Geotechnical Properties of Different Foundation Beds of Sadat City- Egypt

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Abstract: This research involves the geotechnical properties of different foundation beds of Sadat City. The studied area is characterized by very gentle topography and lack of sharp relief and is covered by Quaternary deposits which are mainly composed of sands and gravels intercalated with clay lenses. The investigation results of sands at foundation levels reveal that the values of specific gravity ranged from 2.55 to 2.88 with an average 2.72, effective diameter ranged from 0.16 mm to 0.87 mm, uniformity coefficient ranged from 1.59 to 13.65, and coefficient of curvature ranged from 0.26 to 1.57. According to unified soil classification system the group symbol of the majority of the studied samples are SP. The values of the internal angle of friction obtained from a direct shear test range from 33° to 43°. The investigation results of clays at foundation levels reveal that the values of the initial water content ranged from 7.9 % to 20 %, liquid limit range from 35% to 78 %, plastic limit ranged from 22% to 36%, shrinkage limit ranged from 10.8% to 17%, and the values of free swell ranged from 50 % to 120 %.The results of chemical analysis of the studied samples reveal that the values of pH ranged from 6.1 (moderately aggressive) to 7.9 (non aggressive),sulfates ranged from 0.001% (non aggressive) to 0.88% (aggressive) and chlorides ranged from 25.89ppm (non aggressive) to 1380ppm (aggressive). According to Egyptian code (2001), more than 50% of the studied samples are non aggressive soil. The ultimate soil bearing capacity values of the studied samples using Terzaghi's bearing capacity equation for square foundation range from 1182 kN/m^2 to 5433 kN/m^2.

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Keywords: Soil, uniformity coefficient, coefficient of curvature, bearing capacity.

I- Introduction:

Sadat City lies west of the Nile Delta and eastern side of the Cairo – Alexandria desert road from Kilo 85 to 109. It is bounded by longitude 30° 21` 64" - 30° 39` 55" E and latitude 30° 18` 57" - 30° 38` 19" N (Fig. 1). Sadat City covers about 500 Km^2 and is considered as one of the important urban extension zones. The present research was achieved as an attempt to study the geotechnical properties of different foundation beds of Sadat City. For this purpose, about 86 samples from different boreholes (of depth 10 meters) and from different open cuts (of depth less than 10 meters) that were collected from different localities at the studied area (Fig. 2). These samples have been taken at depth from 0.5 to 10 m. The studied area is characterized by a very gentile topography and lack of sharp relief and is characterized by a long hot summer and a short warm winter, low rainfall rates (50 mm/year) and high evaporation rates.

2. Geologic Setting:

The geology of the studied area and its vicinities had been discussed by several workers such as ***Shedid 1989,*** it is concluded that, the rocks of Miocene, Pliocene, and Quaternary times are the most outcropping sediments dominating the investigated area and its vicinities.

In the subsurface, the sedimentary rocks have a thickness of about 4500 m was recorded in Wadi El Natrun area. The sedimentary rocks succession starts from base by Triassic rocks resting on the basement rocks and ends at top with the recent deposits belonging to the Pliocene and Quaternary. The geological map of the studied area and its vicinities are showed in (Fig. 3). Sadat City is covered by Quaternary deposits which are mainly composed of sand,sand with trace of gravel, sand with some gravels, gravely sand and gravels intercalated with some clay lenses. The thickness of these clay lenses ranges from 1 m to 3 m.Some of these lenses are found at boreholes No. 34, 41, 44 and 45 as well as open cuts No.36, 37 and 46.

3. Geotechnical Studies:

The foundation beds of the urban area at Sadat City are the soil (Quaternary deposits) which are mainly composed of sands and gravels intercalated with clay lenses. The laboratory tests on Sands are specific gravity, sieve analysis, direct shear test and chemical analysis but the laboratory tests of clays (fine grained soil) are the initial water content, atterberg limits and free swell test.

3.1. Geotechnical Properties of Sands:

3.1.1. Specific Gravity (Gs):

Specific gravity is the ratio of the weight of the soil solids to the weight of water of equal volume. The values of the specific gravity of the studied samples are given in table (I) and range between 2.55 to 2.88 with an average 2.72.

3.1.2.: Sieve Analysis:

Grain size analysis is used for different purposes, such as textural, description, testing the behavior of sediments during transportation and deposition. It is also used to interpret the depositional environments under which these sediments were deposited and to evaluate the soil for engineering use. The quantitative data depend upon the mechanical properties such as stiffness and strength. Coarse grained soils have good bearing capacities and good drainage qualities, and their strength volume change characteristics are not significantly affected by change in moisture conditions. Fine grained soils have less load bearing capacities compared with coarse grained. Grain size analysis is required for classifying the soil. The results of the mechanical analysis are tabulated in Table (2) and the data are represented by grain size distribution curves to determine D_{10}, D_{30} and D_{60}.

Where; D_{10} (effective diameter): is a particle diameter at which 10% of the soil is finer.

D_{30}: is a particle diameter at which 30% of the soil is finer.

D_{60}: is a particle diameter at which 60% of the soil is finer.

Fig. (4) shows grain size distribution curves of samples No 1A, 2A, 3A and 3B.

The values of D_{10}, D_{30} and D_{60} are given in table (2). The values of D_{10} of the studied samples range from 0.16 mm to 0.87 mm while the values of D_{30} range from 0.18mm to 0.99 mm but the values of D_{60} range from 0.28 mm to 3.34 mm.

