Analysis of Swelling Characteristics of Expansive Soil

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Abstract

Swelling and expansion are important characteristics of soil. The expansive soil can cause many problems in the foundation due to settlement in the form of shear. Therefore behavior of the expansive soil should be investigated properly before structural design. In this study the effects of swelling and expansive characteristics of soil are analyzed by experimental work. Moisture content and dry density are found to check the effect of their variation on the swelling of soil. Swell potential test and swell pressure test are carried out according to ASTM standards. From the obtained result it is observed that with the increase in the initial moisture content, swelling potential decreases and the increase in dry density causes decrease in swelling potential.

Keywords: Soil; Swelling Deformation; Expansive; Moisture Content; Dry Density

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INTRODUCTION

Soil is an unconsolidated (loose) agglomerate of minerals with or without organic matter found at surface of the earth's crust, upon which the structure loads are transferred. Swelling and expansion are important characteristics of soil. Due to the rapid increase in infrastructure development, it is important to consider the properties of soil like swelling and expansions before design of structures. The swelling of the soil is change in its volume due to sudden increase or decrease of moisture content. The soil that changes its volume with variation in its moisture content called expansive soil. Expansive soil increases with initial dry density but decreases as the initial water content is higher. The effect of the initial water content on the final swelling strain is less important for the low dry densities and the high vertical loads (Technical manual TM 5-818-7, 1983). When the volume of soil increases it exerts upward pressure on foundation due to which failure occurs. The expansive nature soil can causes many problems like cracks on roof or floor of building, disturb slope stability, destroy road pavement and also damage underground water supply system.

Several works (Gens et al., 1992; Cui et al., 2002; Sanchez et al., 2005) have been done to study the influence of water content and dry density on the swelling characteristics of clays from a macroscopic point of view. Back in the seventies the swelling behavior of plastic clays was investigated as a function of suction (Kassiff and Ben Shalom, 1971; Kassiff et al., 1971; Brackley and IJA, 1971). More recently, several authors (Komine and Ogata; 1994; Komine and Ogata, 1996; Komine and Ogata, 1999; Komine, 2004) have studied the swelling behavior of compacted sand mixture. The swelling properties can be also affected by the chemical composition of the saturating fluid (Kassiff and Shalom, 1971). In most regions of Balochistan the soil has low moisture content due to which swelling of soil increases and settlement occurs in foundation of structures. To overcome this critical issue a geotechnical experimental investigation is needed.

A number of papers (Komine and Ogata, 1994; Gens et al., 1992; Cui et al., 2002; Komine, 2004; Sanchez et al., 2005) have already been published to study the different properties of soil. However, further investigation is needed to reduce the swelling of soil. Therefore, in this study an attempt has been made to investigate the swelling. The work was conducted on the soil sample taken from Almas village Quetta. The reason to select this area was the loose characteristic of soil. The undisturbed sample was tested in order to obtain the in-situ density and the in-situ moisture content. The soil sample was prepared to obtain the swell parameter i.e. swell potential and swell pressure. Moisture content and density were varied to check the effect of their variation on swelling of soil.

MATERIALS AND METHODS

Soil sample was taken from Almas village Quetta. Natural moisture content of the soil sample determined by placing it in the drying oven was14.96%. After that in- situ density of the soil sample was determined which was 1147kg/m^3. The particle size analysis and hydrometer analysis were carried according to the procedure given in ASTM D422 and ASTM D4221, respectively, in order to have an idea about the finer percentage of the soil profile types. Atterberg's limit tests were performed according to the standard procedure given in ASTM D4318. The soil sample was then allowed to swell to equilibrium on an addition of water to the Oedometer cell. The free swell test was performed by keeping the initial dry density constant (i.e. in-situ dry density of soil sample (1147kg/m^3) by varying moisture content from 0% to 20%. Free swell test was performed by fixing moisture content at 10% and varying the initial dry density from 11kN/m^3 to 12.8kN/m^3.

RESULTS AND DISCUSSION

Sieve analysis.

The sieve analysis results are shown in Table 1. The results depict that the soil sample from Quetta (Almas) has very small fraction of coarse particle i.e.12.5%. The clay soil was mainly consisted of finer particles.

