IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 5 Ver. IV (Sep. - Oct. 2017), PP 09-15
www.iosrjournals.org

Experimental Study on Control of Swelling Pressure of Expansive Soils Using Bentonite and One Layer of Geosynthtics

Ram Niwas[1], Ankit Laddha[2], Dr. D.G.M. Purohit[3]
[1]*(M.E. Scholar, Dept. of Civil Engineering,M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India)*
[2]*(Asst. Professor, Dept. of Civil Engineering, Jodhpur Institute of Engineering and Technology, Jodhpur, Rajasthan, India)*
[3]*(Professor, Dept. of Civil Engineering,M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India)*

Abstract :*Undesirable ground movements caused by swelling and shrinkage of expansive clays during winter and summer respectively, pose a serious threat to most of civil engineering structures, especially those of imposing light to medium stresses over the underlying expansive clays. In this paper, an attempt is made to control the expansion of swelling clays with bentonite and geosynthetics. Swelling tests were conducted on expansive clays; both natural soils and commercially bentonite clay were selected for the present study such that they exhibit high plasticity, swelling and compressibility characteristics. Sample 1 is obtained from village Sheo (Barmer), Rajasthan, India and sample 2 is obtained from village Hamira (Jaisalmer), Rajasthan, India and geosynthtics as geogrid and geotextile were switched together to form geocomposite. All the tests are done using conventional one-dimensional oedometer apparatus. The results obtained from the experimental study indicate that the measured percent swell and swelling pressure reduce substantially with the bentonite and geocomposite one layer. The reduction in swelling pressures due to geocomposite is more pronounced for soils with higher swell potential.*

***Keywords** –Bentonite clay, Expansive soil, Geogrid, Geotextile, and Swelling Test.*

I. INTRODUCTION

Soils that exhibit volume changes from variation in soil water content are referred to as expansive or swelling soils. Expansive soils are encountered in arid and semi-arid regions of the world, where annual evaporation exceeds annual precipitation. In India expansive soils cover about 20% of the total land area. The volume increase (swell) is resisted by any structure resting on expansive soil and as a consequence, vertical swelling pressure is exerted on the structure. If the swelling pressure exerted by soil on the foundation of a structure is not controlled, it may cause uplifting and distress in the structure. Swelling of expansive clays causes detrimental effects to residential and industrial buildings, buried structures, road ways etc. examined that the soil reinforcements are most effective when they are placed close to the footing. The mechanism of resisting heave in swelling clay does not seem to arise from friction between the clay and the geosynthetics, the possible passive resistances provided by thick meshes seemed to govern the resistance, buried pipe lines, pavements, embankments, floorings etc. Damages to the structures, property and life resulting from swell behavior of expansive clays have been documented from many parts of the world. In India, the expansive clay, often referred as black cotton soils, covers one fifth of the country, mainly in the states of Rajasthan,Tamil Nadu, Maharashtra, Gujarat, Madhya Pradesh, Karnataka and Andhra Pradesh. The existing methods, such as prewetting, lime injection / addition, moisture barrier, heating, increase of surcharge, chemical stabilization, etc., to control the swell – problems of expansive clays.

Two expansive soils viz., Natural soil from Barmer, Jaisalmer district in Rajasthan and sodium Bentonite from Kutch region are used for the experimental study. The EPS geofoam of nominal density 15 kg/m3 referred to as type I as per ASTM C-578 is used for the study. In the present study, Black cotton soil, Bentonite and are designated as BC, B and G, respectively. The main goal of this paper is to develop a correlation between the swelling behaviors of test samples, swell potential and swelling pressure, and fundamental properties of test samples.

