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Geophysical Study for Both HILLA-2 and KARBALA-2 Gas Power Plants / Central IRAQ with the Assistance of the Engineering Information

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***Abstract*- Geophysical techniques were used in this study at both Gas Power Hilla-2 and Karbala-2 Plants which located within Babylon and Karbala Governorates / Central Iraq, in order to investigate their soil foundations with the help of the available engineering information. Electrical survey was firstly carried out throughout this study using vertical electrical sounding (Schlumberger array) at these Plants. The plotted apparent resistivity field curves and the geoelectrical sections for all VES points were interpreted qualitatively and quantitatively. They gave five subsurface layers in these two Plants; however, depths, thicknesses and resistivities of these layers were identified. Water table was also calculated in the studied sites depending on the resistivity interpretations. On the other hand, geoelectrical parameters were also determined. They indicate that the subsurface layers which belonging to Karbala-2 has resistivity values higher than Hilla-2. This is due to the dry soil and higher gypsum content. Moreover, it noticed that the soil of the studied areas was behaved as anisotropy towards all directions beneath all VES points; in addition, a relationship between the grain size percent, moisture content and consistency limits were also drawn versus the true resistivity values and a best fitting was made for each case.**

Seismic refraction method was also surveyed for longitudinal (P) and transverse (S) waves directly above the electrical profiles in Hilla-2 and Karbala-2 Plants; in order to calculate the seismic waves velocities through the subsurface layers and their dynamic elastic constants. The calculations shown that the average of V_P for the 1st layer, Hilla-2 Plant, is equals to 237.5 m/sec and Vs is 116.75 m/sec. Also, the averages for V_P and Vs waves for the 2nd layer are equal to 523 m/sec and 243.75 m/sec respectively. Moreover, the average values for both V_P and Vs that belonging to the 1st and 2nd layers, Karbala-2 Plant, are equal to 186.5, 642.25 m/sec and 112.25, 275.9 m/sec respectively. Four elastic moduli such as poisson, young, shear and bulk were determined and analyzed.

Standard penetration test and bearing capacity values were performed and calculated for the studied soils. The average of the N-values in Hilla-2 Plant was ranged between 13-47 impacts with 6.7-16.1 ton/m^2 at 2, 16 m depth intervals respectively.

We noticed that the N-values are low near the ground surface because of the saturated clay existence; whereas, the values of N which calculated in all drilling Hilla-2 wells at depth intervals between 17-30 m is more than 50 impacts with bearing capacity value more than 17 ton/m^2. This means that the layers corresponding to these intervals were characterized by its hardness. At Karbala-2 Plant, the N-value was reached 50 impacts and more; this indicates that the soil is cohesion and contains high percent of sand and low clays; therefore, all depth intervals or layers in the drilling wells are considered hard media and they have bearing capacity equals to 17 ton/m

***Keywords*-- Hilla and Karbala, Emad Al-Khersan, VES, Refraction, Geoelectrical parameters**

I. INTRODUCTION

Site characterization usually provides subsurface information that assists civil engineers in the design of foundation of civil engineering inside electrical power Plants. The primary purpose of all site investigations is to obtain the data needed for analysis and design. The most challenging part of these efforts is to collect only those data needed with the least amount of money and time [1]. The non-destructive mode of stratigraphy determination of geophysical methods made them necessary while the geotechnical investigation is essential to have an adequate knowledge of the engineering properties of the subsoil materials that would have direct interaction with the proposed structure on the site. In the last decade, the involvement of geophysics and geotechnical methods in civil engineering has become a promising approach [2].

Geophysics affords the opportunity to cost-effectively sample large volumes of the subsurface using such principles as seismic and electrical current flow. The science is technical in its application, and is quantitative in its measurement, yet it provides only the qualitative information about geomaterial properties needed by engineers.

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For example, it does not directly measure moisture content, or stiffness, but provides a relationship between a measured value (e.g., seismic velocity) and the physical parameter that governs it (e.g., density). It is the complement of using a broad view of the subsurface imaged from a geophysical investigation and data directly obtained from drilling that creates the value and benefit of this technology [3].

The proposed sites located at the middle of Iraq represent two small flat areas named "Hilla-2" and "Karbala-2" Gas Power Plants with latitudes (32°31´00.00"- 32°31´06.09"), (32°27´50.75"-32°27´) North, and longitudes (44°23´03.48"-44°23´05.98"), (44°05´59.32"- 44°06´5.09") East respectively (Fig.1).

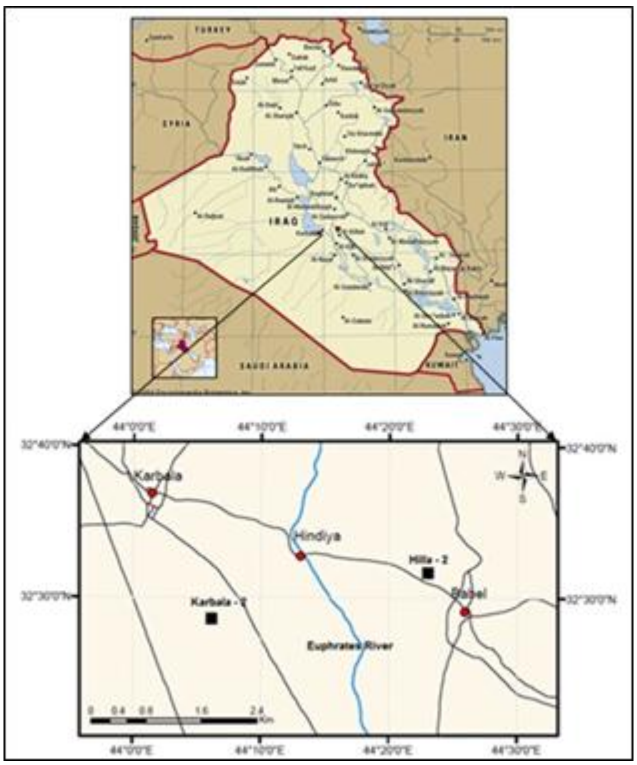

Fig.1 Study area showing the location of Hilla-2 and Karbala-2 Plants

Lithologically, the soils of these two sites were covered by Quaternary deposits during Holocene period; however, the Tertiary deposits were widely exposed in the area which mainly formed from depression fill deposits such as, silt, sand, clay and almost with high gypsum content, especially at Karbala-2 Plant [4]; [5]. Table-1 illustrates layers description of the drilled boreholes No.4 and No.2 inside Hilla-2 and Karbala-2 respectively.

It is also noticed from these boreholes that the water table exceeds 1.5 m and 18 m relative to the natural ground surface of the above two Plants respectively. Tectonically, the sites understudy were situated inside the Unstable Shelf, representing a part of Euphrates subzone, that characterized by the existing of NW-SE structures and faults such as, Abu-Jir Fault which trends parallel to Euphrates River, the natural tectonic boundary between Stable and the Unstable Shelves [6]. [7] mentioned that basement rocks were led at approximately 7-8 km depth.

No one tried to integrate or even combine the geophysical and geotechnical techniques together in the studied area. Fortunately, several studies had been involved in the surrounding of our area were dealing with the geology, hydrogeology, sedimentology, geochemistry and pure geotechnical investigations. It can be help us as a control tools used to match our final results. On the other hand, various investigators outside Iraq have tried to detect the underlying site foundation, such as; [8]. He conducts both DC-resistivity and surface wave seismics that perform well in geotechnical site investigations. This work focuses on the use of these two methods and different approaches for inverse modeling; it illustrates and comments on the value of these approaches, e.g. through field studies. These methods for measurement and inversion of geophysical data provide cost-effective, fast and robust tools for describing geological units. If they are used to complement the traditional geotechnical methods, an improved material model is achieved. This in turn leads to a safer design and at the end most probably a reduction of the construction costs. Also, [9] had been applied both VES and geotechnical methods for subsoil evaluation. The overburden thickness and basement bedrock were determined. There are no indications of the major geologic structure such as faults and the subsoil within the study area are generally competent.

The main objective of this work has been to evaluate the methodologies for site investigations with geophysical methods. This study employed both Vertical Electrical Sounding (VES) and seismic refraction techniques in conjunction with in-situ soil tests within Hilla-2 and Karbala-2 Plants. Therefore, each technique was carried out as a means of determine the overburden thickness at the pre-determined studied locations, delineate the subsurface layers and their geoelectric characteristics, to detect lateral changes and the anomalous geologic conditions, boot to the existence of water table. Moreover, longitudinal and shear waves velocities of the underlying strata were also aimed in order to derive the dynamic elastic properties of the rocks.

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This helps the engineers to deal with the projects property and to provide information on the subsurface sequence, competence and structural disposition with a view to capture geo-engineering data of the subsurface that are inimical to the future engineering projects.

II. THEORY

In a geophysical survey, different techniques can be used to measure a variety of physical properties, each of which is described by certain theoretical principles.

Geophysical methods are cost efficient and provides often new information. However, the need for prior geological knowledge in order to make a correct interpretation of geophysical data and a proper choice of methods must be acknowledged. Early in the site investigation process, geophysics can assist in refining a general geological model so that it contains local variations and major discontinuities; this model can then be used for optimal design of further investigations.

