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Effect Of Soil Geotechnical Properties On The Concrete Foundation Of Buildings

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Abstract *This study has been conducted on the project site of a multi-storey car garage in the district of Al-Saray, which is in center of Al-Nasiriya city, center of Thi-Qar governorate in southern Iraq. Notably, the stability of construction materials and engineering structures for any engineering projects is affected by the geotechnical properties of the soil. In this paper, the geotechnical properties that were studied included: the physical, engineering and chemical properties of the soil such as particle size distribution, consistency limits, the number of blows in the standard penetration test, in addition to sulphate content, gypsum content, total soluble salts, and organic matter content. Soil was classified by using USDA textural triangle in addition to using texture plasticity system into two layers. Based on the values of the consistency limits, soil has low rate of compressibility and exhibits medium to high degree of expansion. As a result, the number of blows in the standard penetration test is between (13-36) blows. Therefore, the results of standard penetration test technique showed that the state of soil is very stiff from (1-7) m and then becomes dense downward. Then, by relying on the same technique, the allowable bearing capacity of the soil is (342-418) kPa for depths from (3-23) m for all boreholes. The results of chemical tests showed that the soil contains proportions that exceeded the acceptable limits for each of sulphate, gypsum, total soluble salts, and organic matter content, which are considered to influence the compression and resistance of the soil. Some problems can be expected due to the results of physical properties of soil and from high proportion of sulphate and gypsum.*

Keywords: *Concrete foundation; Geotechnical properties. Bearing capacity; Al-Nasiriya city.*

1 INTRODUCTION

In different civil engineering projects, the construction of safe engineering structures requires knowledge of the geotechnical characteristics of geological materials below the foundation which includes study of the physical, engineering and chemical properties of the soil to understand the effect of these properties on the foundations of concrete structure. Furthermore, to ensure the stability of the soil and the project built on it, suitable of the required soil foundation and to determine the suitability of the soil for use as or as construction materials a foundation (Mauff et al., 2017; Ali and Shakir, 2022).

Study and evaluation of the physical properties of the soil give an accurate understanding of the engineering behavior on the soil when constructing any engineering project, as it effects the stability of engineering structures (Roy and Bhalla, 2017; Laskar and Pal, 2012).

The chemical properties of soil play an important role in evaluating behavior of soil. Therefore, the increase of the chemical content of any of the chemical properties affects the plasticity of the soil as well as its bearing capacity in addition to attacking the concrete structures (Odell et al 1960; Malkawi et al, 1999). On the other hand, soil physical and chemical properties influence the engineering properties of the soil and thus it is bearing capacity, and this is reflected in the behavior of the soil after the construction of the engineering structures (Bowels,1979).

The study site is in the center of Al-Nasiriya city, which is witnessing a rapid architectural development represented in the construction of many engineering projects within this geographical area. Floodplain sediments cover the total area of Al-Nassiriya city and are characterized by the actual effect and damage on foundation due to swelling soils (clayey soil) caused by absorption of water and then swelling (Khadhim, 2014).

2 Site location

The site of Al-Saray district is in the center of Al-Nasiriya city with latitude 31°03'30"N and longitude 46°15'37"E, 360km southeast of Baghdad. Generally, the site area is characterized by flat and covered by quaternary sediments. The site plan for three boreholes location is illustrated in Fig.1.

