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STUDY OF ENGINEERING PROPERTIES BY USING DOWNHOLE METHOD FOR SOUTH BAGHDAD AREA IN IRAQ

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ABSTRACT

This study is the use of seismic down-hole method in geotechnical studies assessment of a site of origin south of Baghdad. By calculating the speed of the seismic waves and determining the depths of the layers and calculating some of the geotechnical properties of the site. Seismic data was used for (4) boreholes and calculated P waves and S wave's velocity in each borehole and at different depths and using the Pro ABEM Terralloc, digital recording device to record field data. I interpreted all the information recorded in this way and for all wells and calculated the speed of PV and SV seismic waves up to a depth of (12) m. The measured velocity values were calculated to calculate a number of geotechnical properties such as: (poissons ratio (μ), Lames constant (λ), compressibility modulus (K), Bulk modulus (ß), Youngs modulus (E), Shear modulus (G), material index (Im), concentration index (Ic) and coefficient of laterail pressure (Ko). Taking of seismic velocity values Measured and density values measured at the same depths. The results of geotechnical assessment of the site confirmed the weakness of some of the soil layers on which it is based. The measured geotechnical properties showed that there was a weakness in the soil and this weakness led to a difference in bearing capacity

Keywords: downhole, P-wave, S-wave, geotechnical and Elastic modules.

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1. INTRODUCTION

Geophysical prospecting is defined as the “method for deducing underground conditions by observing data of physical phenomena either artificial or natural directly or indirectly related to the underground geological structures. The geophysical methods are now employed not only to investigate the mineral resources but also widely used to clarify the relatively shallow geological structure. (Imai,1979).

Geophysical methods are used in geotechnical investigations to evaluate a site's behavior in a seismic event. By measuring a soil's shear wave velocity, the dynamic response of that soil can be estimated. There are a number of methods used to determine a site's shear wave velocity. The seismic technique, such as Downhole, determines the compressional (P) and shear (S) wave velocities of materials at depths of engineering and environmental concern where the data can be used in problems related to soil mechanics, rock mechanics, foundation studies. All of the dynamic elastic moduli of a material can be determined from knowledge of the in situ density, P-, and S-wave velocities.(Al-Khafaji,2010).

2. SITE LOCATION

The site is located in Baghdad. The boreholes coordinates are shown in Table(1), and site plan for four boreholes location are shown in Fig.(1)

Table 1 boreholes coordination

B.H. No	E(m)	N(m)
1	442732.0	331710.6
2	442731.2	331709.9
3	442729.6	331709.1
4	442729.2	331708.4

Figure 1 Satellite image of the Investigation South Baghdad area

3. THEORETICAL OF DOWNHOLE SEISMIC SURVEYS

Down holes seismic is a simple and cheape method in the suite of borehole seismic technique, as it require only a single borehole. The travel times of the first arrival seismic waves are measure at regular interval down the hole using a string of hydrophone or, in the case of S-wave surveys, a single clamped triaxial geophone that is gradually moved down the hole. The P- and S-wave arrival times for each receiver location are combined to produce travel-time versus depth curves for the complete hole. These are then used to produce total velocity profiles from which interval velocity and the various elastic moduli's can be calculating (in conjunction with density data from geophysical logging of the borehole). Figure (2).Most of the civil engineering projects, challenge by complex and unique geological settings require subsurface information prior to design and construction. Shear wave velocity are one of the more useful engineering properties of soil and rock because they are closely related to the shear strength of a material, and shear strength is what supports structures. Compressional wave velocities are not a reliable indicator of material type or foundation quality. Where V_P = P-wave velocity, V_S = shear-wave velocity, and ρ= density. These are, of course, elastic linear dynamic characteristics and are not always applicable to performance of the foundation material when subjected to large static or dynamic loads, but these are the principal parameters used to predict ground spectral amplification ratios for earthquake site response. Shear waves are generally measured using a seismic energy source that generates mostly shear waves and vibration sensors sensitive to shear waves. The elastic constants are:

