A GEOTECHNICAL ASPECTS OF CASE STUDY DOCUMENTATION IN ANALYSING THE INFLUENCE OF SHRINK SWELL CHARACTERISTICS OF EXPANSIVE SOIL ON LOW RISE STRUCTURES.

Author:Dr.CHANDRA MOHAN (Lecturer, Civil Engineering Department, Motilal Nehru Govt. Polytechnic college, Puducherry (email:ssrajarani10@gmail.com)

ABSTRACT: Expansive soils are considered as problematic soils as they cause serious problems to Civil Engineering structures founded on them. Till recently, the focus of investigations world over is on understanding the effect of swell-shrink on the swelling behavior of such soils and their control. However, in recent years, focus of research is in understanding the influence of Geotechnical characteristics of such soils on the distress of buildings / structures founded on them. Only a few studies have been reported in the Indian context. Hence, in this study four recent buildings covering the entire Pondicherry region, wherein distress in the form of cracks have appeared, are selected and soil samples were collected and various Geotechnical characteristics were determined. The results of this investigation among the selected four sites in Puducherry, the buildings constructed in Krishna nagar area have meet with an enormous damages indicate that soil contains clay (72%), have high liquid limit (55%) and plastic limit (40.32%) which indicate high potential swell ranged as 61.1%. This technical paper presents the study about the Problems, and remedial measures for the structures constructed on expansive Soil. The swelling characteristics of expansive soil and its effects on the structures are being revealed. The cause of failure of the structure are identified by considering the soil properties, intensity of loading, nature of foundation and pattern of cracks developed. From the results it is found that the expansive natures of the soil in the selected area are responsible for causing distress in the forms of cracks in the buildings.

• ***Key words***: Expansive soil, swelling, shrinkage, cracks.

INTRODUCTION

Expansive soils in many parts of the world pose a significant hazard to foundations for light buildings. Swelling clays derived from residual soils can exert uplift pressures of as much as 5,500 PSF, which can do considerable damage to lightly-loaded wood-frame structures. Insurance companies pay out millions of dollars yearly to repair homes distressed by expansive soils. Expansive soils have in-depth swelling characteristics due to the presence of swelling clay minerals. Swelling clays can control the behavior of virtually any type of soil if the percentage of clay is more than about 5 percent by weight. Soils with smectite clay minerals, such as montmorillonite, exhibit the most profound swelling properties. Potentially expansive soils can typically be recognized in the lab by their plastic properties. Inorganic clays of high plasticity, generally those with liquid limits exceeding 50 percent and plasticity index over 30, usually have high inherent swelling capacity. In the field, expansive clay soils can be easily recognized in the dry season by the deep cracks, in roughly polygonal patterns, in the ground surface (Figure. 1).

Figure1: Polygonal pattern of surface cracks in the dry season. These cracks are approximately one inch wide at the top.

Pondicherry is the capital of the union tertiary (UT) of Pondicherry, located in the east coast of India. It is one of the four enclaves constituting the UT of Pondicherry. It extends from 11.93˚ N latitude to 79.78˚ E longitude. The temperature of the above town ranges from 28-36˚C and north-east monsoon is the primary monsoon which contributes to 80% of the annual rainfall. The average annual rainfall is about 1200mm. Ground water is located at shallow depths within the old town area, where several heritage buildings are located. Residential buildings were selected such that they are spread all over the Pondicherry region, covering the old town and also the recently developed areas located far from the old town. Salient details of the selected buildings are given in Table 1.The widespread occurrences of cracking due to alternate swelling and shrinking in lightly loaded structures provided with traditional foundation like the strip footings are covered by swelling soil. In recent years, focus of research is in understanding the influence of Geotechnical characteristics of such soils on the distress of buildings / structures found on them. Hence, in this study four recent buildings covering the entire Pondicherry region, where in distress in the form of cracks have appeared, are selected and soil samples were collected and various Geotechnical characteristics were determined.