TABLE1
Illustrating the layers description of BH.4 and BH.2 inside Hilla-2 and Karbala-2 respectively modified from [10 and 11]

Plant name	***Depth (m)***	***Layers description***
Hilla-2, BH.4	0-0.5	Grayish silty sandy clay soil, soft consistency with organic matter
	1.5-2	Grayish sandy silty clay soil, medium consistency
	2.5-3	
	3.5-4	
	4.5-5	Grayish clayey silty sand soil, medium dense
	5.5-6	
	6.5-7	Brownish sandy silty clay soil, medium consistency
	7.5-8	
	8.5-9	Reddish sandy silty clay soil, medium consistency
	9.5-10	
	10.5-11	Greenish, fine, silty sand soil, dense
	11.5-12	
	12.5-13	Reddish sandy silty clay soil, stiff consistency
	14-14.5	
	15-15.5	Grayish fine to medium clayey silty sand soil, very dense
	16.5-17	Grayish fine silty sand soil, very dense with fine gravel
	18-18.5	
	19.5-20	Greenish medium, silty sand soil, very dense with gypsum content
	20.5-21	
	22-22.5	
	23.5-24	
	24.5-25	Brownish silty sandy clay soil, stiff consistency, with gypsum content
	25.5-26	
	26.5-27	Greenish fine to medium silty clayey sand soil, very dense with gypsum content
	27.5-28	
	28.5-29	
	29.5-30	
Karbala-2, BH.4	0-0.5	Whitish – yellowish, very dense fine to medium silty sand soil with high gypsum content and clay
	1.5-2	
	2-2.5	
	3-3.5	Yellowish, very dense fine to medium silty sand soil (cementation) with high gypsum content
	4-4.5	
	5-5.5	
	6-6.5	
	7-7.5	Reddish silty clayey sand soil, very dense
	8-8.5	

	9.5-10 10.5-11 12-12.5 13-13.5	White-yellow, dense medium to coarse silty sand soil, with high gypsum content with fine gravel
	14-14.5 15.5-16 17-17.5 18.5-19 20-20.5 21-21.5 22-22.5	Yellowish, very dense ,medium to coarse silty sand soil, with high gypsum content
	23.5-24 24.5-25 26-26.5	Reddish silty clayey sand soil, dense with high gypsum content
	27.5-28 28.5-29 29.5-30	Yellowish, very dense, medium to coarse silty sand soil, with high gypsum content

During the detailed investigation (e.g. a drilling program) geophysics can be used to facilitate the interpolation of geological, geotechnical and hydrogeological properties between the discrete investigation points. Many geophysical methods have the potential of providing information that describes sections, areas or volumes; such information would not be readily available from any other investigation method. This information increases the resolution and decreases the uncertainty of the model developed during site investigation. The use of geophysical methods for estimating geotechnical design parameters is not common. Mechanical properties estimated indirectly from geophysical measurements usually have a lower resolution than when estimated from invasive sounding methods. Measurements using traditional geotechnical methods (e.g. probing or laboratory methods) normally have a relatively small uncertainty at the measurement point. The uncertainty increases both with distance and with the degree of disturbance of the material. Sample volume also influences the uncertainty of the result. In order to choose the appropriate geophysical method, it is important to have an idea of the relationship between the physical properties and the desired geotechnical design parameters. Geometry and heterogeneity of geological units and aquifers are important parameters, and with a few exceptions these are the parameters that geotechnical literature claims as useful targets for geophysical surveys. The estimation of shear modulus at small strain from shear wave velocity measurements is probably the only application where a surface based geophysical method has been generally accepted by the geotechnical community for determination of a geotechnical parameter [8].

Electrical resistivity measurements are made by placing four electrodes in contact with the soil or rock. A current is caused to flow in the earth between one pair of electrodes while the voltage across the other pair of electrodes is measured. The depth of measurements is related to the electrode spacing. The resistivity measurement represents the apparent resistivity averaged over a volume of the earth determined by the soil, rock, and pore fluid resistivity, along with the electrode geometry and spacing. Resistivity measurements include sounding by increasing electrode spacing at a fixed location [12].

Seismic refraction is a method to determine the P-wave velocity structure of the subsurface. P-waves are generated on the surface, propagate through the soil and rock, and are recorded by geophones at known distances from the source. When the seismic waves encounter interfaces separating material of different seismic velocities, the waves are refracted according to Snell’s Law. At the critical angle for each interface (energy refracted 90 degrees), the seismic wave will travel along the interface with a velocity of the underlying layer. Since P-waves are the fastest portion of the seismic wave, they represent the first arriving energy at each geophone (either direct or refracted). A seismograph is used to record the travel-times of these first arrivals, after which seismic velocities can be derived. Depths to the refracting layers can also be determined. Note that the refraction method assumes that velocity of the layers increases with depth and those layers must be thick enough and have enough velocity contrast to be resolved [13].

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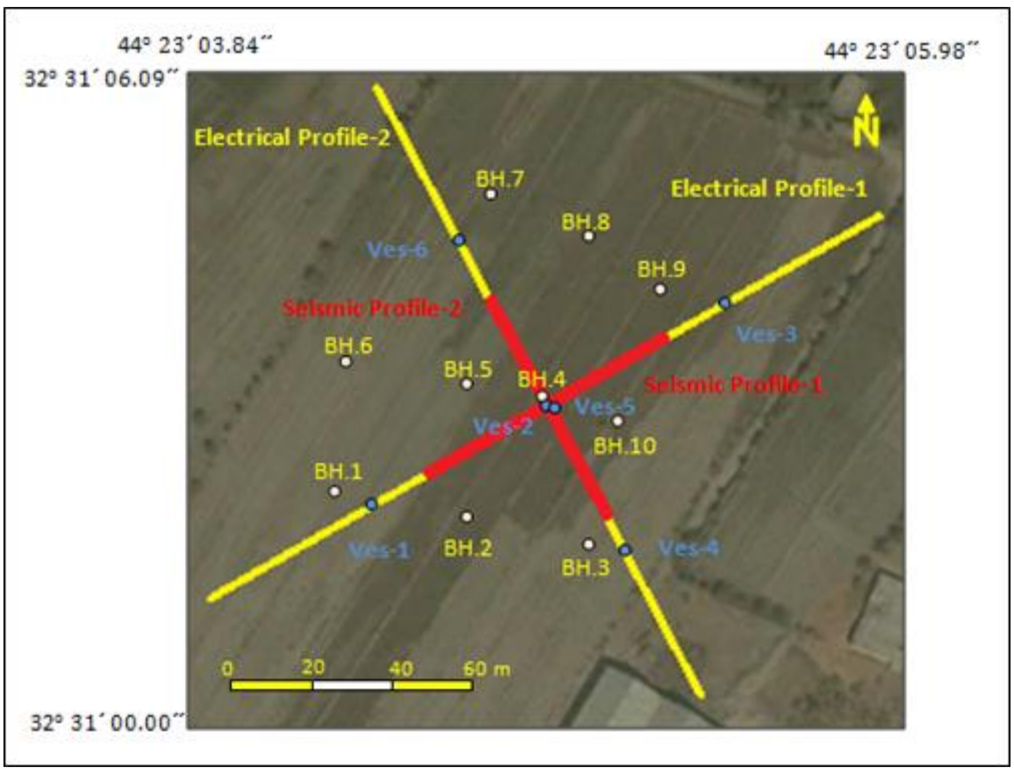
III. Methods And Data Used

On 23 May, 2010, sixteen boreholes were drilled with depth of 30 m inside the whole area using Flight Auger drill machine; ten of them in Hilla-2 and six in Karbala-2 Plants. Two perpendicular electrical profiles with 200 m length were established across each studied sites in the area during February and March, 2011 (Fig.2). Three Vertical Electrical Sounding (VES) points were occupied along each of these profiles using SAS-4000 instrument. A total of 12 VES were carried out using the Schlumberger configuration. The electrode spacing (AB/2) was varied from 1-50 m. The co-ordinate (in degrees) of each of the VES points, profiles and drilling boreholes were recorded with the aid of the Geographic Position System (GPS) unit. The apparent resistivity values were plotted against electrode spacing (AB/2) on a bi-logarithmic graph sheet to generate depth sounding curves. The field curves were then inspected visually for identification of the curve type. Partial curve matching was carried out on the field curves. The interpretation results (layer resistivity and thicknesses) were fed into computer for 1-D computer assisted interpretation involving IPI2Win Russian software.

The final interpreted results were used for the preparation of geoelectric sections and parameters.

During March 2011, two seismic refraction perpendicular profiles were carried out for both P and S-waves inside each site. These profiles were conducted directly over the previous electrical profiles. 12 vertical geophones for P-wave and 12 horizontal ones for S-wave were also deployed with 5 m spacing along 65 m for each profile. Each geophone was individually recorded using ABEM Terraloc Mark-6 seismic system. Three impacts (normal, central, reverse) were applied by using 10 kg hammer, in order to measure the first arrivals of the generating P-waves. Two or even three impacts were also done to generate S-waves by the use of special horizontally polarizing source. First arrival times for P and S waves were picked (using Reflexw Ver.3.5.1 software) from the extracted seismic sections that belonging to Hilla-2 and Karbala-2 Plants. On this fact, time-distance curves had been plotted and therefore, Vp and Vs for each profile were calculated. However, the elastic modulus of the soils understudy within each site were also encountered depending upon the velocity results.