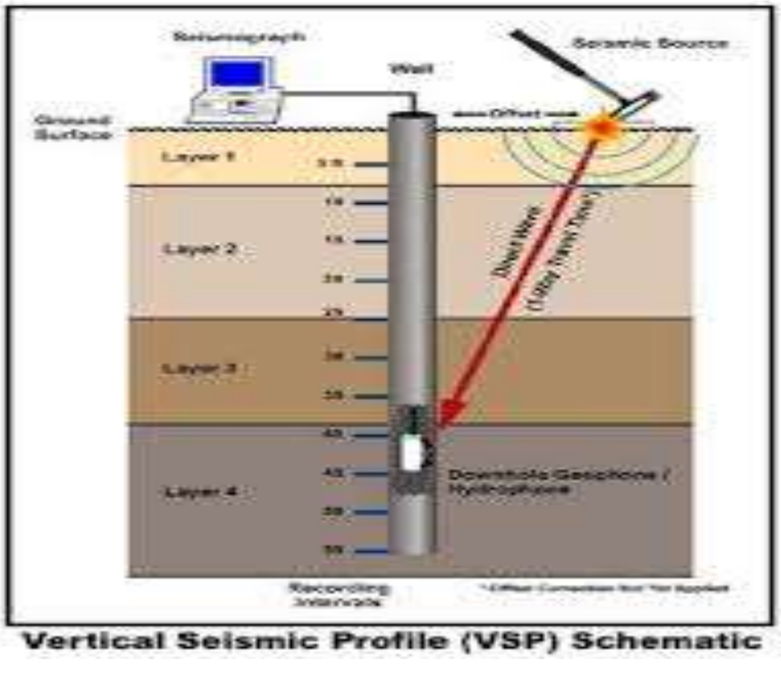

Figure 2 Downhole Seismic Survey

3.1. Young's Modulus (E)

The ratio of the stress to the deformation is a measure of the property of the rock to resist deformation. The Young's modulus also called modulus of elasticity. (Billings, 1972), also can be defined that it is the relationship between the length stress divided by length strain.

$$E = \frac{\left(F/A\right)}{\left(\Delta L/L\right)} = \frac{FL}{A\Delta L}$$

Where: E=Young’s modulus F=Force A=Area L=Length ΔL=Change of length

3.2. Bulk Modulus (B)

The Bulk Modulus is defined as the compressional stress by change in volume (Dobrin and Savit, 1988).

$$B = \frac{\Delta P}{\Delta V/V}$$

Where: B=Bulk modulus ΔP=change in pressure ΔV=change in volume V=volume

Also can be defined as the change in hydrostatic pressure by change in volume.

$$B = \frac{\Delta h}{\Delta V/V}$$

Δh may refer to lithostatic pressure instead of hydrostatic pressure (Billings, 1972) (Telford et al, 1981). The units of B are unit force by unit area.

3.3. Compressibility modulus (K)

The compressibility is the reciprocal of the bulk modulus. (Billings, 1972).

$$K = \frac{1}{B}$$

Where: K=Compressibility modulus ، B=Bulk modulus

3.4. Shear (Rigidity) modulus (G)

That is relative consistency between shearing stress and shearing strain, also it's resistance measurement to shearing strain for materials.

$$G = \frac{\left(F/A\right)}{\phi}$$

Where: A=Area ، F=Force ، ϕ=Angle of deformation

Shear modulus (G) is the ratio of the applied stress to the distortion (rotation) of a plane originally perpendicular to the applied shear stress; it is also termed the modulus of rigidity.

The units of G are units force by units areas, ϕ is a deformation angle as shearing strain.

3.5. Poisson's Ration (μ)

That is Relationship between width strain and length strains while the body under compressional and tensile stress.

$$\mu = \frac{\left(\Delta W / W\right)}{\left(\Delta L / L\right)} = \frac{L \Delta W}{W \Delta L}$$

Where: W=Width strain ∆W=Exchange of width L=Length strain ∆L=Change of length

(μ) is without units. and it's ranged between (zero to 0.5.) The values of Poisson's ratio for hard to moderate in situ rock ranging from (0.27 to 0.35) (Bell, 1980).

Poisson's ratio is often assumed to be (0.2 to 0.4) in soil mechanics work (Bowles, 1984).

3.6. Lame's constant (λ)

Is similar to the rigidity, (shear) modulus that is scale of hardness or force for homogeneous substance so the elastic moduli are equal for all directions. Lame's constant (λ) can be expressed in terms of Young's modulus and poison's ration (Dobrin,1976)

$$\lambda = \frac{\mu E}{(1+\mu)(1-2\mu)}$$

Where:

G= Shear (rigidity) modulus ، μ=Poisson’s ratio ، E=Young’s modulus

The unit of **λ** is force units by area units.