PROBLEMS IN EXPANSIVE SOILS

Numerous masonry houses especially lightweight structures on these expansive soils in Puducherry have met with damages originating from differential heave. While the presence of expansive soil in the area can cause significant problem. Generally, the structures included both superstructure (walls, floors and roofs) and substructures (foundation and soil). Foundations are in turn divided into two main categories:

- Shallow
- Deep foundation

The structures most susceptible to swelling/ shrinkage on expansive soils are those which rest at shallow depths. Damages experienced by these structures include cracks in the foundation and walls. The degree of damage based on observed cracks ranges from hairline cracks, severe cracks, very severe cracks to total collapse. The magnitude of the damage is related to the interaction between the soil and the structure.

SWELL - SHRINK BEHAVIOR

The swell - shrink potential of expansive soils is determined by its initial water content, internal structure and vertical stresses, as well as the type and amount of clay minerals in the soil. Swelling pressures can cause heaving, or lifting, of structures whereas shrinkage can cause differential settlement. Failure results when the volume changes are unevenly distributed beneath the foundation. Generally, the larger the amount of these minerals present in the soil, the greater the expansive potential.

REPORT OF THE PROBLEM

A large number of structures especially lightweight structures (low rise) found on these expansive soils have met with widespread problems associated with serviceability performance mainly in the form of cracks or permanent deformation While very little work has been done to study the extent of expansive soils in Puducherry on one hand, on the other hand the damages in buildings founded on expansive soils have been very poorly documented. The scarce knowledge about the behaviour of foundations in swelling soils is obvious behind the damages of structures supported on the foundations mainly due to the uplift of the foundations (dooming or centre heave) following wetting of the soil.

PURPOSE OF THE STUDY

The beneficial effects of this paper is,

- To study the engineering properties of the clay soils with their origin and to study and understand the important soil properties for the soil swell/shrink potential.
- To understand the influence of the geotechnical characteristics of the soil on the formations of cracks in the buildings and to understand the nature of causes and suggest remedial measures

INVESTIGATION METHODOLOGY

This investigation project is conducted by means of literature review on expansive soils, field and laboratory testing and physical observations of the performance of existing buildings. A substantial extent of time was dedicated to an arranged number of site visits in the study area to ascertain the visible prevailing conditions. To back up the site visits, visual inspections and studies of construction details of the buildings were carried out. The aim of visual inspections was to observe different factors affecting the foundation structures, identify construction type and material, defects and signs of movement. Indicators of soil movement such as diagonal cracks in the walls, sticking doors and windows and cracks in the floors were identified. This study is limited to shallow foundations, thus ‘foundations’ in this work refer to ‘shallow foundations’.

LITERATURE EVALUATION

GENERAL

Provides a basic platform for better understanding of the problems associated with buildings on expansive soils. Relevant literature in the broad field of fundamentals of building damages associated with geotechnical aspects of expansive soils is surveyed. To gain better understanding of the fundamentals of expansive soil as well as building damage aspects the major emphasis is put on the following imperative range of subjects:

- Expansive soil theory and practice
- Building systems (super- and sub-structure) on expansive soils
- Building category
- Damages in structures

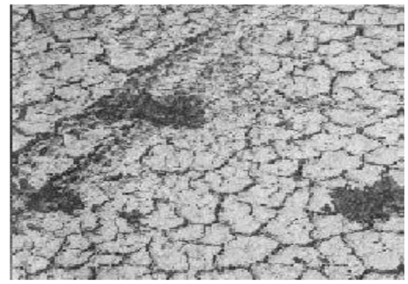
The first phase is therefore identification of the expansive soils and the types of structures and foundations found on soils. For existing structure, which is the focus of this study, an increased attention has been paid to techniques for identifying and classifying the damages.

IDENTIFICATION OF EXPANSIVE SOILS

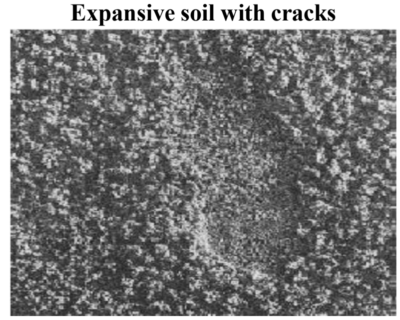
Identification of potential swelling or shrinking subsoil problems is an important tool for selection of appropriate foundation (Hamilton, J. J., 1977 and Van Der Merwe D. H., 1964). Despite the lack of standard definition of swell potential (Nelson, J. D. and Miller, D. J., 1992), there exist various geotechnical techniques to identify the swelling potential of soils. Surface examination, geological and geomorphological description can give indicators of expansive soils. The morphological description includes a host of many things such as ground water table situation, colour of the soil, soil consistence, soil texture, soil structure, texture groups etc. Most of the relevant physical and mechanical properties to give indicators of swell potential are obtained by performing geotechnical index property tests such as Atterberg limits, unit weights and grain size distribution. Other direct tests to determine the swell potential include volume change tests (free swell test).

