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Experimental Study on Swelling Potential of Expansive Soils Under Different Dry Density and Moisture Conditions

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Abstract — *Expansive or swelling soils exist in many part of the world. Such common soils in Australia, India and South Africa. Show excessive volume changes with increase in water content. Results of this volume increase expansive soil apply pressure to the structures located or buried in these regions. In this paper study of swelling behavior of expansive clay is investigate using Consolidometer method. The tests will be carried out on a number of samples obtained from different part of Saurashtra region Rajkot, Bhavnagar, Jamnagar, Ameli. The remolded samples are prepared having different initial dry densities with different initial water contents used to study the effect of these variable parameters on the swelling pressure. It is observed that swell pressures increases with increasing initial dry density and they decrease with increasing initial water content.*

Keywords- About four key words or phrases in Expansive Soils, Swelling Pressure, Dry Density, Molding Water Content.

I. INTRODUCTION

Some of the partially saturated clayey soil are very sensitive to variation in water content and show excessive volume changes, such soil are classified as expansive soil and exist on many part of the world. Many places of India, Africa, Australia, Israel, and South America are covered with such soil. Expansive soils are worldwide problem faced by civil engineer. It is extended nearly one-fifth of our country, chiefly in the states of Maharashtra, Gujarat, Madhya Pradesh, Uttar Pradesh, Rajasthan, Karnataka, Andhra Pradesh and Tamil Naidu. Expansive soils also call black cotton soil.

The swelling phenomena is considered as one of the most serious challenge which the foundation engineer faces, because of the potential danger of unpredictable upward movements of structures founded on such soils.

Any structure located on expansive clay may be subjected to large magnitudes of pressures due to development of swelling pressure when moisture content of clay increases. When moisture content of clay decrease settlement problem create in structure due to differential settlement structure became damage .We can reduce economical loss by evaluating swelling characteristic of soil before starting the construction of important structure. Considerable amount of work has already been done in understanding the behavior of expansive soils. The parent materials associated with expansive soils are either basic igneous rocks or sedimentary rocks. Basic igneous rocks, it is formed by decomposition of feldspar and pyroxene and in sedimentary rocks , it is a constituent of rock itself in any case most expansive soils are rich in montmorillonite clay mineral.

II. METHODOLOGY

2.1 Introduction

The purpose of this experimental study is to measure the evaluate swelling potential of clayey soil and to investigate the pressure induced. And also investigate the effects of initial water content and initial dry density on swelling. Consolidometer swell tests are carried out. To investigate the effects of initial water content and initial dry density, a wide range of water content and densities are used for the tests program.

2.2 Material Investigated

Material investigated: The clayey soil samples used in these studies are collect from different part of saurashtra region Jamnagar (Sample No-1), Bhavnagar (Sample No-2), Amreli (Sample No-3), Rajkot (Sample No-4). The soil sample is plastic clay. The soil is classified as CH soil according to Unified Soil Classification System. Index properties is shown in Table 1.

Table 1: Index Properties Clayey of Soils

Sr. No	Properties of soils	Jamnagar	Bhavnagar	Amreli	Rajkot
1	Liquid limit (%), LL	77	74	58	53

2	Plastic limit (%), PL	26	25	22	25
3	Plasticity index , PI	51	49	36	28
4	% Free swell test	150	140	100	75
5	Specific gravity, G_S	2.57	2.6	2.61	2.63
6	% of Gravel	01	03	01	00
7	% of Sand	20	28	14	36
8	% of Silt and Clay	79	66	85	64
9	% of Clay	44	43	34	28
10	% of Silt	35	26	51	36
11	Shrinkage limits SL	20	19	16.50	18.5
12	O.M.C.%	23.26	23.26	20.70	17.17
13	M.D.D gm/cc, γd	1.41	1.5	1.58	1.7
14	Activity I_P/C%	1.15	1.13	1.07	1.0
15	Type of soil	CH	CH	CH	CH

2.3 Consolidometer Method

2.3.1 General

Total 36 No. of consolidation swell tests were carried out on four types soils-CH at various dry density and water content, to study swelling behavior of expansive soils, 9 no of tests at 90 %, 95%, and 100% of M.D.D and water content 5 %, 10 %, O.M.C are carried out for four types soil.

Figure 1. Consolidation test set up

Figure 2. Dial Gauge of Apparatus

2.3.2 Apparatus

- **Specimen Diameter:** The specimen shall be 60 mm in diameter (specimens of diameters 50, 70 and 100 mm may also be used in special case).