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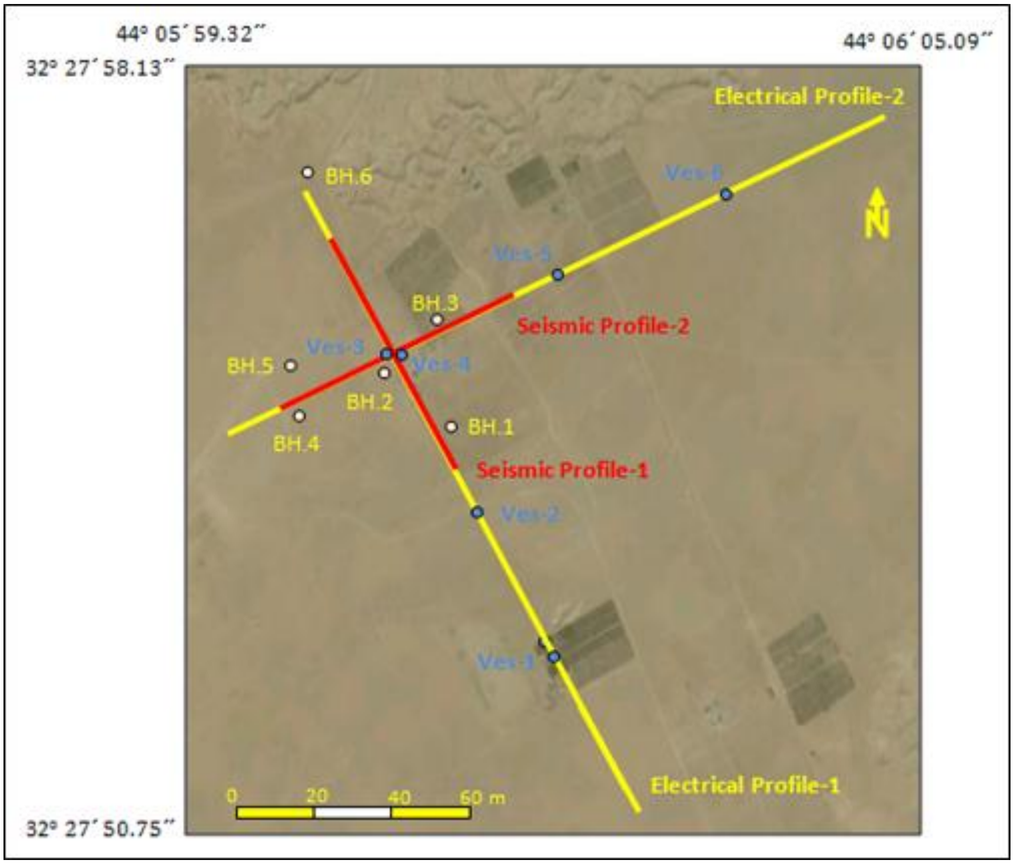

Fig.2 Hilla-2 (above) and Karbala-2 (below) Plants showing profiles, VES and boreholes

IV. RESULTS PRESENTATION AND INTERPRETATION

A. VES and geoelectrical sections

The electrical results of this research were presented as a resistivity field curves, geoelectric sections and geoelectric parameters. The summary of the VES interpretation results is shown in Table-2.

It noticed from this table, that the VES curves are composed of (KHK, HKH, HAK) and (QQ, KK, QKH, KQK, KKQ) types for Hilla-2 and Karbala-2 Plants respectively, representing four to five layers combinations. They showed that the surface layer has high resistivity values in each Plant due to the surface wreathing and erosion processes during the recent times (Fig.3).

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TABLE 2
Electrical resistivity values, thicknesses and curves types obtained from software interpretation

Site	Profile	VES Point	Electrical resistivity (ρ) in (Ohm.m) and thickness (h) in meter										Curve Type
			Layer 1		Layer 2		Layer 3		Layer 4		Layer 5		
			ρ1	h1	ρ2	h2	ρ3	h3	ρ4	h4	ρ5	h5	
Hilla-2	1	1	0.519	0.58	3.44	0.77	0.467	2.31	2.58	19.9	0.571	-	KHK
		2	2.1	1.3	0.896	4.2	2.45	6.15	0.241	7.71	73.4	-	HKH
		3	1.96	0.94	1.34	7.2	2.04	6.47	0.307	11.8	31.6	-	HKH
	2	4	1.89	0.9	0.541	1.17	1.04	8.88	2.95	14.1	0.015	-	HAK
		5	1.92	1.49	0.844	2.84	2.77	3.48	0.559	11.7	52.3	-	HKH
		6	2.486	0.86	0.649	1.19	1.837	7.83	0.391	12.87	50.29	-	HKH
Karbala-2	1	1	46	0.82	8.08	1.84	0.614	26.2	0.0047	-	-	-	QQ
		2	279	0.91	607	4.86	16.3	11.3	14931	-	-	-	KK
		3	9.44	1.14	1.38	3.59	0.196	5.76	2.16	10.9	0.0138	-	QKH
	2	4	31.8	0.46	1027	0.92	28.4	1.74	74.5	-	-	-	KK
		5	136	0.75	644	0.80	140	11.6	42.6	20.6	3144	-	KQK
		6	279	0.55	1480	1.25	37.8	1.3	172	18.5	1.02	-	KKQ

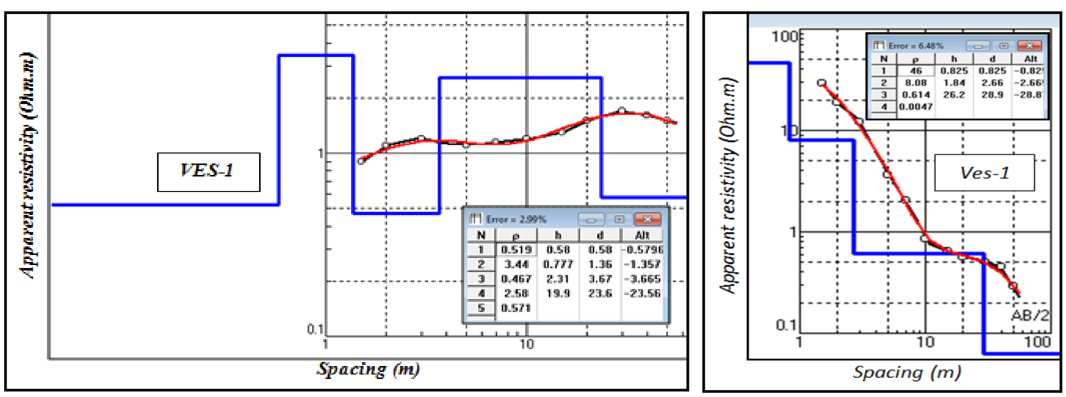

Fig.3 Two examples of apparent resistivity field curves for Hilla-2 (left) and Karbala-2 (right) Plants

The geoelectric section (Fig.4) beneath the survey area inside Hilla-2 Plant identified maximum of five geoelectric / geologic subsurface layers. The top soil is composed of wet silty sandy clay containing low percent of sand, with resistivity values ranging from 0.51 to 2.486 Ohm.m and thickness varies from 0.58-1.49 m. The second layer resistivities are generally within the range of 0.541 and 3.44 Ohm.m, typical of silty sand. The thickness varies from 0.77 m to 7.2 m. About 50 % of the VES curves display the evidence of subsurface partly weathered soil.

The resistivity values of the third layer of silty clay are varying from 0.467–2.77 Ohm.m, while its thickness ranges from 2.31 m to 8.88 m. However, the silty sandy clay fourth layer has resistivity values ranging from 0.241 Ohm.m to 2.95 Ohm.m, with thickness equals to 19.9 m.

Figure 5 shows the geoelectrical section for Karbala-2 Plant. The top layer having values of (9.44-279) Ohm.m, (0.46-1.14) m. represents the silty sand with high gypsum content; the second one consisting of silty clayey sand is (1.38-1480) Ohm.m, (0.80-4.86) m.

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The third layer of silty sand with high gypsum content is ranging between (0.196-140) Ohm.m and (1.3-26.2) m. Forth layer values are (0.0047-14931) Ohm.m (reading 14931 was surveyed more than one and no change observed) and (10-20.6) m is related to silty clayey sand. Finally, the fifth layer of silty sand with high gypsum content having values of (1.02-3144) Ohm.m.