Visual identification

Soil that cracks or fractures when it dries is often a sign that it is expansive; however a lack of cracks does not necessarily indicate that the soil is not expansive (Masoumeh Mokhtari, Masoud Dehghani. 2012 vol.17, Bund.R). Soils containing expansive clays become very sticky when wet and usually are characterized by surface cracks or a "popcorn" texture when dry. Expansive soils take on a popcorn like appearance when they dry, they look like lumps of popcorn shaped dirt on the soil surface, and it is shown in the Figure 2. Expansive soils are often clay like, becoming very sticky when wet and hard and brittle when dry. The best way to determine if the soil at a location is expansive is
to have an expansion test performed by a soil expert.



Expansive soil with cracks



Expansive soil with "popcorn" texture

Figure. 2. Identification of expansive soil from (Masoumeh Mokhtari, Masoud Dehghani.2012 vol.17, Bund.R).

Particle size distribution (PSD)

The inherent swelling potential of soil is directly related to the total amount of clay mineral particles (particles that are <2μ in diameter) in it. The swelling potential increases with the increase of clay minerals. Moreover, particle size distribution of soil mineral separates are critical for getting hold of many soil properties such as water holding capacity, rate of movement of water through the soil, kind of structure of soil, bulk density and consistency of soil. All these are important in the identification of expansive soils.The distribution of particle sizes larger than 0.002 mm is determined by dry sieve, while a sedimentation process using a hydrometer determines the distribution of particle sizes smaller than 0.002 mm.

Atterberg limits

In the year 1911 Atterberg proposed the limits (liquid limit LL , plastic limit PL and shrinkage limit SL) of consistency in an effort to classify the soils and understand the correlation between the limits and engineering properties like compressibility, shear strength and permeability (Casagrande, 1932). The most useful classification data for identifying the relative swell potential are liquid limits (LL) and plasticity index (PI). The liquid limit is the water content at which a soil changes from the liquid state to a plastic state while the plastic limit is the water content at which a soil changes from the plastic state to a semisolid state. The plasticity index is calculated by subtracting the plastic limit (PL) from the liquid limit (LL). i.e., PI = (LL – PL).

Climate and Hydrological Conditions

The climate in particular is one of the most important factors in soil profile development. Climatic factors, such as precipitation, temperature, wind and sunlight accelerate the formation of the basic material of soil. Soils differ depending on how much of these different ingredients they contain, and climate contributes to those differences. Climate change will modify rainfall, actual evaporation, generation of runoff, groundwater level and soil moisture storage. Changes in total seasonal precipitation and in its pattern of variability are both important in the prediction of alternate cycles of swelling and shrinking. The local effects of climate change on soil moisture, however, will vary not only with the degree of climate change but also with properties of soil. Heavy clay soils are thought to have higher water holding capacity than coarse-textured soils. The water-holding capacity of soil will affect possible changes in soil moisture deficits; the lower the capacity, the greater the sensitivity to climate change. That means coarse textured soils dry or drain more rapidly than fine-textured soils.

Swell potential

Studies have been carried out to determine the swelling potential mathematically (P.F. Savage, 2007). Savage (2007) have estimated the clay fraction without any hydrometer analysis and the swell potential of the soil mathematically and a chart giving the swell potential of a soil from the value of R and P425 fraction is presented. The ratio LL/Pl is the product of LL/PI and PI/PL the ratio LL/PL may be accepted as a clay type indicator. LL/PL = R and may be termed the PLASTICITY RATIO.