II. REVIEW OF LITERATURE

Various researchers have been done research on Control of Swelling Pressure of Expansive Clays Using Geosynthtics, like

RamanathaAyyar et.al (1989) examined that thesoil reinforcements are most effective when they are placedclose to the footing. The mechanism of resisting heave inswelling clay does not seem to arise from friction betweenthe clay and the geosynthetics, the possible passiveresistances provided by thick meshes seemed to govern theresistance. **Dange and Thakarae (1996)** reported that theprovision of geomembrane on the top surface of expansivesoil mass effectively restrains the heave and swell pressureof underlying expansive soil. Lesser the amount of heaveas well as swell pressure is observed for expansive clay,in case of rise in water table condition as compared torainfall condition.**Sridharan et al. (1987)** reported that theswelling pressure itself that develops in all directions wouldmobilize the interfacial frictional force between soil andreinforcement due to its normal component on thereinforcement. This frictional force tends to counter theswelling pressure in a direction parallel to the reinforcementand consequently reduces the heave. They opined that themobilization of the interfacial friction, which counters theswelling in a direction parallel to the reinforcement, is dueto the normal component of swelling pressure. **Stalin and Jayapriya (2001)** have shown that the introduction ofgeogrid and geotextiles enhanced the rate of swelling butdid not control the magnitude of swelling of expansive claysand whereas geomembrane controlled the swelling of expansive clay by 50 %.

In this paper, swellingcharacteristics and load carrying capacity of expansive clays with bentonite clays and single layers of geogrid (GG), geotextile(GT) in horizontal orientations were carried out.

III. MATERIALS USED

3.1 Expansive Soil

The expansive soil used in this investigation both natural soils and commercially available Bentonite clay wasselected for the present study such that they exhibit high plasticity,swelling and compressibility characteristics. Three natural soils were collected from Sheo (Barmer), Hamira (Jaisalmer) in Rajasthan,India at a depth of 2.0 m. These samples were air dried beforesubjected to laboratory tests. The natural soils are named as soil sample (1) & soil sample (2) whose liquid limits are 87 % & 94 % respectively. Theindex properties of the natural soil sample (1), (2) are furnished in the table3.1. All the natural soils are classified as clay of very highswelling nature based on plasticity characteristics and free swell indexvalues (IS: 2911 (Part III) – 1981).

Table: 3.1 Physical Properties of Soils Used

Soil Description		**Natural Soil-(1)**	**Natural Soil - (2)**	**Bentonite (1)**
Specific gravity (G)		2.75	2.72	2.79
Grain Size	Sand %	4	0	0
	Silt %	45	45	27
	Clay %	58	60	73
LL%		85	96	320
PL %		40	39.5	50
PI %		60	60	298
SL %		18	16	14.7
FSI %		115	130	290
Standard Proctor Compaction result	γ_d max KN/m^3	17.4 18.5	15.9 17.2	12.7
	OMC %	23.7	25.5	35
Swell Classification		Very High	Very High	Very High

3.2 Bentonite

Bentonite is a family of clay minerals, produced by the weathering of volcanic ash, and is highly hygroscopic in nature. From a variety of commercially available types, sodium bentonite has been used in the current research work. The laboratory investigation classified it as high plastic (CH), exhibiting liquid limit of 322%, plastic limit of 34%, 55% of particles less than 2 micron.

One commercial soil (Bentonites) collected from local marketwas used along with natural soils for comparison. The Bentonite (1) is having liquid limit of the index properties of the commercials soil (1) is shown inthe Table 3.1. All these soils are classified as clay very high swellingnature. These bentonite clays were chosen because of its pure claysystem where changes in swell &compressibility etc., would besignificant and considerable, unlike the natural soils whose behavior ismasked by the presence of non-clay fraction in the form of silt and sand.

3.3 Geosynthetics

Several hundred varieties of geosynthetic products are available in the market and many new types are developed each year. In addition to the five types identified as geotextile, geogrids, geomembranes, geonets, and geocomposites, there are specialty products, such as geomettresses, geocells, geotubes and many more that have been developed for specific applications. Even within each group of geosynthetics, a designer will find a wide variety of materials. This enormous choice can often be quite bewildering for the designer. To help in decision making, regulatory authorities in most countries have laid down minimum specification with respect to the properties that have to be satisfied by the products for different applications. Include geogrid, geotextile, and geocomposite were used in layers both horizontal orientation to control swell – potential of clay. Geogrid used inthis study is having aperture size of 8 mm x 6 mm and tensile strength of 7.68kN/m. The geotextile selected is having narrow strip tensile strength of 10kN/m. The properties of geogrid, geotextile are shown in Table 3.2 and 3.3 respectively. Geogrid and geotextile were stitched together to formgeocomposite. Fig. 3.1 (a), (b), and (c) show view of geosyntheticmaterials used in the present work and they were used in compacted soilfor varying number of layers, orientation, with and without endconfinement, to study their performance in the control of swell-behavior of clays.