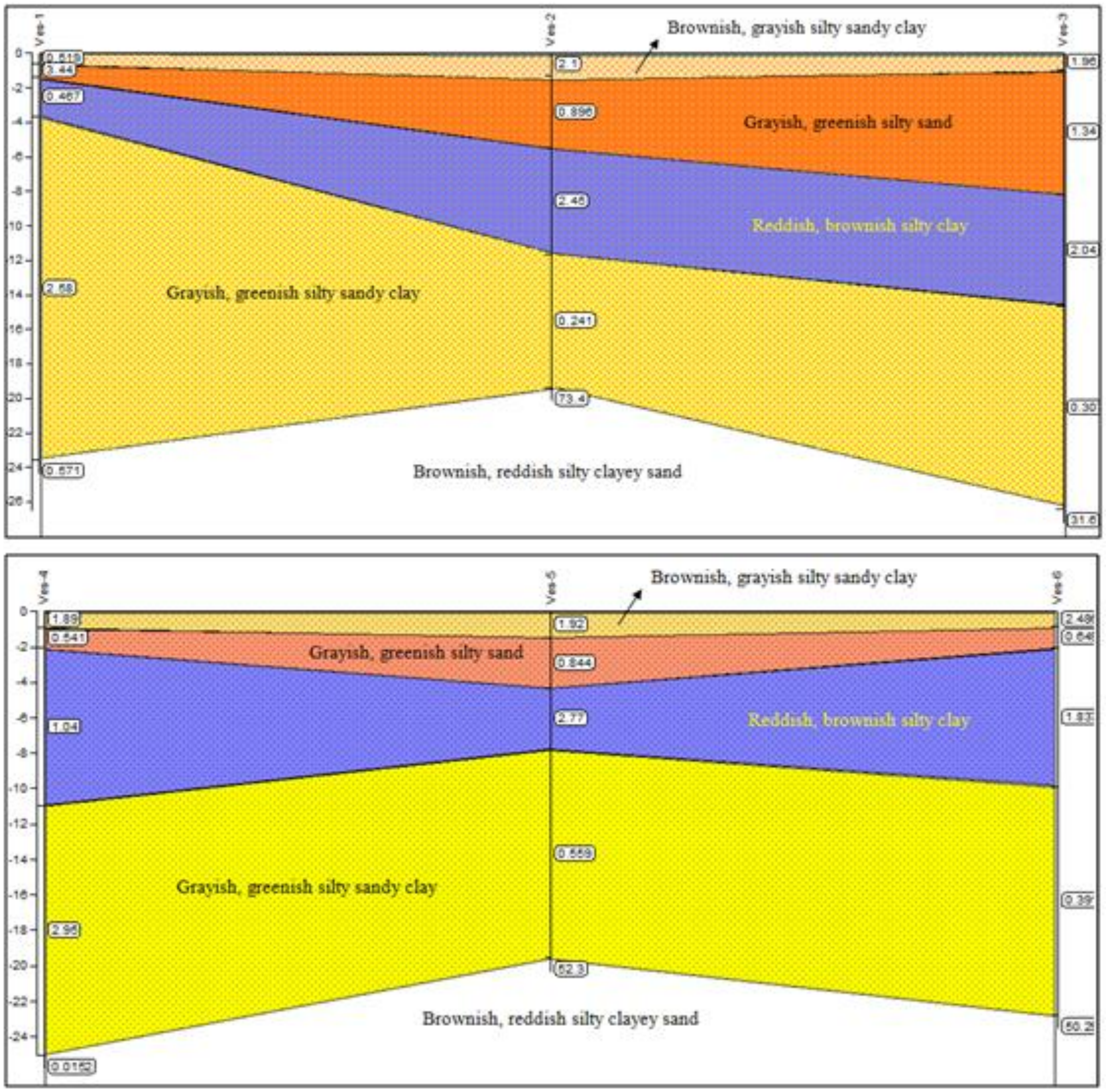

Fig.4 Geoelectrical sections for profiles 1 and 2 inside Hilla-2 Plant

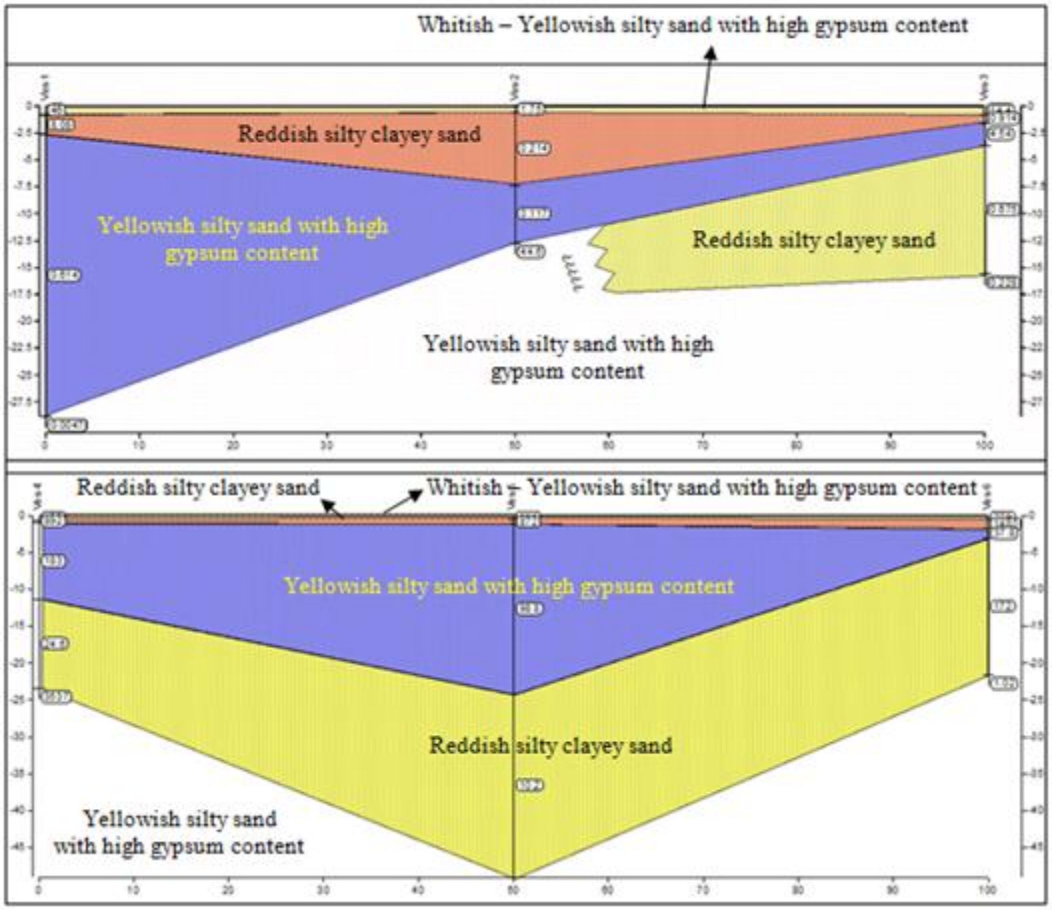

Fig.5 Geoelectrical sections for profiles 1 and 2 inside Karbala-2 Plant

B. Calculation of the geoelectrical parameters

The geoelectrical parameters including total resistivity-R_T, transverse-ρ_T and longitudinal-ρ_L resistivities, longitudinal conductance-S_L and anisotropy-λ, were calculated for both Hilla-2 and Karbala-2 Power Plants (Table-3).

They indicate that the subsurface layers which belonging to Karbala-2 Plant has resistivity values higher than Hill-2 ones. This is due to the dry soil and higher gypsum content. Also, it noticed that the soil is anisotropy towards all directions beneath all VES points of the studied Plants.

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TABLE 3
Geoelectrical parameters values for Hilla-2 and Karbala-2 Power Plants

Site name	*Profile No.*	*VES points*	Σh_i (m)	$R_T = \sum_{i=1}^{m} \rho_i h_i$ (Ohm.m)	$\rho_T = \sum \frac{\rho_i \times h_i}{\sum h_i}$ (Ohm.m)	$\rho_L = \frac{\sum h_i}{\sum \frac{h_i}{\rho_i}}$ (Ohm.m)	$\lambda = \sqrt{\frac{\rho_T}{\rho_L}}$	$S_L = \sum \left(\frac{h_i}{\rho_i}\right)$ (mhos)
Hilla-2	1	1	23.56	55.37	2.35	1.682	1.18	14.008
		2	19.36	23.41	1.21	0.486	1.57	39.808
		3	26.41	28.31	1.07	0.556	1.38	47.460
	2	4	25.05	53.16	2.12	1.569	1.16	15.956
		5	19.51	21.43	1.09	0.741	1.21	26.327
		6	22.75	22.32	0.98	0.578	1.30	39.357
Karbala-2	1	1	28.86	68.67	2.38	0.672	1.88	42.916
		2	17.07	3388.1	198.1	24.233	2.85	0.704
		3	21.42	40.38	1.88	0.576	1.80	37.156
	2	4	3.12	1008.8	323.3	40.837	2.81	0.076
		5	33.75	3118.7	92.41	58.900	1.25	0.573
		6	21.6	5234.5	242.33	149.480	1.27	0.144

Physical laboratory tests for boreholes soil samples were done (Table-4), and a relationships between the true resistivity values versus **grain size** distribution percentage at both sites such as (clay, silt, sand and gravel), **moisture** and **gypsum** contents and **consistency** or **Atterberg** limits were drawn, then a best fit was made for each case. These relationships were given to us an idea about the true resistivity variations versus the above constitutes at the studied plants as follows: (Figs.6, 7, 8 and 9).