- **Specimen Thickness:** The specimen shall be at least 20 mm thick in all cases. However, the thickness shall not be less than 10 times the maximum diameter of the grain in the soil specimen. The diameter to thickness ratio shall be a minimum of 3.
- **Ring:** The ring shall be made of a material which is noncorrosive in relation to the soil tested. The inner surface shall be highly polished or coated with a thin coating of silicon grease or with a low-friction material. The thickness of the ring shall be such that under assumed hydrostatic stress conditions in the sample the change in diameter of the ring will not exceed 0.03 percent under the maximum load applied during the test. The ring shall have one edge beveled suitably so that the sample is pressed into the ring with least disturbance. The ring shall be placed with its cutting edge upwards in the Consolidometer and clamped with a special clamp which should in no way damage the sharp edge. The clamp should be made circular with central hole equal in diameter of the porous' stone and should be perfectly concentric with the sample. The ring shall be provided with a collar of internal diameter same as that of the ring and of effective height 20 mm. The collar shall rest securely on the specimen ring.
- **Porous Stones:** The stones shall be of silicon carbide or aluminum oxide and of medium grade. It shall have a high permeability compared to that of the soil being tested. The diameter of the top stone shall be 0.2 to 0.5 mm less than the internal diameter of the ring. The thickness of the stone shall be a minimum of 15 mm. The top stone shall be loaded through a corrosion-resistant plate of sufficient rigidity and of minimum thickness 10 mm to prevent breakage of the stone. The loading plate &all have suitable holes for free drainage of water.
- **Dial gauge:** Accurate to 0.01 mm with a traverse of at least 20 mm.
- **Soil Trimming Tools:** Fine wire-saw, knife, spatula, etc for trimming sample to fit into the inside diameter of the Consolidometer ring with minimum disturbances.
- **Oven:** Thermostatically controlled oven with interior of non-corroding material to maintain the temperature between 105 and 110°C.
- **Balance:** Sensitive to 0.01 gm and Containers for water content determination.

2.4 Preparation of specimen

- First of all volume of the consolidation ring is determined.
- 90%, 95%, 100% of maximum dry density obtained from standard Procter test is multiplied with volume of the consolidation ring to obtain the soil to be taken for testing.
- The oven dried soil was mixed with water and it was rubbed thoroughly until a uniform color is obtained.
- The wet soil is now compacted in the consolidation ring itself in such a way that it occupies all the space in the ring.

2.4.1 Assembly of apparatus

The porous stones shall be saturated. All surfaces of the Consolidometer which are to be enclosed shall be moistened. The porous stones shall be saturated by boiling in distilled water for at least 15 minutes. The Consolidometer shall be assembled with t he soil specimen (in the ring) and porous stones at top and bottom of the specimen, providing a filter paper rendered wet between the soil specimen and the porous stone. The loading block shall then be positioned centrally on the top porous stone.

This assembly shall then be mounted on the loading frame such that, the. Load when applied is transmitted to the soil specimen through the loading cap. The assembly shall be so centered that the load applied is axial.

Figure 3. Consolidation Ring

In the case of the lever loading system, the apparatus shall be properly counterbalanced. If a jack with load measurements by platform scales is used as the loading systems the tare weight with the empty consolidation apparatus, excluding those parts which will be on top of the soil specimen, which rest on the plat form shall be determined before filling the ring with the soil and this tare weight shall be added to the computed scale loads required to give the desired pressures at the time of loading the soil specimen.

The holder with the dial gauge to record the progressive vertical heave of the specimen under no load, shall then be screwed in place and adjusted in such a way that the dial gauge is near the end of its release run, allowing small margin for the compression of the soil, if any.

An initial setting load of 50 gf/cm^2 (this includes the weight of the porous stone and the loading pad) shall be placed on the loading hanger and the initial reading of the dial gauge shall be noted.

The system shall be connected to a water reservoir with the level of water in the reservoir being at about the same level as the soil specimen and water allowed to flow in the sample. The soil shall then be allowed to swell.

2.5 Procedure

The free swell readings shown by the dial gauge under the seating load of 5 kN/m2 (0.05 kgf/ cm) shall be recorded at different time intervals 0, 0.25, 0.5, 1, 2, 4, 8, 12, 16, 20, 24, 36, 48, 60, 72, 96, 120, and144 hours. Total readings noted at total elapsed time since starting shown therein.

The dial gauge readings shall be taken till equilibrium is reached. This is ensured by making a plot of swelling dial reading versus time in hours, which plot becomes asymptotic with abscissa (time scale). The equilibrium swelling is normally reached over a period of 6 to 7 days in general for all expansive soils.

The swollen sample shall then be subjected to consolidation under different pressures 0.05 to 0.1 kg /cm^2, 0.1 to 0.25 kg /cm^2, 0.25 to, 0.5 kg /cm^2, 0.5 to 1.0 kg /cm^2, 1 to 2 kg /cm^2, 2 to 4 kg /cm^2. Compression of the dial gauge readings shall be recorded till the dial gauge readings attain a steady state for each load applied over the specimen. The consolidation loads shall be applied till the specimen attains its original volume.

