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Geophysical, Geotechnical and Geochemistry Investigation for The Area of Kerbela`s Cement Factory

التحريات الجيوفيزيائية والجيوتكنيكية والجيوكيميائية لتربة معمل سمنت كربلاء

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Abstract

Geophysical, Geotechnical and geochemical investigation was conducted. The samples of four boreholes were examined for classification and chemical test. In this study the surface Seismic Refraction profile showed three layers were distinguished light marl silty clayey sand with gravel, silty sand with fragment of carbonate rocks and the third layer consist of carbonate rocks. The seismic cross hole survey result showed that the fill material is non homogenous in thickness and in degree of compaction which resulted in different settlement, and the cavities and weak zones are located. .

From geotechnical and geochemical study , the types of soil is CL – ML , this indicates that the soil of studies area is mainly fine grained soil to coarse grained soil with a lens of very dense white marly limestone silty gravel with sand .The MC, IC, P.L,L.L are measured too.

The chemical properties of the soil of study area were investigated. The results showed that the percentages of sulphate as $CaSo_4.2H_2O$ was(o.32– 2.1)% ,Organic matter was(0.0)%,Carbonate was (39 - 94)%, Chloride was (o,11 – 0.14) % respectively. PH of the soil was (7.4 – 7.9).

الخلاصة

التحريات الجيوفيزيائية والجيوتكنيكية والجيوكيميائية لمنطقة تقع ضمن معمل سمنت كربلاء .واوضحت نتائج المسح الزلزالي الانكساري والجسي (المتقاطع) والفحوصات الموقعية والتحاليل المختبرية لنماذج التربة من سطح الارض الطبيعية ولغاية العمق (15)متر تتكون من ثلاث طبقات : طبقة متكونة من الطين والرمل مع الحصى وطبقة الرمل والسلت الوقطع صخرية كاربونايتية وهاتين الطبقتين تمثلان طبقة الدفن والطبقة الثالثة طبقة صخرية تمثل صخور كاربونية (اللايمستون). واوضحت نتائج المسح الزلزالي الجسي (المتقاطع) ان طبقة الدفن غير متجانسة السمك وان وجود الفجوات وانطقة الضعف ودرجة الانضغاطية الواطئة كانت السبب وراء حصول الهبوط في امان مختلفة من المنشأ.

اما الدراسة الجيوتكنيكية والجيوكيميائية ان نوع التربة هو مابين CL-ML وهذا يدل على ان التربة لموقع الدراسة بصورة رئيسية متكونة من حبيبات ناعمة الى خشنة مع وجود لعدسات من قطع صخرية من الايمستون المارلي والسلت مع الرمل. وقد تم حساب المحتوى المائي للتربة بالاضافة الى حساب حدود الليونة والدونة للتربة .واوضحت نتائج واوضحت نتائج التحاليل المختبرية لهذه الدراسة ان نسبة الجبسوم($CaSO_4.2H_2O$) مابين(2,1-0,32)% والمواد العضوية (0,0)% والكاربونات (94-39)% والكلوريدات (0,14-0,11)% وان الاس الهيدروجيني للتربة يتراوح مابين (7,9-7,4).

Introduction

The relationship between geophysical, geochemical and geotechnical techniques has showed very good indicators to investigate the movement causes cracks and distortion in the building and to locate cavities and weak zones, and also for checking grouting effect after grouting processes.

So the present study uses the three techniques to study the case of Kerbela's Cement Factory for the previous reasons.

Geological Setting

The Cement Factory situated in Karbala located at (189)Km. from center of Kerbela City .So it lies in Tigris subzone at Mesopotamian zone which is in unstable shelf (Fig.1)according to Buday and Jassim ,1987.Dibdiba formation expose at the surface associated with Injana formation[2] .

Methodology

Materials and Work Methods:

Geophysical and geotechnical investigation are made in this study. Four boreholes were drilled to a depth of (15)meters for collecting geotechnical samples and executing S.P.T after that these boreholes were caused by using galvanized pipes (2.5)inch diameter.For Cross hole survey another four boreholes were drilled and used as an energy source to generate seismic waves for cross hole survey[(13),(3),(16)].

The samples of each borehole were examined for classification test and chemical test as in table(1) and (2).The underground water table appears at (2)meters depth during the execution depth of investigation . The soil profile for the four boreholes are showed in the fig.3 and 4).Four samples were examined to determined L.L,P.L and P.I as in the table (1 and 2).

Results

From the seismograph record of the thirteen surface seismic refraction profile ,the first arrival time of compressional wave was determined[7] as in the table (3)which summarizes the results of surface seismic profile P/1-P/13 (fig.2)and present the range of comprssional velocities and thickness of each subsoil layers.

From the seismograph record of the four cross hole profiles, the first arrival time of the compressional and shear waves was determined[(6),(15),(18)] .

The velocities of shear wave (Δv_s)and compressional wave (Δv_p)for each depth was calculated[(16),(3)] as in table (4,5,6,7).

From the results mentioned above, the study determined the profile location of cavities and weak zones[5] as in table (8) and in the fig. (3).

Also this study record of the chemical tests to determine the SO_3%, $CaCO_{3\%}$, OR, Gyp%, and Cl% and to determine PH of the soil. This part of the study showed that the rang of SO_3% is(0.1-3.5),$CaCo_3$% is(42-94),Gyp. is (0.32)for one sample from B.H.1 at depth (9-9.5)meter. The present of Cl rang between (0.12-0.14) .No organic materials in the studied area.

The PH ranged from (7.4) to (7.9) showed that the soil of the studied area is slightly alkalize.

Discussion and conclusion

We summarize the conclusion of this study in conclude two parts, firstly, the geophysical conclusion and secondly, geotechnical conclusion.

First; Geophysical Conclusions

The geophysical study which is divided into two kinds, surface seismic refraction and cross hole methods ,the results of these methods agreement with In-situ information, boring, drilling, sampling, this indicate that:

1. From the results of the surface seismic refraction profile exacted in this area, three layers were distinguished depending on compressional wave velocity.

a. Top layer ,which consist of white to light marl silty clayey sand with gravel , the compressional wave velocity was range (200 – 1113) m/sec .The depth of first contact was (0.1 – 3.0)m. between the first and second layer.

b. The second layer, which consist of silty sand with fragment of carbonate rocks. The compressional wave velocity was range (1219 – 2305) m/sec .The depth of second contact was (3.0 – 8.6)m. between the second and third layer.

c. The third layer consists of carbonate rocks. The compressional wave velocity was (>3000) m/sec .This layer extends to the end of investigation depth (5 – 15) meters.