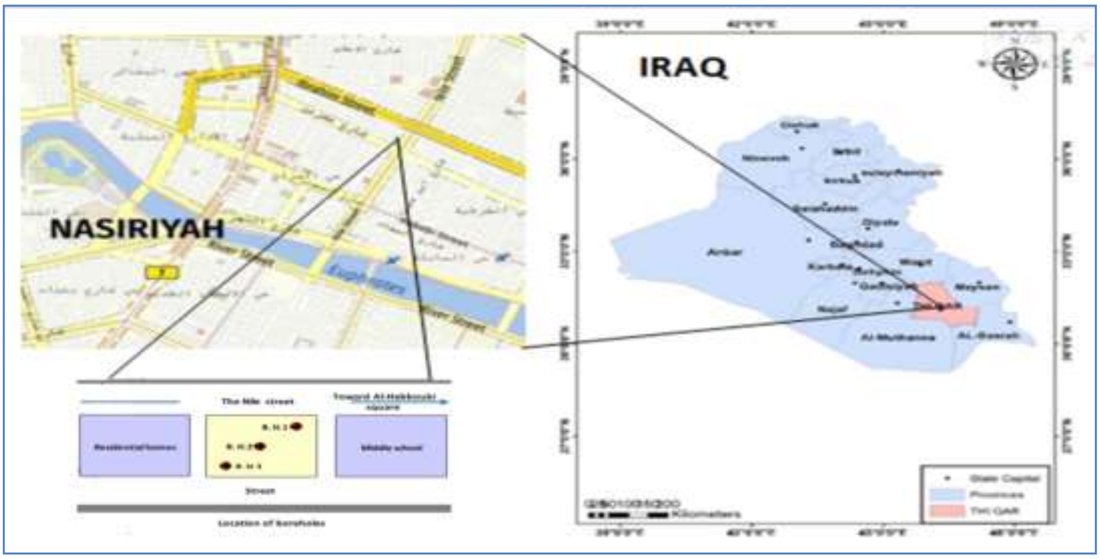

Fig. 1. Location of the study area

3 Geology of the study area

The study area is located in the southern part of the lower Mesopotamian plain. Generally. Holocene age sediments cover its surface, the subsoil of Al-Nasiriya city is Mesopotamian plain sediments which consist of fluvial sediments, flood plain sediments, marshes sediments, in addition to Aeolian deposits (Mahmoud and Muttashar,2012, Mandhour, 2020).

4 METHODOLOGY

The data of this study are obtained from soil investigation report conducted by technical institute/Mosul for the purpose of constructing a multi-storey building, the ground and second floors include shopping stores, while the rest of the floors are designated as car parks. The work involved three boreholes to depths of 25m for each. Table 1 represents the results of physical and engineering tests of soil such as distribution of grain size, moisture content atterberg's limits, dry density, number of blows per meter in standard penetration test N_{SPT}, While Table 2 represents the results of chemical tests for soil. Results of laboratory tests were evaluated by depending on (ASTM D422-6, 2004; ASTM D4318-00,2004) in addition to BS 1377,1990).

Table 1. Results of physical and engineering properties.

B.H.	Depth(m)	Grain size analysis (%)				Atterberg limits (%)			Moisture content, WC (%)	Dry density, γ_d (kN/m^2)	N_{SPT}
		Clay, C	Silt, M	Sand, S	Gravel, G	Liquid limit, L.L	Plastic limit, P.L	Plasticity index, P.I			
1	1.0-3.0	27	56	17	0	42	21	21	11.9	16.80	26
	3.0-5.0	40	53	7	0	41	22	19			
	5.0-7.0	40	53	7	0	41	22	19	13.3	16.80	28
	7.0-10.0	54	42	4	0	38	26	12	13.4	16.90	
	10.0-13.0	4	12	84	0	30	28	2	13.8	16.80	13
	13.0-16.0	3	11	86	0	30	28	2	14.2	16.80	24
	16.0-20.0	3	11	86	0	30	28	2			32
	20.0-23.0	4	10	86	0	30	28	2			36
	23.0-25.0	4	10	86	0	30	28	2	14.9	16.80	

	1.0-3.0	30	55	15	0	40	22	18	10.9	16.90	
	3.0-5.0	36	54	10	0	40	21	19			
	5.0-7.0	34	56	10	0	40	21	19	13.3	16.90	25
	7.0-10.0	4	10	86	0	37	25	12	13.5	17.00	
	10.0-13.0	4	10	86	0	37	26	11	13.9	17.00	27
2	13.0-16.0	3	11	86	0	37	26	11			27
	16.0-20.0	4	12	84	0	37	26	11	14.3	16.90	25
	20.0-23.0	4	10	86	0	36	26	10			34
	23.0-25.0	4	10	86	0	36	26	10	14.5	16.80	
	1.0-3.0	32	50	18	0	40	22	18	10.9	17.50	13
	3.0-5.0	42	52	6	0	39	23	16	11.2	17.60	
	5.0-7.0	42	52	6	0	39	23	16			20
	7.0-10.0	7	6	87	0	36	27	9	13.4	17.00	
	10.0-13.0	4	10	86	0	32	29	3	13.8	17.20	22
3	13.0-16.0	3	11	86	0	33	30	3			24
	16.0-20.0	3	11	86	0	33	30	3	14.2	16.80	30
	20.0-23.0	4	10	86	0	37	29	8			33
	23.0-25.0	4	10	86	0	37	29	8	14.9	16.90	

Table 2. Results of chemical properties.