Table 1: Results of Sieve Analysis

Sieve #	Dia (mm)	Weight of soil(Retained) gm	% Weight Retained	Cumulative % Retained	% Passing
#4	4.75	0.00	0.00	0.00	100
#10	2	0.00	0.00	0.00	100
#40	0.425	0.47	0.47	0.47	99.53
#100	0.15	5.35	5.35	5.52	94.48
#200	0.075	6.38	6.38	12.5	87.5

Hydrometer analysis.

Hydrometer analysis was then carried out to observe the particle size distribution of the finer portion of soil. The results of hydrometer analysis are shown in Fig 1. From the obtained results it was observed that with the increase in grain size of soil the swelling potential of the soil increases.

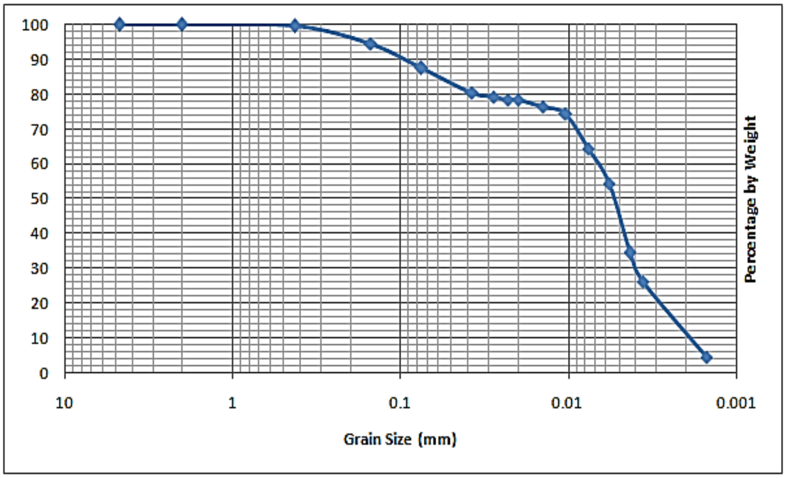

Figure 1: Gradation Curve for Soil Sample

Plasticity index

From the obtained results as shown in Fig. 2 the liquid limit was observed 61% while the plastic limit was 26.62 % as shown in Table 2. The plasticity index was 34.4% according to US Army Engineer Waterways Experiment Station and United States Bureau of Reclamation (USAEWES and USBR) classification system. These values suggest that the swelling potential of this soil is "High".

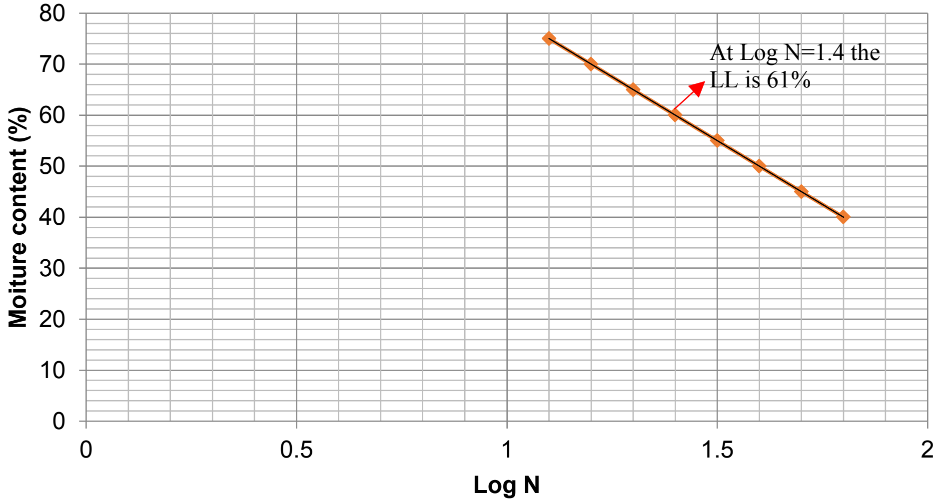

Figure 2: Percentage of Moisture Content (%) vs. Log N (Number of blows).

Table 2: Results of Plastic Limit Test

Weight of wet soil + can.(gm)	24.3	22.5	27.1
Weight of dry soil + can ,(gm	21.4	20.3	24.1
Weight of the can ,(gm)	10.9	11.5	12.8
Weight of dry soil , (gm)	10.5	8.8	11.3
Weight of moisture ,(gm)	2.9	2.2	3
Water content ,w%= w_p	27.61	25	27.27
Avg. PL%	**26.62%**		

Oedometer observations for constant density by varying moisture condition.