These agree with soil description as in soil profile for borehole (1, 2, 3, 4) fig. 4, 5).

2. From fig .(6)and (7)which shows the relationship of V_s,V_{s^-} and Δv_s, the shear wave velocity with depth. The highest thickness of fill material appears at depth (10.0 m.)at profile (S_1) while at (5.0 – 6.0)m. at profile (S_2 , S_3 and S_4). The shear wave velocity is in range (400 - 600)m/sec.

   This result represent that the fill material is non homogenous in thickness and in degree of compaction which resulted in different settlement.

   From the result of surface seismic survey, cavities and weak zones were located as in table (8) and shown on fig.(3).From seismic cross hole survey ,weak zones were located as following :

   * S/1 located between crushers and control building, weak zone appears at depth (1.5 – 9.0)m.

   **S/2 and S/3 weak zone appears at depth (1.0 – 6.0)m.

3. From the geotechnical study, the type of soil according to USCS is CL – ML consist (45.9%) and ML consist (36.3%) and the type GM consist (18.1). This indicate that the soil of the area is mainly fine grained soil in borehole (2,3,4)but it fine to coarse grained soil in borehole(1) exactly in the sample No. 3,4,5,6 at the depth (3– 3.5)m.,(5 – 5.5)m.,(7 – 7.5),(9 – 9.5)m. which alones of very dense white marly limestone silty gravel with sand.

   Mitchell,1993 refers that the soil with L.L less than 20% are non cohesive soil and this study shows that L.L of the studied area ranges (24– 29)% so the soil of this study area is cohesive soil[14]. Terzaghi and Peack etal,1974 mention that a direct relationship join between swell potential of the soil and liquid limit as in the table (1 &2)[19].

Table 1 :Swell potential and plasticity Index

Swell potential	Plasticity index
Low	0 – 15
Medium	10 – 35
High	20 – 55
Very high	35 and above

The liquid limit of the studied area ranges (12 - 24) so the swell potential of it may be low to medium.

On the other hand Lamb & Whitman, 1969 found that the hardness of the soil increase with increase of plasticity values[12].

The moisture content (MC) values show the range (4 – 17)% .This range refers to be low – medium which related to the soil texture and permeability that differ from borehole to another so the moisture content in samples from borehole (2) is 17% as the texture is clay and silt while the moisture content of the borehole (1) rang (4 – 9)% related to coarse grained texture to the soil and very dense marly limestone silty sand.

Maharaj ,1995 refers to this properties that may help to create problems to underground geometrical buildings especially which related to unless the internal cohesive of the grains and the ability to swell.

From the equation below[12],[4]:

$I_c = L.L – M_c /P.I$

I_c=consistency Index

M_c=moisture content

P.I=plasticity Index

The present study showed that I_c of the soil range (0.76 – 1.58)% this values refer to consistency to be stiff – very stiff as in table (10)also this table refers to relationship between I_c & unconfined compressive strength (q_u). This will refer to unconfined compressive strength of the studied are range (100 – 400)KN/m^2.

Table 2 : The relationship between soil consistency & unconfined compressive strength[(10),(11)]

un confined compressive strength qu KN/m^2	Consistency	consistency Index
0 – 25	Very soft	o.o – 0.25
25 – 50	Soft	0.25 = 0.5
50 – 100	Medium	0.5 – 0.75
100 – 200	Stiff	0.75 – 1.0
200 – 400	Very stiff	>1.0
➢ 400	Hard	➢ 1.0

Secondly; Geochemical study

This study results in the chemical composition of the soil of the study area consists of:

Sulphate (SO_3)%

The sulphate percent in the studied area range (0.1 – 3.5).The vertical distribution of sulphate in bore hole (1) fluctuated between (0.13 – 0.87) while the vertical distribution in borehole (2) is nearly alike (0.7-0.75).In borehole (3) the percent fluctuated from (0.1 – 3.5) in vertical distribution. The horizontal distribution was showed that the percent of SO_3 increase from boreholes 1, 2, 3 and 4 sequentially with difference in some samples.

Generally the difference in SO_3 value from borehole to another obvious from the abundance sources that SO_3drived from the source of SO_3 are gypsum sediments which found as crystal or as ions transport by Tigris and Euphrates and their tributaries from the high regions that the rivers cross then like Fatha, Injana and Mugdadia outcrops.

Vozbutskya, 1977 refers to SO_3 increase in soil of dry region more than the soil of humid region.

Tomlinson, 1988 advise to use resistance cement if SO_3%is more than 0.2% and the cement amount must be (310) Kg/m^3 or more ,and the percent of W/C doesn't increase than 0.5,in this case the sewage pipes prefers to be paint with more permeability matter to keep them from corroding , and if the percent of SO_3 is more than 1%, It is necessary to use super sulphates equal to 0.4% and the concrete foundation must treat with adhesive plastic sheeting.

Gypsum ($CaSO_4.2H_2O$)

Gypsum percent in the soil of studied area ranges (0.9 – 2.1). Gypsum assurance in the soil of studied area obvious from the sediments of Fatha formation in the first degree and sediments which transport by Tigris and Euphrates.

The risks of gypsum on the resistance of soil or differential settlement of building and foundations causes voids and cavities because of the ability gypsum to be soluble in ground water .

Gypsum has an effect on the concrete because of the reaction of sulphate with slacked lime $Ca(OH)_2$ and the volume expansion of gypsum causes fractures in concrete[(10)].

As gypsum has the ability to be soluble in water so some gypsum content in soil may dissolve because of the fluctuation of the ground water table or seepage of water into soils , thus the voids may increase and enlarge so the may cause the soil settlement under heavy loads[(8),(17)]. Arutyunyan &Manutyan,1981 ensure if the percent of gypsum is more than 10% of the sample dangerous on the foundation .

Organic matter

There is no an organic matter in the soil of the studied area so the soil is far from the problems that may create from assurance of organic matter.

Carbonates ($CaCO_3$)

Carbonates percent of the soil in the studied area range (39 – 94) so it is very higher than the average which mentions that the soil is of high content of $CaCO_3$ may cause geometrical problems.

Carbonate of the studied area result from occurrence of calcium ions in the ground water, also the source in the studied area which is alluvial resulted from the erosion of dolomite and limestone from the formation which Tigris & Euphrates pass through.