2.6 Calculation

Plotted with elapsed time as abscissa and swelling dial reading as .ordinates on natural scale. A smooth curve shall be drawn joining these points. If the curve so drawn becomes asymptotic with the abscissa, the swelling has reached its maximum and hence the swelling phase shall be stopped, and the consolidation phase shall be started.

A plot of change in thickness of expanded specimen as ordinates and consolidation pressure applied as abscissa in semi logarithmic scale shall be made. The swelling pressure exerted by the soil specimen under zero swelling condition shall be obtained by interpolation and expressed in kN/m^2 (kgf/cm^2).

Table 2. Test Results of Consolidometer Method

	90% of MDD	95% of MDD	100% of MDD
Jamnagar	**Swell pre. kg/cm^2**	**Swell pre. kg/cm^2**	**Swell pre. kg/cm^2**
OMC	**0.65**	**0.7**	**0.75**
10 %	**0.7**	**0.75**	**0.8**
5 %	**0.75**	**0.8**	**0.95**
Bhavnagar			
OMC	**0.6**	**0.65**	**0.75**
10 %	**0.6**	**0.7**	**0.75**
5 %	**0.7**	**0.8**	**0.9**
Amreli			
OMC	**0.2**	**0.4**	**0.45**
10 %	**0.35**	**0.55**	**0.6**
5 %	**0.35**	**0.55**	**0.6**
Rajkot			
OMC	**0.2**	**0.25**	**0.35**
10 %	**0.25**	**0.35**	**0.4**
5 %	**0.35**	**0.45**	**0.52**

2.6.1 Effect of Initial Water Content

Swelling mechanism depends on the amount of water absorbed by the soil mass. As the initial water content increases, for specimens having the same dry unit weight, the initial degree of saturation will also increase and the affinity of soil to absorb water will decrease. It follows that the amount of water absorbed for complete saturation will become smaller, and consequently the amount of swelling will decrease as the initial water content increases (El . Sohby and Rabba, 1981). As the absorbed water is decreased for the same initial dry density the interparticle forces developed during swelling will become smaller. This in turn will be resulted in smaller swell pressures.

Swelling pressure decreases as the initial water content increases in Consolidometer for all soil types which are used in this study.

Fig 5.2 show relationship between swelling pressure and initial water content for different initial dry densities for Consolidometer method and sample No. 4 Rajkot.

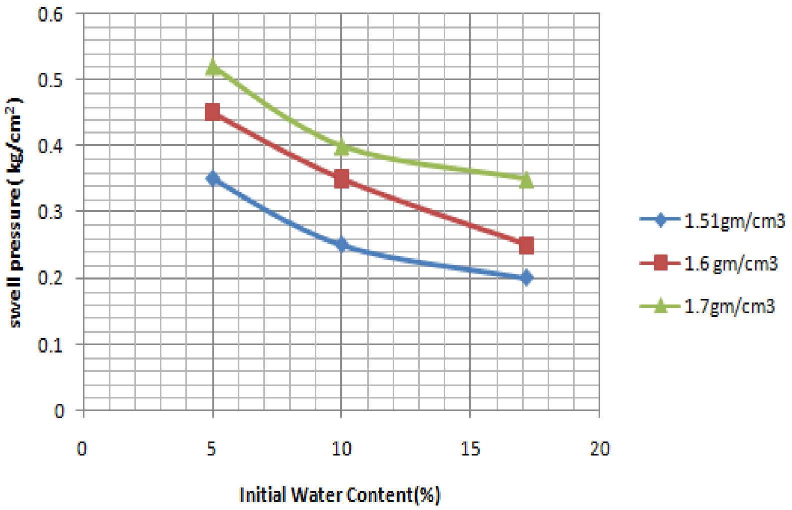

Figure 4. Relationship between the swelling pressure and the initial water content for different initial dry densities by Consolidometer

2.6.2 Effect of Initial Dry Density

Swelling pressure in both method Constant volume and Consolidometer results of interparticle forces developed during swelling as a result of water absorption. As density increases, volume of voids decreased, water particle has smaller volume to move. During Water absorption in to soil media water practical has to apply more force to the surrounding soil particles to achieve the complete saturation for higher initial dry densities. The swelling pressure increases as the initial dry density increases for all soil types which are used in this study.

The swelling pressure increases as the initial dry density increases. Figure 5.4 shows relationship between the swelling pressure and the initial dry density for different initial water contents and Consolidometer method used for sample No. 4 Rajkot.

