30	>40	>400

Table (10) the values average of N and bearing capacity to BH1, BH2, and BH$_3$ and consistency of Al Sinbad soil locations

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

Depth (m)	Average SPT(N) Total	Ave. Qa T/M²	consistency	Depth (m)	Average SPT(N) Total	Ave. Qa T/M²	consistency
1.0	25	٢٠	V. Stiff	16.5	8	١٢	Stiff
2.5	23	٢٠	V. Stiff	17.0	٩	١٦	Stiff
3.5	١٠	19	V. Stiff	18.5	٨	١٥	Stiff
٥	٩	١٨	V. Stiff	19.0	9	١٣	Stiff
6.5	٧	٩	M. Stiff	20.5	١١	١٤	Stiff
7.0	٥	٦	M. Stiff	21.0	١٤	٢٤	V. stiff
8.0	3	1.6	Soft	22.5	١٥	٢٥	V. stiff
9.0	2	1.4	Soft	23.0	15	٢٨	V. stiff
10.5	4	2	Soft	24.5	24	٣٠	V. stiff
11.0	٦	٧	M. Stiff	25.0	19	٣٠	V. stiff
12.5	٥	٦	M. Stiff	26.5	37	٣٠	V. stiff
13.0	٧	٩	M. Stiff	27.0	52	٤٥	Hard
14.5	٨	١٠	M. Stiff	28.5	50	٤٢	Hard
15.0	١٠	١١	Stiff	29.0	50	٤٢	Hard
16.0	١١	١٢	Stiff	42.0	٥٠	٤٣	Hard

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

Table (11) the values average of N and bearing capacity to BH1, BH2, and BH_3 and

Depth (m)	**Average SPT(N) Total**	**Ave. Qa T/M^2**	**consistency**	**Depth (m)**	**Average SPT(N) Total**	**Ave. Qa T/M^2**	**consistency**
1.0	٣٠	32	V.stiff	24.0	١٩	8.8	V.Stiff
3.0	٢٠	٢٥	V. Stiff	25.0	27	١٦	V. Stiff
5.0	١٤	19	Stiff	26.0	25	١٥	V. Stiff
6.5	٩	١١	Stiff	28.0	٢٦	١٣	V. Stiff
7.5	3	1.6	Soft	29.0	٢٥	٣٠	V. Stiff
9.5	3	1.6	Soft	32.5	١٥	١٥	Stiff
11.5	8	4.0	M.Stiff	33.0	٥٠	٢٥	Hard
12.0	6	3.0	M. Stiff	34.0	٥٠	٢٨	Hard
14.0	5	2.6	M. Stiff	35.0	٥٠	٣٠	Hard
15.5	4	2.0	Soft	36.0	٥٠	٣٠	Hard
16.0	7	3.6	M. Stiff	37.0	٥٠	٣٠	Hard
19.0	13	6.7	Stiff	38.0	٥٠	٤٥	Hard
20.0	١٤	9.3	Stiff	39.0	50	٤٢	Hard
23.5	٣١	12.0	Hard	40	50	٤٢	Hard

consistency of Sehan soil location

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

Table (12) the values average of N and bearing capacity to BH1, BH2, and BH_3 and consistency of Al Bhar soil location

Depth (m)	Average SPT(N) Total	Ave. Qa T/M²	consistency	Depth (m)	Average SPT(N) Total	Ave. Qa T/M²	consistency
1.0	٢٧	٤١	V.stiff	21.5	24	10	V.Stiff
2.5	٢٢	٢٥	V.stiff	24.0	41	14.5	Hard
4.0	١٦	19	V.stiff	25.5	43	15.1	Hard
5.0	٩	١١	Stiff	27.0	46	15.8	Hard
8.0	6	3.0	M.Stiff	29.0	٤٧	16.1	Hard
10.0	7	3.6	M.Stiff	30.0	31	17.4	Hard
11.0	8	4.5	M.Stiff	31.5	48	16.4	Hard
12.5	7	3.6	M.Stiff	34.0	٣٢	12.2	M.Stiff
14.0	8	8.0	M.Stiff	35.5	36	20.2	M.Stiff
17.0	8	8.0	M.Stiff	٣٧	٥٠	٣٠	Hard
18.0	7	5.7	M.Stiff	٣٩	50	٣٠	Hard
20.0	22	9.6	V.stiff	٤٠	٥٠	٤٠	Hard