Fig 3 shows comparison of the percentage swell of specimens at different initial moisture content with change in time. The applied load at constant cross sectional area (1140.1mm^2) was 15826.8g, 9297.45g, 7240.75g, 5499.56g, 15826.8g at 0%, 5%, 10%, 15% and 20%, respectively as shown in Table 3. While the swell pressure was 136.2 Kpa, 80 Kpa, 62.3Kpa, 47.3 Kpa, 42 Kpa, respectively. The steep initial gradient for 0% moisture sample readily swelled when it received water. The curve for 0% initial moisture has shown the maximum percentage swell. With the increase in initial moisture content, from 0 to 20%, the percentage swell decreased. With passage of time, change in percent swell is small and curve becomes flat. Fig 3 shows the percentage swell against time on logarithmic scale, giving a better comparison of swelling behavior of the five samples.

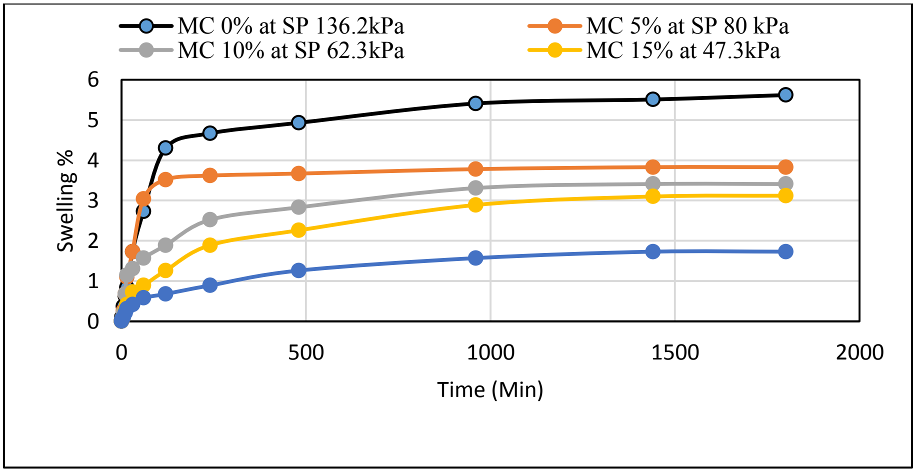

Figure 3: Swell % vs Time

Oedometer observations for constant moisture by varying density

Fig 4 shows comparison of the percentage swell of specimens at different dry densities with change in time. The applied load at constant cross sectional area (1140.1mm^2) was 5585.8g, 7240.75g, 12876.9g, 23069.1g, 25206.61g at 9.50 kN/m^3, 10 kN/m^3, 10.30 kN/m^3, 10.40 kN/m^3 and 10.8 kN/m^3, respectively, as shown in Table 4. While the swell pressure was 48.1 Kpa, 62.3 Kpa, 110.8 Kpa, 198.5 Kpa, 216.9Kpa, respectively. The steep initial gradient shows that soil readily swelled when it received water. With the increase in initial dry density from 11 KN/m^{3}to 12.8 KN/m^3, the percentage swell increased from 4.78% to 9.66%. With passage of time, change in percent swell is small and curve becomes flat. Fig 4 shows the percentage swell against time on logarithmic scale, giving a better comparison of swelling behavior of the five samples.