3.7. Material Index (I_m)

The material index is more important than geotechnical index and refers to degree of materials value to depend upon numbers of elastic moduli on ratio of (G / B) and (**λ** / B) (Adbdel Rahman, 1989). (I_m) influenced on material content, degree of consolidation, Joints, fracture, and liquid in porous (or water content), for this reason the elasticity of materials and seismic wave velocities were influenced too. (Abdel Rahman, 1989) in (Al-Salihi, 1999).

$$I_m = \frac{3 - \left(V_p / V_s\right)^2}{\left(V_p / V_s\right)^2 - 1} \quad I_m = \frac{3\left(V_s / V_p\right)^2 - 1}{1 - \left(V_s / V_p\right)^2}$$

The limit of this index is between (-1) that (G=0.0) for liquid material and (1) where λ = 0.0 for very solid material the G = **λ** for elastic material the I_m=zero. (Al-Salihi, 1999).

3.8. Coefficient of lateral earth pressure at rest (K_o)

K_o is very important coefficient in geotechnical engineering and is one of the most common in the civil engineering field (Cernica, 1995) It is called the coefficient of lateral earth pressure at rest. It expresses the stress conditions in the ground in terms of effective stresses (Holtz and Kovacs, 1981). K_o is the ratio of the lateral (horizontal) to vertical stress in the ground as:

$$K_o = \frac{s_H}{s_v}$$

s_H =Lateral (horizontal) stress. s_V=Vertical stress.

The pressure in liquid is the same in any direction-up, down, sideways, or at any inclination, it does not matter. However this is not true in soils. Rarely in natural soil deposits is the horizontal stress in the ground equal exactly to the vertical stress Fig.(3). In other words the stresses in situ are not necessarily hydrostatic (Holtz and Kovacs, 1981).

The ground water table can fluctuate and the total stresses can change.

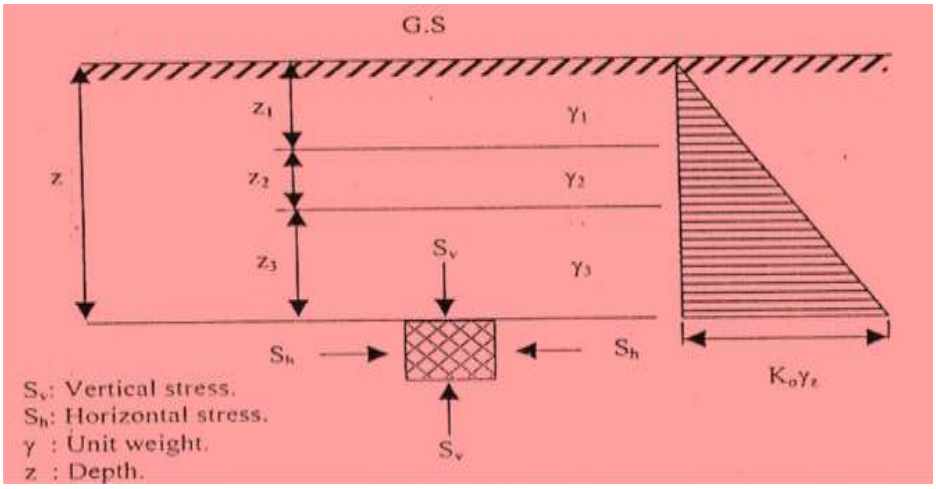

Figure 3 Coefficient of lateral earth pressure at rest (K_o)

(after Hunt, 1986)

Then K_o expresses the stress conditions in the ground in terms of effective stresses, and it is independent of the location of the ground water table. Even if the depth changes, K_o will be a constant as a long as we are in the same soil layer and the density remains the same.

The best known equation for estimating K_o was derived by Jaky (1944, 1948), which is a theoretical relationship between K_o and the angle of internal friction**Φ** . (Holtz and Kavacs, 1981).

$$\sin \Phi = 1 - K_\circ$$

K_o may be calculated from seismic compressional and shear wave velocity ratio (v_p/v_s), (v_s/v_p) (Al-Salihi,1999).

$$K_o = 1 - 2\left(V_s / V_p \right)^2$$

3.9. Concentration Index (I_c)

The concentration index specially used to measure the qualification of foundation and other engineering objects. The concentration index that is soil depend (Bowles, 1984).

