

*Full Length Research Paper*

## Effect of battery effluent on plasticity and swelling characteristics of expansive soil

S. Bali Reddy<sup>1</sup> and A. V. Narashima Rao<sup>2</sup>

<sup>1</sup>Indian Institute of Technology Guwahati, India.

<sup>2</sup>Department of Civil Engineering, S. V. University, Tirupathi, India.

Received 4 March, 2014; Accepted 7 July, 2014

Ground pollution is perpetuated by humans due to many reasons. Industrial activity is necessary for the socio-economic progress of a country, but at the same time, it generates large amount of solid and liquid wastes. Among various means available, disposal through land is simple and widely used. All types of pollution have either direct or indirect effect on soil properties. Behaviour of any contaminant in soil depends upon the physical and chemical properties of the contaminant as well as its interactivity with that of soil. The effect of battery effluent on plasticity, swelling characteristics of black cotton soil has been presented in this paper. The soil used in this investigation falls under "SC" group as per I.S. classification and its differential free swell index is 254.54% indicating very high degree of expansiveness. The battery effluent used in this investigation is a colourless liquid and soluble in water.

**Key words:** Plasticity, expansive soil, battery effluent.

### INTRODUCTION

The index and engineering properties of the ground gets modified in the vicinity of the industrial plants mainly as a result of contamination by the industrial wastes disposed. The major sources of surface and subsurface contamination are the disposal of industrial wastes and accidental spillage of chemicals during the course of industrial operations. The leakages of industrial effluent into subsoil directly affect the use and stability of the supported structure.

Extensive damage to the floors, pavements and foundations of a light industrial building in Kerala State

was reported by Sridharan et al. (1981; 2002). Joshi et al. (1994) reported that severe damage occurred to the interconnecting pipe of a phosphoric acid storage tank in particular and also to the adjacent buildings due to differential movements between pump and acid tank foundations of fertilizer plant in Calgary, Canada. A similar case of accidental spillage of highly concentrated caustic soda solution as a result of spillage from cracked drains in an industrial establishment in Tema, Ghana caused considerable structural damage to a light industrial building in the factory, in addition to localized

\*Corresponding author. E-mail: [sodom@iitg.ernet.in](mailto:sodom@iitg.ernet.in)

Author(s) agree that this article remain permanently open access under the terms of the [Creative Commons Attribution License 4.0 International License](http://creativecommons.org/licenses/by/4.0/)

**Table 1.** Properties of soil.

S/No	Property	Value
<b>Atterberg limits</b>		
1	(a) Liquid Limits	77%
	(b) Plastic limit	30%
	(c) Plasticity index	47%
	(d)	
<b>Compaction characteristics</b>		
2	(a) Maximum dry Unit Weight	18.48 kN/m <sup>3</sup>
	(b) Optimum Moisture Content	12.8%
3	Specific Gravity	2.76

**Table 2.** Chemical composition of battery effluent.

S/No.	Parameter	Value
1.	Color	White
2.	pH	8.45
3.	Sulphates	250 mg/L
4.	Chlorides	30 mg/L
5.	Lead monoxide	27.77%
6.	Lead sulfate	63.08%
7.	Free lead	7.44%
8.	Total lead	75.42%
9.	BOD	110 mg/L
10.	COD	320 mg/L

subsidence of the affected area (Kumaplay and Ishola, 1985). Therefore, it is better to start ground monitoring from the beginning of a project instead of waiting for complete failure of the ground to support human activities and then start the remedial actions.

Expansive soils have high shrinkage and swelling characteristics. In general, these soils are very much sensitive to changes in environment. The environment includes the stress system, the chemistry of pore water in the system, the seasonal variations in ground water table and temperature variations. Hence, an attempt is made in this investigation to study the effect of battery effluent on the plasticity and swelling characteristics of an expansive soil.