The importance of carbonate study related to it is high percent cause's problems on the bearing capacity and resistance of soil because of the high ability to dissolve in water and acids and this causes cavities and increase the void volume especially in the lower bed of soil which become no fit to use as bases of foundation.

Jumikis, 1962 ensure that the percent 30%of carbonate or more has a risk because it causes geometrical problems as settlement building or weakness of soil[9].

From the above the percent of carbonate in the studied area is higher than while may be taken with considerable so this may cause all the problems if there is no treatment.

Chloride

Chloride percent in the soil of the studied area range (0.11– 0.14) whereas the higher value is in the borehole (2)and the least value in the borehole (1).Considerably the percent of chloride more than 0.1 in the soil is high and it is possible to cause risks on the foundation and steel rods. To avoid the effect of high chloride in foundation needs to put shield from concrete with thickness of (5–15) m. round the foundation[1].

The importance of PH value of the soil related to the corroding of the concert wheeze the concert is alkaline and its Ph 13 so it is exposed to attract by acids formal near it where calcium hydroxide and produced acid to produce soluble matter. Soil became alkaline because of the oxidation of carbon to CO_2 and the percent of be carbonate increase so the water and soils because alkaline and the other reason to the high occurrence of calcium carbonate in the soil produce from the erosion of dolomite and limestone. This agree with the high occurrence of carbonate in the studied area soil. The values of PH to the studied area soil range (7.4 -7.9) it is slightly alkaline.

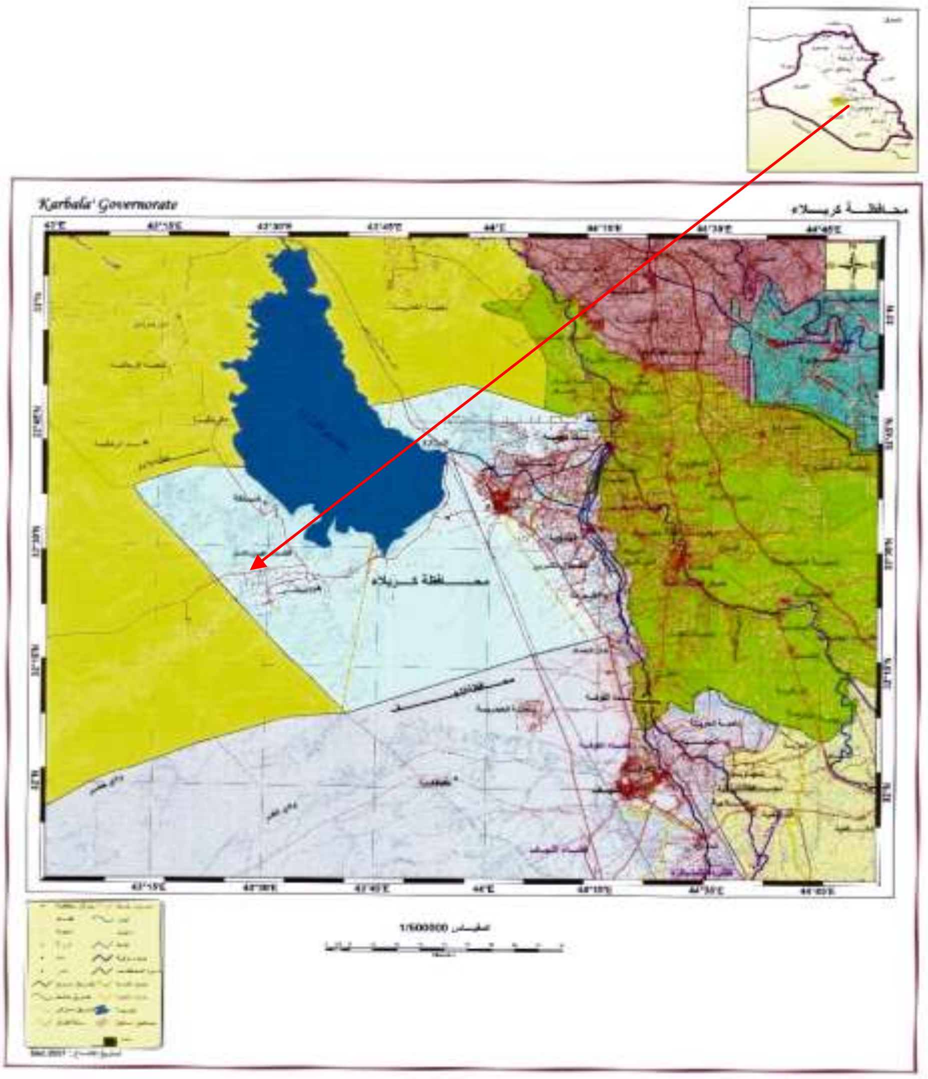

Figure (1) : Location map of study area (General commission on survey, 2007) .