Table 3.2 Physical Properties of Geogrid

Description	Values
Type	Netlon 121
Aperture size (mm)	8x6
Mesh thickness (mm)	3
Weight (g/m^2)	736
Tensile strength (kN/m)	7.68
Extension at maximum load (%)	20.2
Load at 10% extension (kN/m)	6.8

Table 3.3 Physical Properties of Geotextile

Description	Values
Narrow strength (kN/m)	10
CBR plunger load (kN)	0.5
Trapezoidal tear lod (kN)	0.27
Stiffness (mg-cm)	9342.72
Diameter of the hole (mm) (using cone drop test)	15

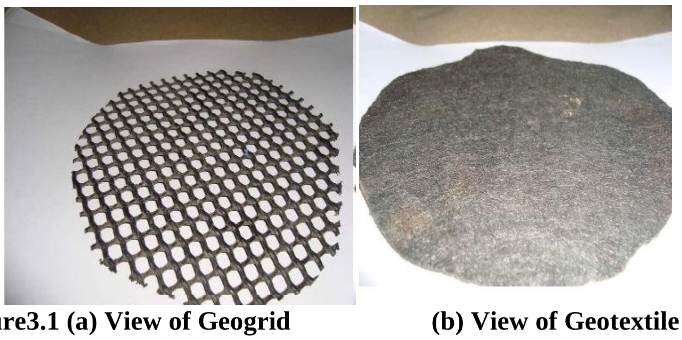
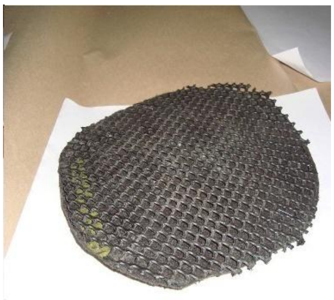


Figure3.1 (a) View of Geogrid (b) View of Geotextile



(C) View of Geocomposite(Geotextile + Geogrid)

IV. EXPERIMENTAL INVESTIGATION

4.1 Basic Tests

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. This is the limiting moisture content at which the cohesive soil passes from plastic state to liquid state.

The plastic limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dry soil, at the boundary between the plastic and semisolid states of consistency. It is the moisture content at which a soil will just begin to crumble when rolled into a thread ⅛ in. (3 mm) in diameter using a ground glass plate or other acceptable surface.

The minimum water content at which the soil is still in liquid state but has a small strength against flowing which can be measured by standard available means.Plastic limit minimum water content at which soil will just begin to crumble water rolled into a thread approximately 3mm in diameter, Plasticity index is determined as difference of L.L. and P.L.

4.2 Swelling Test

A structure built in a dry season, when the natural water content is low shows differential movement as result of soils during subsequent wet season. This causes structures supported by such swelling soils to lift up and crack. Restriction on having developed swelling pressures making the structure suitable.

4.2.1 Odeometer Apparatus

The soil samples were statically compacted in the mould to a required density at specified water content and inundated with distilled water and then allowed to swell until it reached equilibrium values of swelling. Conventional odeometer apparatus was used for the determination of swelling behavior of natural soil (1), (2) and bentonite. The % swell and swell pressure were determined.

4.2.2 Model Tank

The odometer setup from soil mechanics is based on consolidation tests, i.e. a settlement is expected and therefore only the porous plate and the load plate on the top of the specimen will move within the ring . In the case of swelling tests a heave is expected which can also move the ring upwards. With the result that oedometric conditions are not valid anymore. A modification of the setup can help to avoid this situation. The porous plate at the bottom of the specimen should fit in the ring. Furthermore, a higher and thicker ring should be considered in a mould of diameter 100 mm and height of 36 mm, the soil sample was statically compacted in layers to a height of 12 mm at 8 % moisture content. The geosynthetic materials were cut into a size equalto the inner diameter of the swelling mould and placed at 1/2 and 2/3 of the sample height respectively for one layer of geosynthetics. The samples were then submerged in water with a surcharge pressure of $5kN/m^2$. Dial gauges were fixed and the time-swelling observationswere taken until equilibrium values reached. The schematic view of swelling test set up for soil alone, soil with one layer of horizontally placed geosynthetics, soil respectively are shown in Figure 4.1. Figure4.2 shows the view of fabricated mould used for swelling test In connection with the experiments, swelling test was conducted.