Act = 0.16 $R^{2.13}$

P0002 = 6.25 Pg $R^{-2.1}$

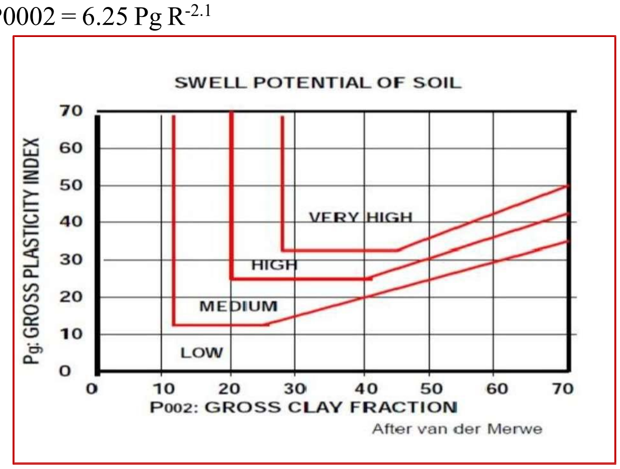


Figure 3.Van der Merwe chart

Van der Merwe (1964) investigated the potential of clays to swell and drew up a chart of Gross PI (Pg) versus gross clay fraction (P002 g) in which zones of swell potential were defined ranging from low , medium, high, very high by a series of straight lines (Above Figure 3).

IDENTIFICATION OF DAMAGES IN STRUCTURE

Foundations resting on expansive soils may move differentially in the vertical direction and show sign of unacceptable cracks as the position of ground water table changes with season (Hussein Elarabi,). Heaving of the building generally starts sometime after completion of the structure, of the order of one year. It should be noted that cracks are more likely to occur in lightly loaded structures than in heavily loaded structures. This fact appears clearly in severe cracking of single storey domestic houses of rigid construction like load bearing brick walls which are constructed in many places of arid and semi-arid areas. Damage caused by expansive soil appears firstly as cracks on external and internal walls, joints of brick and concrete elements or stones, and interior plaster walls. The types of cracks appearing in structures are: diagonal shear cracks, horizontal and vertical shear cracks, horizontal and vertical cracks caused by bending moments and horizontal and vertical tension cracks, Figure.4.

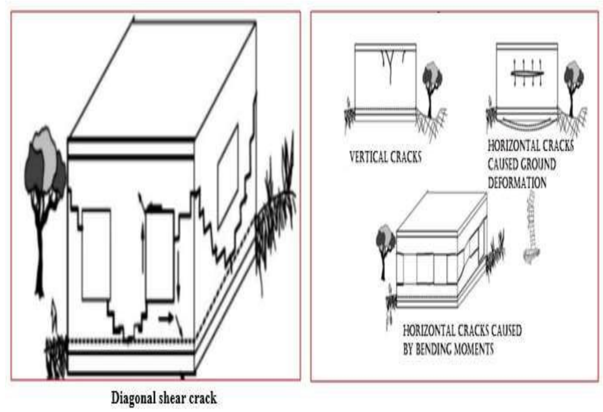


Figure 4.

Foundation Damage

In Figure 5, the exterior corners of a uniformly-loaded rectangular slab foundation will only exert about one-fourth of the normal pressure on a swelling soil of that exerted at the central portion of the slab. As a result, the corners tend to be lifted up relative to the central portion. This phenomenon can be exacerbated by moisture differentials within soils at the edge of the slab. Such differential movement of the foundation can also cause distress to the framing of a structure.

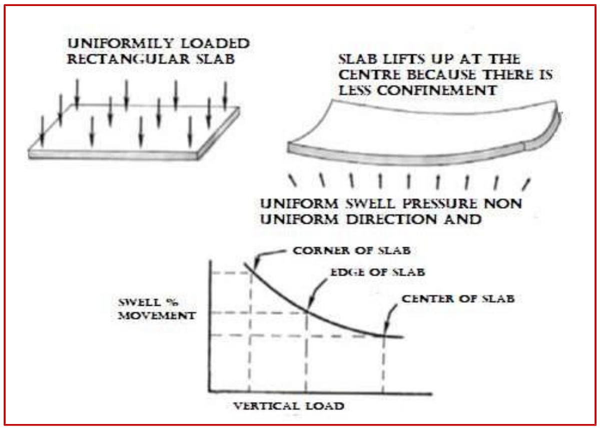


Figure 5: A rectangular slab, uniformly loaded, will tend to lift up in the corners because there is less confinement. Damage mechanism of expansive soils (Hussein Elarabi,)

The classification of the damage is very important to assess whether the building calls for strengthening, repair, renovation or demolition. Various researchers (Burland, J. B., et al., 1977, Boscardin M. D. and Cording E. J., 1989) put forward many definitions, specifications and guidelines for classification of damage in structures. Visible damages based on observed crack width as suggested by Burland are reproduced in Table 1.