We can use Hooke’s law to obtain a relationship between (k_o) and (μ) as:

$$K_o = \frac{\mu}{(1-\mu)}$$

Where:

K_o = Coefficient of lateral earth pressure at rest μ=Poisson’s ratio

K_o = refine in the discussion by Cummings (1936) who show that:

$$I_c = 2 + \frac{1}{Ko}$$

I_c is the concentration Index Substitute(k_o) as: $I_c = \frac{(1+\mu)}{\mu}$

So that for an incompressible material such as water $\mu = 0.5$ giving $k_o = 1$ and $I_c = 3$. It would appear that the range of $I_c$is $3 < I_c < 6$ (Bowles, 1984).Near the ground surface some experimental evidence indicates that $I_c < (3)$ but may well approach (3) at depths in the ground where the soil is more dense, stiffer, and substantially " confined ". I_c is more than 6 for solid rocks (Al-Khafaji-2004).For the relationship between the shear and compressional wave velocities we can define I_c:

$$I_c = \frac{3 - 4(V_s/V_p)^2}{1 - 2(V_s/V_p)^2}$$

4. FIELD WORK

The seismic refraction survey was carried out at South Baghdad Station site using the 3 channels seismic refraction system (ABEM Proterraloc System, and Downhole instrument, ABEM AB, Sweden) (fig. 4). The survey was conducted on 2017.Downhole seismic surveys are the simplest and cheapest method in the suite of borehole seismic techniques, as they require only a single borehole. Seismic energy is generated on surface at a fixed distance from the top of the borehole. It was four bore holes of 12 meters depth (Fig. 1). Techniques were applied in the investigated site; one is for P-wave and S-wave velocity measurements. Eleven successive shot points were applied which resulted in three records for S-wave and one records for P-wave per each Borehole. The records were obtained using an array of 3 geophones. Two geophones were used for S-wave measurements, and, one geophones for P-wave was used.

The impacts for S-wave and P-wave measurements were generated by using 15.0 kilos hammer hits. (fig.4).

Figure 4 Instruments and working field team

5. DETERMINATION OF ENGINEERING PROPERTIES

The longitudinal and shear wave velocities (V_p and V_S)and density(ρ) can be used to determine the elastic modulus from the previous equations.

Young's modulus (E) and Poisson's ratio (μ) can be derived if the density (ρ) and compressional and shear wave velocities are known by using the following expressions: (Bell,1980) (Davis and Schultheiss, 1980) (Hunt,1986).

$$E = 2(V_s)^2 \rho(1+\mu) \quad E = \rho V_\rho{}^2 (1-\mu)(1-2\mu)$$

$$B = \rho V_P^2 - \frac{4}{3}G \quad B = \frac{1}{3} \bullet \frac{E}{1-2\mu} \quad K = \frac{1}{B}$$

$$G = \rho V_S^2 \quad \mu = \frac{0.5(V_p/V_s)^2 - 1}{(V_p/V_s)^2 - 1}$$

$$\lambda = \rho(V_p)^2 - 2(V_s)^2 \quad \lambda = \frac{\mu E}{(1+\mu)(1-2\mu)}$$

6. RESULTS AND CONCLUSIONS

First, measuring the distance between the source of the seismic waves and the well receiver (McCann et al. ,1975) (Hamdi, et al., 1993).then calculate the slat of depth (R) .

Second, measuring the time for traveling compressional (P) and (S) waves to travel from a source point to receiver hole. The seismic signal travels as an elastic wave to three-component geophone that is positioned at the same elevation in the receiver hole. Then calculate the slant time T_s that is lead to calculate the vertical time T_z . Draw the relationship between vertical time with the depth, the velocity may be calculate by L Square method for curves which represent for this relationship.

The results shown in Table (2-5) and Figure (5 ,6a-b) and Table (6-9), The results of geotechnical assessment of the site confirmed the weakness of some of the soil layers on which it is based. The measured geotechnical properties showed that there was a weakness in the soil and this weakness led to a difference in bearing capacity.

