WEST INDIAN JOURNAL OF ENGINEERING TECHNICAL PAPER

A SIMPLE SEDIMENT TEST FOR A FIRST-ORDER RECOGNITION OF EXPANSIVE CLAYS OF TRINIDAD

K.V. Ramana*

ABSTRACT

Structures built on expansive soils without precautionary measures develop cracks due to swelling and shrinkage of the foundation soil. The soils of the central and southern regions are typical examples of such highly expansive soils and hence, present problems in the construction of foundations, pavements and buried utilities. This paper discusses briefly the relevant aspects of expansive clays and presents a simple test for recognizing an expansive soil as a first step from the point of view of a small builder.

1.0 INTRODUCTION

Many buildings in Trinidad constructed on expansive soils exhibit cracks on their facades bearing testimony to the havoc caused by the soil beneath. Lack of knowledge, either of the treacherous nature of the expansive soil, or the methods of foundation construction on such a soil is the root cause of this state of affairs. Therefore, the first and the most important step is to recognise if an expansive soil exists at the site of construction.

Structures erected on expansive clays, without proper precautionary measures, suffer great damage caused by cracking due to swelling and shrinkage of the clays with absorption and loss of moisture respectively. At times the damage can be so severe that the structure will either have to be demolished and rebuilt or totally abandoned. The problem of foundations on expansive soils has been experienced all over the world, especially in the regions where the climate alternates between prolonged dry and wet periods, and thus subjects the soil to cycles of desiccation and saturation.

Many of the soils of central and southern regions of Trinidad are typical examples of expansive soils. They exhibit high volume expansion by absorbing moisture during rainy season, and exert high swelling pressures on the foundation footings which prevent these soils from expanding. They also shrink considerably in both horizontal and vertical directions by losing moisture in the dry season. This situation gets aggravated if big trees are close to the structure as their root system sucks away water from the soil surrounding foundations in the dry season. The horizontal stresses are partly relieved by vertical cracks in the ground, and the vertical shrinkage causes settlement of foundations.

It has been observed that the soil movement in expansive soils, with changes in moisture content is appreciable only to a certain depth known as the 'active zone', and the amount of swelling diminishes with depth as the overburden pressure increases. Though this depth depends largely on physical, chemical and climatic factors, many research workers have set a common limit at about 5m for semi-arid regions (Fig. 1). Perhaps it is somewhat lower than this, 2 to 3m, for semi-humid regions.

2.0 DESIGN CONSIDERATIONS

2.1 Foundations

The three important design criteria for any foundation are:

i) The foundation should be placed at an adequate depth to prevent damage due to frost action, soil erosion and volume changes of soil;

ii) It should have adequate strength to support the structure and be safe against breaking into the ground; and

iii) It should not undergo excessive settlement under the load of the structure.

Generally, most design engineers concentrate on the latter two criteria and do not pay enough attention to the first one. Failure to recognize the existence of an expansive soil or lack of knowledge to deal with such a soil might be the predominant cause.

In Trinidad, expansive soils occupy more than 60% of the areas of central and southern regions and scores of structures have suffered considerable damage on account of the deleterious effects of the