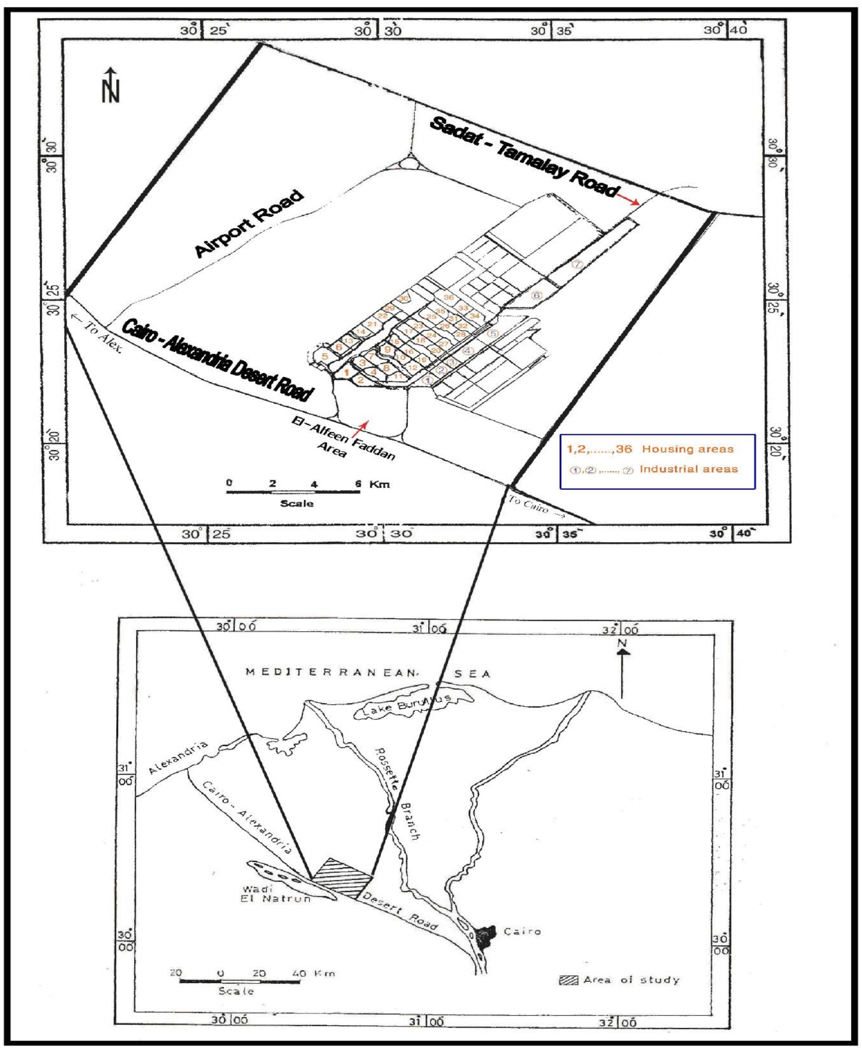

Fig. (1): Location map of the study area ***(After Gad, 2005)***

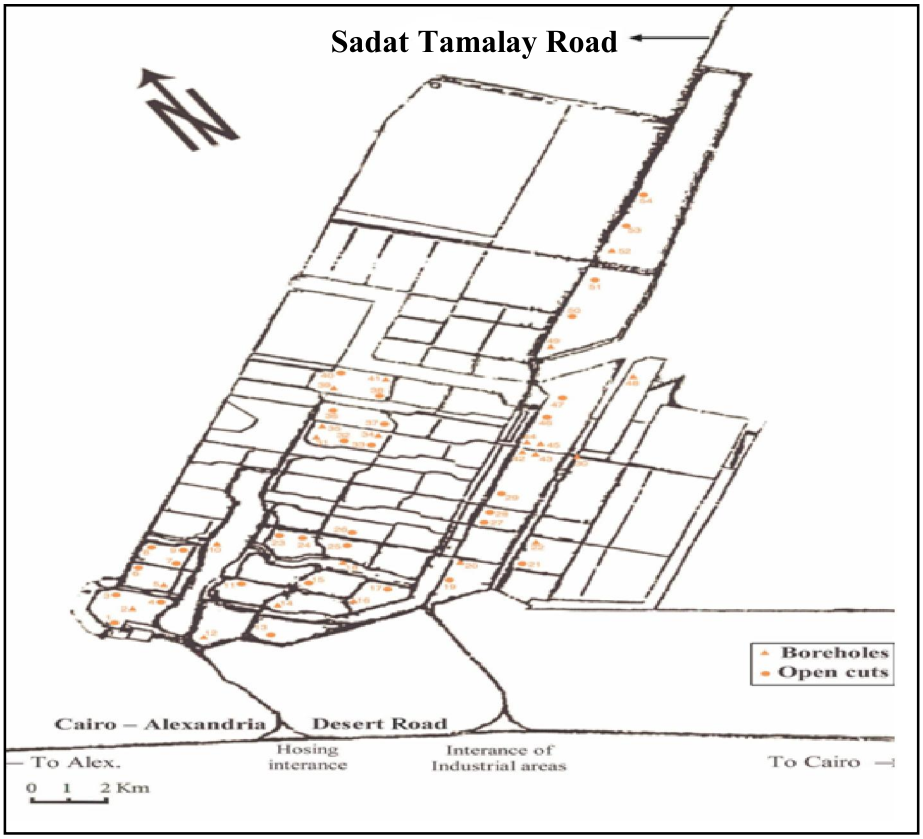

Fig.(2): Location map of examined sections

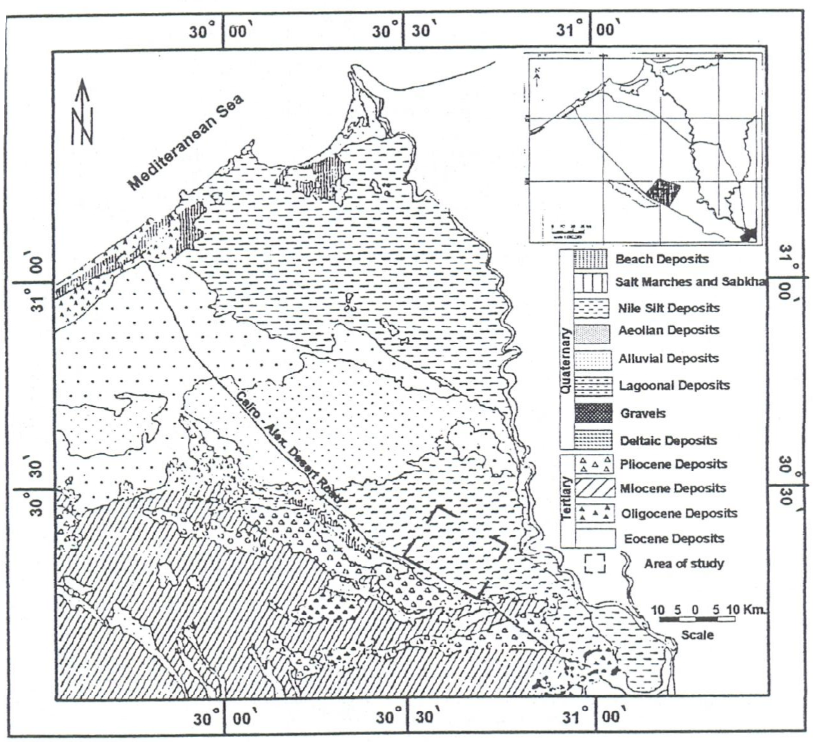

Fig. (3): Geological map of the area under study and its vicinities ***(After CONCO/EGPC, 1987)***

Table (1): Specific gravity of the studied samples

Sample No.	Specific gravity (g/cc)	Sample No.	Specific gravity (g/cc)
1 A	2.79	31 A	2.82
3 A	2.55	32 A	2.71
6 A	2.61	37 A	2.67
7 A	2.56	40 A	2.63
8 A	2.68	44 A	2.56
9 A	2.87	45 A	2.74
11 A	2.56	45 B	2.87
11 B	2.63	50 A	2.88
11 C	2.81	50 B	2.78
11 D	2.55	50 C	2.63
13 A	2.59	51 A	2.87
17 A	2.87	51 B	2.87
17B	2.86	51 C	2.56
17 C	2.75	51 D	2.56
23 A	2.83	51 E	2.57
24 A	2.55	53 A	2.57
25 A	2.55	53 B	2.88
25 B	2.56	53 C	2.86
26 A	2.59	53 D	2.69
27 A	2.55	54 A	2.88
28 A	2.55	54 B	2.55
29 A	2.86	-	-