B.H.	Depth(m)	SO3%	Gyp.	T.S.S.%	ORG.%
	1.0-3.0	3.04	7.18	3.70	3.20
	3.0-5.0				
	5.0-7.0	3.20	7.20	4.62	
	7.0-10.0	4.20	7.50		2.15
1	10.0-13.0				
	13.0-16.0	2.90	3.70		
	16.0-20.0				
	20.0-23.0				
	23.0-25.0	2.90	3.70	5.21	3.70
	1.0-3.0	2.14	6.80		
	3.0-5.0				
	5.0-7.0	2.18	6.75	4.96	3.95
	7.0-10.0	4.10	6.70		
2	10.0-13.0				
	13.0-16.0	2.80	3.65	3.15	2.81
	16.0-20.0	3.20	3.60		
	20.0-23.0				
	23.0-25.0	3.20	3.54		

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	1.0-3.0	2.4	6.75		
	3.0-5.0				
	5.0-7.0	3.08	5.70		
	7.0-10.0				
3	10.0-13.0				
	13.0-16.0				
	16.0-20.0	2.90	3.60	3.15	2.81
	20.0-23.0				
	23.0-25.0	3.10	4.90		

5 Groundwater table

The groundwater depth level of the study area is 1m from the ground level. This depth changes or fluctuates during the seasons of the year. Therefore, this affects the foundation of engineering structures.

6 RESULTS AND DISCUSSION

6.1 Physical properties of soil

Most of the physical properties of soil have different effects on the engineering structures. In addition, they also affect some others. The physical properties of soil are discussed as below:

6.1.1 Grain size analysis

Mostly, soil properties are inferred based on the grain size distribution, the soil often contains coarse and fine grains. And knowing distribution of grain size of soil contributes to knowing other physical properties such as specific gravity, porosity and permeability in addition to void ratio. According to USDA soil textural triangle (Tabor, 2001; USDA, 2017), the upper layers of the study site consist of silt loam to silty clay loam then a layers of silty clay and loamy sand appear respectively below it. While according to texture plasticity classification chart (Moreno-Maroto and Alonso-Azcarate, 2018), the upper layers are silty clay to silty loam or silty clay loam and then below it, layers of loamy sand or sand. As a result, the texture of soil has been shown in Figure 2.

Mores, based on grain size gradation we observed variation in soil sequence. It has been observed predominantly fine grains from surface to a depth of 10.0m at the site1 and to a depth 7.00m at the site of 2 and 3 as shown in Table 3. and depending on the variation in particle size gradation, the strata soil sequence can be subdivided into two units (A and B) as shown in Figure 3.

Fig.2 **Classification of soil in the study area: (a) texture triangle; (b) texture plasticity chart.**