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

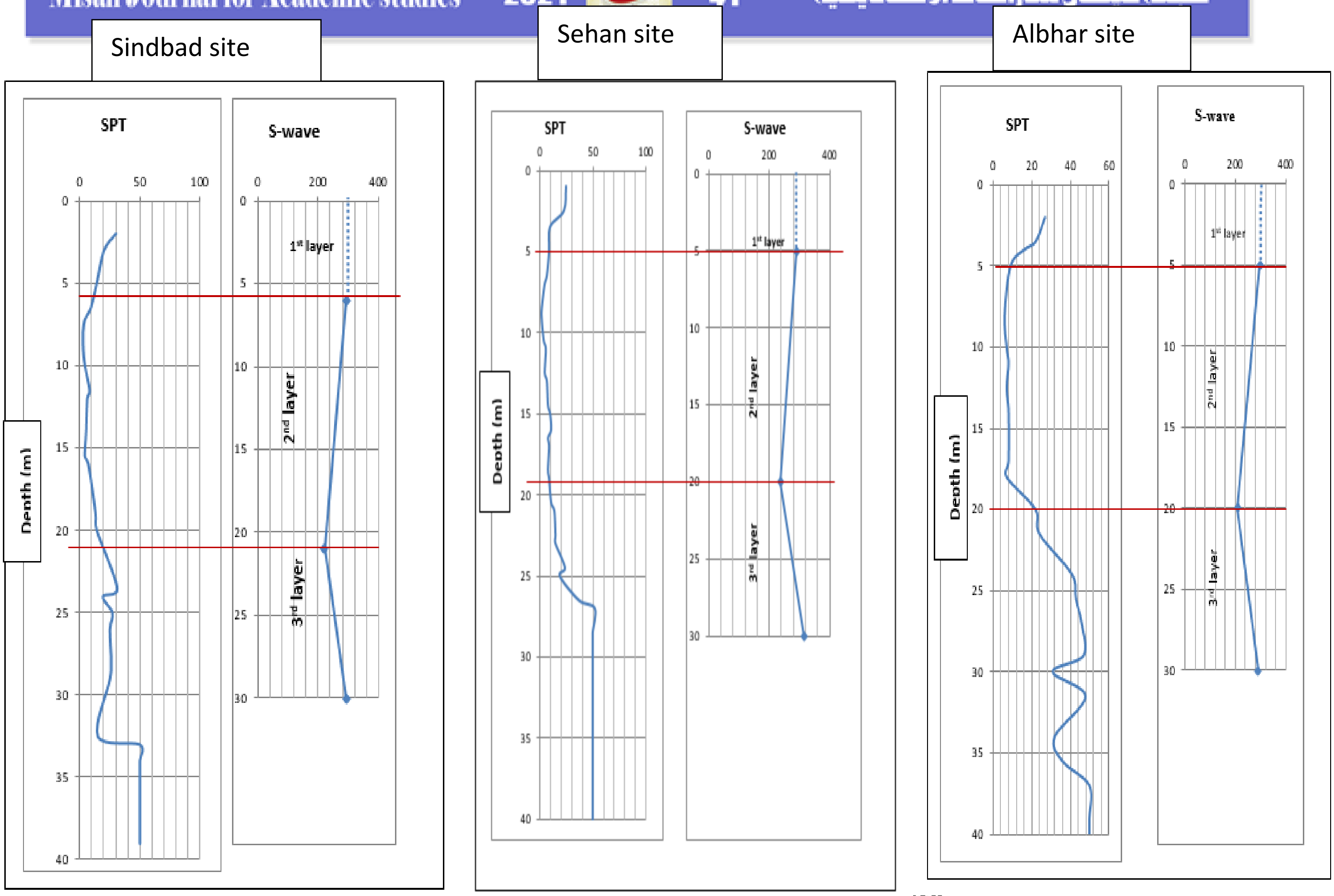


Fig (17) SPT and S-wave velocity with depth in Al bhar site

- **Ground Water Table Observation (W.T)**

The underground water level was measured at end of boring at the time of sub-soil investigation (April, 2017) from the natural ground surface Table (13). The specified depth was fixed after 24 hours of boring termination. However, this depth fluctuates during the seasons of the year.

Table (13) the ground water level

Study sites	The date of measurement	ground water table W.T (m)	Bored method	Bored Depth (m)	Bored Diameter (m)	BH.NO
Sindbad	April -2017	1.7	Flight Augers	40	0.10	1
	=	1.8	=	40	=	2
Sehan	April -2017	3.10	Flight Augers	40	0.10	1
	=	3.20	=	40	=	2

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

Al-Bhar	April -2017	3.30	Flight Augers	40	0.10	1
	=	3.40	=	40	=	2

Conclusions

1. Seismic and engineering surveys were conducted for three selected sites, and three layers were identified Sindbad site, Sehan site and Albhar site.