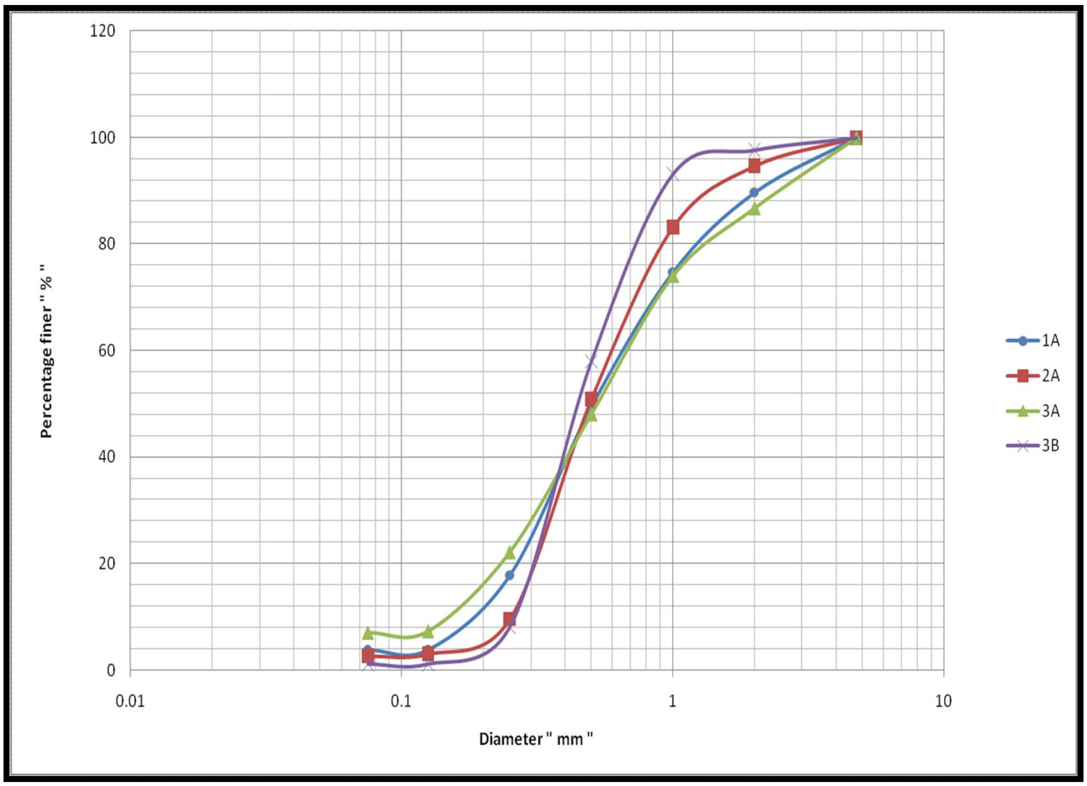

Fig.(4): Grain size distribution curves of samples No. 1A, 2A, 3A and 3B.