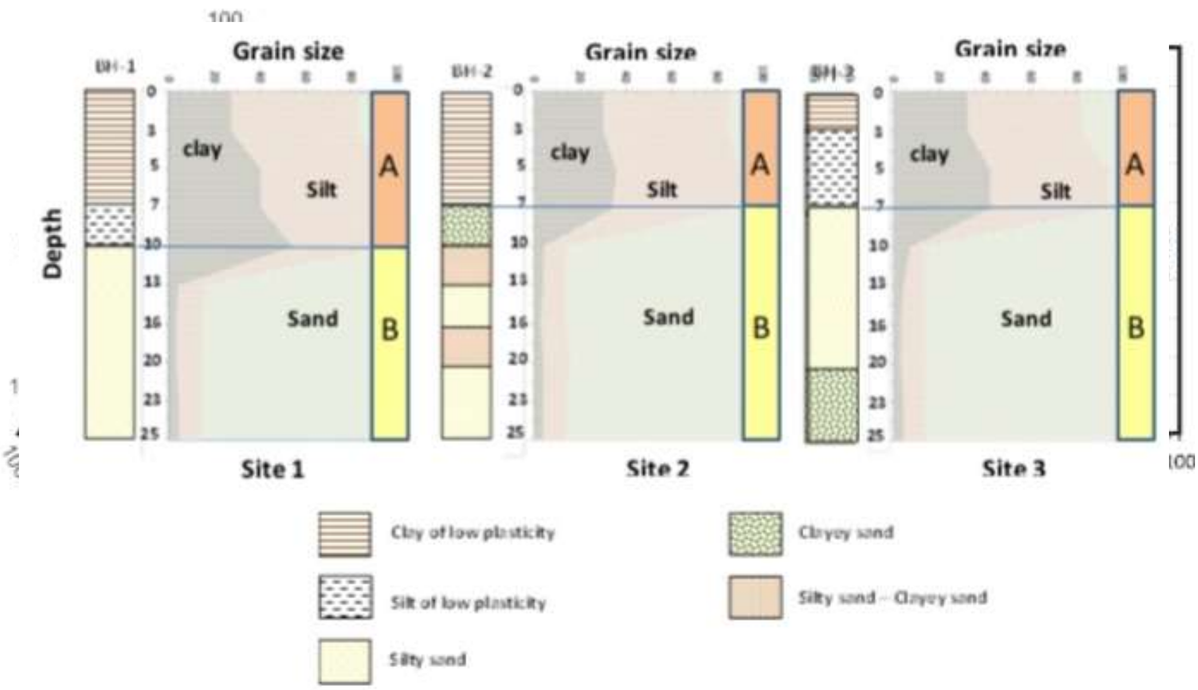

Fig. 3: Variations of grain size of soil strata.

Table 3. Various soil texture based on texture triangle and texture plasticity.

B.H.	Depth(m)	Grain size analysis				Texture triangle classification (USDA, 2017)	Plasticity index, P.I	Liquid limit, L.L	Clay factor, C_F P.I/L.L ratio	Texture plasticity classification (Moreno-Maroto and Alonso-Azcarate, 2018)
		C	M	S	G					
1	1.0-3.0	27	56	17	0	Silty loam	21	42	0.5	
	3.0-5.0	40	53	7	0	Silty clay loam	19	41	0.463	Silty clay
	5.0-7.0	40	53	7	0		19	41	0.463	
	7.0-10.0	54	42	4	0	Silty clay	12	38	0.315	Silty loam
	10.0-13.0	4	12	84	0		2	30	0.06	Loamy sand
	13.0-16.0	3	11	86	0		2	30	0.06	
	16.0-20.0	3	11	86	0	Loamy sand	2	30	0.06	Sand
	20.0-23.0	4	10	86	0		2	30	0.06	
	23.0-25.0	4	10	86	0		2	30	0.06	
2	1.0-3.0	30	55	15	0	Silty clay loam	18	40	0.45	
	3.0-5.0	36	54	10	0		19	40	0.475	Silty clay
	5.0-7.0	34	56	10	0		19	40	0.475	
	7.0-10.0	4	10	86	0		12	37	0.324	
	10.0-13.0	4	10	86	0		11	37	0.324	
	13.0-16.0	3	11	86	0	Loamy sand	11	37	0.324	Loamy sand
	16.0-20.0	4	12	84	0		11	37	0.297	
	20.0-23.0	4	10	86	0		10	36	0.277	
	23.0-25.0	4	10	86	0		10	36	0.277	
3	1.0-3.0	32	50	18	0	Silty clay loam	18	40	0.45	Silty clay
	3.0-5.0	42	52	6	0		16	39	0.41	Silty clay loam
	5.0-7.0	42	52	6	0	Silty clay	16	39	0.41	
	7.0-10.0	7	6	87	0		9	36	0.25	Sand
	10.0-13.0	4	10	86	0		3	32	0.093	
	13.0-16.0	3	11	86	0		3	33	0.09	
	16.0-20.0	3	11	86	0	Loamy sand	3	33	0.09	Loamy sand
	20.0-23.0	4	10	86	0		8	37	0.216	
	23.0-25.0	4	10	86	0		8	37	0.216	

6.1.2 Consistency limits

From a geotechnical point view, the consistency limits of fine-grained soil are used as good indicators of soil engineering behavior, and they are largely influenced by the moisture content of soil. Also, the particle size distribution has an important role in soil swelling potential, So the more the amount of clay materials (amount of clay size less than 0.002mm), the more possibility of soil swelling (Abu Seif,2017). The plasticity of soil reflects its consistency and workability, so these soil properties play a major role in many civil engineering projects (Lakade et al., 2020; Deshmukh, 2023).