Table 2 Shows the Down hole survey results for (B.H.1)

Offset (X)m.	Depth m.	Slant distance (R)m.	Time msec		Slant time (T_z) msec		Average Velocity (V_{ava}) m/sec		Layer No.
			T_p	T_s	T_p	T_s	V_p	V_s	
3.0	1	3.16	6.01	15.01	1.90	4.75	417	137	**1st**
	2	3.60	7.61	21.33	4.23	11.85			
	3	4.2	9.37	26.95	6.69	19.35	616	281	**2nd**
	4	5	10.76	29.19	8.60	23.35			
	5	5.8	11.56	31.30	9.96	26.98			
	6	6.7	13.68	33.5	12.25	30.01	772	357	**3rd**
	7	7.6	14.63	35.54	13.47	32.73			
	8	8.5	15.14	37.69	14.25	35.48			
	9	9.4	16.78	40.02	16.06	38.32			
	10	10.4	18.47	43.30	17.76	41.63			
	11	11.4	19.53	45.77	18.84	44.16			

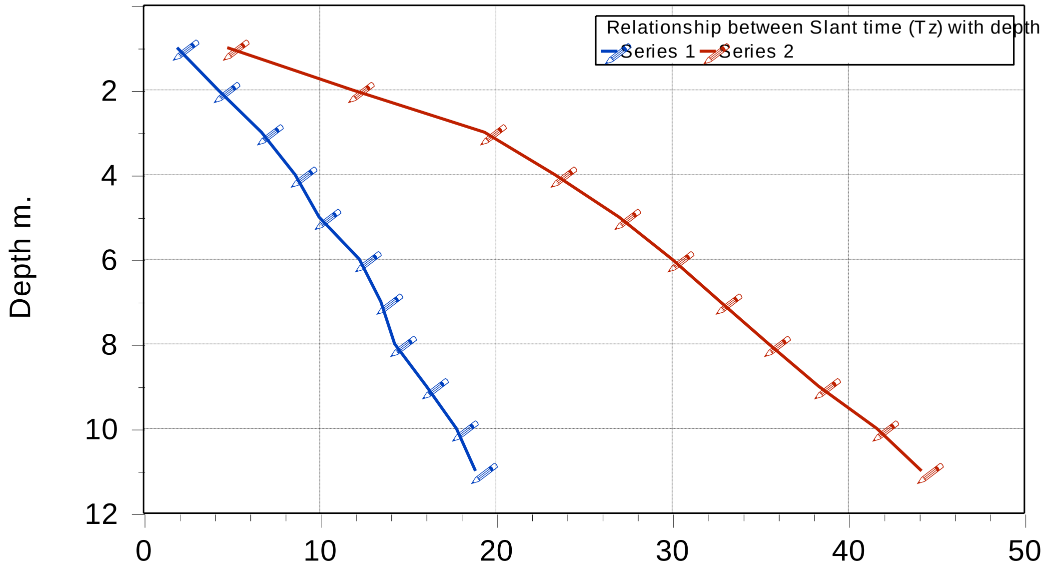

Figure 5 Relationship between Slant time (T_z) with Depth For B.H.1

Table 3 Shows the Downhole survey results for (B.H.2)

B.H. No.	Offset (X)m.	Depth m.	Slant distance (R)m.	Time msec		Slant time(T_z) msec		Average Velocity (V_{ava}) m/sec		Layer No
				T_p	T_s	T_p	T_s	V_p	V_s	
2	3.0	1	3.16	4.92	18.76	1.55	5.93	363	186	**1st**
		2	3.60	6.41	19.84	3.56	11.02			
		3	4.2	9.93	23.86	7.09	17.04			
		4	5	12.27	27.56	9.81	22.04	543	242	**2nd**
		5	5.8	13.70	30.35	11.81	26.16			
		6	6.7	15.07	32.49	13.49	29.09			
		7	7.6	16.36	36.18	15.07	33.32	779	377	**3rd**
		8	8.5	17.01	37.76	16.00	35.54			
		9	9.4	18.54	40.17	17.75	38.46			
		10	10.4	19.68	42.76	18.92	41.11			
		11	11.4	20.3	45.77	19.58	44.16			