Table 1.Categorization of visible damages in structures (Burland, J. B., et al.,1977)

Crack width (mm)	Category	Classification
Less than 2mm	Very slight	Aesthetic
2mm to 5mm	Slight	Aesthetic
5mm to 15mm	Moderate	Serviceability
15mm to 25mm	Severe	Serviceability
Over 25mm	Very severe	Stability

Conclusions:

Damages in buildings are varied some insignificant, while others are very severe. Likewise, the causes of damages are varied ranging from construction materials and methods to type of sub soils. Categorization of visible damages in structures is critical for assessing the potential effect of expansive soils. This part has highlighted on different approaches to estimating potential damage.. The degree of damages is either slight, moderate or severe. The slight, moderate, and severe categories are in most cases based on crack size and pattern. The assessment presented here will be employed together with the laboratory test results to judge the level of damages on the structures.

EXPERIMENTAL WORK

A primary goal of the effort in this study is to identify the key geotechnical information in the field studies. To accomplish this goal, the overall study has been split into the following areas:

- Field investigation
- Laboratory test results
- Empirical formulas to predict potential swell

FIELD METHODOLOGY

The study was carried out in three stages;

- Reconnaissance survey
- Building inspection
- Laboratory testing of soil samples collected from the study areas.

The reconnaissance survey was aimed at studying the immediate environment of the building in question, and building inspection was carried out to diagnose the distress i.e. Cracks in the buildings based on their location, width, depth, orientation and pattern. Understanding of subsoil conditions in the field should be preceded by collections of existing data on their geotechnical characteristics.

Collection of samples

The exploration composed of opening trial pits up to about 1 m below ground level at carefully earmarked locations. The chosen depth took into account the shallow depth of most of the foundations and the anticipated depth of active zone in the study area. The pits were excavated manually using pick-axes and shovels. Some of the photographs taken during the excavation are shown in Figure 6. Undisturbed samples from the pits were recovered from carefully marked depths using hand tools such as knives, trowels and shovels disturbed samples were also retrieved from the pit, sealed, packaged, logged and transported to the laboratory.

STUDY OF EXISTING BUILDINGS IN PUDUCHERRY REGION

The survey was carried out to assess the performance and conditions of existing buildings in various regions of Puducherry. The identification started-off with the site, namely

- Krishna nagar –L1 and followed by
- Venkata nagar,-L2
- Bahore,-L3
- Koodapakkam,-L4

Visual inspection techniques were the primary methods used to evaluate the conditions of the majority of the existing buildings and footing systems within Puducherry region.

Figure 6.Typical open pits manually excavated using pick-axes and shovels

Table 2 Salient details of the selected buildings

No.	Description	L1	L2	L3	L4
1.	Type of structure	Framed	Framed	Framed	Framed
2.	Type of foundation Pile	Pile	isolated	isolated	isolated
3	No. of storey	G	G+1	G+1	G+1
4.	Age of building(app) in years	15	10	15	15

LABORATORY TESTS

Purpose

The purpose of the experimental study is to investigate the properties of expansive soil such as liquid limit, plastic limit, plasticity index, shrinkage limit, grain size analysis, hydrometer analysis, unconfined compressive strength and compaction of expansive soil and also to investigate the effect on structures. Physical and engineering properties of soil sample were determined adopting relevant IS Codes. The above data is used to interpret the cause of cracks in the buildings.

ANALYTICAL METHODS FOR SOIL CHARACTERIZATION

The Following are the tests conducted for the soil samples collected from the site:

i) Atterberg limits (Liquid Limit, Plastic Limit and Shrinkage Limit)
ii) Hydrometer analysis
iii) Unconfined compressive strength
iv) Free swell index
v) Field density and Natural moisture content
vi) Wet sieve analysis
vii) Specific gravity

These standard values give an idea about the behaviour of the soil according to the IS Classification given in the Table 3 to Table 5.