## MATERIALS AND METHODS

The soil used for this investigation is obtained from Tirupati (India). The soil is classified as 'SC' as per I.S. Classification indicating that it is clayey sand. It is highly expansive as the free swell index is 254.5%. The properties of the soil are given in Table 1. Battery effluent is a colorless liquid and soluble in water in proportions. The chemical properties of the effluent are shown in Table 2.

## Procedure for contamination

The soil from the site is dried and the pebbles and vegetative matter present, if any, are removed by hand. It is further dried and pulverized and sieved through a sieve of 4.75 mm to eliminate gravel fraction, if any. The soil mixed with different percentages of battery effluent, from 0 to 100%, in increments of 20%. The contaminated soil prepared thus is stored for a day in air tight containers for uniform distribution of battery effluent. The soil effluent mixtures are mixed thoroughly before testing.

## Tests conducted

The following tests are conducted in the presented investigation:

### Liquid limit tests

Liquid limit tests are conducted at various percentages of battery effluent. About 120 g of an air-dried sample passing through 425  $\mu$  I.S. sieve is taken in a dish and mixed with certain amount of water to form a uniform paste. A portion of this paste is placed in the cup of the liquid limit device and surface is smoothened and leveled with a spatula to a maximum depth of 10 mm. A groove is cut through the sample along the symmetrical axis of the cup, preferably in one stroke, using a standard grooving tool. After the soil pat has been cut by a proper grooving tool, the handle is turned

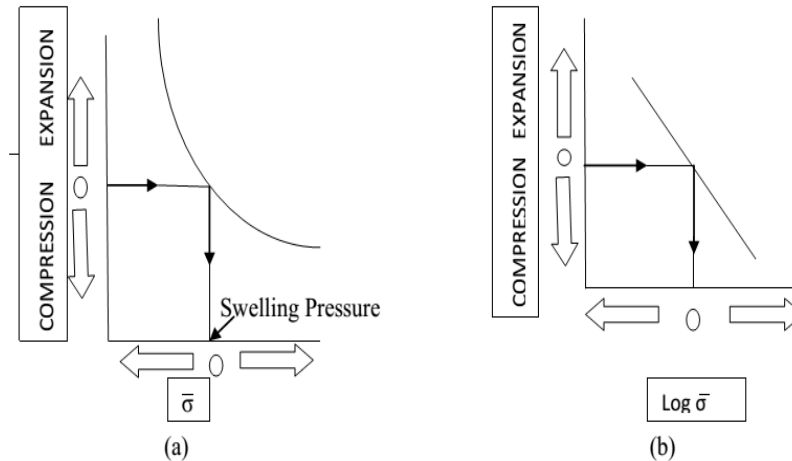


Figure 1. Pressure-volume change plots.

at a rate of 2 revolutions per second until the two parts of the soil sample come into contact at the bottom of the groove along a distance of 12 mm. About 15 g of soil near the closed groove is taken for water content determination. The liquid limit is the water content at which the soil is sufficient fluid to flow when the device is given 25 blows. As it is difficult to get exactly 25 blows for the sample to flow, the test is conducted at different water contents so as to get blows in the range of 10 to 40. The soil in the cup is transferred to the dish containing the soil paste and mixed thoroughly after adding more water. The soil sample is again taken in the cup of the liquid limit device and the test is repeated.

#### Plastic limit tests

About 30 g of soil, passing through 425  $\mu$  I.S. Sieve, is taken in evaporating dish. It is mixed thoroughly with water till it becomes plastic, and can be easily moulded with fingers. About 10 g of the plastic soil mass is taken in one hand and a ball is formed. The ball is rolled with fingers on a glass plate to form a soil thread of uniform diameter. The rate of rolling is kept about 80 to 90 strokes per minute. If the diameter of the thread becomes approximately 3 mm and if it starts just crumbling that water content is known as the plastic limit.