Table (5): Sieve analysis of the studied samples

Sieve opening (mm)	Finer (Passing) weight (%)							Statistical parameters					
Sample No.	4.75	2	1	0.5	0.25	0.125	0.075	D_{10}	D_{30}	D_{60}	C_U	C_C	Group symbol
1A	100	89.7	74.76	49.5	17.84	3.88	3.88	0.18	0.34	0.66	3.67	0.97	SP
2A	100	94.68	83.18	50.89	9.58	3.06	2.66	0.26	0.37	0.6	2.31	0.88	SP
3A	100	86.78	74.08	48.06	22.16	7.32	7.04	0.16	0.32	0.68	4.25	0.94	SP-SM
3B	100	97.68	93.18	57.94	8	1.06	1.06	0.27	0.35	0.52	1.93	0.87	SP
4A	100	88.79	74.8	46.9	14.36	4.2	4.2	0.22	0.36	0.68	3.09	0.87	SP
4C	100	100	94.55	64.35	19.02	5.22	4.72	0.18	0.31	0.47	2.61	1.14	SP
5A	100	92.75	77.62	37.5	20.2	3.7	3.3	0.17	0.38	0.74	4.35	1.15	SP
6A	100	91.13	80.14	53.25	31.09	17.51	17.51	-	0.24	0.59	-	-	SM
7A	85.48	69.83	45.18	17.8	4.8	1.6	1.6	0.37	0.7	1.62	4.38	0.82	SP
8A	100	82.03	66.04	38.18	13.08	2.82	2.82	0.23	0.41	0.85	3.7	0.86	SP
9A	100	73.47	61.48	44.58	18.74	4.92	4.42	0.18	0.33	0.93	5.17	0.65	SP
11A	91.88	77.3	57.38	31.72	7.8	1.84	1.84	0.27	0.48	1.24	4.59	0.69	SP
11B	89.78	41.74	30.39	16.36	6.12	1.19	0.69	0.34	0.99	2.83	8.32	1.02	SW
11C	100	83.66	60.72	22.6	4.58	0.82	0.82	0.34	0.59	1	2.94	1.02	SP
11D	100	98.66	95.04	75.28	8.82	0.88	0.88	0.27	0.32	0.43	1.59	0.88	SP
13A	93.41	69.32	51.84	30.17	9.3	2.28	2.28	0.27	0.5	1.46	5.41	0.63	SP
14A	100	93.53	75.33	32.31	14.21	2.49	2.11	0.21	0.48	0.79	3.76	1.39	SP
15A	100	88.87	76.62	32.65	19.36	3.24	3.24	0.18	0.47	0.78	4.33	1.57	SP
15A	100	82.08	79.48	55.48	17.47	4.49	4.13	0.19	0.33	0.56	2.95	1.02	SP
16A	100	91.54	81.78	53.38	19.79	3.66	3.16	0.18	0.33	0.58	3.22	1.04	SP
16B	100	95.63	74.33	34.23	8.28	3.6	3.2	0.27	0.44	0.79	2.93	0.91	SP
17A	92.72	66.92	56.88	40.2	23.66	12.6	12.1	-	0.34	1.35	-	-	SM
17B	91.66	57.12	48.18	30.78	15.9	6.86	6.68	0.17	0.49	2.32	13.65	0.61	SP-SM
17C	100	84.59	53.06	24.1	8.02	2.12	2.12	0.28	0.59	1.35	4.82	0.92	SP
19A	90.57	67.77	54.5	18.39	4.63	3.52	3.52	0.37	0.64	1.43	3.86	0.77	SP
19B	100	86.17	64.07	28.63	13.49	5.2	4.7	0.21	0.52	0.91	4.33	1.41	SP
20A	96.24	79.85	58.74	32.19	15.3	2.99	2.99	0.19	0.47	1.21	6.37	0.96	SP
23A	95.38	76.54	67.7	48.86	28.64	13.72	13.4	-	0.24	0.59	-	-	SM
24A	100	94.78	83.12	58.7	18.78	4.92	4.56	0.17	0.32	0.52	3.06	1.16	SP
25A	89.87	71.46	54.52	30.72	16.5	3.36	4.96	0.17	0.49	1.38	8.12	1.02	SP
25B	100	88.4	69.43	24.46	8.22	2.44	2.44	0.28	0.57	0.86	3.07	1.35	SP
21A	100	73.67	16.32	1.21	0.52	0.25	0.25	0.87	1.41	1.81	2.08	1.26	SP
21B	100	89.1	75.82	57.39	23.23	4.62	4.62	0.17	0.29	0.53	3.12	0.93	SP
22A	95.63	87.01	54.53	17.2	5.67	3.47	3.47	0.41	0.61	0.81	1.98	1.12	SP
22B	100	86.15	74.19	54.47	30.65	3.43	3.43	0.17	0.26	0.6	3.53	0.66	SP
26A	100	92.71	81.95	51.98	18.09	5.2	4.7	0.18	0.34	0.6	3.33	1.07	SP
27A	100	89.18	69.22	24.68	6.12	1.1	1.1	0.32	0.56	0.86	2.69	1.14	SP
28A	100	95.42	73.88	24.38	4.84	1.12	1.12	0.2	0.53	0.8	2.5	1.09	SP
29A	94.77	80.26	56.34	16.54	3.06	0.2	0.2	0.41	0.64	1.31	3.2	0.76	SP
31A	100	89.08	76.92	44.88	11.04	2.43	2.43	0.25	0.38	0.7	2.8	0.83	SP
32A	100	93.95	81.76	62.09	27.59	3.73	3.23	0.17	0.28	0.48	2.82	0.96	SP
33A	100	92.05	80.77	38.77	3.46	0.61	0.61	0.29	0.43	0.7	2.41	0.91	SP
34A	100	83.5	70.08	43.25	19.44	1.69	1.69	0.18	0.34	0.76	4.22	0.85	SM
35A	100	86.2	76.7	43.06	13.21	4.65	4.65	0.22	0.38	0.7	3.18	0.94	SP
36D	100	84.2	67.7	50.4	22.9	2.6	2.2	0.18	0.31	0.73	4.06	0.73	SP
37A	100	90.56	80.41	59.63	29.13	4.29	3.89	0.17	0.26	0.51	3	0.78	SP
38A	93.77	76.2	49.26	9.02	1.08	0.2	0.2	0.52	0.82	1.57	3.02	0.82	SP
39A	100	85.33	70.27	41.16	18.97	5.17	4.67	0.17	0.26	0.78	4.59	0.98	SP
40A	100	81.53	61.17	38.86	6.48	1.37	0.87	0.28	0.42	0.98	3.5	0.64	SP
41C	100	90.09	75.6	51.82	15.37	3.04	2.54	0.22	0.35	0.62	2.82	0.9	SP
42A	100	79.3	55.23	27.66	13.39	0.76	0.26	0.22	0.53	1.6	6.18	0.94	SW
43A	100	91.79	48.09	4.75	0.76	0.4	0.4	0.57	0.77	1.35	2.37	0.77	SP
46A	100	91.54	74.92	38.84	8.96	1.58	1.58	0.27	0.42	0.74	2.74	0.88	SP
47A	100	81.5	66.8	37.7	9.38	1.84	1.82	0.26	0.42	0.83	3.19	0.82	SP
47B	100	95.08	84.32	39.1	5.84	1.16	1.16	0.28	0.43	0.68	2.43	0.97	SP
44B	100	90.45	78.15	37.05	8.65	3.11	3.11	0.26	0.43	0.72	2.77	0.99	SP
45A	100	90.4	35.3	57.2	30.6	0.2	0.2	0.17	0.26	0.55	3.23	0.72	SP
49A	100	96.7	64.41	29.2	11	4.2	4.2	0.23	0.52	0.93	4.04	1.26	SP
50A	82.48	62.54	49.76	30.94	11.5	2.18	2.18	0.23	0.49	2.78	12.09	0.38	SP
50B	100	98.18	95.4	87.34	51.16	4.22	4.22	0.16	0.18	0.28	1.75	0.72	SP
50C	100	96.33	86.77	63.1	32.84	4.4	4.4	0.27	0.35	0.52	1.93	0.87	SP
51A	96.89	87.58	72.6	43.38	11.86	2.98	2.98	0.23	0.38	0.72	3.13	0.87	SP
51B	100	89.22	77.62	55.1	26.12	0.04	0.04	0.16	0.28	0.57	3.56	0.86	SP-SM
51C	86.49	31.76	27.78	19.66	7.04	1.46	1.46	0.3	0.51	3.34	11.13	0.26	SP
51D	100	88.02	68.03	39.6	10.84	1.76	1.76	0.26	0.41	0.8	3.08	0.8	SP
51E	100	94.56	85.3	46.94	11.3	0.94	0.94	0.24	0.37	0.62	2.58	0.92	SP
52A	100	90.72	78.21	43.21	17.81	3.5	3.1	0.18	0.37	0.7	3.89	1.09	SP
53 A	100	91.21	79.22	56.5	29.48	4.84	4.48	0.17	0.26	0.56	3.29	0.71	SP
53B	100	92.38	81.14	57.02	27.4	4.18	4.18	0.17	0.27	0.54	3.18	0.79	SP
53C	90.18	48.48	42.38	29.28	13.56	1.76	1.76	0.2	0.36	0.68	3.4	0.95	SP
53D	100	92.7	78.2	45.78	16.18	2.08	2.08	0.2	0.37	0.68	3.4	1.01	SP
54A	100	93.88	82.1	43.52	12.46	1.9	1.9	0.23	0.38	0.68	2.96	0.92	SP
54B	100	97.88	93.42	82.34	29.82	1.98	1.98	0.17	0.26	1.37	8.06	0.29	SP

3.1.2.1. Uniformity coefficient (C_U):

$$C_U = \frac{D_{60}}{D_{10}}$$

Uniformity Coefficient is a measure of the particle size range and is given by the relation:

Uniformity coefficient is also called Hazen coefficient The results of C_U values of the studied samples are given in table (2). The value of C_U range from 1.59 to 13.65. The majority of the studied samples are very uniform.

3.1.2.2. Coefficient of Curvature (C_C):

Coefficient of curvature is a measure of the shape of the particle size curve and is given by the relation:

$$C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

The results of C_C values of the studied sample are given in table (2). The values of C_C range from 0.26 to 1.57. The majority of the studied samples are poorly graded.

3.1.3. Direct Shear Test (Shear Box):

$$\sigma = \frac{N}{A}$$

The importance of shear strength of soil becomes of primary importance in all stability problems such as bearing capacity of shallow foundation, stability of slopes, lateral earth pressure used to design of retaining wall and sheet pile walls. The aim of this experiment is to estimate the shear strength parameters (angle of internal friction (∅) and cohesion (C)). The angle of friction of the studied samples can be determined by plotting peak shear stresses against corresponding normal stresses. The values of (∅) and (C) are given in table (3). The values of friction angle of the studied samples range from 33° to 43° but the value of cohesion (C) is 0.00 KPa. The relationship between shear stress and horizontal displacement at different normal stresses is showed in Fig. 5 to Fig. 8 but Fig. 9 shows shear stress versus normal stress of samples No. 1A and 3B. Normal stress can be determined from the following relation:

Where: σ = Normal stress.

N = Norma load

A = area of the shear box (6 * 6)

Shear stress can be determined from the following relation.

$$\tau = \frac{T}{A}$$

Where: τ = Shear stress.

T = The value of approving ring calibration factor * reading of horizontal dial ring. The internal friction angle can be calculated from the following equation:

$$\phi = \tan^{-1}\left(\frac{\tau}{\sigma}\right)$$

Table (3): Friction angle and cohesion of the studied samples.