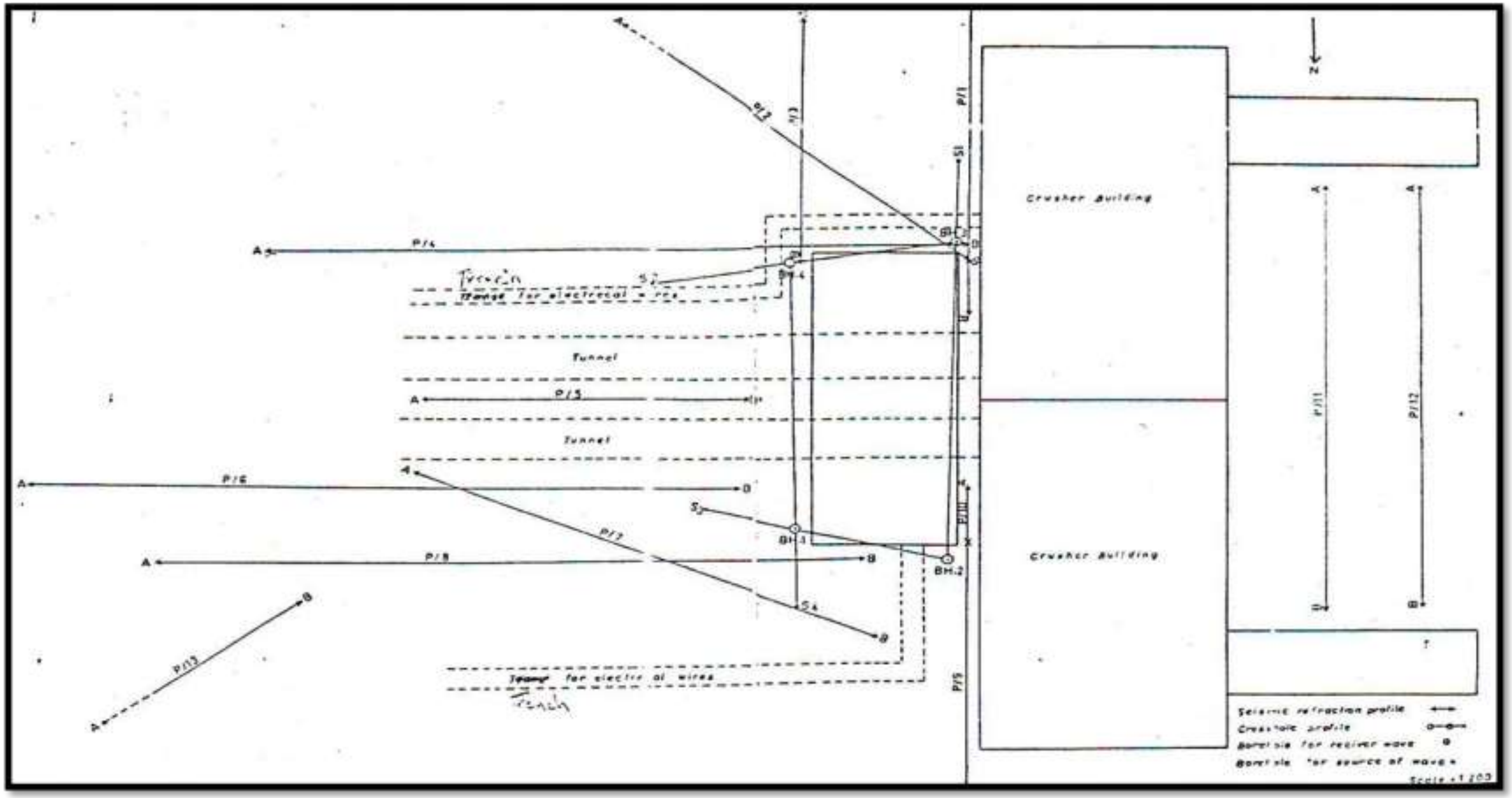

Fig. 2: Seismic refraction &cross hole profiles and boreholes location for cement building for crusher in Kerbela cement factory