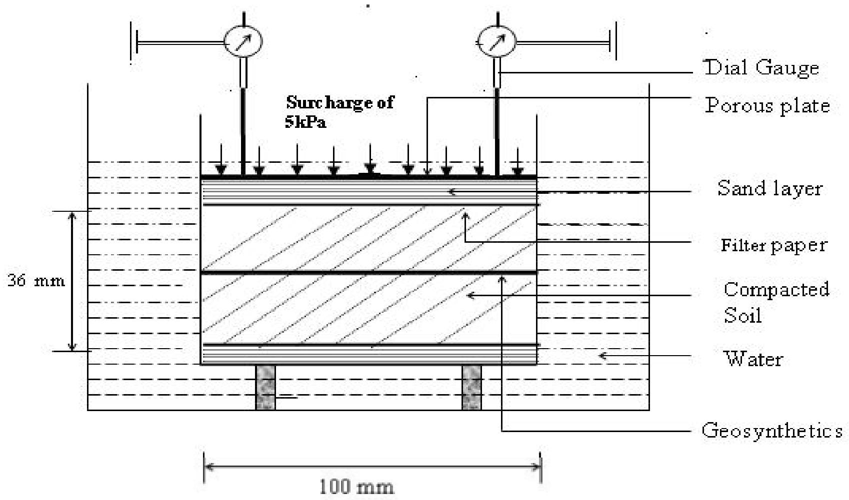


Figure4.1Swelling Test Setup for Soil+ One Layer Geosynthetics in Horizontal Orientation

Figure4.2 View of Swelling Setup

V. RESULTS AND DISCUSSIONS

Several of swelling tests were conduct on both natural soils (expansive soils) with bentonite and one layer of geocomposite. Below table 5.1 shows that the details of test programme of swell test with varying dry density and initial moisture content with time.

Table 5.1 Details of Test Programme: (Swell Test for Varying Dry Density and IMC)

Description	Swell Test	
	Dry Density (kN/m3)	IMC%
Soil Sample (1)	14.25 15.8 17.5	0, 8, 13, 18, 22, and 27
Soil Sample (2)	15 16.5 16.7	0, 8, 13, 18, 22, and 27

The dependence of swelling deformation on water content and the lack of correlation between initial water content and swelling pressures that have been found in this work can also be analysed using the double-structure Models proposed by Gens and Alonso (1992) and Sánch et al. (2005). In the swelling pressure tests, The slope of the percent swell and density relationship is very steep for Soil sample (1) and (2) and at the 0% moisture content and corresponding differences in swelling is ranging from 4% to 15%. For bentonite, the% swell is varying from 40% to 57% with the density variation from11kN/m^3 to 15kN/m^3. Interestingly at 15% and 30% moisture content even though the density increases, the % swell is not proportional to the respective densities.

In other words, the slope of % swell Vs initial density is almost flat for 30% moisture content for soil sample (1) and (2) and mild slope for bentonite. This above behavior clearly indicates that when moisture content exceeds (approximately higher than plastic limit water content) the effect of initial density on swelling is insignificant. It may be mentioned here the plastic limit of soil sample (1), (2) and bentonite are respectively 28%, 29%, 56% and the optimum moisture content corresponding to d_{max} of these three soils are respectively 23.4%, 27.5% and 33%.

Figure 5.1 and 5.2 show the effect of density on the magnitude of percent swell on soil sample (1), (2) and bentonite respectively. For a given density when moisture content is lesser than the plastic limit water content effect of density is significant in influencing the % swell and also the swell pressure. Even though both initial densities and initial moisture content influence shown that irrespective of initial moisture content, the density influences the magnitude of swelling. In the present study, it is found that density swelling pressure.