### SWELLING CHARACTERISTICS

#### Differential free swell index

This test is conducted on the local soil contaminated with battery effluent in varying percentages from 0 to 100% in increments of 20%. Two samples of the dried soil weighing 10 g each passing through 425  $\mu$  I.S. sieve are taken. One sample is put slowly in a 100 ml graduated glass cylinder having kerosene (a non-polar liquid). The other sample is similarly put in another 100 ml glass cylinder having distilled water. Both the samples are left for 24 h and then their volumes are noted. Differential free swell index is calculated by the formula given below:

$$\text{DFSI} = \frac{(V_1 - V_2)}{V_2} \times 100$$

$V_1$  = Soil volume in distilled water,  $V_2$  = Soil volume in kerosene.

#### Swelling pressure

This test is conducted on the local soil contaminated with battery effluent in varying percentages from 0 to 100% in increment of 20%, such as 0, 20, 40, 60, 80 and 100%. Two methods are in common use for measuring the swelling pressure of soils in the laboratory. In the first method, the swelling pressure of an undisturbed or a remolded soil is measured for 'no volume change' condition. The method requires continuous adjustment of pressure on the soil specimen taken in a consolidation cell, so that the soil volume at any time is equal to its initial volume. Details of the test procedure are given in IS: 2720 (Part XLI)- 1977. Remolded specimens are taken at the density and moisture content of the field soil, as for example, in an earth embankment where the moisture content of compaction and the required compacted density are known. Undisturbed specimens, taken carefully from the field soil, are tested for estimating the swelling behavior of an existing deposit.

The second method consists of taking a few (more than three) initially identical soil specimens in consolidation cells of fixed ring type, subjecting them to different magnitudes of pressures and then allowing the soil to saturate. Under the different load intensities, some of the soil specimens would compress after saturation while some others would swell. In fact, the load intensities ought to be properly selected to produce this kind of differential behavior. After the volume change (compression or swelling) is complete and has been recorded, load intensity versus volume change plot is obtained (Figure 1a). From this plot, the pressure corresponding to zero volume change is read and is denoted as the swelling pressure for the soil. It is much more convenient to a plot the load intensity to a logarithmic scale, as this would produce a straight line (Figure 1b).

### RESULTS AND DISCUSSION ON PLASTICITY CHARACTERISTICS

Consistency represents the relative ease with which the soil can be deformed. This term is mostly used for

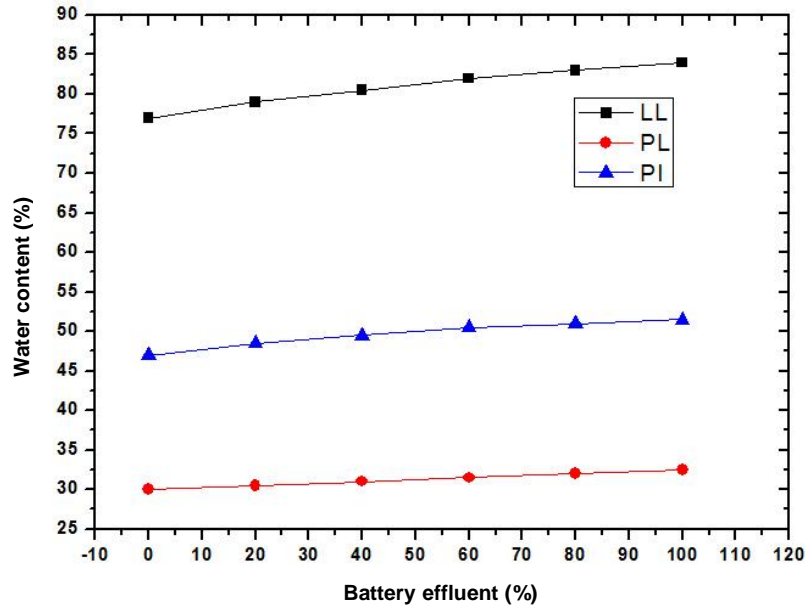


Figure 2. Variation of LL, PL and PI with battery effluent.