Sample No.	Normal stress (KPa)	Peak shear stress (KPa)	Friction angle (∅)	Cohesion(C) (KPa)
1A	220.7 320.7 420.7	186.878 249.067 344.233	38°	0.00
3B	320.7 320.7 420.7	170.636 248.243 335.639	38°	0.00
6A	220.7 320.7 420.7	176.242 256.389 350.675	39°	0.00
11D	220.7 320.7 420.7	191.422 239.278 367.617	40°	0.00
17A	220.7 320.7 420.7	197.948 288.221 406.772	43°	0.00
21A	220.7 320.7 420.7	194.141 273.538 363.811	41°	0.00
23A	220.7 320.7	188.771 259.399	40°	0.00

	420.7	357.985		
28A	220.7 320.7 420.7	185.984 279.52 354.566	42°	0.00
29A	220.7 320.7 420.7	197.948 288.221 398.071	43°	0.00
35A	220.7 320.7 420.7	148.864 216.315 283.766	34°	0.00
36A	220.7 320.7 420.7	143.324 208.265 273.206	33°	0.00
37A	220.7 320.7 420.7	167.242 247.918 319.166	37°	0.00
40A	220.7 320.7 420.7	154.536 224.557 294.577	35°	0.00
46A	220.7 320.7 420.7	167.373 223.772 320.412	36°	0.00
50A	220.7 320.7 420.7	194.998 263.985 365.669	40°	0.00
53D	220.7 320.7 420.7	190.334 258.855 320.849	38°	0.00

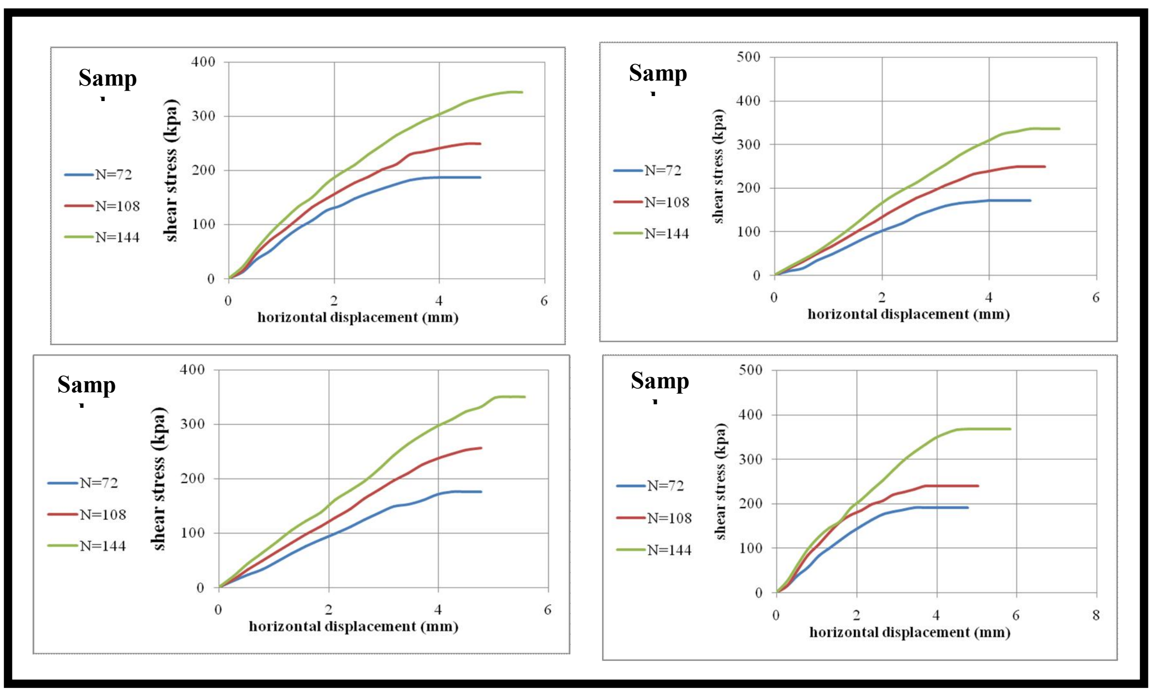

Fig. (5): Shear stress and horizontal displacement at different normal stresses of samples No. (1A, 3B, 6A and 11D)

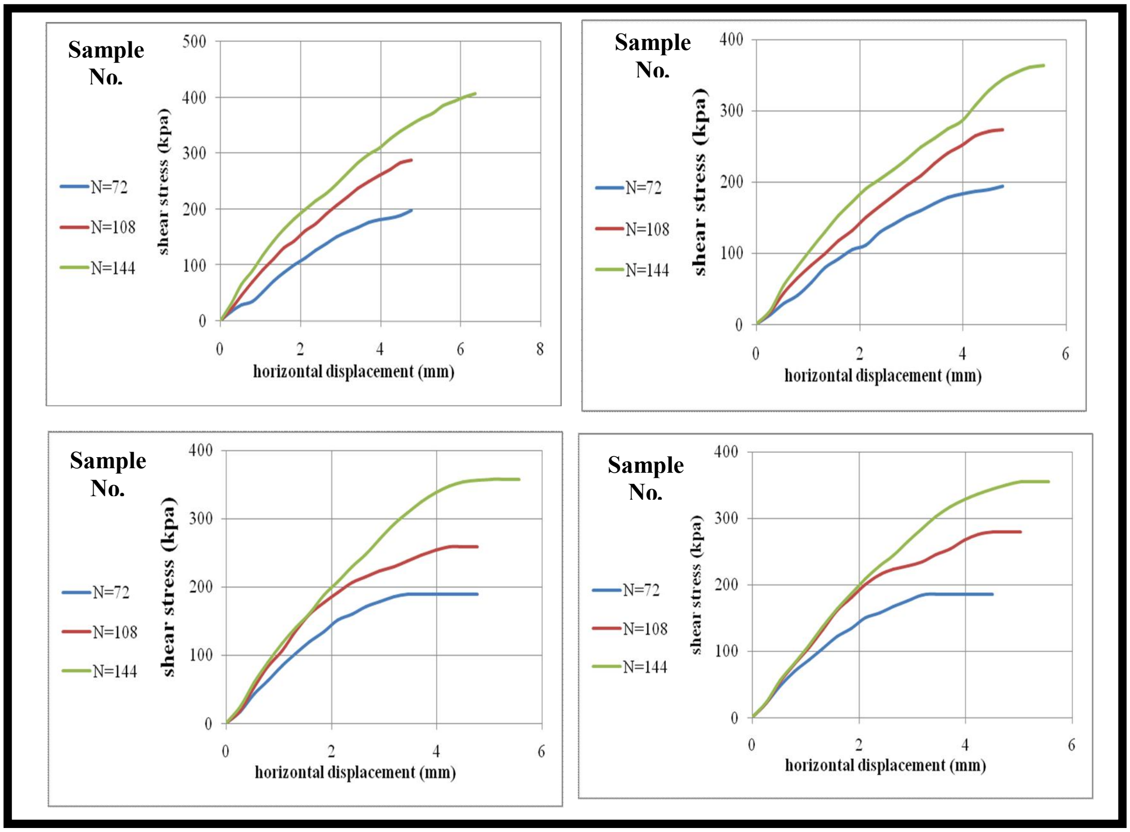

Fig. (6): Shear stress and horizontal displacement at different normal stresses of samples No. (17A, 21A, 23 A and 28A)