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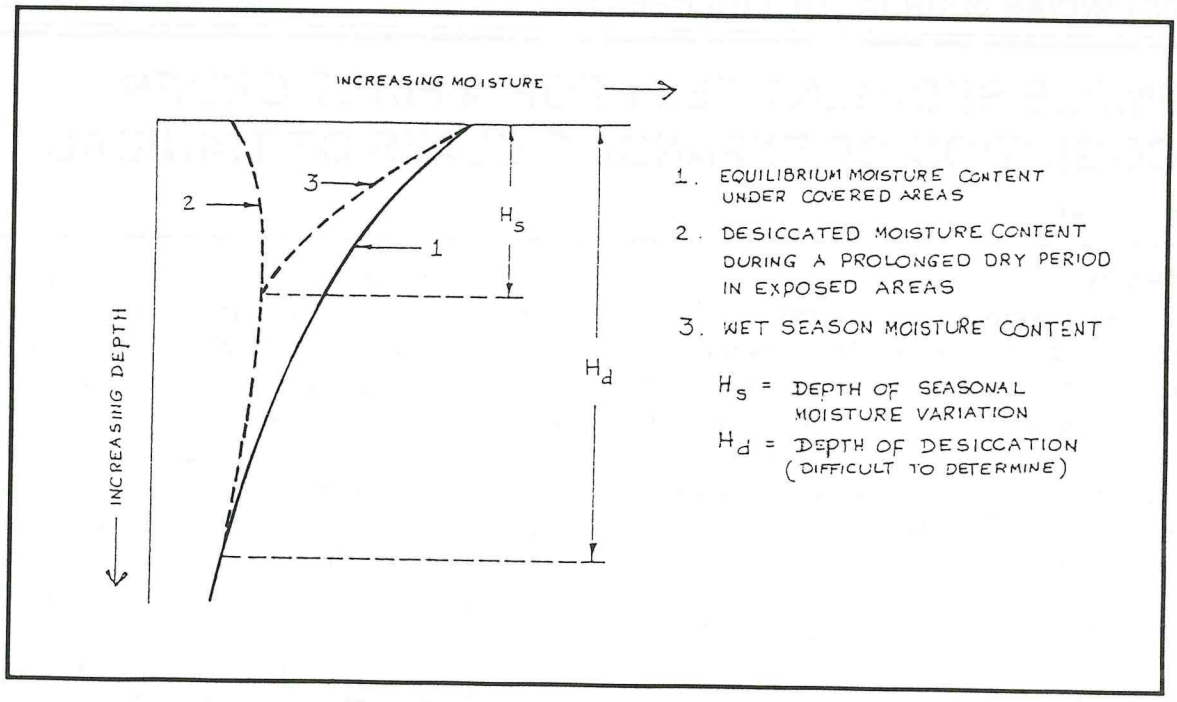

Fig. 1: Depth of Seasonal Moisture Variation

expansive soils. Once the structure develops cracks, it is hardly possible to rehabilitate it, in most cases, without significant expense. This means that the investment made on the structure becomes a total loss. Low-cost housing and school buildings which require large areas of land are invariably being located on expansive soil areas. Therefore, there is a pressing need for a preliminary investigation in order to find out if an expansive soil problem exists at the site of construction. A small amount spent in this investigation is well worth it and it saves the penny-wise and pound-foolish consequences. The objective of this paper is to enlighten the small builder or a practitioner with relevant aspects of expansive soils and recommend a simple procedure of recognizing them so that he is aware of the type of soil over which he intends to build. From the results of such a test, it is possible to tentatively classify the soil as low, medium, high and very high expansive type. If the test indicates a medium to high expansive soil, there is need for performing further laboratory tests for confirmation.

2.2 Topography

The houses constructed on slopes are in a more dangerous situation than those built on a flat ground. The expansive soils on a slope move both in the vertical and horizontal directions, more perceptibly in the latter direction, under the influence of repeating seasonal weather conditions. Steeper the slope, greater is this movement. The damage to many houses raised on slopes of expansive soils, especially in the central region of Trinidad, is observed to be quite significant. The buildings have developed serious horizontal cracks due to the movement of soil.

Further, these expansive soils on a slope aggravate landslide problems with their slow lateral movement. Therefore, land slope is also an important criteria. Slopes steeper than 14°(an estimated residual frictional angle for Trinidad clays) will lead to movement in both directions whereas flatter slopes are likely to move only in the vertical direction. It is always advisable to avoid sites steeper than 14° in view of additional landslide problems if the expense of a slope stabilization technique is too great.

Drainage feature of a site is yet another important criteria in expansive soils. Streams, ditches, depressions and lowlying areas are prone to flooding and provide adequate supply of water to activate the expansive soils. The direction of flow of surface runoff or from storm water drain should be away from the building and quicker the flow out, the better. Leaking water pipes are another source of risk as they cause localized swelling of soil. Maintenance of a constant moisture in the ground around the building is an important consideration.