R_t α 1/ moisture (%)

R_t α 1/ gravel (%)

R_t α 1/ saturated sand (%)

R_t α 1/ wet clay (%)

R_t α dry sand (%)

R_t α dry silt percent (%)

R_t α dry clay (%)

R_t α dry silt percent (%)

R_t α gypsum percent (%)

R_t versus consistency includes:

R_t α 1/liquid limit

R_t α 1/plastic limit

R_t α 1/plasticity index

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TABLE 4
Physical laboratory tests and Atterberg limits for the studied soil samples

Site name	B.H. No.	Depth (m)	Density (gm/cm^3)		Moisture content (%)	Gypsum content (%)	Soil classification (%)				Atterberg limits (%)		
			Dry	Wet			Clay	Silt	Sand	Gr	PL	LL	PI
Hilla-2	1	0.5-1	1.44	1.8	-	0.58	54	26	20	0	18.0	51.0	33.0
		4.5-5	1.47	1.83	24.4	0.97	62	18	20	0	17.0	58.0	41.0
		7-7.5	1.46	1.84	26	1.27	54	26	20	0	18.0	51.0	33.0
		8-8.5	1.5	1.85	-	2.21	53	26	21	0	17.0	49.0	32.0
		11.5-12	1.54	1.87	27.5	5.36	41	31	28	0	12.4	44.0	31.6
		15-15.5	1.64	2.05	21.4	6.15	71	22	7	0	19.0	62.0	43.0
	2	2-2.5	1.45	1.84	26.8	0.62	54	24	22	0	20.0	53.0	33.0
		10.5-11	1.47	1.84	25.1	3	45	31	24	0	17.0	48.0	31.0
		25-25.5	1.58	1.89	19.6	12.91	47	29	24	0	14.0	43.0	29.0
		26.5-27	1.6	1.91	20.1	13.2	27	20	53	0	8.0	30.0	22.0
	3	3.5-4	1.45	1.84	26.2	0.83	51	22	27	0	18.0	47.0	29.0
		13.5-14	1.56	1.97	26.4	6.03	23	21	52	0	8.0	25.0	17.0
		27-27.5	1.6	1.9	18.8	14.7	53	27	20	0	21.0	54.0	33.0
	4	6.5-7	1.47	1.84	25.1	2.25	57	24	19	0	18.1	54.5	36.4
	5	5-5.5	1.47	1.85	25.1	1.15	24	20	56	0	8.7	26.0	17.3
	6	8- 8.5	1.46	1.84	26	2.95	47	32	21	0	15.9	44.0	28.1
	7	8.5-9	1.47	1.85	25.8	5.3	49	24	27	0	14.0	45.0	31.0
		26.5-27	1.61	1.9	18	13.8	41	25	34	0	13.0	43.0	30.0
	8	9.5-10	1.47	1.86	26.1	3	46	31	23	0	14.2	45.0	30.8
		14.5-15	1.48	1.85	25	6.23	45	34	21	0	7.0	41.0	34.0
	9	4.5-5	1.45	1.84	26.8	2.56	50	27	23	0	16.5	48.0	31.5
	10	7-7.5	1.47	1.84	25.1	2.39	73	23	4	0	20.9	63.8	42.9
		12.5-13	1.57	1.89	22.7	5.29	65	29	6	0	20.5	58.0	37.5
		27.5-28	1.63	1.91	17.2	14.2	27	20	53	0	6.6	29.0	22.4
Karbala-2	1	24.5-25	1.73	2.31	19.3	19.88	27	14	59	4	10.8	28.1	17.3
	2	23.5-24	1.53	1.88	22.5	17.72	27	13	60	2	6.7	29.0	22.3
	3	19.5-20	1.92	2.24	28.3	19.15	26	16	58	1	8.7	28.3	19.0
	4	22-22.5	1.97	2.28	26	17.7	24	15	61	2	11.0	26.0	15.0
	5	22.5-23	1.86	2.19	17.6	18.2	28	16	55	2	10.6	29.6	19.0
	5	22.5-23	1.86	2.19	17.6	18.2	28	16	55	2	10.6	29.6	19.0

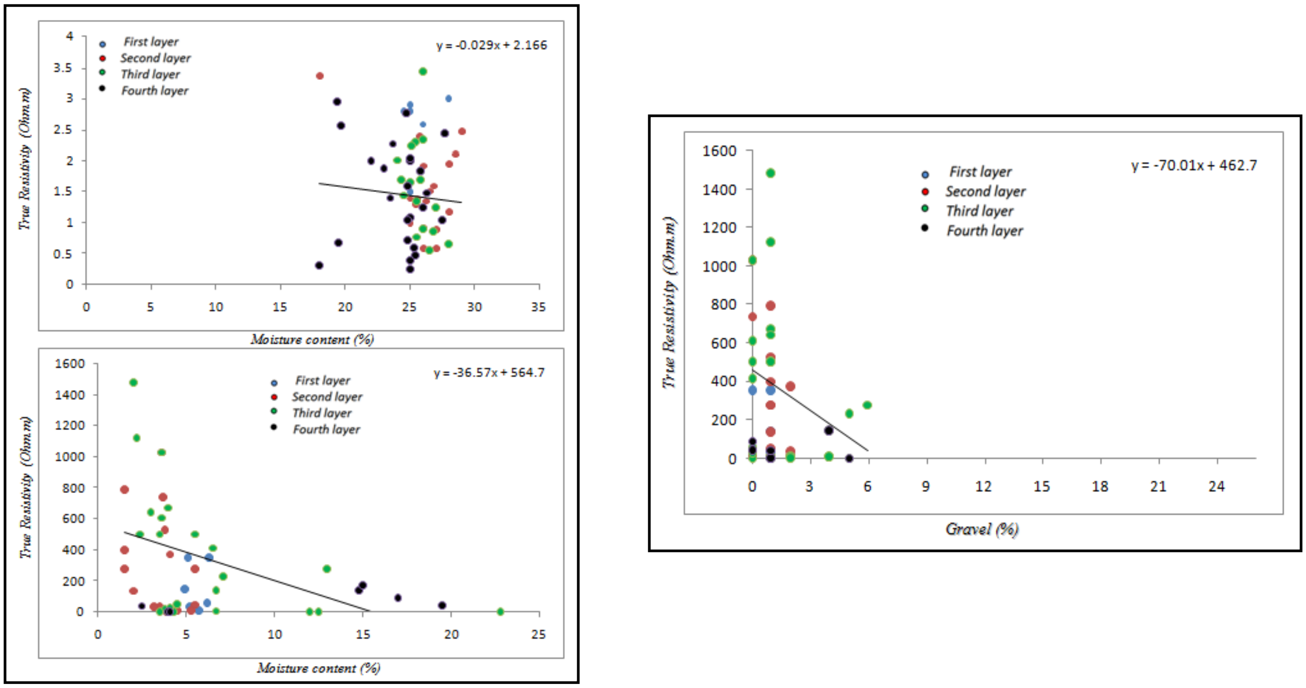


Fig.6 True resistivity versus moisture content at Hilla-2 and Karbala-2 (left) and gravel at Karbala-2 Plant (right)

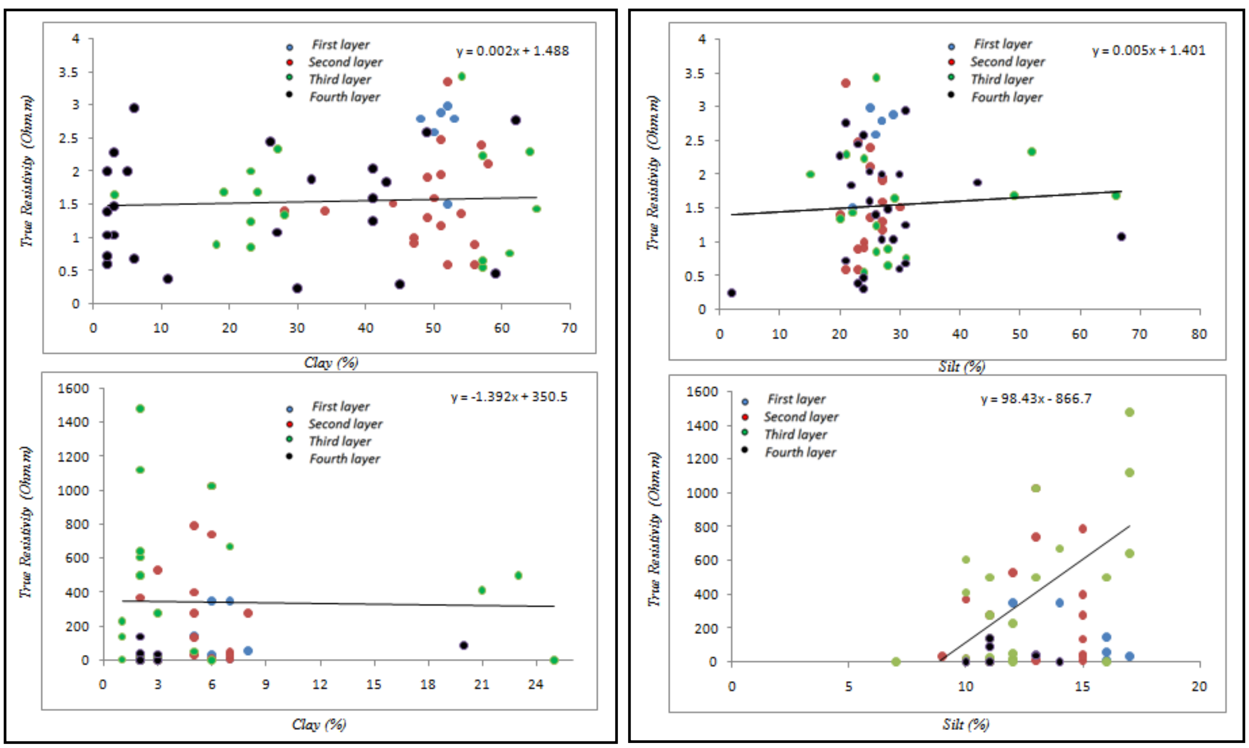


Fig.7 True resistivity versus clay (left) and silt (right) contents at Hilla-2 and Karbala-2 Plants