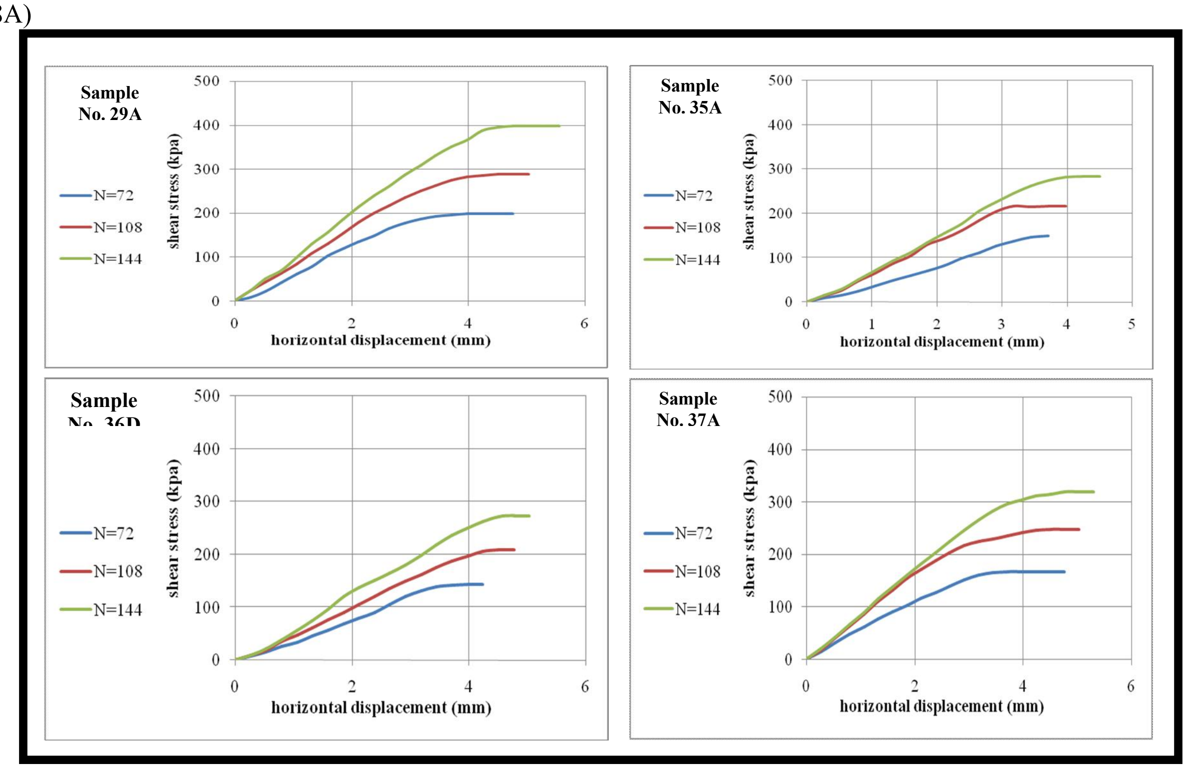

Fig. (7): Shear stress and horizontal displacement at different normal stresses of samples No. (29A, 36A, 36D and 37A)

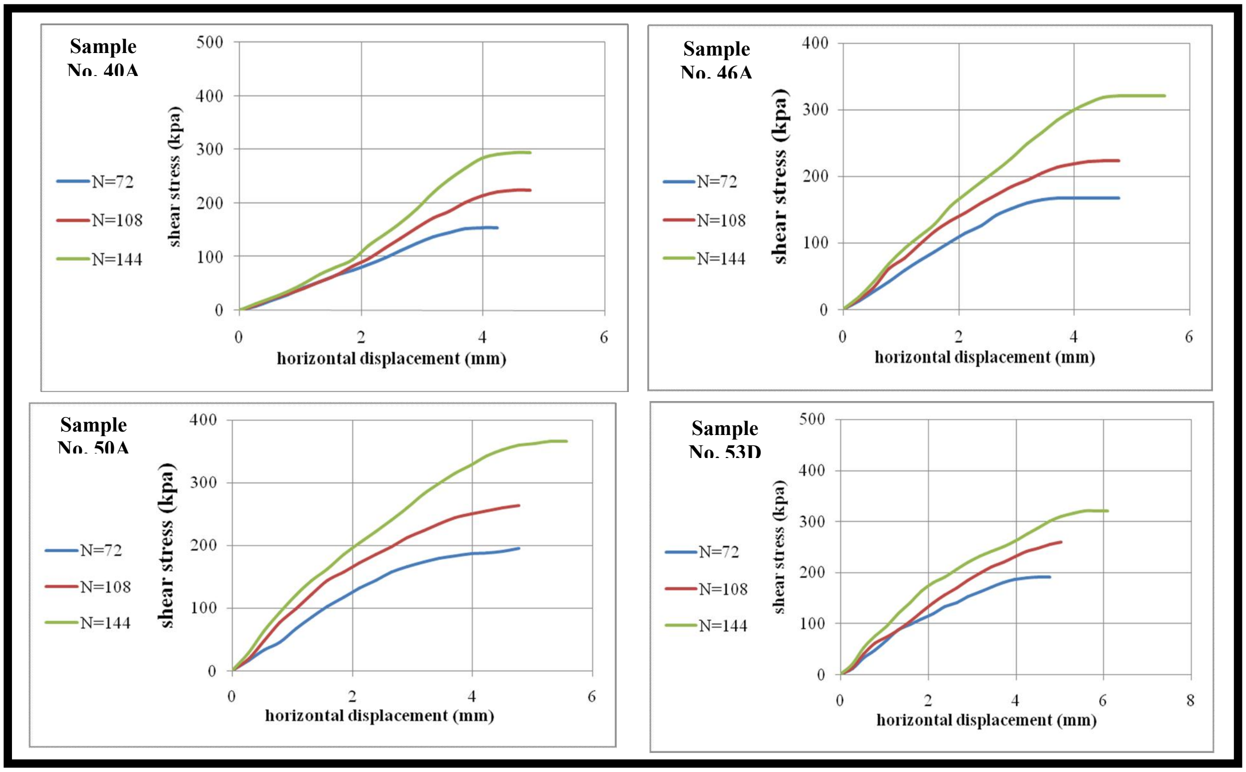

Fig. (8): Shear stress and horizontal displacement at different normal stresses of samples No. (40A, 46A, 50A and 53D)