2.3 Vegetation

While trees are most desirable around a house, they have a deleterious effect on the building if situated close

to it. They continuously absorb water from the nearby foundation soil through their root systems and cause shrinkage in the soil. The amount of loss of moisture by transpiration from trees depends on the size and type of the tree. Broad leaf decidous type draw considerable amount of moisture and dessicate the soil. This is the reason why big trees should not be located with a distance of 1 to 1 1/2 times their mature height. Cutting down the existing trees brings in opposite changes in the soil moisture. This prevents transpiration losses and the soil moisture accumulates and allows the soil to swell. Therefore, the trees have to be felled far in advance of commencement of the construction.

2.4 Climate

The climatic factors that influence the soil potential for volume changes are:

(i) the intensity of rainfall,

(ii) temperatures,

(iii) relative humidity,

(iv) duration of dry spell periods, etc.

However, the soil moisture condition is controlled by the rainfall and evapo-transpiration. The difference between these two components of the hydrologic cycle indicates the moisture excess or deficiency in the soil. This condition is usually expressed by Thornthwaite Moisture Index (TMI). It is defined as the difference in the mean annual rainfall in inches and the amount of water in inches that is returned to the atmosphere by evaporation from the ground surface and transpiration from vegetation. A positive TMI indicates a net surplus moisture. If TMI of an area is in the range of 0 to 20, the area is sub-humid and -40 to -20, it is semi-arid. Locations falling in the range of -20 to +20 will have problems of significant volume changes in soils and hence, are problematic to foundations, pavements, buried structures etc. Fig. 2 shows the humidity map of Trinidad. In the areas demarcated as continuously moist, the effect of even highly swellable soils will be limited because of substantial moisture retained in the soil throughout the year. Whereas in areas having a strong dry season, the state of moisture in the soil is reflected by this climatic factor. Fortunately for Trinidad, the semi-humid climate and short dry periods keep the moisture levels pretty high and consequently the potential swell of the expansive soils is somewhat contained. As such, the damage to structure will not be as intense as in arid and semi-arid regions.

2.5 Soil Profile

The thickness of expansive soil layer and the depth to which the soil moisture varies govern the design of foundations. Variations in the thickness of this layer over the area of the building will lead to differential heaving. This causes differential movement of foundations which may be catastrophic to the structure if it is not designed for this eventuality. If the layer is homogenous and extends to a significant depth, then the heaving may be uniform but its magnitude may be high. If it is shallow, then it can be excavated and replaced by a non-swelling soil. If the ground water table is high, the problem of swelling soil is less because of a shallow depth of desiccation. On the contrary, the depth of desiccation