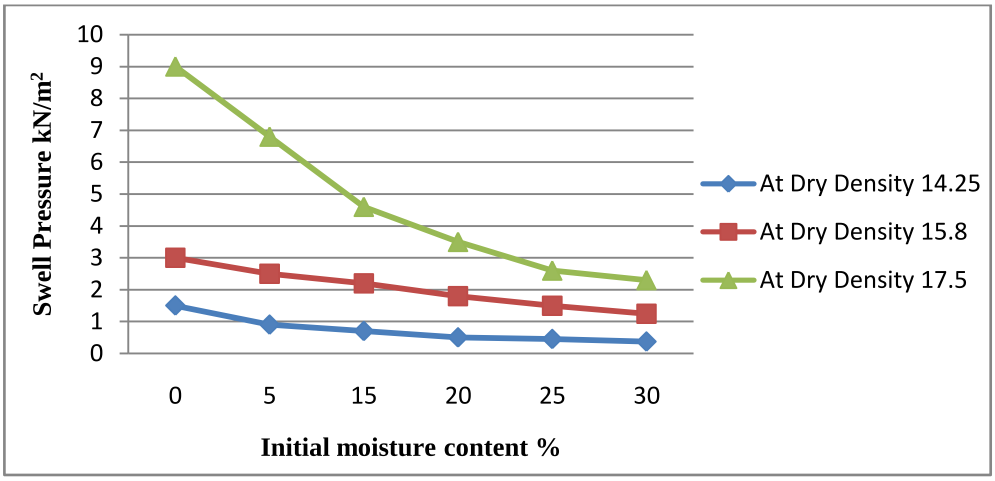


Figure 5.1 Swell Pressure Vs IMC Relationship for Soil Sample (1)

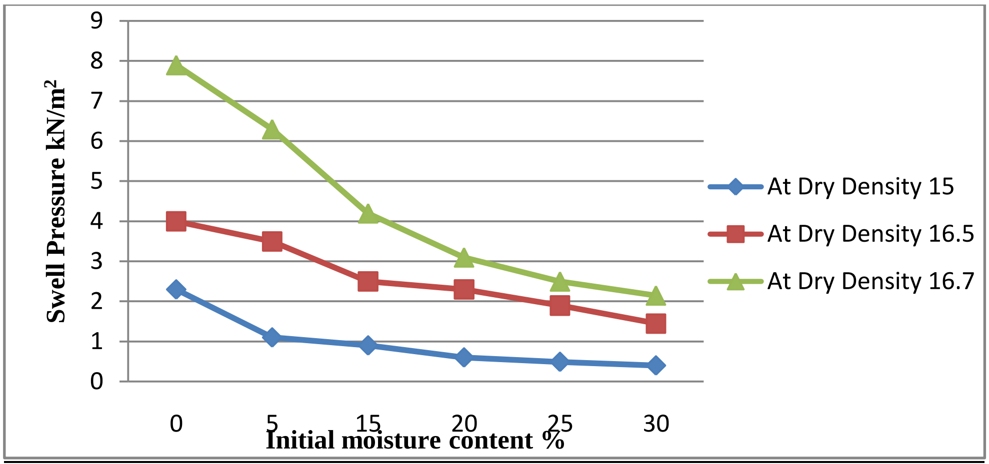


Figure 5.2 Swell Pressure Vs IMC Relationship for Soil Sample (2)

VI. CONCLUSION

Effect of Initial Moisture Content and Density on Swelling: Behavior Even though % swell and swell pressure decrease with increasing moisture content, its effect on the swelling magnitude is significant only when the initial moisture content is lesser than limit water content and beyond which the same is insignificant irrespective of soil type and initial density.The % swell and swell pressure increase with initial density only when moisture content is relatively low and on the other side even at higher densities, swelling remains the same when initial moisture content is greater than plastic limit water content. Even though, both initial moisture content, and density together are responsible for the magnitude of swelling, but still initial moisture content over rides the effect of initial density especially at low water content. These observations are different from findings of earlier researchers.

Control of Swell Behavior by Geosynthetics: For any geosynthetic material, the one which is confined found to control the swelling 25 to 35 % higher than the same material without confinement. In the case of soil + one layers of geocomposite with end confinement, the swell reduction is 21 % .The swell reduction is attributed to the passive resistance mobilized on the geocomposite. Above Figure 5.1 and 5.2 clearly show that the reduction in swelling by 20 to 25% of both soils sample.