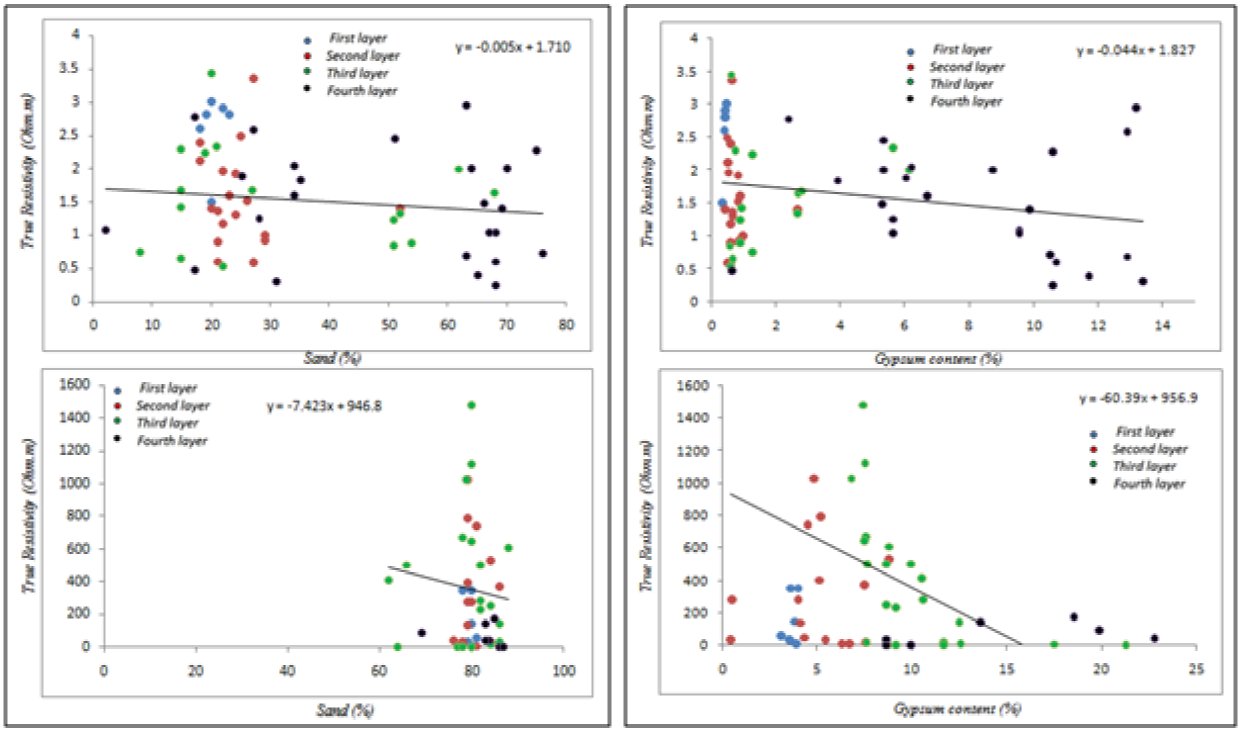
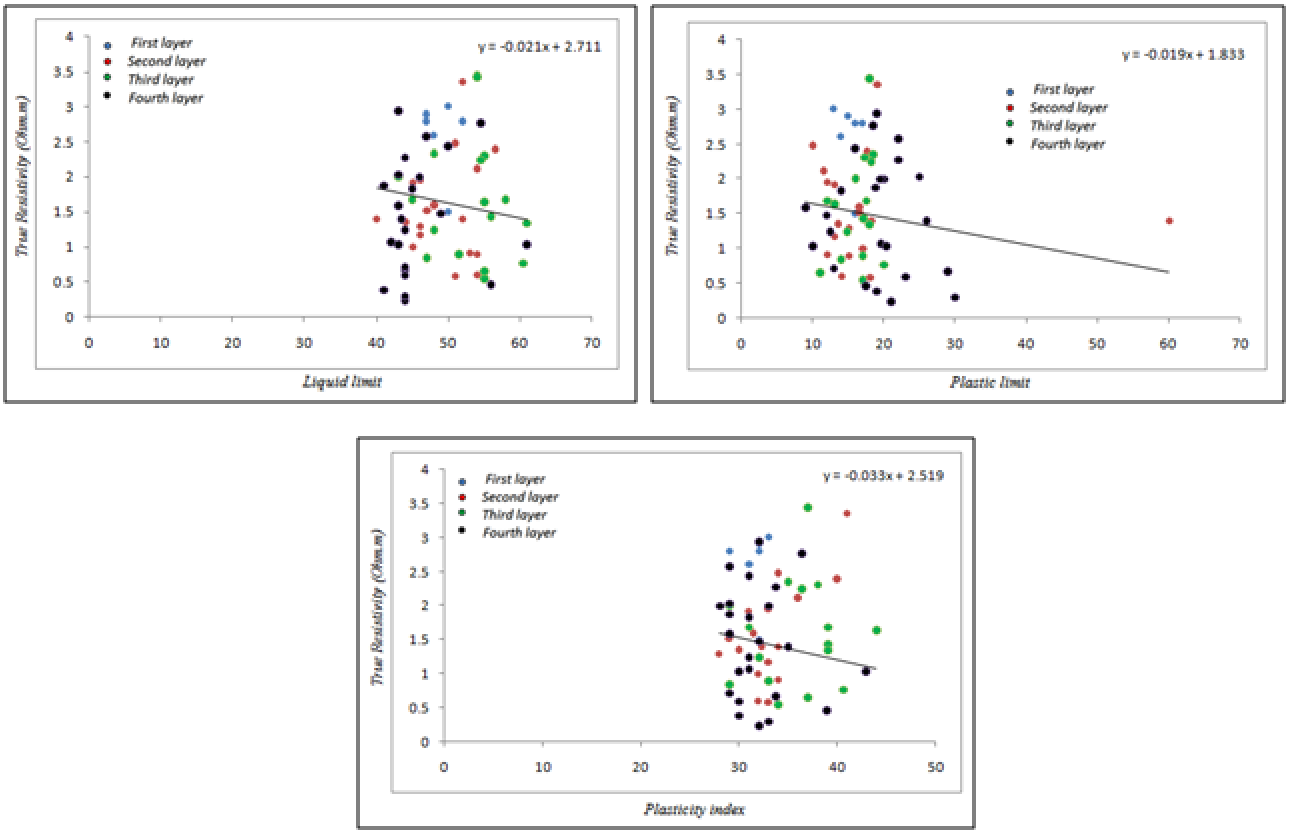


Fig.8 True resistivity versus sand (left) and gypsum (right) contents at Hilla-2 and Karbala-2 Plants



(Fig.9) True resistivity versus Atterberg (liquid and plastic limits and plasticity index at Hilla-2 and Karbala-2 subsurface soils

B. Seismic refraction survey

As is often the case, P and S-waves were masked by other larger amplitude data, included lower frequency surface waves, and roadway noise. Traffic noise was attenuated by band pass filters from (35-120) Hz [14 and 15], and gain control of all channels. The time distance curves were interpreted by least square fitting, ABC, ABEM, plus-minus and T-minus mean methods [16]. These methods showed no significant difference between the velocities of layers and thicknesses. The first arrival times for each seismic trace were picked for 72 full seismic records of 12 channels (traces), 36 records for either P or S wave measurements. The time-distance curves of the above records were plotted for all profiles. The velocity and the intercept time of each refractor were calculated, while the following equations were used to determine the thicknesses and depths of the seismic layers beneath each shot point [12], (Table-5).

$$Z_0 = \frac{T_i}{2} \frac{V_1 V_0}{\sqrt{V_1^2 - V_0^2}}$$

$$Z_1 = \frac{1}{2}\left(T_{i2} - 2 Z_0 \frac{\sqrt{V_2^2 - V_0^2}}{V_2 V_0}\right) \frac{V_2 V_1}{\sqrt{V_2^2 - V_1^2}}$$

Z_0: Thickness of the top layer, Z_1: Thickness of the first layer, Ti_1: The intercept time of the top layer and Ti_2: The intercept time of the first layer.