Table 3: Soil expansivity prediction by liquid limit (IS 1498)

Degree of expansion	Liquid limit (%)
Low	20-35
Medium	35-50
High	50-70
Very high	70-90

Table 4: Soil expansivity prediction by plasticity index (IS 1498)

Degree of expansion	Plasticity index (%)
Low Less	12
Medium	12-23
High	23-45
Very high	Greater than 32

Free swell index

Based on the Modified free swell index of clay values give an idea about the behaviour of the soil expansivity according to the ASTM Classification given in the Table 5

Table 5.Typical Values of Modified free swell index (MFSI) ASTM (1988)

MFSI	Clay type	Soil expansivity
< 1.5	Non swelling	Negligible
1.5 – 2.0	swelling	Moderate
2.0 – 4.0	Swelling	High
> 4.0	Swelling	Very high

RESULT AND DISCUSSIONS

RECONNAISSANCE SURVEY

The preliminary survey conducted indicates that the building was constructed on a water logged area and the formation is capped with thinly laminated silt and clay. There are no any matured trees near the building which can influence the initiation of the cracks and all the drainage systems within the building area are concrete lined channels. Therefore, the cracks in the building are neither caused by ingress of tree roots in to the building nor due to movement of water penetrating into the ground due to lack of proper drainage system.

BUILDING INSPECTION

At the beginning of the study, the length and width of the cracks were marked and were monitored from time to time finding out whether there is any change in the above over a period of time.

- The building found in Krishna nagar (L1) presents a typical case history on the expansive soils., constructed in the year 2000. This is the typical study of what happens when a lightweight structure rests on expansive soil without considering the swell pressure. Figure.7 shows a building in a state of damage due to heaving occurred in Krishna nagar. Cracks found in building originated in the corners and radiated either up or down at about 45º. Most of the buildings had developed diagonal cracks with a stair-step pattern in external walls.

- In Venkata nagar (L2) the sample covered a mixture of buildings ranging from single-storey buildings to 2-storey residential buildings. Most of the single-storey structures have masonry walling or cement bricks, laid directly on the foundation wall supported by a spread plain concrete footing cast continuously around the perimeter of the building. Figure.8 (a) and (b) shows the building damage in Venkata nagar having horizontal crack developed between the ground slab and the external substructure wall. In many cases, the initial cracks have been propagating and increasing in width as with time goes.
- In Bahore (L3) buildings ranging from single-storey buildings to 2-storey buildings. Most of the buildings are constructed by isolated foundations. Figure. 9 shows the typical damage of external wall in 2 storey building with multiple hairline cracks of varying length.
- In Koodapakkam (L4) the building was constructed according to the standard engineering practice but the expansive soils were not taken into account because of the lack of adequate soil investigation. The cracks were originating from floor towards the roof and it is classified as moderate to severe degree of visible damages according to classification in Table 1. The figure 10.shows the typical crack pattern observed in the building constructed in year 2000. It clearly shows that building undergone significant settlement.

Table 6.Details of cracks like length, width and orientations in all the buildings

No.	Approximate length of cracks and details	width of cracks (mm)
L1.	Diagonal cracks with a stair-step pattern in external walls 1000 mm in length	7
L2.	Horizontal crack 1800 mm in length	4
L3.	Hairline cracks varying in length	3
L4.	Shear crack length >1000 mm	6

Based on width of cracks, it can be stated that the visible damages may be classified as slight to severe, based on the categorization suggested by Burland et.al (1997).