Some of subjects and suggestions that could be pursued in the future research: It should be considered that the current study focused mainly on mixtures of bentonite and kaolinite in different percentages. The equations developed through this study cannot be used for all specimens. Since the values according to which predictive models are developed pertain to artificial test samples, it is suggested to use more natural test samples with different degree of swell potential to develop other correlations which can predict swelling behavior of natural soils, swell potential and swelling pressure, more exactly. In the current study, two predictive models are developed based on some of the fundamental properties of test samples and the other two predictive models are based on swell determination tests maximum dry density and initial water content. Observations depict that to develop more precise correlations, especially for natural samples, it is recommended to determine their mineralogy and develop predictive models that incorporate mineralogical properties of test samples.

REFERENCES

[1] ASTM C-578 (2009). Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation, Annual Book of ASTM Standards C578, 04.06, 6, ASTM, West Conshohoken, PA, USA.

[2] Basma, A.A., Al-Homoud, A.S., HuseinMalkawi, A.I. & Al- Bashasheh, M.A. (1995). Laboratory assessment of swelling pressure. Applied Clay Science, 9, 355-368.

[3] Chen, F.H. (1988). Foundations on Expansive Soils. Elsevier Scientiûc Publishing Co., Amsterdam.

[4] Chun, B. S., Lim, S. H., Sagong, M. S. & Kim, K. (2004). Development of a hyperbolic constitutive model for expanded polystyrene (EPS) geofoam under triaxial compression tests. Geotextiles and Geomembranes, 22(4), 223–237.

[5] Jean-Louis Briaud. Xiong Zhang. And Sangho Moon. (2003),“Shrink Test – Water Content Method for Shrink and SwellPredictions, ” Journal of Geotechnical and GeoenvironmentalEngineering, Vol. 129 No. 7, pp. 590-600.

[6] Jones Colin J.F.P. (1985), "Earth Reinforcement and SoilStructure", Butterworths advanced series in GeotechnicalEngineering London.

[7] Katti R. K. (1978), “Search for solutions to problems in BlackCotton Soils” IGS Annual Lecture, Geotechnical Engineering – Indian Experiences , XIII International Conference on SoilMechanics and Foundation Engineering, New Delhi. pp. 1-58.

[8] Koerner R. M. (1999), “Designing with Geosynthetics” FourthEdition Prentice Hall, New Jersey.

[9] Komornic K. and Zeitlen (1970), “Laboratory determination oflateral and vertical stresses in compacted swelling clay”American society of Testing and Materials. Vol. 4, pp. 108–128.

[10] Mishra, A. K., Dhawan, S. & Rao, M. S. (2008). Analysis ofswelling and shrinkage behavior of compacted clays.Geotechnical and Geological Engineering, 26(3), 289–298.

[11] Nagaraj, H. B., Mohammed M. M., &Sridharan, A. (2009).Critical evaluation of determining swelling pressure byswell-load method and constant volume method.Geotechnical Testing Journal, 32(4), 1-10.

[12] Ossa, A. &Romo, M. P. (2009). Micro- and macro-mechanicalstudy of compressive behavior of expanded polystyrene(EPS) geofoam. Geosynthetics International, 16(5), 327–338.

[13] Sharma, R. S. &Phanikumar, B. R. (2005). Laboratory studyof heave behavior of expansive clay reinforced withgeopiles. Journal of Geotechnical andGeoenvironmental Engineering, 131 (4), 512–520.

[14] Sridharan, A. &Gurtug, Y. (2004). Swelling behavior ofcompacted ûne-grained soils. Engineering Geology,72(1-2), 9–18.

[15] Wong, H. & Leo, C. J. (2006). A simple elastoplastic hardeningconstitutive model for EPS geofoam. Geotextiles andGeomembranes, 24 (5), 299–310.

Ram Niwas Experimental Study on Control of Swelling Pressure of Expansive Soils Using Bentonite and One Layer of Geosynthtics.” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 14, no. 5, 2017, pp. 09-15.