6.1.3 Classification of study area soil

The soil in the study area is classified into two main types: cohesive soils and non-cohesive soils which are considered because of transported deposits belonging to quaternary period sediments. Cohesive soils consist of clay and alluvial soils, while non-cohesive soils consist of loose sandy soils. Mores, the results reveal that the soil of the study area is classified using the unified soil classification system (USCS) into

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five groups, which are: in organic clays of low plasticity CL, in organic silts of low plasticity ML, silty sands SM, clayey sands SC and silty sands-clayey sands SM-SC as shown in Fig. 3.

Table 4: Classification of soil based on USCS.

B.H.	Depth(m)	Atterberg limits (%)			USCS	Description of soil
		Liquid limit, L.L	Plastic limit, P.L	Plasticity index, P.I		
	1.0-3.0	42	21	21		
	3.0-5.0	41	22	19	CL	Low plasticity clay
	5.0-7.0	41	22	19		
	7.0-10.0	38	26	12	ML	Low plasticity silt
1	10.0-13.0	30	28	2		
	13.0-16.0	30	28	2		
	16.0-20.0	30	28	2	SM	silty sands
	20.0-23.0	30	28	2		
	23.0-25.0	30	28	2		
	1.0-3.0	40	22	18		
	3.0-5.0	40	21	19	CL	Low plasticity clay
	5.0-7.0	40	21	19		
	7.0-10.0	37	25	12	SC	clayey sands
2	10.0-13.0	37	26	11		
	13.0-16.0	37	26	11	SM-SC	silty sands-clayey sands
	16.0-20.0	37	26	11		
	20.0-23.0	36	26	10	SM	silty sands
	23.0-25.0	36	26	10		
	1.0-3.0	40	22	18	CL	Low plasticity clay
	3.0-5.0	39	23	16	ML	Low plasticity silt
	5.0-7.0	39	23	16		
	7.0-10.0	36	27	9		
3	10.0-13.0	32	29	3	SM	silty sands
	13.0-16.0	33	30	3		
	16.0-20.0	33	30	3		
	20.0-23.0	37	29	8	SC	clayey sands
	23.0-25.0	37	29	8		

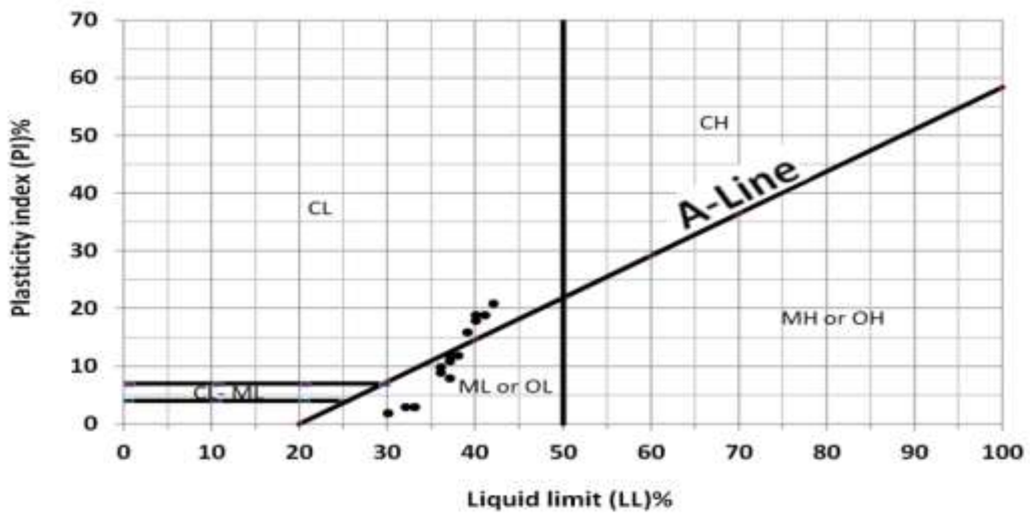

Fig. 3. Casagrande diagram and soil classification in the study area.

