UNIT-4

Foundation on Expansive Soil

→ Expansive soils are the soils which expand when the moisture content of the soils is increased.

→ The clay mineral montmorillonite is mainly responsible for expansive characteristics of soil. The expansive soils are also called swelling soils or black cotton soil.

→ Expansive soils are generally residual soils ~~left~~ left at the place of their formation after chemical decomposition of the rocks such as basalt & trap. The soils are generally dry because the water table there is quite deep. During rainy season, they become wet. The soils expand as the water content is increased. Severe movement of the soil mass may occur. Structure built on such soils may experience cracking & damage due to differential heave.

→ Large part of central India and a part of South India is covered with expansive soils. Although these soils are good for growing cotton, they are not suitable for foundation of structures.

→ Heavy damages may occur to buildings, road, runway, pipe lines etc. if proper preventive measures are not adopted.

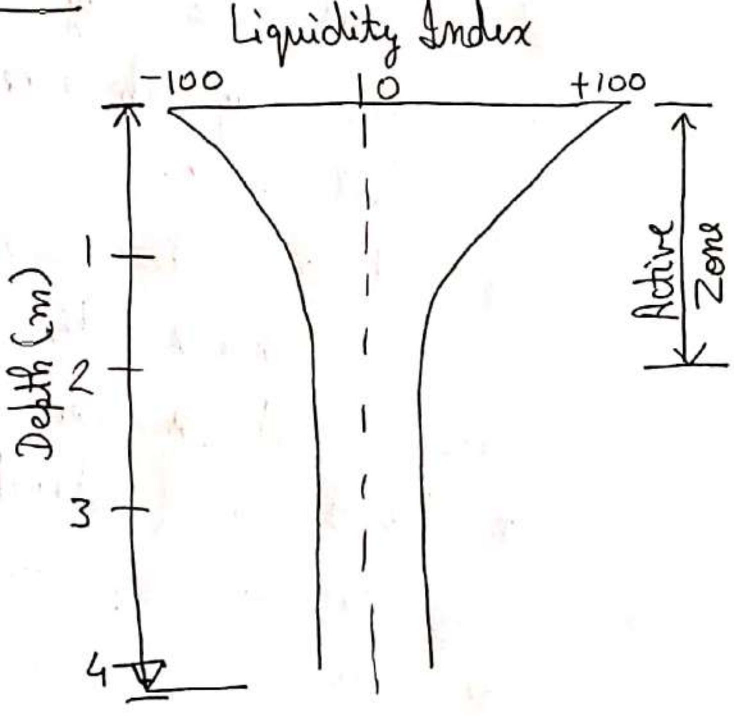
→ The damages can be prevented to large extent if the characteristic of expansive soils are properly assessed & suitable measures are taken in design & construction on Expansive soil.

→ When the water content is increased, it expands. When the water content is reduced it shrinks and develop cracks.

→ The maximum width of shrinkage crack is limited to 20mm.

→ The depth of the expansive soil in which periodic change of moisture content occurs to cause swelling & shrinkage is known as active zone. The soil below the active zone is not affected. The depth of active zone at various location is different. In most cases, the depth of active zone is limited to 3 to 4 m.

→ The depth of active zone can be obtained by plotting the liquidity index of the soil against depth for several seasons. In active zone there is a large variation in liquidity index of soil for different seasons. Below the active zone, the variation in the liquidity index is negligible.



Fig

Parameters of Expansive Soils:

Various parameters are used for identification of expansive soils. Some of the commonly used parameters are:

1) Free Swell: Free Swell (S_f) is defined by relation:

$$S_f = \frac{V_f - V_i}{V_i} \times 100$$

where S_f = free swell (percent)
V_f = Final volume of Soil
V_i = Initial Volume of Soil

The determination of free swell (S_f) is given by Holtz and Gibbs (1956)

Method: Ten cubic centimeter (V_i) of dry soil passing through Sieve No. 40 (425µ sieve) is poured into a 100 cm^3 graduated ~~cm~~ cylinder containing distilled water. The cylinder is kept undisturbed for 24 hrs, and then the final Volume (V_f) of settled soil is measured. Free swell is calculated by above equation.

→ Free swell is not adequate to predict the swelling characteristics of soil & is rarely used.

2) Unrestrained Swell Test: The unrestrained swell test is commonly used to determine free swell.

→ In this test, soil specimen is placed in consolidometer (oedometer) and small surcharge of 6.9 kN/m^2 (1 psi) is applied to it.

→ Water is then added to the specimen so that it is fully submerged in water. As the cross-sectional area of the specimen remains constant, the expansion is also equal to percentage increase in thickness. The increase in thickness is measured after equillibrium has reached.

→ The percent free swell (S_{wf}) is calculated as:

$$S_{wf} = \left(\frac{\Delta H}{H}\right) \times 100$$

S_{wf} = free swell (in percent)
ΔH = inc. in height of specimen
H = Initial height of specimen

3) Differential free Swell: Differential free swell (DFS) is a parameter used for the identification of an expansive soil.

→ For the determination of the differential free swell of a soil, 20g of dry soil passing 425μ size sieve is taken. The soil is divided into two ~~samg~~ samples of 10g each. One sample of 10g is poured into a 100 cm^3 capacity graduated cylinder containing water, and the other sample of 10g is poured into a 100 cm^3 capacity graduated cylinder containing kerosene oil. Both the cylinders are kept undisturbed in laboratory for 24hrs and settled volume of both the samples are measured.