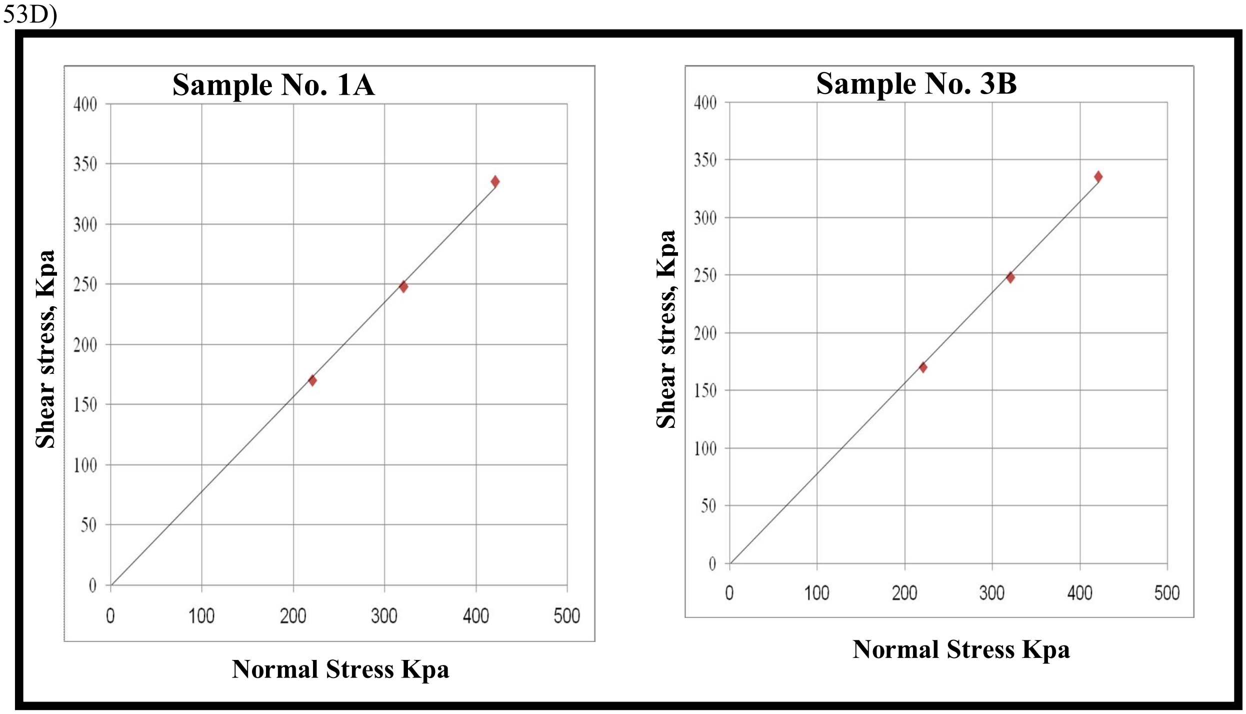

Fig. (9): Shear stress versus normal stress of samples No. (1A and 3B)

3.1.4. Chemical Analysis:

The purpose of chemical analysis is to determine the degree of aggressive for soil samples. The water extraction method can be used for determining the sulfates, chlorides contents and pH values. The results of chemical analysis are given in table (4).

The values of pH of the studied samples range from 6.1 (moderately aggressive) to 7.9 (non aggressive), sulfates range from 0.001% (non aggressive) to 0.88% (aggressive) and the values of chlorides range from 25.89ppm (non aggressive) to 1380ppm (aggressive). According to Egyptian code (2001), more than 50% of the studied samples are non aggressive soil.

3.2. Geotechnical Properties of Clays:

3.2.1. Initial Water Content:

The initial water content (moisture content) is defined as the ratio of the weight of water present in a given soil mass to the dry weight of solid soil particles. The results of this test of the studied samples are given in (Table 2). These results range from 7.9% to 20 %.

Table (4): Guide values for some aggressive elements and factors determining aggressive degrees of the soil at Sadat City.

Sample. No	E.C.	T.D.S	Sulfates	Chlorides	pH
2A	1468	938.98	0.412	330	7.2
3A	1636	1047.04	0.013	299.07	7
3B	572	366.08	0.003	150.14	7.1
4B	1298	830.72	0.034	113.9	7
5A	1321	999.81	0.48	620	7
6A	5130	3283.2	0.082	1113.12	7
7A	3490	2233.6	0.081	657.52	6.1
9A	5240	3353.6	0.089	1190.78	6.1
11D	714	456.96	0.007	160.5	7
14A	832	854.81	0.139	400	7
16A	1211	763.21	0.037	220	7.3
17C	1415	905.6	0.015	295.11	7.1
19A	1642	2860	0.013	1150	7.9
20A	1951	4960	0.206	1380	7.6
21A	948	6375	0.288	864	7.2
22A	1120	7013	0.445	791	7.1
24A	376	240.64	0.004	67.3	7
25B	432	276.48	0.004	108.72	7
26A	196	125.44	0.002	25.89	7.1
28A	558	357.12	0.005	129.43	7.3
29A	1784	114176	0.078	103.55	7
32A	1653	1254.22	0.45	840	7.2
34A	1251	871.35	0.1	490	7.5
37A	999	743.56	0.88	420	7.1
44A	596	381.44	0.002	139.79	6.5
45A	3280	2029.2	0.052	693.76	6.4
49A	994	590.18	0.03	840	7.9
50A	1011	647.04	0.001	269.22	7.1
50B	586	375.04	0.002	142.38	7
50D	394	252.16	0.001	96.6	7.1
51E	757	484.48	0.007	147.55	7
53D	898	574.72	0.002	238.16	7

Table (5): Initial water content of the studied samples

Sample No.	Initial water content %	Sample No.	Initial water content %
4B	12.1	41 B	16
34B	12	42 B	16.6
36A	19	43 B	9.6
36B	20	44 A	11.2
36C	17	46 B	12.1
37B	17	47 B	7.9
41A	17	-	-

3.2.2. Atterberg Limits and Consistency of Fine Grained Soils:

The aterberg limits are the boundaries between four states of soil. The term consistency of soil means the relative ease which soil can be deformed, this term used for fine grained soil and is related to a large extent to the water content. The soil passes through various states of consistency, these states are liquid, plastic and semisolid states.

3.2.2.1. Liquid limit (L.L):

The liquid limit is the water content corresponding to a limit between liquid and plastic states of consistency. The results of the liquid limit of studied samples are given in Table (5). These results range from 35% to 78 %.

3.2.2.2. Plastic Limit (P.L.):

The plastic limit for the part of soil passing from sieve No. 40 (425 µm) of studied samples are determined by laboratory test. It is depends on the type and amount of clay fraction in soil. The results of the plastic limit are given in table (5). These results range from 22 % to 36 %.

3.2.2.3. Shrinkage Limit (S.L):

According to ***Arora 1988*** the shrinkage limit is the water content below which no appreciable change in volume is observed. This limit is determined in the laboratory. The results of this test are given in table (5). These results range from 10.8 % to 17 %.

3.2.2.4. Plasticity Index (P.I.):

Plasticity index is defined as the numerical difference between the liquid limit and plastic limit. The plasticity index values of the tested soils are shown in table (6).These results range from 10 % to 49 %.

3.2.2.5. Liquidity Index (L.I.):

The liquidity index (L.I) according to ***Withlow, 1983*** can be used to predict the physical state of the soil and its natural moisture content. The values of this liquidity index are given in table(6). These results range from -2.07 % to 0.13 %.

3.2.2.6. Consistency Index (C. I):

The consistency index is defined as the ratio of the difference between the liquid limit and natural water content to the plasticity index. The values of this index are given in table (6). These results range from 1.13 % to 3.07 %.

Table (5): Atterberg limits of the studied samples.