Table 5 presents the relationship between compression index with values of liquid limit of studied soil, and when comparing the values of compression index with the liquid limits, we observed that the soil with a lower liquid limit has less compression index. In addition, the percentage of clay content is low. As can be guessed, the compressibility of soil by the values of liquid limit and plasticity index based on (Hazelton and Murphy, 2007) the ratings for compressibility are low according to liquid limit and plasticity index as shown in Table 3.

Table 5 Predicted compression index and rating of compressibility of the soil used in the present study.

B.H.	Depth(m)	Predicted compression index by liquid limit		Compressibility based on Hazelton and Murphy (2007)			
		L.L	Cc = 0.009(LL-10) Skempton, 1944	LL	Rate	PI	Rate
	1.0-3.0	42	0.288	42		21	
	3.0-5.0	41	0.279	41		19	
	5.0-7.0	41	0.279	41		19	
	7.0-10.0	38	0.252	38		12	
1	10.0-13.0	30	0.18	30	Low	2	Low
	13.0-16.0	30	0.18	30		2	
	16.0-20.0	30	0.18	30		2	
	20.0-23.0	30	0.18	30		2	
	23.0-25.0	30	0.18	30		2	
	1.0-3.0	40	0.27	40		18	
	3.0-5.0	40	0.27	40		19	
	5.0-7.0	40	0.27	40		19	
	7.0-10.0	37	0.243	37		12	
2	10.0-13.0	37	0.243	37	Low	11	Low
	13.0-16.0	36	0.234	37		11	
	16.0-20.0	37	0.243	37		11	
	20.0-23.0	36	0.234	36		10	
	23.0-25.0	36	0.234	36		10	
	1.0-3.0	40	0.27	40		18	
	3.0-5.0	39	0.261	39		16	
	5.0-7.0	39	0.261	39		16	
	7.0-10.0	36	0.234	36		9	
3	10.0-13.0	32	0.198	32	Low	3	Low
	13.0-16.0	33	0.207	33		3	
	16.0-20.0	33	0.207	33		3	
	20.0-23.0	37	0.243	37		8	
	23.0-25.0	37	0.243	37		8	

Liquid limit values are also used to calculate the soil swell potential (S) which is in turn used to estimate the degree of soil expansion as shown in Table 6

Table 6. Soil expansion predicted below.
by liquid limit.

B.H.	Depth(m)	LL	Degree of expansion based on Seed et al. 1962	
			Swelling% $S = 3.75 \times 10^{-4} \times LL^{2.658}$	Degree of expansion
	1.0-3.0	42	7.737	
1	3.0-5.0	41	7.257	High
	5.0-7.0	41	7.257	
	7.0-10.0	38	5.930	

	10.0-13.0	30	3.163	
	13.0-16.0	30	3.163	
	16.0-20.0	30	3.163	Medium
	20.0-23.0	30	3.163	
	23.0-25.0	30	3.163	
	1.0-3.0	40	6.796	
	3.0-5.0	40	6.796	
	5.0-7.0	40	6.796	
	7.0-10.0	37	5.524	
2	10.0-13.0	37	5.524	High
	13.0-16.0	37	5.524	
	16.0-20.0	37	5.524	
	20.0-23.0	36	5.136	
	23.0-25.0	36	5.136	
	1.0-3.0	40	6.796	
	3.0-5.0	39	6.354	High
	5.0-7.0	39	6.354	
	7.0-10.0	36	5.136	
3	10.0-13.0	32	3.755	
	13.0-16.0	33	4.076	Medium
	16.0-20.0	33	4.076	
	20.0-23.0	37	5.524	High
	23.0-25.0	37	5.524	

The results showed that the soil which has of the highly degree of expansion in the study area are from ground surface to a depth of 7 meters, while the soil which has a medium degree of expansion are below the depth of 7 meters in both sites 1 and 3 whereas we find that site 2 did not change in degree of expansion, and it can be seen that the soil which was classified as silty sand SM showing medium degree of expansion, possibly due to increased sand ratios. Swelling is one of the serious problems facing engineering projects, when swelling clay soils applied load on foundations and floors due to their expansion and increase in volume because of increasing moisture content. Thus, cracks occur in buildings, especially buildings with light loads (Muttag et al, 2019).