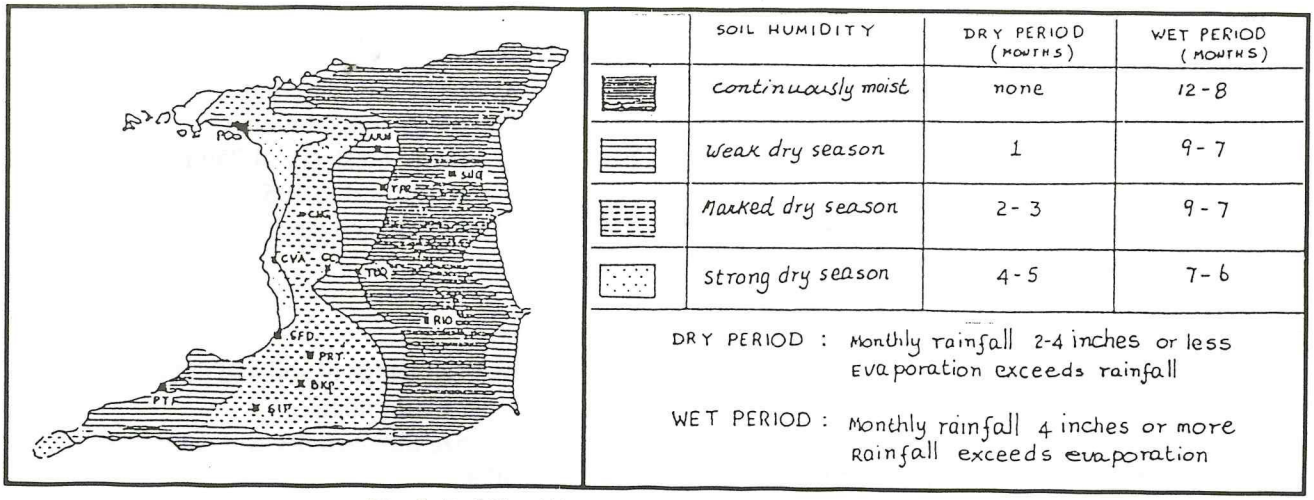

Fig. 2: Soil Humidity Map of Trinidad (Mohr's Scheme)

will be significant and the problem will be severe if the dry spell period is long and levels of water table fluctuate significantly. These conditions are determined by the active depth. This active depth for any region can be determined by measuring moisture variations with depth and time.

3.0 THE IDENTIFICATION PROCESS

The first order identification process consists of:-

(i) field survey and

(ii) a simple sediment test.

3.1 Field Survey

The soil properties and the environmental conditions obtaining at the site have to be analyzed, as a preliminary step, by paying a visit to the site. The site survey should include visual inspection of the soil condition, topography, type of vegetation, climatic condition and the performance of the neighbouring buildings.

3.1.1 Visual Inspection

The first indications of the soil from visual inspection of the ground may be obtained by answering the questions posed in the check-list below. If the answer to most of the questions is a "yes", then the indications are that the expansive soil problem exists.

Check List:

1. By local enquiry or from soil data available, are the soils around known to be of expansive type?

2. If the visit is made in the dry season, do you find shrinkage cracks on the ground surface appearing like a turtle-back pattern?

3. If the visit is made in the wet season, do you find the soil very sticky, sticking to shoes, car tyres, etc.?

4. If you try to break a dry clod of soil between your fingers, do you find it hard to break?

5. If you cut the dry clod with a knife, does it show a glossy surface?

6. If you take some moist soil and roll it between your palms or on a glass plate into a thread of roughly 3mm in diameter and a few centimetres long, will it stand on its own weight when held down at one end?

7. If you inspect the neighbouring buildings, do you find cracking of walls, floors, jammed doors, heaved-up side walks, etc.?

8. Do you find the pavements cracked and their surface rough?

9. Do you find big trees adjacent to the cracked buildings within a distance of 1 to 1 1/2 times their height?

10. Upon enquiry, do you find that the ground water table is quite deep?

The answers to the above questions show an evidence to the presence of an expansive soil. The next step should be to collect disturbed soil samples from some depth and perform the sediment test in order to confirm the visual observations. The test procedure is described below.

3.2 Sediment Test

After the field survey is completed, the disturbed soil samples obtained may be used for testing to confirm the field observations. The test to be performed is known as the Sediment Test. This test is so named merely to distinguish it from the usual sedimentation test (Hydrometer) performed in the laboratory for grain size analysis. The test is a simple one and does not require any special equipment or the skill of a technician. The test procedure is as follows:

Aim:

To find the sediment volume of the given soil.

Materials and Apparatus:

(1) 200 gms of soil sample
(2) 40 ml of Calgon solution
(3) No. 4 sieve (mesh size 4.75mm)
(4) Over to heat soil to 105
(5) 100 ml graduated jar
(6) Bowl

Procedure:

1. Break the lumps of soil and put in the oven in a bowl for 24 hours.
2. Pulverize the oven dry soil using a wooden mallet.
3. Sieve the dry soil through No. 4 sieve to