Sample No.	Liquid limit (L.L)	Plastic limit (P.L)	Shrinkage limit (S.L)
3A	47	36	-
4A	55	22	16.8
6A	36	26	-
17A	41	28	-
17B	45	33	-
23A	40	28	-
34B	39	26	16
36A	45	22	16
37B	44	29	17
41B	45	29	14
42B	44	24	17
43B	78	34	14
44A	48	36	17
46A	72	23	17
47B	66	26	13
51B	35	25	-

Table(6): Plasticity, liquidity and consistency index of the studied samples:

Sample. No.	Plasticity index%	Liquidity index %	Consistency Index %
4B	33	-0.3	1.3
34B	13	-1.08	2.08
36A	23	-0.13	1.13
37B	15	-.08	1.8
41B	16	-0.81	1.81
42B	20	-0.37	1.37
43B	44	-0.55	1.55
44A	12	-2.07	3.07
46A	49	-0.22	1.22
47B	40	-0.45	1.45

3.2.3. Free Swell Test:

The free swell test is a qualitative indicator of expansive soil. The values of free swelling of the studied samples are given in table (7) and range between 50 % to 120 %.

Table (7): Free swell of the studied samples

Sample. No.	Free swell %	Sample No.	Free swell %
4 B	120	41 B	50
34 B	60	42 B	55
36 A	53	43 B	50
36 B	60	44 A	60
36 C	50	46 B	50
37 B	50	47 B	54
41 A	70	-	-

3.3. Classification of Engineering Properties of Soil:

The purpose of soil classification is to arrange various types of soil into groups according their engineering characteristics.

The classification of coarse grained soils (sand and sand with gravel) according to USCS (Unified soil classification system) is showed in table (2). Some samples of coarse grained soil contain more than 12% of finer fractions or contain from 5% to 12% of finer fractions, the liquid limit and plastic limit tests are estimated and plotted on plasticity chart (Fig. 7) to determine the symbol of fine fractions.

The fine grained soils of the studied sample are classified by using plasticity chart according to Casagrand's (1948), (Fig. 10) shows the classification of fine grained soils of the studied samples.

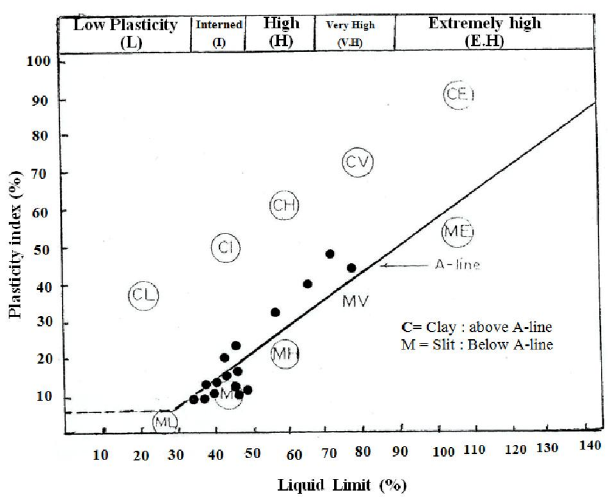

Fig. (10): Classification of fine – grained soil *(After Casagrand, 1948)*

3.3. Bearing Capacity:

The supporting power of a soil or rock is referred to as its bearing capacity. The term bearing capacity is defined as described below after attaching certain qualifying prefixes.The ultimate soil bearing capacity can be determined by using Terzaghi's bearing capacity equation for square footing:

$Qu = 1.3\ c\ Nc + \gamma D\ Nq + 0.4\gamma B\ N\gamma$

Where: C: Cohesion of soil, γ: unit weight of soil, D: depth of footing, B: width of footing Nc, Nq, Nr: Terzaghi's bearing capacity factors depend on soil friction angle, φ.

$Nc=\cot\varphi(Nq-1)$

$Nq=e2(3\pi/4-\varphi/2)\tan\varphi \ / \ [2\cos2(45+\varphi/2)]$

$N\gamma=(1/2)\tan\varphi(Kpr/\cos2\ \varphi -1)$

Kpr=passive pressure coefficient.

Also, these factors can be determined from (Fig.11).

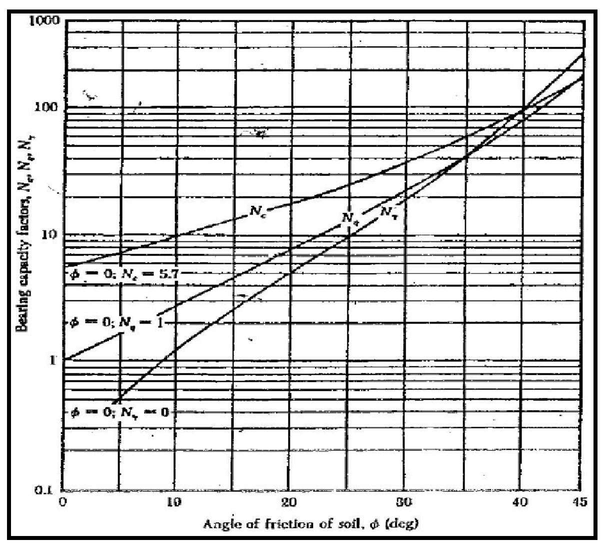

Fig. (11): Terzaghi's bearing capacity factors for general shear failure

In this research, A square foundation is (1.5 m * 1.5 m), the unit weight of soil is 18 kN/m^3, the depth of the foundation is 1.5 m. The results of the ultimate soil bearing capacity for different friction angles of the studied samples are showed in table (8). The values range from 1182 kN/m^2 to 5433 kN/m^2.

Table (8): The ultimate soil bearing capacity of the studied samples.

Sample No.	Friction angle (∅)	Cohesion (C) (KPa)	Nc	Nq	Nγ	Qu (kN / m²)
1A	38°	0.00	82.2	63.5	73.1	2504
3B	38°	0.00	82.2	63.5	73.1	2504
6A	39°	0.00	95.7	73.2	89.2	2940
11D	40°	0.00	146.7	81.3	100.4	3279
17A	43°	0.00	99.5	132.3	172.3	5433
21A	41°	0.00	95.7	85.4	116.5	3564
23A	40°	0.00	123.2	81.3	100.4	3279
28A	42°	0.00	146.7	97.5	144.5	4193
29A	43°	0.00	52.6	132.3	172.3	5433
35A	34°	0.00	48.8	36.5	36	1374
36A	33°	0.00	72.4	32.6	27.9	1182
37A	37°	0.00	57.8	52.7	58.9	2059
40A	35°	0.00	68.2	41.4	42.4	1576
46A	36°	0.00	68.2	51.1	48.3	1901
50A	40°	0.00	95.7	81.3	100.4	3279
53D	38°	0.00	82.2	63.5	73.1	2504

Conclusion:

The soil of Sadat City from the foundation point of view is divided into three types: sandy soil, gravel soil and clay soil (clay lenses).From the geotechnical parameters, the first and second types of soils are suitable for direct foundation above them. These two types are classified as coarse grained soils. Which have good load bearing capacities and good drainage qualities, and their strength and volume change characteristics are not significantly affected by changes in moisture conditions. So, it is recommended here to build a lot of buildings.

The third type is not allowed to direct foundation because of its high swelling property, which has a dangerous effect on the buildings that are found there. If it is necessary to use this type of soil for building, this soil should be replaced by a soil of clean sand taken from another spots to be distributed under the foundation. This replacement layer should not be less than 1.5m thick. It is also recommend to create green and open play grounds on this type of soil. If it is needed to build on it, villas and small housings can be constructed.

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