- The seismic wave velocities in Sindbad site are detailed as the following:

a. The compressive wave velocities Vp for layers was 500.23 m/s in Sindbad site ,425.37 m/s in Sehan site and 558.86 m/s, in Albhar site

b. The shear wave velocities Vs. for layers were 290 m/s, 237 m/s and 316 m/s, respectively.

- The seismic wave velocities in Sehan site are detailed as the following:

a. The compressive wave velocities Vp for layers was 511.83 m/s, in Sindbad site 397.9 m/s in Sehan site and 510.21 m/s in Albhar site.

b. The shear wave velocities Vs. for layers were 293.15 m/s, 220.85 m/s and 292.77m/s, respectively.

- The seismic wave velocities in Albhar site are detailed as the following:

a. The compressive wave velocities Vp for layers was 517.44 m/s in Sindbad site, 402.42 m/s in Sehan site and 527.96 m/s in Albhar site.

b. The shear wave velocities Vs. for layers were 296.7 m/s, 209.54 m/s and 289.38m/s, respectively.

2. Elasticity moduli to the sites of Sindbad, Sehan and Albhar are calculated from seismic velocities: Young modulus E, Bulk modulus K, Shear modulus G, constrained modulus M, and Poisson's ratio **σ**.

3. The geotechnical properties for soil to the sites of Sindbad, Sehan and Al bhar are calculated: Material Index Im, Coefficient of Lateral Earth Pressure at Rest Ko, Concentration Index Ic, effective angle of internal friction Ø, safety factor SF and Ultimate Bearing Capacity Qu.

4. The calculated ultimate bearing capacity from seismic survey was 20.0 T/m^2 at Sindbad site, While in Sehan and Albhar sites was 21.2 T/m^2 at 1st layer and these values reduced in 2^{nd}

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)- 1994-697X (Online)-2706-722X

layer at three sites to be 17.0T/m^2 at Sindbad, while 15.9 T/m^2 at Sehan and 15.4 T/m^2 at Albhar site, then the values increased in the 3rd layer to be 30.1 T/m^2 in Sindbad site , and ranged between 22-22.6 T/m^2 at Sehan and Albhar sites respectively .

5. The total of Standard Penetration test (SPT) for three locations shows the N values 1st layer ranged between (9-30) in (1-6) m depth, at 2nd layer ranged between (3-13) in (7-20) m depth, while ranged (12-50) in (20-40) m depth at 3rd layer.

6. The study shows a close behavior of SPT log and S-wave with depths.

7. The values of bearing capacity (qa) and internal friction angle(Ø) obtained from the seismic method were close to bore hole data and close results of bearing cabacity qu and study sites

8. The consistency layers of study sites is divided in to: 1st layer is a stiff to very stiff in two study sites and ranged between (1 to 5, 6 m) depths and is suitable for light loads of shallow foundation. 2nd layer is a soft to medium stiff which ranged between (5 to 14) in Sindbad and (5, 7 to 18m) in Sehan and Albhar site that unsubtle for foundation may led to settlement .3rd layer is a very stiff to hard and ranged between (20 to 40 m) because increase the bulk density with depth as a result to compaction or load of the layers with appears dense silty sand strata this layer suitable for loads of deep foundation such as spillway structure.

9. The depth of the groundwater table ranged from (1.7-1.8) m in Sindbad site, (3.10-3.20) m in Sehan site and (3.30-3.40) m in AlBhar site below the normal ground surface (N.G.S).

10. From the calculated geotechnical properties obtained from the seismic method and borehole information are consistent and suggest the Albhar site is best serve location for a spillway construction.

Recommendations

- In case of building on the area of weak zones (soft strata) in mentioned depths, should be used the pillars or injection to prevent the risks.
- A hydrological study is proposed to complete the information that relate with the water of river at three sites.

References

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)- 1994-697X (Online)-2706-722X

ASTM (1973). American Standards for Testing and Materials, Manual Book, Part II, (1970) and (1973).

ASTM D5777 – 00, (2011). "Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation" United States.

Al-Salim, M., Hassan, I.A. and Jabbo, A.D. (1989). Characteristics of body waves velocities in Iraq. Proceedings of the fifth Scientific Conference, 4: 1 – 12, Baghdad, Iraq.

Al-Kafaji, A.J. M., (2004). The use of seismic methods for investigating weak zones, and geotechnical evaluation of Al-Hussain pure water site- Kerbala: M.Sc thesis, college of science, university of Baghdad. (Unpublished) .