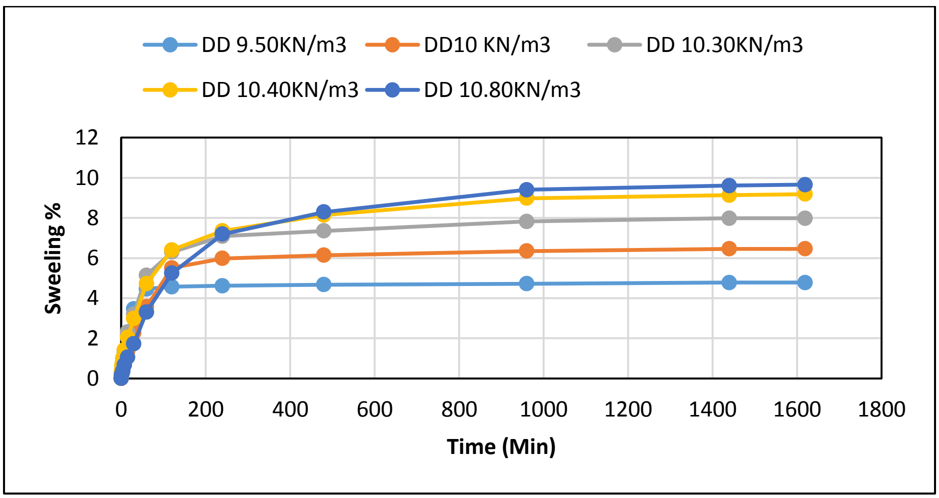

Figure 4: Swell % vs Time

Table 3: Oedometer observations for constant density by varying moisture Condition.

Moisture Content= 0%		**Moisture Content= 5%**		**Moisture Content= 10%**		**Moisture Content= 15%**		**Moisture Content= 20%**	
Time (min)	**% Swell**	**Time (min)**	**% Swell**	**Time (min)**	**% Swell**	**Time (min)**	**% Swell**	**Time (min)**	**% Swell**
0	0	0	0	0	0	0	0	0	0
1	0.1	1	0.05	1	0.05	1	0.05	1	0.05
5	0.37	5	0.26	5	0.21	5	0.1	5	0.1
10	0.63	10	0.68	10	0.68	10	0.26	10	0.21
15	0.84	15	1.1	15	1.15	15	0.42	15	0.31
30	1.73	30	1.73	30	1.31	30	0.73	30	0.42
60	2.73	60	3.04	60	1.57	60	0.89	60	0.58
120	4.3	120	3.52	120	1.89	120	1.26	120	0.68
240	4.67	240	3.62	240	2.52	240	1.89	240	0.89
480	4.93	480	3.67	480	2.83	480	2.26	480	1.26
960	5.41	960	3.78	960	3.31	960	2.89	960	1.57
1440	5.51	1440	3.83	1440	3.41	1440	3.1	1440	1.73
1800	5.62	1800	3.83	1800	3.41	1800	3.12	1800	1.73

Table 4: Oedometer observations for constant moisture by varying density Condition.

Dry Density 9.50kN/m^3		**Dry Density 10kN/m^3**		**Dry Density 10.30kN/m^3**		**Dry Density 10.40kN/m^3**		**Dry Density 10.80kN/m^3**	
Time (min)	**% Swell**	**Time (min)**	**% Swell**	**Time (min)**	**% Swell**	**Time (min)**	**% Swell**	**Time (min)**	**% Swell**
0	0	0	0	0	0	0	0	0	0
1	0.26	1	0.16	1	0.21	1	0.37	1	0.16
2	0.47	2	0.26	2	0.31	2	0.63	2	0.21
3	0.63	3	0.37	3	0.47	3	0.79	3	0.31
4	0.79	4	0.47	4	0.79	4	1	4	0.37
8	1.36	8	0.84	8	1.31	8	1.42	8	0.68
15	2.15	15	1.36	15	2.31	15	2.05	15	1.05
30	3.46	30	2.26	30	3.2	30	2.99	30	1.73
60	4.46	60	3.57	60	5.14	60	4.72	60	3.31
120	4.57	120	5.51	120	6.3	120	6.4	120	5.25
240	4.62	240	5.98	240	7.09	240	7.35	240	7.19
480	4.67	480	6.14	480	7.35	480	8.14	480	8.29
960	4.72	960	6.35	960	7.82	960	8.98	960	9.4
1440	4.78	1440	6.46	1440	7.98	1440	9.13	1440	9.61
1620	4.78	1620	6.46	1620	7.98	1620	9.19	1620	9.66

CONCLUSION

This study was basically carried out to develop the understanding of how the soil sample of Almas village Quetta behaves when its density or initial water content varies. It was observed from the results that with the increase in dry density the swell potential of the expansive soil increases. Also with the increase in initial moisture content, swelling potential decreases. From a practical point of view the results are helpful to design structures on swelling soil. However it should be noted that this conclusion is based on the results of soil samples taken from selected site. Further studies with more tests on different sample soil from different location are needed to gain more confidence on this aspect.

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