6.1.4 Water Content and Dry density

There is no doubt that the water content is one of the most important factors affecting soil behavior, and the effectiveness of this factor increases in fine grained soil especially clay soil. The variation in water content causes volume change of dry clayey soil, in turn causes damage to the overlying engineering structures (Yilmaz, 2000; Yilmaz, 2009). The moisture water content ranged between 10.9-14.9%. The dry density of the soil greatly affects the volume changes of the soil (Abu Seif, 2017). The values of the dry density of the study area ranged between 16.80-17.20kN/m^3.

6.2 Engineering properties of soil

In recent years, different soil properties have been determined using field technology. Furthermore, subsurface investigation became greatly dependent on standard penetration test technology to know the engineering properties of soil (Kasim and Raheem, 2021).

6.2.1 Standard penetration test SPT

This test is considered one of the most important field tests which is commonly used to estimate or determine the bearing capacity of soil by knowing SPT-N values to all depths (N = number of blows for SPT). Generally, the value of N indicates the strength of the soil and its resistance to stress and external loads. According to Terzaghi and peck (1948) the measured blow counts values of SPT-N need to be corrected only if its values are more than 15. The equation is as follows:

$$N_C = 15 + 0.5\ (\mathrm{N} - 15)$$

Where is:

N = measured blow count
Nc = corrected blow count
Overall, it can be noticed from table 7 that SPT-N values range from 13-36 and soil state is very stiff to depths of (1.0-7.0m) for borehole-1 and to depths (1.0-13.0m) for boreholes 2 and 3 while the soil becomes medium below these depths.
The value of N is a function of consistency of cohesion of soil (clayey or silty) or relative density of cohesionless soil (sandy or gravelly). The values of N indicate that the consistency of the cohesive soil strata is very stiff from (1.0m to7.0m), and its relative density is dense for the non-cohesive soil strata from 7.0m toward the bottom.

Table 7. Relationship between N-Value (SPT blow count) with condition of soil.

Depth(m)	SPT (N) total for 300mm, B.H.1	SPT (N) total for 300mm, B.H.2	SPT (N) total for 300mm, B.H.3	Average SPT (N) total for 300mm	Correction SPT (N_C) total for 300mm	Depth of footing (m), D_f	Width of footing (m), B	Allowable bearing capacity (kPa), q_a for total settlement 25mm	Safety factor, Sf	Ultimate bearing capacity(kPa), q_{ult} for total settlement 25mm, safe factor =2
1.0-3.0	26		13	19	17	3.0	3.0	342		684
5.0-7.0	28	25	20	24	19.5	7.0	7.0	353		706
10.0-13.0	13	27	22	20	17.5	13.0	13.0	305		610
13.0-16.0	24	27	24	25	20	16.0	16.0	345	2	690
16.0-20.0	32	25	30	29	22	20.0	20.0	377		754
20.0-23.0	36	34	33	34	24.5	23.0	23.0	418		836

Depth(m)	SPT (N) total for 300mm, B.H.1	SPT (N) total for 300mm, B.H.2	SPT (N) total for 300mm, B.H.3	Average SPT (N) total for 300mm	Correction SPT (N_C) total for 300mm	State of soil
1.0-3.0	26		13	19	17	Very stiff
5.0-7.0	28	25	20	24	19.5	
10.0-13.0	13	27	22	20	17.5	
13.0-16.0	24	27	24	25	20	Medium dense
16.0-20.0	32	25	30	29	22	
20.0-23.0	36	34	33	34	24.5	

6.2.3 Bearing capacity

The bearing capacity of the study soil is calculated by dynamic method by using N-SPT values. The bearing capacity of the soil was calculated based on the Meyerhof equation (Meyerhof, 1965) and as follows:

$$q_a = \frac{N}{0.08}\left(\frac{B+0.3}{B}\right)^2\left(1+0.33\frac{D_f}{B}\right)$$

6.3 Chemical properties of soil

The study of chemical content in soil is very important because it affects the physical properties and engineering behavior of the soil which is reflected in the stability of foundation (Jaafer et al., 2019).

where:qa= allowable bearing capacity.N= number of blow count.B= width of footing.
D_f= depth of footing.
thus, from results of standard penetration test, the allowable bearing capacity (q_a) and net of ultimate bearing capacity (q_{ult}) of soil for depths from (3.0m to 23.0m) are ranging from (342 - 418) kPa and from (684 – 836) kPa respectively as shown in Table 8.