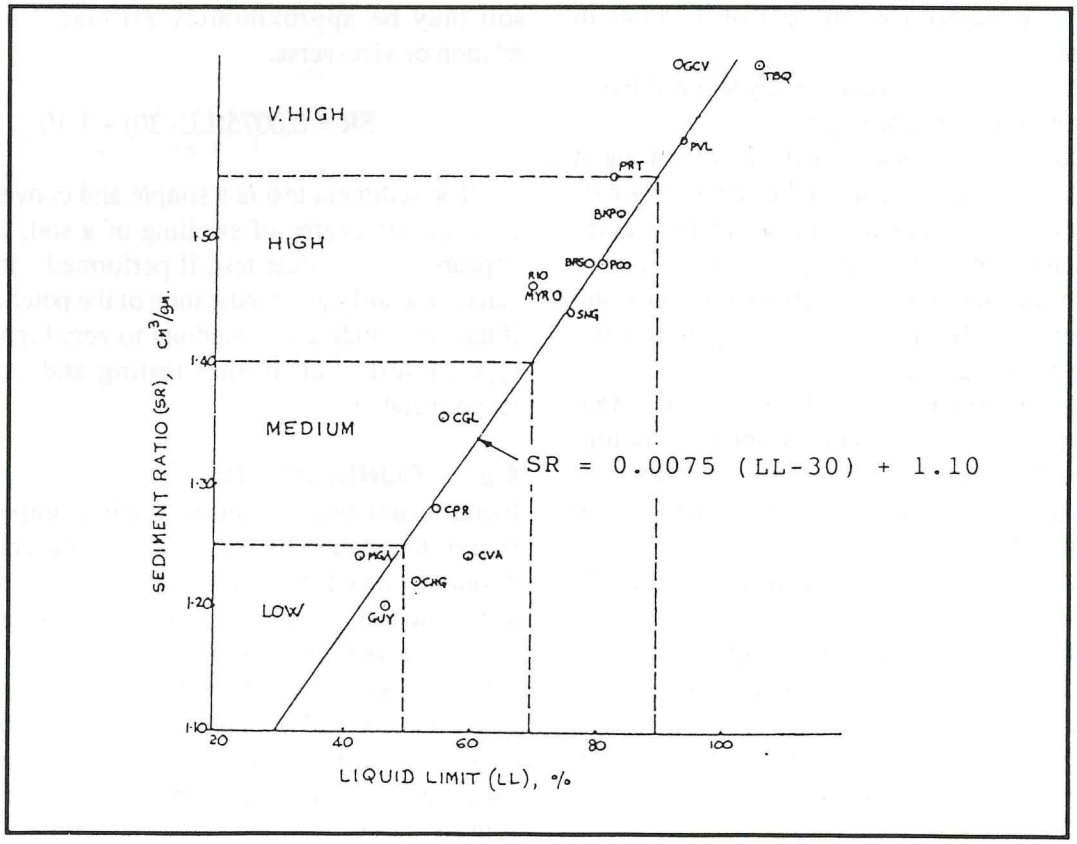

Fig. 3: Sediment Ratios

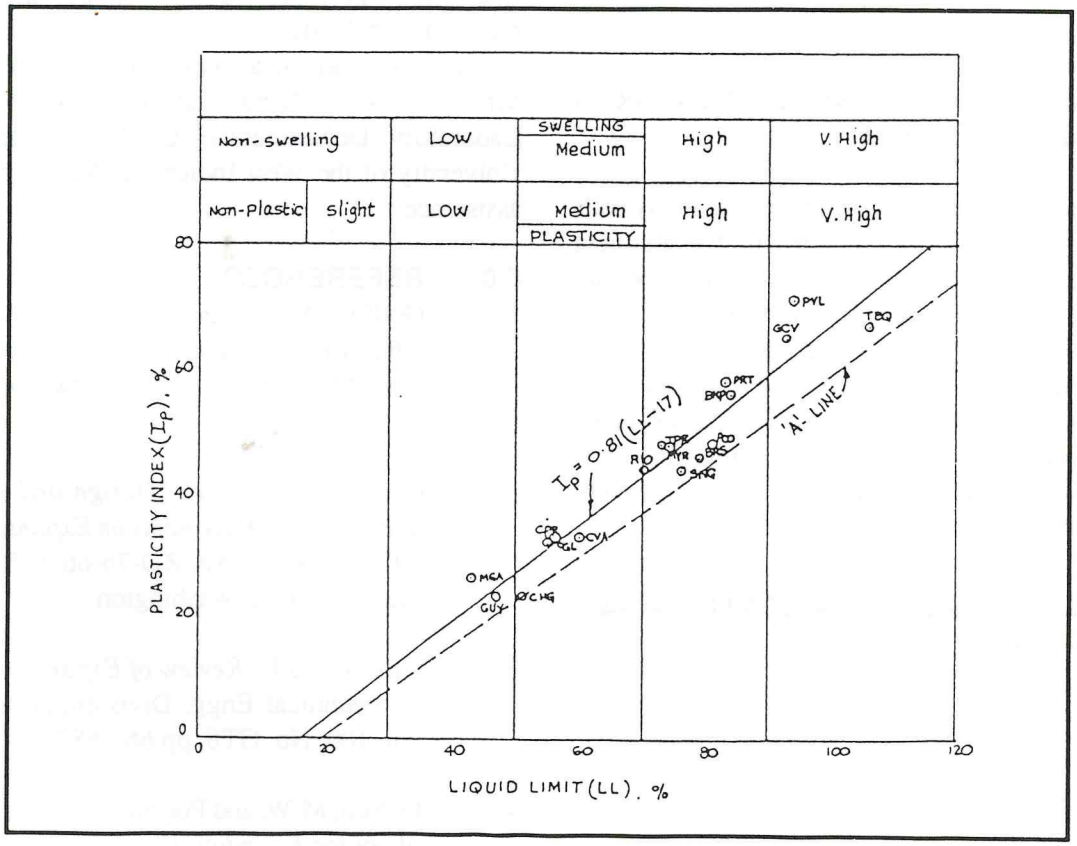

Fig. 4: Modified Plasticity Chart

remove big particles greater than 4.75 mm in size.

4. Weigh 50 gms of the sieve dry soil and transfer it to the jar carefully.
5. Add distilled water and 20 ml of Calgon solution and stir it up well using a glass rod. Calgon is a deflocculating agent to prevent aggregation of soil particles. Sodium Hexametaphosphate is another flocculating agent. In the absence of this agent, stirring has to be vigorous.
6. Fill the jar with distilled water up the 100ml mark and stir the solution vigorously. Before withdrawing the glass rod, wash the soil particles sticking to it down into the jar carefully.
7. Place the jar on a table and leave it for 48 hours for the soil to sediment.
8. When sedimentation is complete, read the sediment volume from the graduations on the jar.
9. Repeat the test once more and take the average of the sediment volumes, say 70ml.

Computation:

Take the ratio of the sediment volume in ml and dry weight of soil in grammes, i.e., 70/50 = 1.40ml/gm.

Applications:

Use this ratio called Sediment Ratio (SR) to obtain the degree of swelling.

The sediment test is performed on many soils of the central and southern regions and the sediment ratios are plotted against liquid limit values. The plot results in a straight line as shown in **Fig. 3.**

Based on the work of the author in which the liquid limit values correlated with the measured potential swell of expansive clays of Trinidad as shown in **Fig. 4**, different categories into which the soils expansivity is divided are related to the sediment ratios and this relation is shown below.

Sediment Ratio (SR) (ml/gms)	Degree of Swelling
< 1.25	Low
1.25 - 1.40	Medium
1.40 - 1.55	High
> 1.55	Very

Knowing the sediment ratio, the liquid limit of the soil may be approximately estimated using the relation or vice-versa.

$$SR = 0.0075(LL - 30) + 1.10$$

The sediment test is a simple and convenient test to judge the degree of swelling of a soil. Though it appears to be a crude test, if performed with care, it can give a fairly good indication of the potential swell. If the result indicates a medium to very high swelling type of soil, then further testing and analysis is recommended.

4.0 CONCLUSIONS

Identification of an expansive soil is an important first step in foundation design, design of pavements, etc. A simple procedure, consisting of a field survey and a sediment test, is suggested to enable even a small builder to perform the operation to identify if an expansive soil exists at the site. The sediment test helps to classify the soil on a preliminary basis in terms of Low, Medium, High and Very High degrees of swelling for him to initiate further investigation if there is need.

5.0 ACKNOWLEDGEMENT

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