Differential free swell (DFS) is determined from the relation:

$$DFS = \frac{\text{Settled Vol. of soil in Water} - \text{Settled Vol. of soil in Kerosene}}{\text{Settled Vol. of soil in kerosene.}} \times 100$$

∴ As kerosene is a non-polar liquid, it does not cause any swell of the soil.

(Non-polar: Molecule have net zero dipole moment as the individual dipoles cancel eachother.)

S. No.	Degree of Expansion	DFS
1.	Low	< 20%
2.	Moderate	20 to 35%
3.	High	35 to 50%
4.	Very High	> 50%

Note: If DFS is greater than 35%, its expansiveness characteristics should be considered for designing foundation.
(Means if DFS is greater than 35%, the foundation should be designed by taking preventive measure and necessary actions to prevent damages).
And Conventional shallow foundations cannot be used for such soils, whose DFS >35%.

4) <u>Swelling potential</u>: Swelling potential (S) is defined as the percentage of swell under the pressure of 6.9 kN/m² (= 1 psi) surcharge of a laterally unconfined specimen <u>compacted</u> at the <u>optimum</u> moisture content to <u>maximum dry density</u> in standard compaction test (<u>Modified Proctor Test</u>).

→ Swelling potential of soil can be determined in a laboratory by conducting a test in oedometer & measuring swell.

→ Following empirical relation can be used to determine swelling potential (S):

(i) Swelling potential: $SP = (3.6 \times 10^{-5}) A^{2.44} C^{3.44}$

SP → Swelling potential (%)
C = % of Clay
A = Activity of Clay (A = Plasticity Index / C)

(ii) Empiral Relation on basis of plasticity index of soil:

$$SP = (2.16 \times 10^{-3}) (P.I)^{2.44}$$

P.I = Plasticity index.

⇒ Degree of on basis of swell potential:

S.No.	Degree of Expansion	S.P
1.	Low	0 – 1.5
2.	Medium	1.5 – 5
3.	High	5 – 25
4.	Very high	> 25

(iii) Ranganatham & Satyanarayan Method :

$$S.P = 41.13 \times 10^{-5} (S.I)^{2.67}$$

S.I = Shrinkage Index

S.I = LL − SL (Liquid Limit − Shrinkage Limit)

Degree of expansion based on shrinkage Index are as:

S.No.	Degree of Expansion	S.I
1.	Low	0 to 20%
2.	Medium	20 to 30%
3.	High	30 to 60%
4.	Very High	>60%

5) Swelling pressure : It is defined as pressure required to be applied over the swelling soil specimen to prevent its expansion when it is in contact with water. Swelling pressure is denoted by (p_s).

→ Swelling pressure test is conducted in an oedometer. This test requires continuous adjustment of pressure on soil specimen.

→ If swelling pressure of soil is < 30 kN/m² → it indicates the expansiveness is low and conventional design of shallow foundation can be adopted.

→ For high values of swelling pressure, special designs are adopted.

→ Some types of clays, such as bentonite, may have swelling pressure even 2000 kN/m².

* Classification of Expansive Soils :

→ An expansive soil has a large clay content.
→ When dry, it has distinct shrinkage cracks. The soil becomess sticky when wet.
→ Generally soils classified as CL, CI or CH are expansive soils. The soils classified as ML, MI or MH may also be expansive.
→ Investigators are classified expansive soils on basis of index properties such as plasticity index, shrinkage limit, linear shrinkage, clay content etc.
→ There is no fool-proof classification of expansive soil.
→ We will only see one classification of expansive soil on basis of plasticity index ; as classified by Chen (1988)

S.No.	Plasticity Index (%)	Degree of Expansion
1.	$\leq$ 15%	Low
2.	10 to 35%	Medium
3.	20 to 35%	High
4.	$\geq$ 35%	Very High

⇒ **Causes of Moisture changes in soils:**

Even a soil having a high swelling potential may not cause trouble if there are no moisture changes.

- Moisture changes may occur due to change in Water Table.
- Moisture may increase due to irrigation of lawns & kitchen garden around building.
- If the surface water drainage becomes defective & the runoff is obstructed, the water will infiltrate the ground and cause moisture changes.
- If vegetation around the building is removed, the transpiration will stop & moisture will increase.

⇒ **Effect of Swelling on Buildings:**

→ In arid & semi-arid regions, the water content of the soil is considerably reduced due to heat in summer. The water table goes down. The soil becomes stiff and shrinkage cracks develop.

→ During the rainy season, the water content of soil is increased, resulting in swelling. Thus they is large moisture variation in the soil due to seasonal change.

→ When the building is constructed on a swelling soil, the soil below the building is protected from excess heat even in summer. This soil swells up as evaporation is obstructed.

→ However, the soil adjacent to building which is open to atmosphere will experience normal swelling & shrinkage. Thus, differential movement occurs during hot weather.

→ The depth of zone of appreciable ground movement due to seasonal variation in moisture changes depend on nature of soil. This zone is called active zone.

→ As per Central Building Research Institute (CBRI), Roorkee. depth of active zone in India is 3.5m.

→ The movement of soil with swelling & shrinkage causes damages to floor slabs & external walls of building. ~~Bec~~ Because of swelling, the floor slab is pushed up. And cracks are developed in the floor. Footing wall is pushed outward due to swelling. It causes the cracking of the end wall of building. (Figure below).

→ Cracks are also developed at the corners of the window and door openings because of diagonal cracking of walls.

→ All damages occurs very slowly & are usually visible after several years of construction.

→ Loss can be avoided by taking preventive measures.