Three different velocities (V_0, V_1 and V_2) had been obtained in this research depending upon the constructed time-distance curves as mentioned above. They represent three subsurface layers at the studied area. Table-4 reveals the results of the above calculations. Seismic waves have always been an available as part of any civil engineering site investigation; the velocity data derived when used in any diagnostic manner nearly always refer to the P-waves propagation. For a complete assessment of the dynamic elastic constants, there is a need to measure shear wave phenomena.

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Dynamic elastic (Poisson's ratio-σ, young-E, shear-μ and bulk-K) modulus of the three subsurface soil layers (seismic layers) were also determined depending upon velocities of P and S-waves, and the densities measured from the drilling boreholes at different depths. The relevant interrelationships between P-wave, S-wave and various elastic moduli are mentioned below [17], and the results are tabulated in table 5. Depth sections had been extracted along the conducted profiles for Hilla-2 and Karbala-2 Plants (Fig.10).

$$Dynamic\ Shear\ Modulus\ (\mu) = V_S^2\ \frac{\ell}{g}$$

$$Dynamic\ Bulk\ Modulus\ (\kappa) = \frac{\ell}{g} V_S^2 \left[\left(\frac{V_P}{V_S} \right)^2 - \frac{4}{3} \right]$$

$$Dynamic\ Young\ Modulus\ (E) = \frac{V_S^2\ \ell}{g} \left[\frac{3 (V_p/V_s)^2 - 4}{(V_p/V_s)^2 - 1} \right]$$

$$Poisson\ \text{Ratio}\ (\sigma) = \frac{(V_P / V_S)^2 - 2}{2\,(V_P / V_S)^2 - 2}$$

ℓ : Unit weight.

g: Acceleration of gravity.

C. Standard Penetration Test-SPT and Bearing capacity

This insitu field test can measure the compressional resistance of the underlying soil.. Distinct variations in the soil composition with depth were recognized as mentioned before. Therefore, the measured SPT(N) needs to be corrected using the equation below especially in case of fine and silty sands saturated with water (compressional resistance>15) [18].

$$V_s = 89.8\ N^{0.341} \qquad \textit{for clayey sand sturated soils}\ [19]$$

$$N_{corrected} = 15 + 0.5\ (N_{measured} - 15)$$

Bearing capacity (Q_u) values in T/m^2 was also determined for all drilled boreholes inside both studied sites. In here, the calculations mainly depend on the horizontal component (S_h) of Vs because the vertical one (S_v) may convert to P-wave during reflections when intact interfaces and visversa [20] as follows:

$$Q_u = \frac{1}{3} \left(\frac{V_p}{240} \right)^{2.38} \qquad \textit{for unconsolidated soils}\ [21]$$

Depending upon Parry equation (1977), [22] have been derived a relationship between Vs and Q_u as given below:

$$Log\ Q_u = 2.398\ (log\ V_s - 1.45)$$

Tables 6 and 7 illustrate SPT (N) and Qu results for both Hilla-2 and Karbala-2 Power Plants subsurface soils. In Hilla-2, it noticed that at the shallower depth 2 m, N=13 and Q_u=6.7 Ton/m^2. This is because of the existence of the saturated clay which leading to occur swelling phenomena. Whereas, from depths ranged between (17-30) meters, N-values reach more than 50 impacts and Qu equals 17 Ton/m^2 owing to its hard soil layers (Fig.11). At the other site, it is observed that N is more than 50 impacts and have Q_u>17 Ton/m^2 for all boreholes. This gives an indication that the subsurface soils are cohesion consist of high percent of sand with few clays (Fig.12). Finally, we tried to superimpose our results on Hunt, 1986 relationship between Vp/Vs and Poisson's ratio for different types of rocks [23]. It seems from figure 13 that Poisson's ratio in both sites has high values especially those related to layer one might owed to the existence of soft silty sand deposits with saturated clays the matter which lower the cohesive of this layer. However at most of Karbala site area, the second layer locates nearby the compacted rocks which mean that these types of rocks were strongly subjected to the overburden pressure and empty from clays and groundwater.

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TABLE 4
Vp, Vs and the mean thickness of the underlying layers within Hilla-2 and Karbala-2 Power Plants

Site name	*Profile No.*	*Layer*	*Seismic wave velocities (m/s)*						*Mean thickness (m)*
			Normal		Central		Reverse		
			Vp	*Vs*	*Vp*	*Vs*	*Vp*	*Vs*	
Hilla-2	1	First	257	-	226	117	235	138	2.77
		Second	517	-	458	294.5	530	247	-
	2	First	270	104	196	-	243	108	2.4
		Second	584	217	458	-	595	218	-
Karbala-2	1	First	212	116	-	92	203	116	2.77
		Second	408	231	-	277	407	210	-
	2	First	178	116	138	-	178	117	3.2
		Second	1078	354	431	-	1122	271	-

TABLE 5
Mean of the elastic modulus of the underlying layers inside Hilla-2 and Karbala-2 soils

Plant name	*Profile No.*	*Layer*	Mean							
			Vp (m/s)	*Vs (m/s)*	*Vp/Vs*	*Density (Kg/m^3)*	*σ*	*in Mega Pascal*		
								E	*μ*	*K*
Hilla-2	1	First	239	127.5	1.874	1650	0.699	91.1	26.8	58.6
		Second	501	270	1.855	1880	0.7	466	137.1	289.1
	2	First	236	106	1.360	1650	1.088	207.4	49.7	25.8
		Second	545	217.5	2.505	1880	0.59	282	88.9	440
Karbala-2	1	First	207.5	108	1.921	1650	0.68	64.6	19.2	45
		Second	407.5	239.3	1.702	1880	0.76	378.9	107.6	169
	2	First	164.6	116.5	1.412	1650	1.008	89.9	22.4	14.9
		Second	877	312.5	2.806	1880	0.57	576.5	183.9	1201.7

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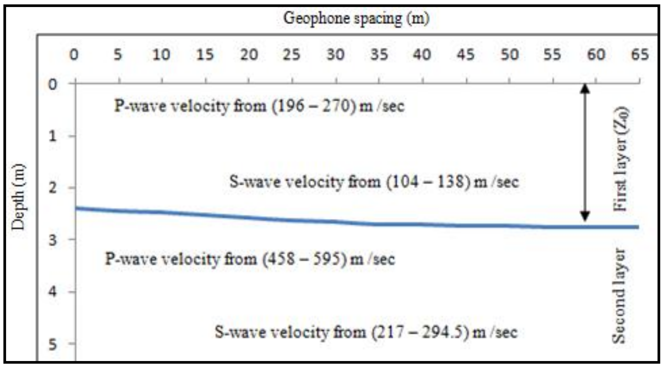

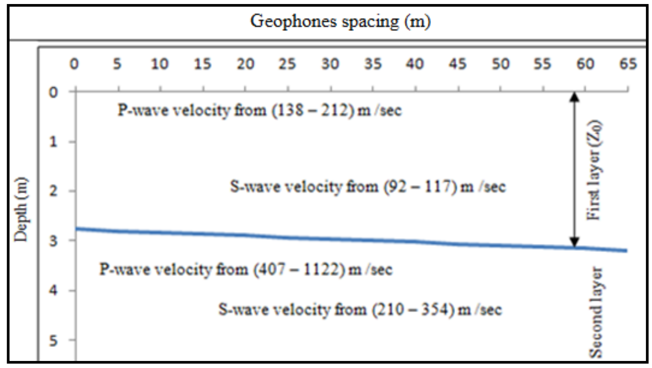

(Fig.10) Depth sections for Hilla-2 (left) and Karbala-2 (right)

TABLE 6
Average values of both Standard Penetration Test - SPT (N) and Bearing Capacity for Hilla-2 site

Depth (m)	*Standard Penetration Test - SPT (N) total for (300) mm*										*Aver. SPT*	*Ave. B.C T/m²*
	BH.1	*BH.2*	*BH.3*	*BH.4*	*BH.5*	*BH.6*	*BH.7*	*BH.8*	*BH.9*	*BH.10*		
2.0	-	-	-	11	-	-	-	13	16	-	13	6.7
3.0	18	17	14	-	12	15	17	-	-	18	17	8.3
4.0	-	-	-	-	-	-	-	-	18	-	18	8.5
5.0	-	-	-	15	-	-	-	21	-	-	25	10.4
6.5	15	-	27	-	-	28	-	-	16	15	18	8.5
7.0	-	21	-	-	20	-	18	-	-	-	20	9.1
8.5	22	-	-	26	-	-	-	-	-	22	23	9.8
9.0	-	16	-	-	-	27	-	27	28	-	25	10.4
10.5	28	-	32	-	29	-	25	-	-	28	28	11.2
11.0	-	-	-	33	-	-	-	-	-	-	33	12.5
12.0	-	-	36	-	-	-	24	-	-	-	30	11.7
13.0	-	-	-	38	-	38	-	-	-	-	38	13.7
14.0	51	-	-	-	38	-	-	42	40	51	44	15.3
15.5	-	35	46	-	-	-	-	-	-	-	40	14.3
16.0	-	-	-	-	47	44	>50	-	-	-	47	16.1
17.0	>50	-	-	>50	-	-	-	-	-	>50	>50	>17.0
18.5	-	52	>50	-	-	-	66	-	61	-	>50	>17.0
19.0	-	-	-	-	-	-	-	>50	-	-	>50	>17.0
20.0	62	-	-	-	43	>50	-	-	-	62	>50	>17.0
21.0	-	>50	-	-	-	-	52	-	-	-	>50	>17.0
22.5	>50	-	>50	30	60	-	-	-	>50	>50	>50	>17.0
23.0	-	-	-	-	-	-	-	68	-	-	>50	>17.0
24.5	-	>50	-	-	-	>50	-	-	-	-	>50	>17.0
25.0	>50	-	>50	-	-	-	>50	-	-	>50	>50	>17.0
26.0	-	-	-	>50	>50			-	-	-	>50	>17.0
27.0	-	>50	-	-	-	-	-	-	-	-	>50	>17.0
28.0	>50	-	-	-	-	-	-	>50	-	>50	>50	>17.0
29.0	-	-	-	-	-	>50	-	-	>50	-	>50	>17.0
30.0	>50	>50	>50	>50	>50	-	>50	-	-	-	>50	>17.0