fine-grained soils for which the consistency is related to a large extent to water content. Atterberg (1911) formally distinguished the following states of consistency – liquid, plastic, semi-solid and solid. The water contents at which the soil passes from one of these states to the next have been arbitrarily designated as consistency limits-liquid limit, plastic limit, and shrinkage limit, in that order. Liquid limit is the water content corresponding to the arbitrary limit between liquid and plastic states of consistency of a soil. The minimum water content at which the soil made a standard grove by a Casagrande tool will flow together for a distance of 12.5 mm under the impact of 25 numbers of blows in a Casagrande apparatus. It is also defined as the maximum water content at which the soil is still in the liquid state, but has a small shearing strength against flowing, which can be measured by standard available means. Plastic limit is the water content at which a soil will just begin to crumble when rolled into a thread of approximately 3 mm in diameter. Plasticity index is defined as the numerical difference between the liquid limit and plastic limit of a soil. When soil is contaminated with battery effluent at various percentages such as 0, 20, 40, 60, 80 and 100%, the liquid limit, plastic limit and plastic index may vary.

The results of liquid limit and plastic limit tests conducted at different percentage of battery effluent are presented in Figure 2. From this figure, it is found that the liquid limit value of the contaminated soil increases slightly with the increase in percentage of battery effluent. The plastic limit value of the uncontaminated soil is 30%. From this figure, it is found that plastic limit value of contaminated soil increases with increase in percentage

of battery effluent. The plasticity index of uncontaminated soil is 47%. The plasticity index values of the contaminated soil increase with percentage increase in battery effluent. Consistency limits (liquid limit, plastic limit, and plastic index) and swelling pressures increases due to absorption of sulphates that is known to be present in battery effluent on to the clay surface. Absorption of sulphates causes expansion of double layer leading to increase in consistency limits and swelling pressure.

### Swelling characteristics

Expansive soils or swelling soils are those soils, which have the tendency to increase in volume when water is available and to decrease in volume if water is removed. These volume changes in swelling soils are the cause of many problems in structures that come into their contact or constructed out of them. From the engineering point of view, it will be sufficient to get an indication of the possible swelling behavior by performing simple tests. Almost all over the world, the surface/surficial deposits consist of expansive (black cotton) soils, which are found to be problematic for engineering construction. These expansive (black cotton) soils on coming into contact with water heave considerably and lose strength. If swelling is not allowed, swelling pressure of varying order occurs. Swelling pressure of the order of 150 to 300 kPa is commonly encountered. Though problematic for engineering construction, nevertheless, a large number of major and minor irrigation projects must necessarily be

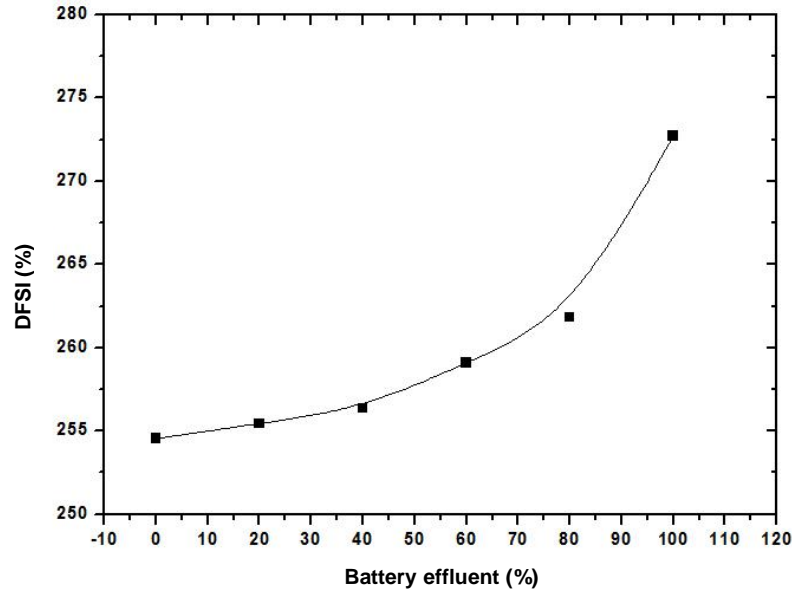


Figure 3. Variation of DFSI with battery effluent.