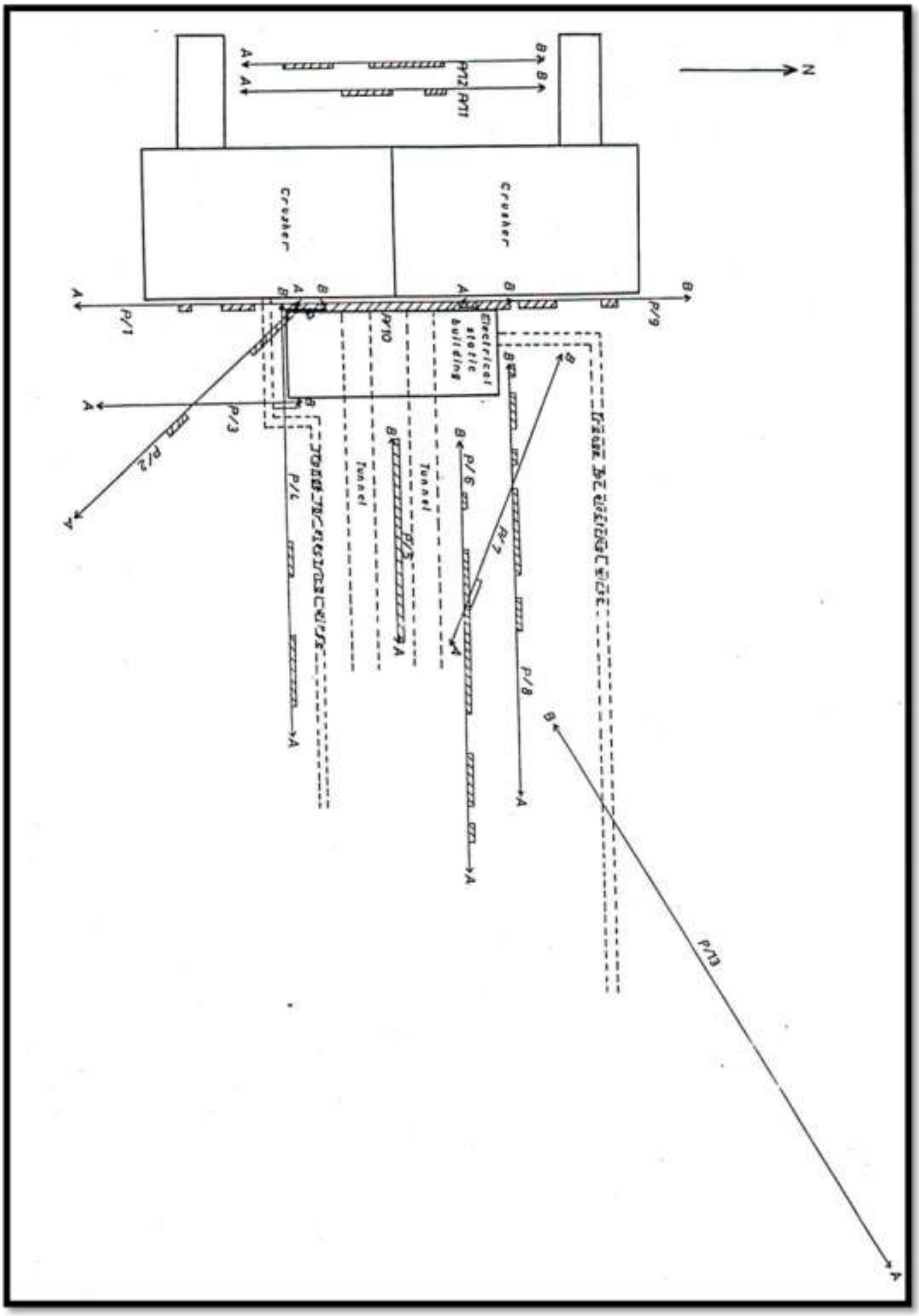

Fig. 3: Seismic refraction &cross hole profiles

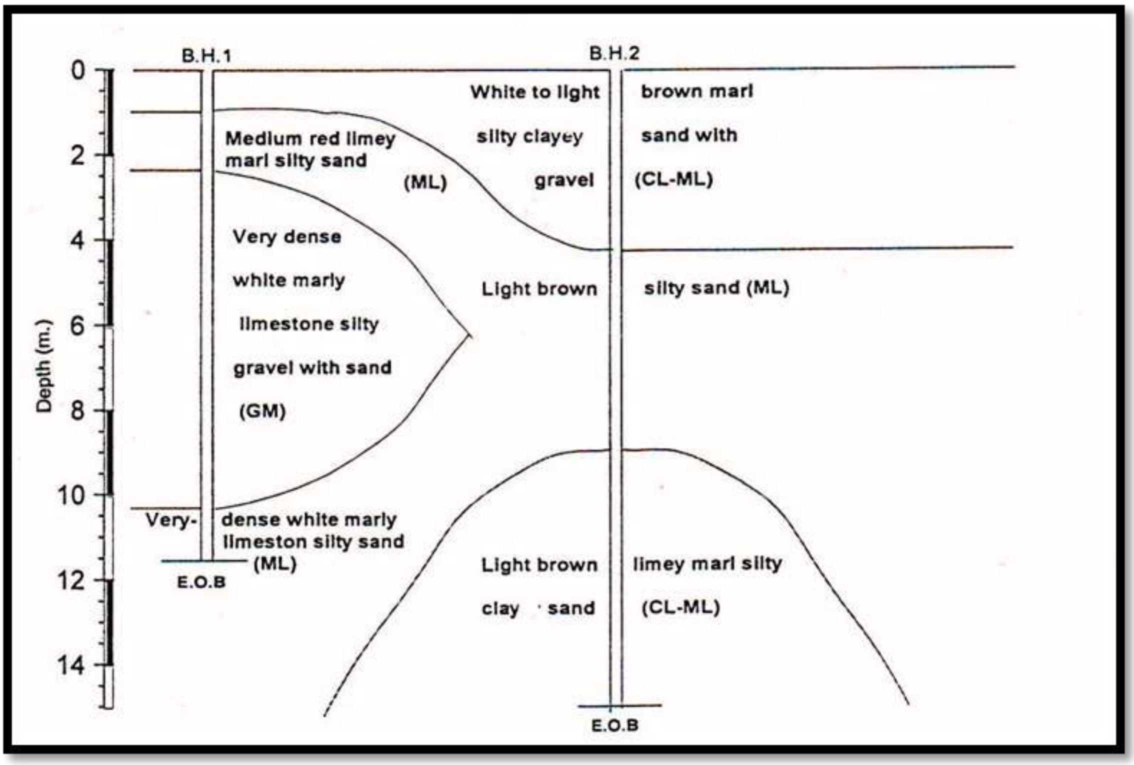

Fig. 4: Soil profile for bore holes 1&2

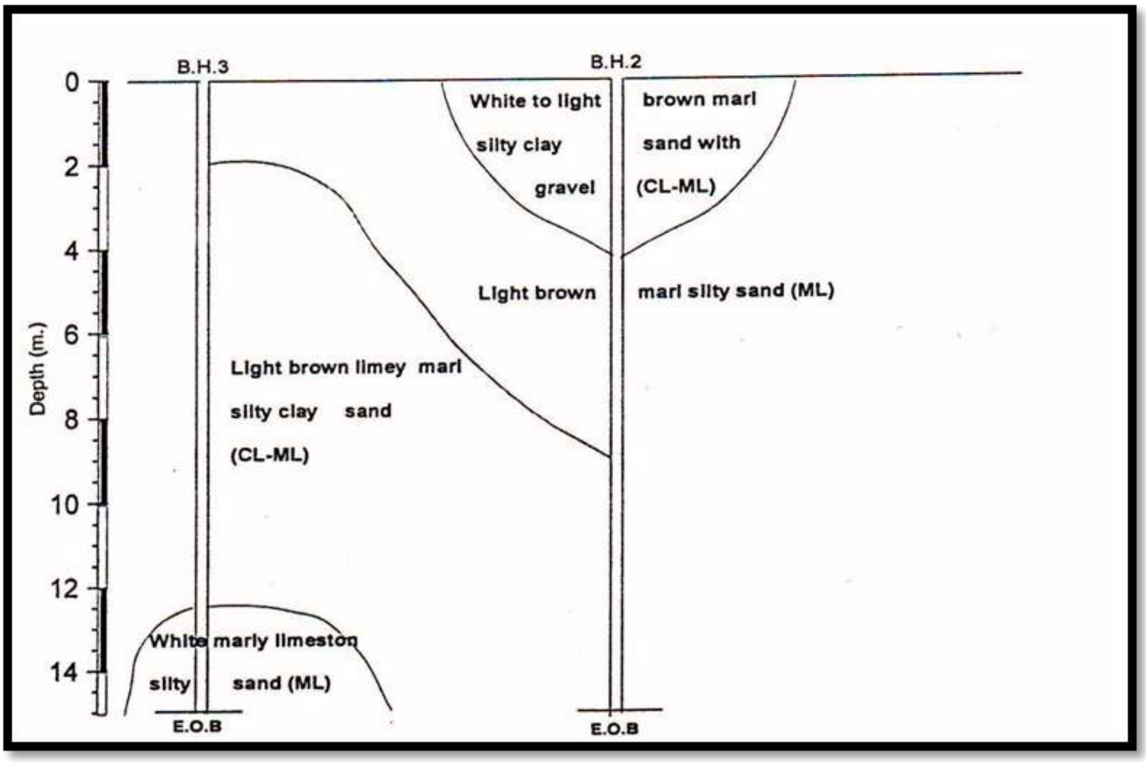

Fig. 5: Soil profile for bore holes 3&4

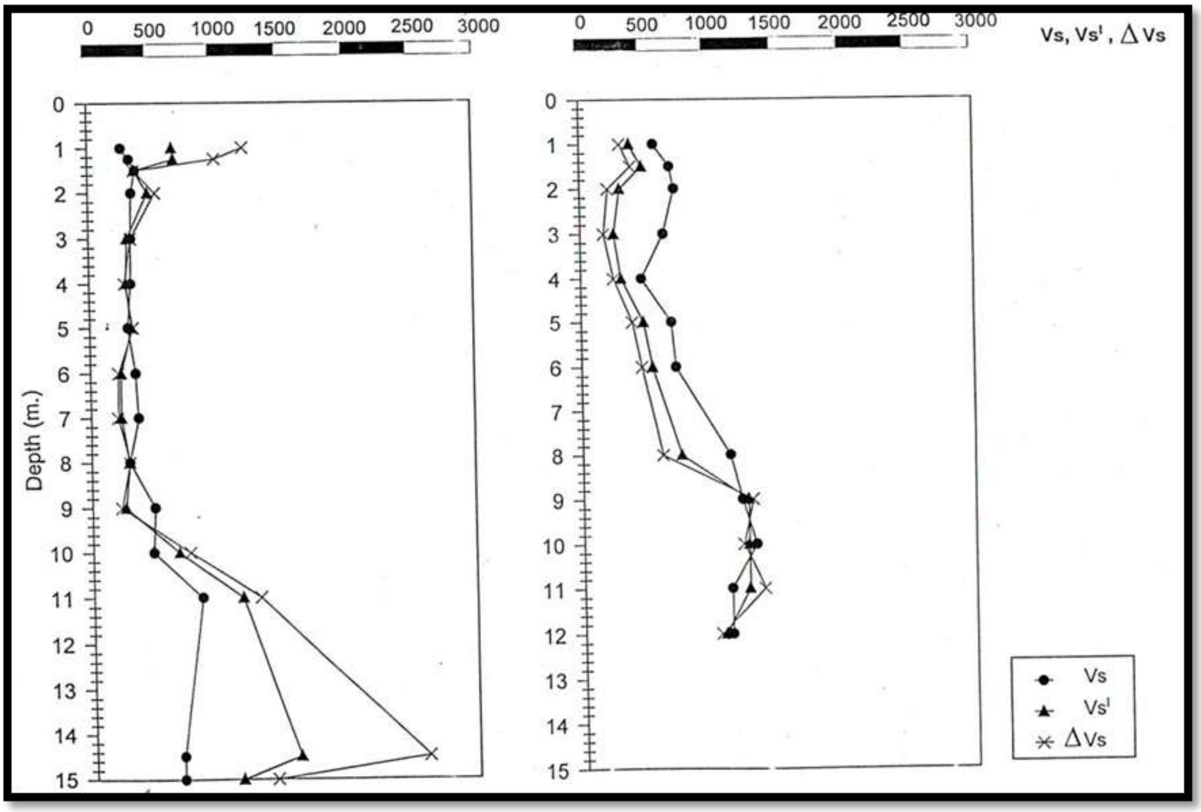

Fig. 6: Relation between V_s, Vs^{-} and ΔV_s with profiles S_1 ,S_2

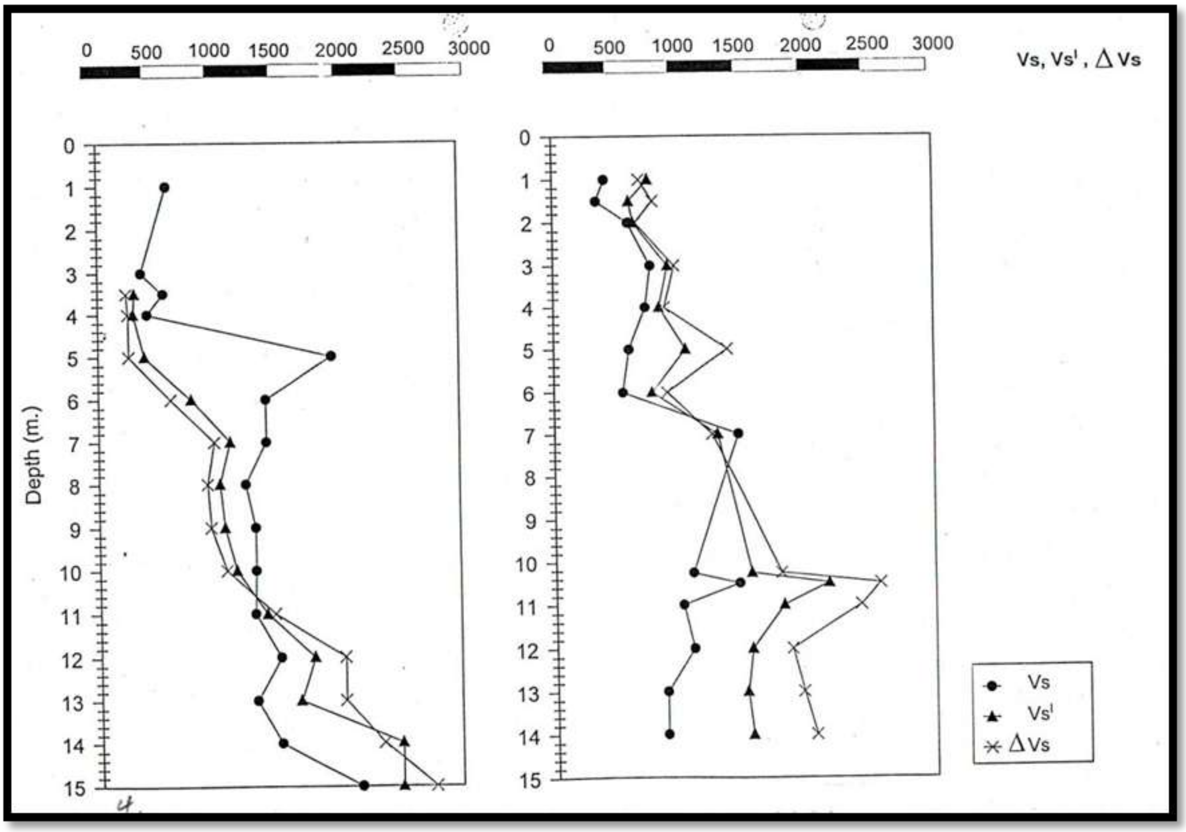

Fig.7: Relation between V_s, Vs^{-} and ΔV_s with profiles S_3 ,S_4

Table 1: Record of Test Results

Samples		Type	Depth of sample		MC	Index Property			Particle size Distribution & Hydrometer analysis				GS	SPT "N" val.	Symb	Description of Soil	Chemical tests					
ield No	lab No		From	to	%	L.L %	P.I %	L.sh. %	clay %	silt %	sand %	gravel %					SO3 %	CaCo %	OR. %	Gyp. %	PH	CL %
									BOREHOLE NO.1													
1	7044	D	0.0	1.0	9	28	12	1.58	(- 27	-	48	25)			CL-ML	Red silty clayey sand with gravel						
2	7045	SS	1.0	1.5					(- 45	-	55	0)	2.83	10	ML	Medium red limy marl silty sand	.87	70				
3	7046	SS	3.0	3.5										50	GM	very-dense white marly limestone silty gravel with sand	.13	94			7.9	.11
4	7047	SS	5.0	5.5					(- 17	-	25	58)		50/5	GM	Do.						
5	7048	SS	7.0	7.5										50/5	GM	Do.	.37				7.8	
6	7049	SS	9.0	9.5										50/5	GM	Do.	.17	83		.32		.13
7	7050	SS	11.0	11.5	4				(- 24	-	62	14)		50/5	ML	Very-dense white marly limestone silty sand						
									BOREHOLE NO.2													
1	7051	D	0.0	0.5					(- 30	-	41	29)			CL-ML	Whit to light brown silty clayey sand with gravel						
2	7052	D	1.0	1.5					(- 18	-	19	63)			CL-ML	Whit to light brown Marl silty clayey sand with gravel	.73	63			7.7	
3	7053	D	3.0	3.5					(- 25	-	48	27)			CL-ML	Whit to light brown silty clayey sand with gravel	.75					.14