Al-Khafaji, A. J. M., (2010). Geophysical and geotechnical investigations of soil underneath the foundation of Al-Abbas holy shrine site in Karbala Governorate: College of science, university of Baghdad. (Unpublished).

Ameen, N. N. (2006)." Laboratory seismic study for some geotechnical properties of rocks for engineering purposel. MSC. Thesis, College of Science, University of Basra. (Unpublished).111p. (In Arabic).

Bowles, J. E., (1988). Foundation analysis and design: 4th edition.

Domenico, S.N., (1984), Rock lithology and porosity determination from shear and compressional wave velocity: Geophysics, 49, 1188-1195.
Eastwood, R.L. and Castagna, J.P., 1983, Basis for interpret.

Jassim, S. Z. and. Goff, J. C., (2006). Geology of Iraq. Dolin, Prague and Moravian Museum, Brno. 341 P.

Khalil, M.H. and Hanafy, S.M.2008. Engineering applications of seismic refraction method: A field example at Wadi Wardan, Northeast Gulf of Suez, Sinai, Egypt, J. Appl. Geophys. 65 :132–141

Mark, G., Erica, G., and Claire, G., (2010). Large scale constrained modulus test, Plastic pipes institute. MCG Geotechnical Engineering, 89 p.

Obert, l., and Duvall, W.I., 1967, "Rock mechanics and the design of structures," in Rock, Wiley, New York.

R. A. Mahmood, & A.A. Albadran, Geotechnical Classification and Distribution of the Quaternary Deposits in Basrah City, South of Iraq. Journal Iraqi of Earth Science, Special Issue, Part 1 (2002) pp 6-16.

Sjogren, B., (1984) .Shallow refraction seismic. Champman and Hall, London.

Yagiz, S., (2011), P-wave Velocity Test for the Assessment of Some Geotechnical Properties of Rock Materials, Bull. Mater. Sci. V.34, pp. 943-957.

دراسة الخواص الجيوتكنيكية المحسوبة من السرع الزلزالية الانكسارية وبعض معلومات الحفر الاختبارية لغرض انشاء ناظم في مواقع مختارة من مدينة البصرة جنوبي العراق

ايمان مال الله جعفر ا.م.د. علي زباري المياحي
ا.د. عامر عطية لفتة

قسم علم الارض/ كلية العلوم/جامعة البصرة

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X

المستخلص

يهدف البحث الى اختيار انسب موقع لانشاء ناظم على شط العرب في مدينة البصرة. تضمنت الدراسة حساب المعاملات الجيوتكنيكية باستخدام الطريقة الزلزالية الانكسارية لثلاث مواقع مختارة وتم مقارنة النتائج مع معلومات الحفر الاختبارية لمزيد من المصداقية وتكامل الدراسة .انجز ٢٤ مسار زلزالي انكساري بطول ١٢٠ متر .تراوحت سرعة الموجات الانضغاطية (PW) (٥٠٠-٥١٧) م/ ثا في الطبقة الاولى للمواقع الثلاثة، بينما تناقصت الى (٣٩٧-٤٢٥) م/ ثا في الطبقة الثانية ووصلت الى (٥٢٧-٥٥٨) م/ ثا في الطبقة الثالثة.اما قيم سرعة الموجات القصية(SH) فقد تراوحت مابين(٢٩٠-٢٩٦) م/ ثا في الطبقات الاولى للمواقع الثلاثة ، في حين كانت في الطبقة الثانية مابين(٢٠٩-٢٣٧) م/ ثا ، اما الطبقة الثالثة فقد بلغت (٢٨٩-٣١٥) م/ ثا . بالنسبة لمعلومات الابار فقد تم الاستعانة بتقارير الحفر الاختبارية المنجزة بواسطة شركة المعول لتحريات التربة باعماق وصلت الى ٤٠ متر.اظهرت نتائج فحص الاختراق القياسي سلوكا متقاربا مع سلوك السرعة القصية خلال اعماق الطبقات الثلاثة . كما تقاربت نتائج السعة التحميلة وزاوية الاحتكاك الداخلي المستخرجة من حسابات السرع الزلزالية مع نتائج الحفر الاختبارية .من الخواص الجيوتكنيكية المحسوبة يتبين ان موقع ناحية البحار هوافضل موقع مناسب لانشاء الناظم

.

www.misan-jas.com (Arabic Impact Factor) - 1.1 ISSN (Paper)-1994-697X (Online)-2706-722X