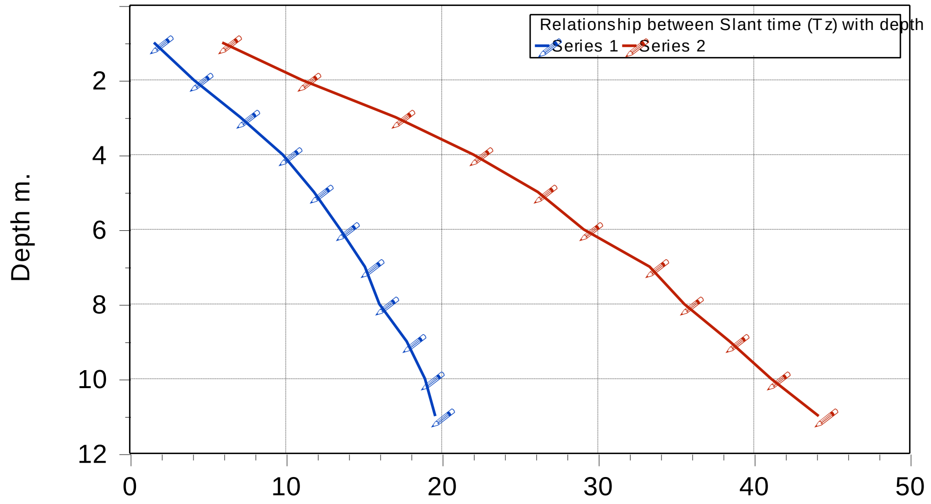

Figure 6 a Relationship between Slant time (T_z) with Depth For B.H.2

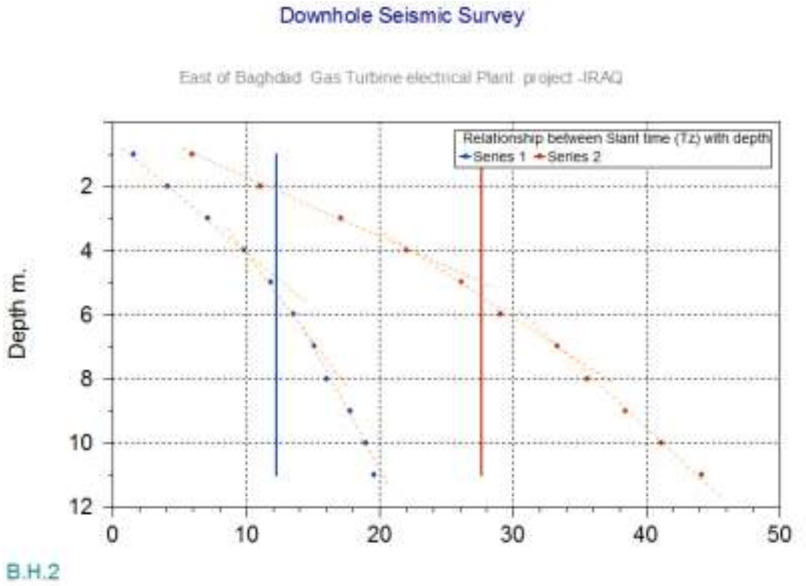

Figure 6 b Relationship between Slant time (T_z) with Depth For B.H.2

(L Square Method)

Table 4 Shows the Downhole survey results for (B.H.3)

Offset (X)m.	**Depth m.**	**Slant distance (R)m.**	**Time msec**		**Slant time (T_z) msec**		**Average Velocity (V_{ava}) m/sec**		**Layer No**
			T_p	**T_s**	**T_p**	**T_s**	**V_p**	**V_s**	
5.3	1	5.39	8.4	29.5	1.55	5.47	363	181	**1st**
	2	5.66	10.08	31.2	3.56	11.02			
	3	6.09	14.4	34.6	7.09	17.04			
	4	6.64	16.3	36.6	9.8	22.04	570	265	**2nd**
	5	7.28	17.2	38.1	11.8	26.16			
	6	8.00	18.0	38.8	13.5	29.1			
	7	8.78	18.9	41.8	15.06	33.32	781	385	**3rd**
	8	9.59	19.2	42.6	16.01	35.53			
	9	10.44	20.6	44.6	17.7	38.44			
	10	11.31	21.4	46.5	18.9	41.11			

Table 5 Shows the Downhole survey results for (B.H.4)