4	7054	D	5.0	5.5	17				(- 40	-	52	8)			ML	Light brown silty sand						
5	7055	D	9.0	9.5					(- 47	-	47	6)			ML	Do.	.75				7.9	
6	7056	D	10.5	11.0		27	13	0.76							CL-ML	Light brown limey Marl silty clayey sand	.70	74				
7	7057	D	14.0	15.0		29	14	0.76							CL-ML	Light brown marl silty clayey sand		39				

Table 2 :Record of Test Results

Samples field No	Samples lab No	Type	Depth of sample From	Depth of sample to	MC %	Index Property L.L %	Index Property P.I %	Index Property L.sh. %	Particle size Distribution & Hydrometer analysis clay %	silt %	sand %	gravel %	GS	SPT "N" val.	Symb	Description of Soil	Chemical tests SO3 %	TSS %	OM. %	CaCo3 %	PH	CL %
									BOREHOLE NO.3													
1	7058	D	0.0	1.0				Cl	(- 23 -		65	12)			ML	Red silty sand.						
2	7059	D	1.0	1.5											ML	Red Marl silty sand.	.82			42		
3	7060	D	2.5	3.0	5.6				(- 18 -		62	20)			CL-ML	Red silty clayey sand with gravel.	2.17				7.4	
4	7061	D	4.5	5.0		24	12	1.35							CL-ML	White to light brown limey marl silty clayey sand.				66	7.7	.12
5	7062	D	7.0	7.5					(- 24 -		76	0)			CL-ML	Light brown silty clayey sand.	3.5					
6	7063	D	9.0	9.5					(- 49 -		40	11)			CL-ML	Do.					7.7	
7	7064	D	14.0	15.0					(- 41 -		59	0)			ML	Wight marly limestone silty sand.	0.1			85		
																				68	7.8	
									BOREHOLE NO.4													
1	7065	D	14.0	15.0					(- 43 -		55	2)			ML	Red limey marl silty sand.	.67					

Table 3 : The measured compressional wave velocity and for different contacts

Profile No.	Profile length m.	V_1 M/sec	V_2 m/sec	Depth of contact m.	V_3 m/sec	Depth of contact m.
1	27.5	833 – 113	1388 – 1428	1.7 – 2.0	2339	7.2
2	33	468 – 681	1474	0.7 – 1.8	2201 – 2205	4.7