Table 8. Allowable bearing capacity of soil

6.3.1 Sulphate Content (SO_3)

The solubility of sulfates in the soil water leads to attacking concrete by interaction with cement compounds. Sulfate salts are one of the most prevalent salts in the soil, especially the sodium, magnesium, and calcium sulfate salts. Gypsum is one of the most important sources of sulfate. The constant evaporation of gypsum water ($CaSO_4.2H_2O$) leads to the deposition of calcium sulfate salts ($CaSO_4$). The sulfate ion ratio for the study area ranges between 2.90-6.70% and for different depths as shown in Table 2. The percentage that higher than 5% is unacceptable (NCCLR, 2003), so in order to resist sulfate salts, it is advised to use sulfate – resistant cement and coat the foundation with anti-corrosion layer (Al-Humairi, 2015).

6.3.2 Gypsum Content (GYP.)

The importance of studying gypsum content in the study site is coming because of the risks that gypsum poses to soil resistance, differential settlement of foundation, and the occurrence of cavities. The sulfate ion interacts with the lime in the Portland cement and the crystalline gypsum forms, so cracks in the concrete are formed by expansion of gypsum (Kezdi, 1980). In addition to this, the presence of gypsum reduces the maximum dry density of the soil, increases the moisture content and reduces soil resistance. The results of the gypsum content test for the soil of the study area show that the percentage of gypsum ranges between 3.6-7.50%. moreover, the British standard (BS 1377,1990) requires that the content of gypsum in the soil not exceed 2.5% therefore the percentage of gypsum in the soil of the study area is influencing the engineering behavior of the soil.

6.3.3 Total Soluble Salts (T. S. S.)

Total soluble salts are defined as total soil soluble salts in water, the degree of solubility of salts in water is different according to their nature. Chlorides salts are generally faster and easier to dissolve than carbonate and sulfate salts, where the solubility of salt is affected by the following factors: temperature degree, pH value, and amount of dissolved CO_2 gas in addition to the effect of the evaporation and moisture process. The presence of salts or dissolved salts cause many impacts such as: corrosion of concrete, steel pipe and reinforcing steel as well as increase strain in clay soils by changing the distance between the grains. Thus, the effect of salt on the physical and chemical properties of soil and foundation must be clarified (Duong and Thi Nu, 2020; Thi Nu et al., 2020). The percentage of dissolved salts in the soil of the study site ranged between 3.15-5.21% as shown in Table 2 and for the various depths. The ratio is high if it reaches more than it acts to increase the strain in the layers of clay soil.

6.3.4 Organic Matter Content (ORG.)

Soil that contains high organic matter (more than 2%) is called organic soil and this in turn has many problems with civil engineering construction. The organic soil is characterized by a high-water absorption capacity up to five times greater than their weight, which in turn leads to the occurrence changes in their volumes and the occurrence of swelling phenomenon. Furthermore, increasing the organic matter content leads to an increase in soil plasticity (Odell et al., 1960; Malkawi et al., 1999). The presence of organic matter in the soil prevents consolidation of cement and there is also the presence of high content of sulfates in soil that causes crashing of concrete (Khalaf and Mahmood, 2019). The values of organic matter in the study area ranged between 2.15-3.95% as shown in Table 2. The results show that there is a high value of organic matter in the soil, and these affect the compressibility of the soil and cause a decrease in its bearing capacity (Al-Humairi, 2015; Al-Rawi et al., 2017; Khalaf and Mahmood, 2019).

7 CONCLUSIONS

From the results of the current work, we can include the following conclusions:

1- The increased moisture content in the A layer makes it unfit for constructing a concrete structure unless it is treated by compacting the soil or drawing water from it.

2- Despite decreasing soil susceptibility to compressibility according to consistency limits, the increased organic matter content leads to an increase in soil compressibility.

3- the effect of the presence of sulphate, gypsum and total soluble salts on the behavior of the soil is negative because they are in high proportions that exceed the specified percentages.

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