Figure7.Building inspection in Krishna nagar

Figure.8 (a) horizontal crack formation near window-(L2)
Figure.8(b) horizontal crack formation developed between the ground slab and the external substructure wall

Figure.9crack developed in external wall (L3)

Figure.10 crack developed in external wall (L4)

LABORATORY TEST RESULTS

The purpose of the experimental study is to investigate the properties of expansive soil such as liquid limit, plastic limit, plasticity index, shrinkage limit, grain size analysis, hydrometer analysis, unconfined compressive strength and compaction of expansive soil and also to investigate the effect on structures. Physical and engineering properties of soil sample were determined adopting relevant IS Codes. The above data is used to interpret the cause of cracks in the buildings. Results of the tests conducted on the disturbed and undisturbed soil samples collected from locations L1 to L6 are summarized and given in Table 7

Table 7.Results of the Laboratory Test on Soil Samples from L1 to L4

Description of Tests		L1	L2	L3	L4
composition	Clay %	72.0	70.35	73.00	73.52
	Silt %	28.0	29.65	27.00	26.48
Liquid limit (%)		55.0	54.0	80.50	85.20
Plastic limit (%)		24.9	29.90	40.30	42.00
Plasticity index (%)		30.10	33.08	40.20	43.20
Shrinkage limit (%)		8.70	10.00	10.40	8.10
Plasticity ratio		2.21	2.57	1.99	2.03
Swell potential		H	H	H	VH
Percentage of clay (%) mathematically		34.84	27.66	57.58	59.80
Maximum dry density (KN/m3)		14.23	15.80	13.68	13.19
Optimum moisture content (%)		35.80	23.40	32.10	32.30
Specific gravity (Gs)		2.22	2.61	2.20	2.20
Free swell (%)		42.90	37.50	61.10	70.60
Modified free swell index		2.00	2.70	2.90	1.90
UCC (KPa)		43.75	55.23	53.15	47.02
Un-drained cohesion (KPa)		21.88	27.62	26.57	23.50

CONCLUSIONS OF THE STUDY OF EXISTING BUILDINGS IN PUDUCHERRY REGION

- It is seen that the liquid limit (LL) of soil samples in L1, L2, L3, and L4 are greater than 50 and hence they are classified as 'silt and clays of high compressibility' i.e. 'CH' soil as per Is code.
- The shrinkage limit (Sl) value of L1, L2, L3, and L4 and indicate 'high shrinkage'.
- Further, it is seen that the natural moisture content in locations 2 to 4 is less than half the liquid limit of the soil specimens in the locations. This shows that the clay layer has undergone significant desiccation, this responsible for causing distress in buildings in locations 2 to 4.
- On the other hand, due to constant water logging the natural moisture content is on the higher side and that is reasonable for causing distress in the building in location-1.
- The higher the unit weight the higher the hardness as well as the swelling potential (swell percent and swell pressure). The soils are mostly in greyish colour which is another indicator of the presence of expansive minerals and all the tested samples satisfied the expansive soil criteria and have potential expansion rating from 'high' to 'very high'.

- The soils contain content of swelling clay minerals (59.8 % to 27.66 %), have high liquid limits (85.20 % to 54 %), plasticity index (30.10 % to 43.20 %).
- The experience of constructing buildings and structures in the semi-arid region of Puducherry without appropriate measures or with under estimation of the complexity of design and construction on swelling soils has led to damages of the structures triggered by the presence of expansive soils.

CONCLUSIONS AND RECOMMENDATIONS

Most of the damages caused by expansive soils are due to the communities have insufficient knowledge about the features and behaviour of the expansive soils.

Based on field data collected, and laboratory test results and visual observations of cracks in buildings in location 1 to 4, it can be concluded that:

- The distress in buildings at locations 1 to 6 is attributed to the presence of CH type of soil and their significant desiccation caused distress in buildings also attributed to constant water logging over CH type of soil.
- The presence of the expansive clay soil have great influence on the distress of the buildings.
- Soil investigations prior to construction are not carried out adequately thus footings and slabs are placed directly on the expansive soils.

RECOMMENDATIONS

Many investigators (D. Nagarajan and K. Premalatha., et al 2014, Kartikey Tiwari1, Sahil Khandelwal, Aman Jatale et al., 2012) have suggested measures to mitigate potential problems associated with expansive soils. For the study at hand, the recommendations summarized here below have been single out based on the results of visual observations and field and laboratory investigations:

1. Control the shrink-swell behaviour through the following alternatives;

• Replace existing expansive soil with non-expansive soil.
• Maintain a constant moisture content.
• Improve the expansive soils by stabilization

2. Tolerate the damage.
3. Underpinning the existing foundations.
4. Repair the cracked walls.
5. Enforcement of construction industry regulations.

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