3	22	441 – 1071	2095 – 2140	0.5 – 0.7	…..	…..
4	46	333 – 608	1111 – 1524	0.9	2148	4.0
5	22	400 – 617	1219 – 1463	0.8 – 3.0	…..	…..
6	46	507 – 770	1818 – 1873	0.7 – 1.4	2703 – 2777	2.9 – 7.0
7	33	394 – 400	1222 -1635	0.6 – 1.2	2500	6.8
8	46	333 – 666	965 – 1260	0.1 – 0.3	2584 – 3891	4.4 – 8.6
9	27.5	625	1229 -1368	2.17	3632	7.95
10	23.5	200 – 333	945 – 1500	0.3 – 0.6	……	…..
11	33	250 – 500	1242 – 1584	0.6 – 0.7	2727 – 2815	4.0 – 6.6
12	33	300 – 500	1276 – 1787	0.7	2500 – 4000	5.2 – 5.7
13	69	567 – 704	2305 – 3043	1.9 – 2.8	4200 – 4238	13.23 – 13.97

Table 4: Seismic wave velocity for profile No. S_1

Profile No.	Depth m.	V_p m/sec	V_s m/sec	V_p^- m/sec	V_s^- m/sec	ΔV_p m/sec	ΔV_s m/sec	Remarks
S_1	1.0	604	254	1335	654	2066	1209	
	1.5	659	362	344	356	800	354	
	2.0	580	329	142	457	840	516	
	3.0	630	322	801	291	870	320	
	4.0	500	315	801	278	972	269	
	5.0	659	290	641	320	635	330	
	6.0	725	345	641	233	620	213	
	7.0	725	362	…..	228	……	206	
	8.0	659	290	843	291	918	291	
	9.0	1208	483	582	256	506	225	
	10.0	1208	468	2564	675	3815	763	
	11.0	1611	852	4273	1165	8266	1305	
	14.5	1812	690	4273	1602	7085	2610	
	15	1611	690	2564	1145	3100	1417	

Table 5 : Seismic wave velocity for profile No. S_2

Profile No.	Depth m.	V_p m/sec	V_s m/sec	V_p^- m/sec	V_s^- m/sec	ΔV_p m/sec	ΔV_s m/sec	Remarks
S_2	1.0	1316	564	945	378	785	305	
	1.5	1975	686	1080	472	815	386	
	2.0	1316	718	540	300	1222	211	
	3.0	1975	632	840	252	594	176	
	4.0	1128	459	756	304	6111	274	
	5.0	1755	687	1512	472	1375	386	
	6.0	1975	718	1890	540	1833	458	
	8.0	2633	1128	2520	756	2440	611	
	9.0	3160	1215	2520	1260	2200	1294	
	10.0	2633	1316	2520	1260	2444	1222	
	11.0	2633	1128	2362	1260	2200	1375	
	12.0	2257	1128	2362	1080	2444	1047	