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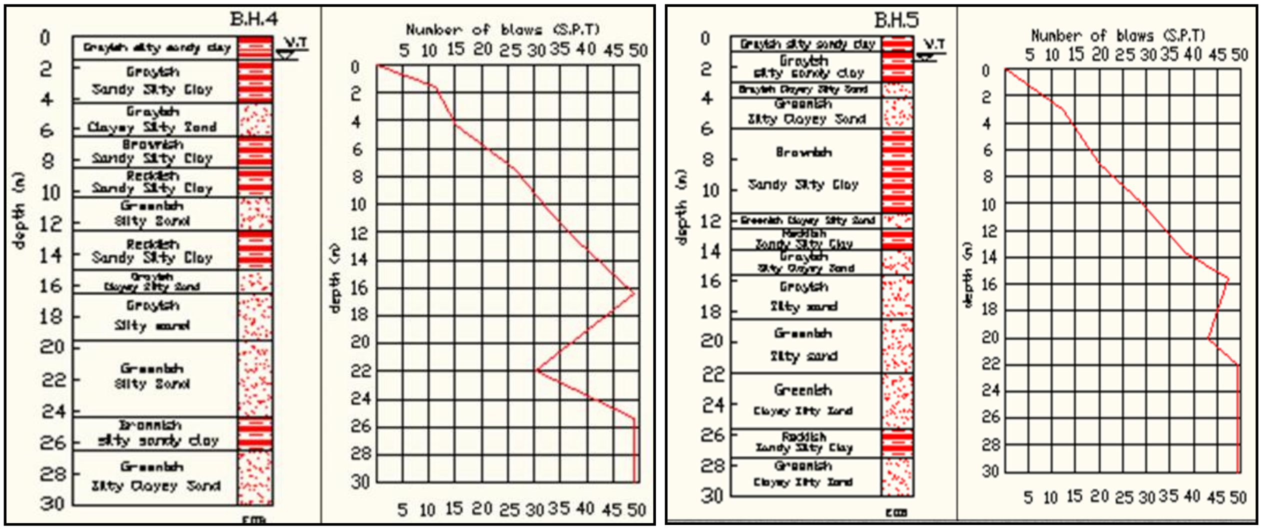

(Fig.11) Two examples of SPT for boreholes 4 and 5 inside Hilla-2 site

TABLE 7
Average values of both Standard Penetration Test - SPT (N) and Bearing Capacity for Karbala-2 site

Depth (m)	*Standard Penetration Test - SPT (N) total for (300) mm*						*Aver. SPT*	*Ave. B.C T/M²*
	BH.1	*BH.2*	*BH.3*	*BH.4*	*BH.5*	*BH.6*		
2.0	-	>50	>50	-	>50	>50	>50	>17.0
3.0	>50	-	-	>50	-	-	>50	>17.0
4.5	-	>50	-	-	-	-	>50	>17.0
5.0	>50	-	>50	-	>50	>50	>50	>17.0
6.5	>50	-	-	>50	-	-	>50	>17.0
8.5	-	>50	>50	-	>50	-	>50	>17.0
9.5	>50	-	-	>50	-	-	>50	>17.0
10.5	-	-	>50	-	-	>50	>50	>17.0
11.0	-	>50	-	-	>50	-	>50	>17.0
12.0	>50	-	-	-	-	-	>50	>17.0
13.5	-	-	-	>50	-	>50	>50	>17.0
14.5	-	>50	>50	-	>50	-	>50	>17.0
15.5	>50	-	-	-	-	-	>50	>17.0
17.0	-	-	-	>50	>50	>50	>50	>17.0
18.5	>50	-	>50	-	-	-	>50	>17.0
19.0	-	>50	-	-	-	-	>50	>17.0
20.5	-	-	-	>50	-	-	>50	>17.0
21.5	-	>50	>50	-	>50	>50	>50	>17.0
22.0	>50	-	-	-	-	-	>50	>17.0
24.0	-	-	-	>50	-	-	>50	>17.0
25.0	>50	-	-	-	-	>50	>50	>17.0
26.5	-	>50	>50	>50	-	-	>50	>17.0
28.0	>50	-	-	-	-	-	>50	>17.0
29.0	-	>50	-	-	>50	-	>50	>17.0
30.0	>50	-	>50	>50	-	>50	>50	>17.0
2.0	-	>50	>50	-	>50	>50	>50	>17.0
3.0	>50	-	-	>50	-	-	>50	>17.0
4.5	-	>50	-	-	-	-	>50	>17.0
5.0	>50	-	>50	-	>50	>50	>50	>17.0

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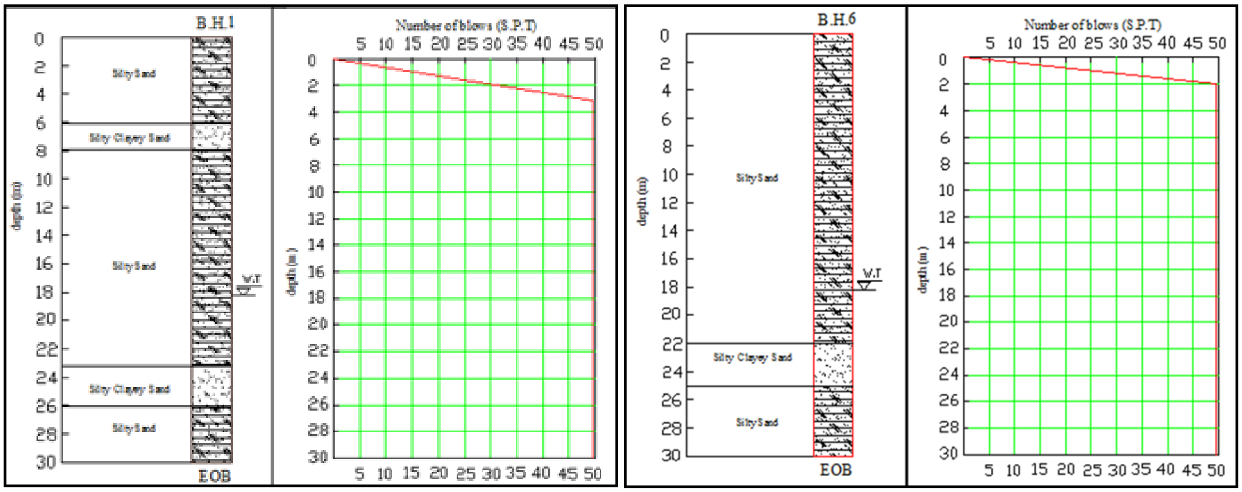
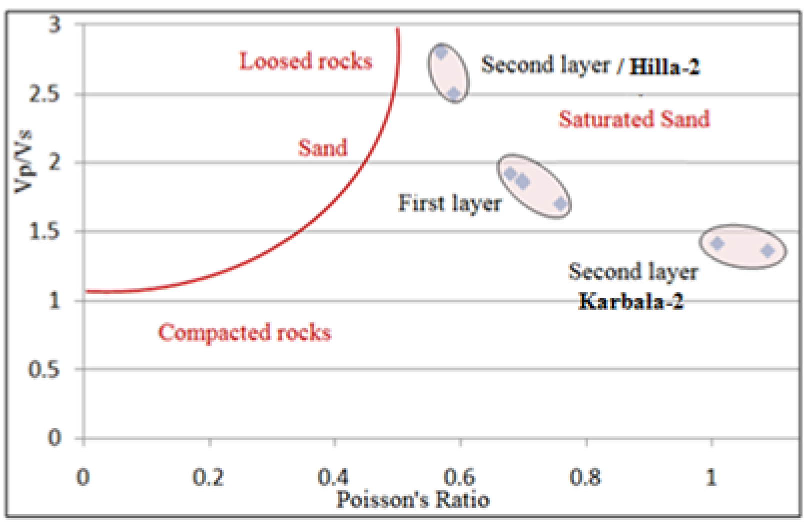


(Fig.12) Two examples of SPT for boreholes 1 and 6 inside Karbala-2 site



(Fig.13) Relationship between VP/Vs and Poisson's ratio for both Hilla-2 and Karbala-2 sites

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