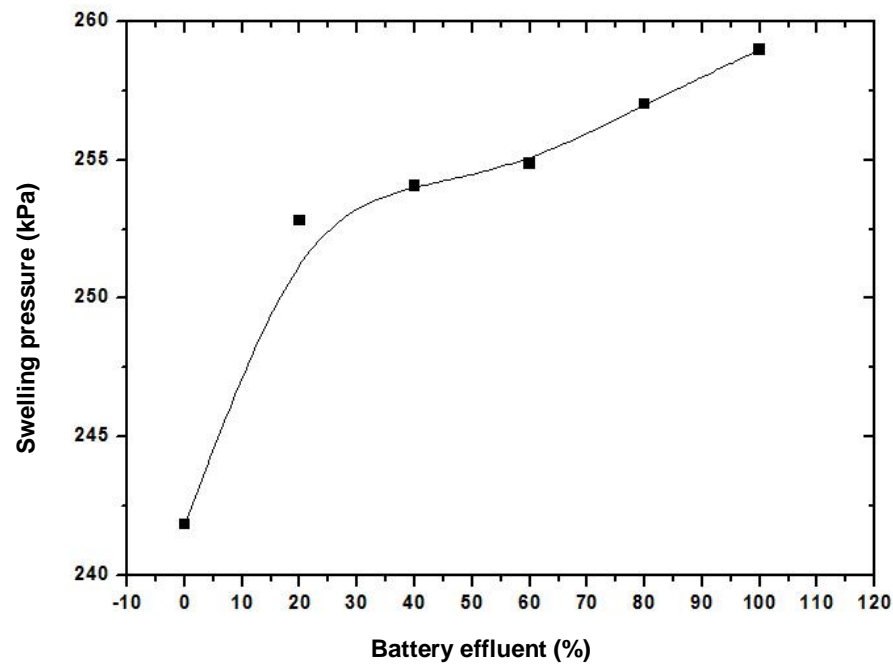


Figure 4. Variation of swell pressure with battery effluent.

executed in such soils. They are almost mainly encountered in all the regions of the world. The variation of differential free swell index with percent battery effluent is shown in Figure 3. From the figure, it is observed that the differential free swell index increases slightly with percent increase in battery effluent. The percent increase

in the differential free swell index is about 7 at 100% of battery effluent.

Swelling pressure of the soil admixed with the various percentages of battery effluent are determined and presented in Figure 4. The value of swelling pressure of natural soil is 246 kPa. From the figure, it is observed that

there is slightly increasing trend from 0 to 100% battery effluent.

### Conclusions

Based on experimental results, the following conclusions are drawn. If increasing battery effluent, liquid limit and plastic limits are increased. Swelling characteristic like differential free swell index and swelling pressure are also increased with increasing battery effluent. Further more study is required in micro level to understand the behaviour of soil when mixing with battery effluent.

### Conflict of Interests

The author(s) have not declared any conflict of interests.

### REFERENCES

- Atterberg A (1911). *Über die physikalische Bodenuntersuchung, und über die Plastizität des Ton*. International Mitteilungsblatt für Bodenkunde Verlag für Fachliteratur Vol-1 Berlin.
- Joshi RC, Pan X, Lohinta R (1994). Volume change in calcareous soils due to phosphoric acid contamination. Proc. XIII CSMFE, New Delhi 4:1569-1574.
- Kumapley NK, Ishola A (1985). The effect of chemical contamination on soil strength. Proc. XI ICSMFE, San Francisco, A. A. Balkema, Rotterdam 3:1199-1201.
- Sridharan A, Nagaraj TS, Sivapullaiah PV (1981). Heaving of soil due to acid contamination. ICSMFE, Stockholm, 6:383-386.
- Sridharan, A, El-Shafei A, Miura N (2002). Mechanisms controlling the undrained strength behavior of remolded Ariake marine clays. In: Mar. Georesour. Geotechnol. 20(1):21-50.
- I.S: 2720 (Part XLI)-1977: Swelling Pressure Test.