Table 6 : Seismic wave velocity for profile No. S_3

Profile No.	Depth m.	V_p m/sec	V_s m/sec	V_p^- m/sec	V_s^- m/sec	ΔV_p m/sec	ΔV_s m/sec	Remarks
S_3	1.0	722	382	…..	…..	…..	…..	
	3.0	722	240	…..	…..	…..	…..	
	3.5	722	361	…..	202	…..	158	
	4.0	722	271	556	196	485	167	
	5.0	2600	1300	1113	256	816	170	
	6.0	2166	928	2226	514	2266	400	
	7.0	2166	928	…..	726	…..	637	
	8.0	3250	812	3340	668	3400	600	
	9.0	4330	866	4175	695	4080	618	
	10.0	2600	866	3340	759	4080	703	
	11.0	2600	860	3340	927	4080	971	
	12.0	3250	1000	3340	1192	3400	1360	
	13.0	1857	866	2783	1113	4080	1360	
	14.0	2600	1000	4800	1670	4080	1569	
	15.0	3250	1444	2385	1670	2040	1854	

Table 7 : Seismic wave velocity for profile No. S_4

Profile No.	Depth m.	V_p m/sec	V_s m/sec	V_p^- m/sec	V_s^- m/sec	ΔV_p m/sec	ΔV_s m/sec	Remarks
S_4	1.0	650	306	1588	750	2928	683	
	1.5	812	342	1227	600	1464	788	
	2.0	1181	590	1588	635	1782	650	
	3.0	2166	764	1800	900	1708	953	
	4.0	1444	722	1800	830	1782	872	
	5.0	1857	590	2700	1038	3153	1366	
	6.0	1625	541	1800	771	1863	891	
	7.0	2600	1444	5400	1285	8200	1242	
	10.25	2166	1083	4500	1542	6833	1782	
	10.5	3250	1444	5400	2160	6833	2562	
	11.0	2166	1000	4500	1800	6833	2411	
	12.0	2500	1083	3600	1542	4100	1863	
	13.0	2500	866	3857	1500	7659	1952	
	14.0	2500	866	3600	1542	4183	2050	

Table 8 : Location of cavities and weak zones

Profile No.	Location of weak zone in first layer Geophone No.	Expected depth m.	Location of weak zone in second layer Geophone No.	Expected depth m.	Location of weak zone in second layer Geophone No.	Expected depth m.
1	6	0.7	6,11,12	2.5,5.5	8,9	10.5
2	10,11,12	2 -3	6,11	0.6 – 3.6	……	…….
3	11,12	2.2	…….	…….	…….	…….
4	22,23	0.8	3,4,5,6,10,11	5.0 – 8.5	14,15,16	5.0 – 9.8
5	Weak zone	0.0	Weak zone	4	…….	…….
6	Weak zone	0.0 – 0.9	3,5,6,7 10,11,12,13,14, 15,16,17,18 ,21	4 – -17 6.8 8.0	3,5,6,7 9,10,11,12,13	6.8 -7 4.4 -6
7	…….	…….	3	1.2	…….	…….
8	Weak zone	…….	10,11 ,13,14,15,16,17, 19,21,22, 24	4 1.3 – 5.6 7.2 – 8.4 5.6	…….	…….
9	1	0.5	4,5,8	1.5 – 5.0	8	11.o
10	Weak zone	0.5	Weak zone	6.0	……	…….
11	Weak zone	0.5	…….	…….	5,6,8	2.4 – 4.2
12	…….	…….	3,4 ,6,7,8	o.9 – 2.1 3.6 – 4.2	1	6.6
13	…….	…….	…….	…….	…….	…….

References

1- Bowles,J.E.(1984):physical and geotechnical properties of soils Mc Graw- Hill. International Book Co., London, 578p.

2- Buday ,T., and Jassim, S.Z.(1987): The regional geology of Iraq .Tectonism , magmatism and metamorphism, GEOSURV, Baghdad ,325p.

3- Butler,D.K.and Curro,R.J.(1981):Cross–hole seismic testing–procedures and pitfalls Geophysic,46,23-29

4- Craig,R.F,(1983):Foundation on Expensive soils , Elsevier Scientific Publishing Company.

5- Davis, A. M. and Savit, C. H., (1988): Seismic signal processing in engineering. Engineering site investigation – a case history ground.

6- Griffiths,D.H.and king,R.F.,(1981):Applied geophysics for geologists and engineers. pergam on press. 230p.

7-Hamdi,F.AI.andSaid,I.,(1986):Applicationofseismic refraction technique insolving geotechnical problems.Jour.Geo.Soc.Iraq.vol.9,No. 3, 261-273.

8- Hess P.R.(1971).A text book of soil chemical analysis .Chemical Publishing Co.,Inc.,New York,250 P.

9-Jumikis A.R.(1967). Soil mechanics. 2nd edition. New Jersey. 791P.

10- Kezdi,A.,(1974);Hand book of soil Mechanics ,Vol.1,soil physics.

11 -Lamb,T,W.,(1951):Soil Testing for Engineering ,John Willey and sons Inc. London,Sydney,165 P.

12- Lamb, T,W. and Whitman, R.V.,(1969): Soil Mechanics, John Willey and Sons Inc. New Yoork,533P.

13- McCann, D.M., Baria, R. Jackson, P.D. and Green, A.S.P.,(1986):Application of cross –hole seismic measurements in site investigation surveys. Geophysics. 51, 914- 929.

14- Mitechell,J.(1993): Compaction of sediments Under Laying Areas of land subsidence in Centric California, U.S.G.S. No. 497-D,40p.

15- Mooney, H.M.(1973) :Handbook of engineering geophysics. Bison Instruments,Minneapolis.

16-National Center for Construction Laboratories(NCCL),(1993):Geophysical investigation for Al- Abbas shrine. Report. (Un published).

17- Peck R.B.,Hanson W.E. and Thormburn T.H.(1974).Foundation Engineering .2nd Edition ,John Wiley and Sons, Inc

18- Sjogren, B.,(1984):Shallow refraction seismic Champ man and Hall London 270P.

19- Terzaghi , K., and Peack, R.B.(1967):Soil Mechanics in engineering practice ,2nd ed., Johwilley and Cons.Inc.,New York, 729p.