Offset (X)m.	**Depth m.**	**Slant distance (R)m.**	**Time msec**		**Slant time (T_z) msec**		**Average Velocity (V_{ava}) m/sec**		**Layer No**
			T_p	**T_s**	**T_p**	**T_s**	**V_p**	**V_s**	
7.4	1	7.46	14.2	36.4	1.9	4.87	418	140	**1st**
	2	7.66	16.2	45.4	4.2	11.8			
	3	7.98	17.8	51.2	6.69	19.2	540	278	**2nd**
	4	8.41	18.1	49.1	8.6	23.35			
	5	8.93	17.8	48.2	9.9	26.9			
	6	9.5	19.4	47.5	12.25	30.0	763	355	**3rd**
	7	10.18	19.6	47.6	13.47	32.7			
	8	10.89	19.4	44.3	14.75	44.3			
	9	11.65	20.8	49.6	16.06	38.3			
	10	12.44	22.1	51.8	17.76	41,6			
	11	13.25	22.7	53.2	18.8	44.1			

Table 6 Elastic Moduli and Geotechnical Properties of soil for (B.H.1)

Depth m.	**Average Velocity (V_{ava}) m/sec**		***P*** **gm/cm^3**	***μ***	***E (MN/m^2)***	***B (MN/m^2)***	***K*** **x10^{-6}**	***G (MN/m^2)***	***λ (MN/m^2)***	***I_m***	***I_c***	***K_o***	**Layer No.**
	V_p	**V_p**											
1	417	137	1.83	0.43	9.9	27.2	3.6	3.4	28.06	-0.34	3.66	0.34	1st
2													
3													
4	616	281	1.84	0.37	39.77	50.4	1.9	14.5	54.03	-0.58	3.42	0.58	2nd
5													
6													
7	772	357	1.86	0.36	64.6	79.2	1.2	23.7	85.3	-0.57	3.43	0.57	3rd
8													
9													
10													
11													

Table 7 Elastic Moduli and Geotechnical Properties of soil for (B.H.2)

Depth m.	**Average Velocity (V_{ava}) m/sec**		***P*** **gm/cm^3**	***μ***	***E (MN/m^2)***	***B (MN/m^2)***	***K*** **x10^{-6}**	***G (MN/m^2)***	***λ (MN/m^2)***	***I_m***	***I_c***	***K_o***	**Layer No.**
	V_p	**V_p**											
1	363	186	1.81	0.32	16.55	15.5	6.4	6.26	16.9	-0.47	3.53	0.47	1st
2													
3													
4	543	242	1.84	0.37	29.65	39.8	2.5	10.77	42.5	-0.60	3.4	0.60	2nd
5													
6													
7	779	377	1.85	0.35	70.8	77.20	1.2	26.29	83.83	-0.53	3.47	0.53	3rd
8													
9													
10													
11													

Table 8 Elastic Moduli and Geotechnical Properties of soil for (B.H.3)

Depth m.	**Average Velocity (V_{ava}) m/sec**		***P* gm/cm^3**	μ	***E(MN/m^2)***	***B(MN/m^2)***	***K* x10^{-6}**	***G* (MN/m^2)**	λ **(MN/m^2)**	I_m	I_c	K_o	**Layer No.**
	V_p	**V_p**											
1	363	181	1.78	0.33	15.56	15.67	6.3	5.8	16.9	-0.5	3.5	0.5	1st
2													
3													
4	570	265	1.86	0.37	35.88	43.01	2.3	13.06	46.38	-0.56	3.44	0.56	2nd
5													
6													
7	781	385	1.87	0.34	74.25	77.10	1.2	27.7	84.4	-0.51	3.49	0.51	3rd
8													
9													
10													
11													

Table 9 Elastic Moduli and Geotechnical Properties of soil for (B.H.4)

Depth m.	**Average Velocity (V_{ava}) m/sec**		***P* gm/cm^3**	μ	***E* (MN/m^2)**	***B* (MN/m^2)**	***K* x10^{-6}**	***G* (MN/m^2)**	λ **(MN/m^2)**	I_m	I_c	K_o	**Layer No.**
	V_p	**V_p**											
1	418	140	1.81	0.43	10.19	26.89	3.7	3.5	27.7	-0.76	3.24	0.76	1st
2													
3	540	278	1.84	0.32	37.5	34.69	2.8	14.22	38.19	-0.47	3.53	0.47	2nd
4													
5													
6	763	355	1.88	0.36	64.5	77.8	1.2	23.69	85.7	-0.56	3.44	0.56	3rd
7													
8													
9													
10													
11													

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