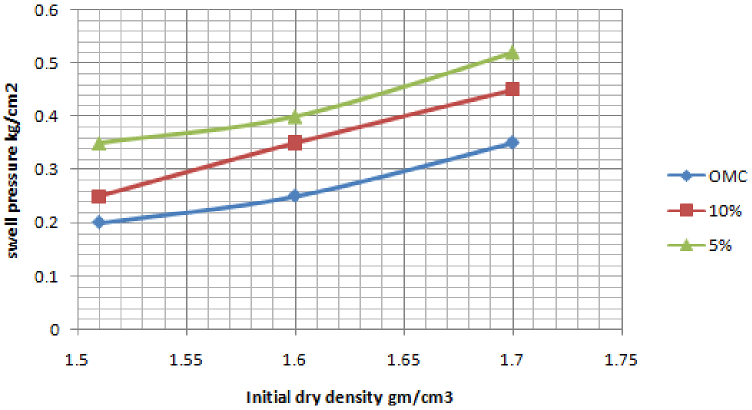

Figure 5. Relationship between the vertical swelling pressure and the initial dry density for different initial water contents. (Consolidometer method) sample No.4.

2.6.3 Rate Of Development Of Swell Pressures

When a compacted soil specimen is exposed to water, time is required for the movement of water into the specimen under the hydraulic gradient set up by the negative water pressure within the soil relative to free water i.e., the soil suction. The amount of swell that occurs within a given period of time depends on the quantity of water that enters the soil; thus, the rate of swell is proportional to the hydraulic gradient and the conductivity. These quantities, in turn, are influenced by the soil structure or by the treatment during compaction.

It is found that rate of development o swell pressures for a compacted specimen is different. Figure 5.5 shows development of swell pressures in time respectively for initial water content of 17.17 % (OMC) and for three different initial dry densities.

As it can be seen from figures that at the time of inundation, there is a sharp increase in swelling pressures. A gradual decrease in rate of swell pressure is observed, attaining equilibrium in 1000 to 2500 minutes.

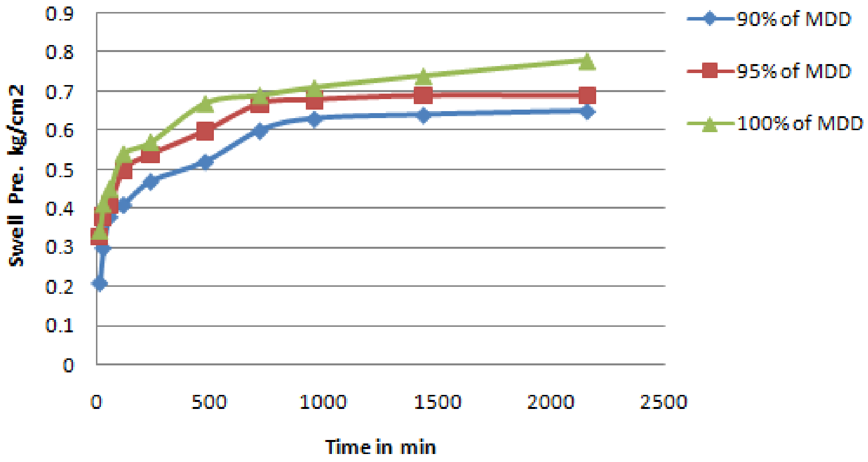

Figure 6. Swell pressures in time for initial water content of 17.17 %(OMC) and for tree different initial dry densities

III. DISCUSSION OF TEST RESULTS

During constant volume swell tests and Consolidometer swell tests it has been found that both initial dry density and initial water contents affect on swelling pressure. Swell pressure is function of density.

IV. CONCLUSION

The paper aimed at investigating the effect of insitu dry density and insitu moisture content on swelling potential of expansive soils obtained from location Jamnagar, Bhavnagar, Amreli, Rajkot. The following observations are made.

- ❖ It was observed that significant effect of swelling pressure with the change of dry density and water content of the soil.
- ❖ With increased dry density, swelling pressure increases for all soil types.
- ❖ With decrease initial water content, swelling pressure increases for all soil types.

V. FUTURE SCOPE

Swelling of soil creates a serious problem for foundation design of structure, which may lead to catastrophic failure of structure as whole here in this thesis, the swelling potential of soil for few locations is evaluated based on dry density and water content further work on the same thesis can be carried out as follows.

- ❖ The effect of seating load on the swelling potential of the soil can be studied to assess the performance of foundation.
- ❖ The same work can be carried out for more location, so that map can be prepared for such type of soils.
- ❖ Further, new and innovative measure can be developed to place the foundation on such type of soil and same can be evaluated experimentally.

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