Construction of Expansive Soil

→ For construction to be done on expansive soil, having high swell potential, preventive measures are required.

** Preventive measures for Expansive soil:

Preventive measures are broadly classified into following categories:

① Replacement of expansive soil
② Modification of expansive soil
③ Design of Foundation to withstand swelling.

1) Replacement of Expansive Soil:

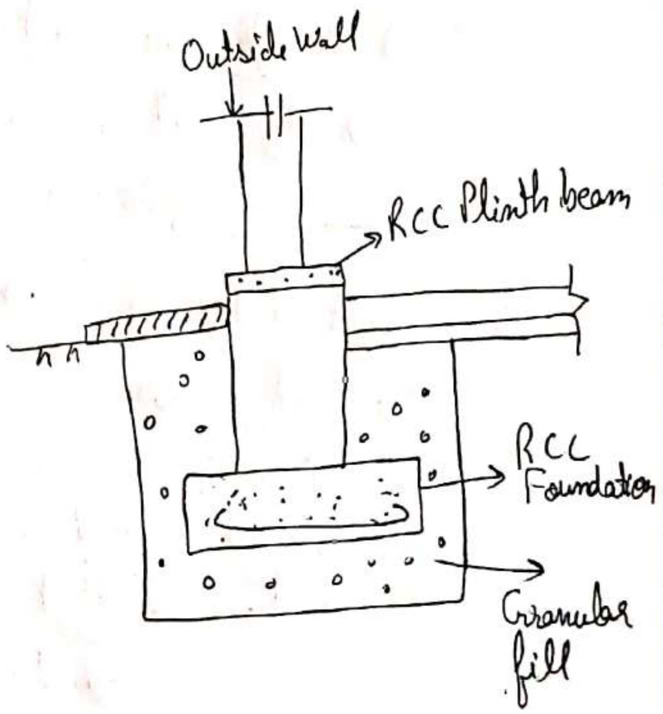
→ If the soil is only moderately expansive soil and it has a shallow depth, it is economical to remove that soil and replace it with a good quality granular soil. The granular soil should be properly compacted.

→ In this case, excavation of expansive soil is carried out for a width greater than width of footing.

→ Generally extra width of 15 cm on either side is excavated.

→ A freely draining granular soil such as gravel, sand or a mixture of gravel and sand, is placed in the trench up to the base level of the footing and compacted.

A footing usually of reinforced concrete, is then constructed at this level & wall is raised.



→ Foundation on expansive soil is generally constructed in summer season when soil has shrink to its minimum level.

2) Modification of Expansive Soils:
The characteristics of an expansive soil can be modified to reduce its swelling potential [alteration of soil condition]. Commonly used methods are given below:

a) Stabilisation of Soil: The expansive soil can be stabilised with lime (or cement). Lime stabilisation is effective in reducing the liquid limit & the plasticity index of the soil. Consequently the swelling potential is also reduced. The quantity of lime required is about 3 to 8%. Generally 5% is suitable in most cases. After mixing lime the mixture is compacted at OMC.
Stabilisation can be done up to a depth of 1 to 1.5 m.

b) Compaction: Swelling potential is reduced if it is compacted wet of optimum Moisture content (OMC).
Generally soil is compacted at water content 3 to 4% above of optimum moisture content.

c) Installation of moisture barriers: Moisture variation in the soil below the foundation can be controlled by installation of moisture barrier. A trench about 1.5 m deep is excavated around the perimeter of building and is filled with gravel. Thus effect of differential heave on foundation is considerably reduced.

d) Prewetting: If an expansive soil is prewetted by ponding at a water content equal to the equillibrium moisture content before construction of foundation, so that most of potential heave could occur before construction. This method is quite time consuming.

e) Pressure Injection: The soil can be stabilised by injection of lime slurry into expansive soil to a depth of 4 to 5m or up to active zone. Depending on the soil conditions at the site of construction, either single or double injection can be used.

3) Design of foundations on swelling soils:

The following types of structures are commonly constructed to withstand heave due to swelling soil.

a) Strong & Rigid Structures: The structures are made strong and rigid to withstand heave because in rigid structures, uniform settlements would occur.

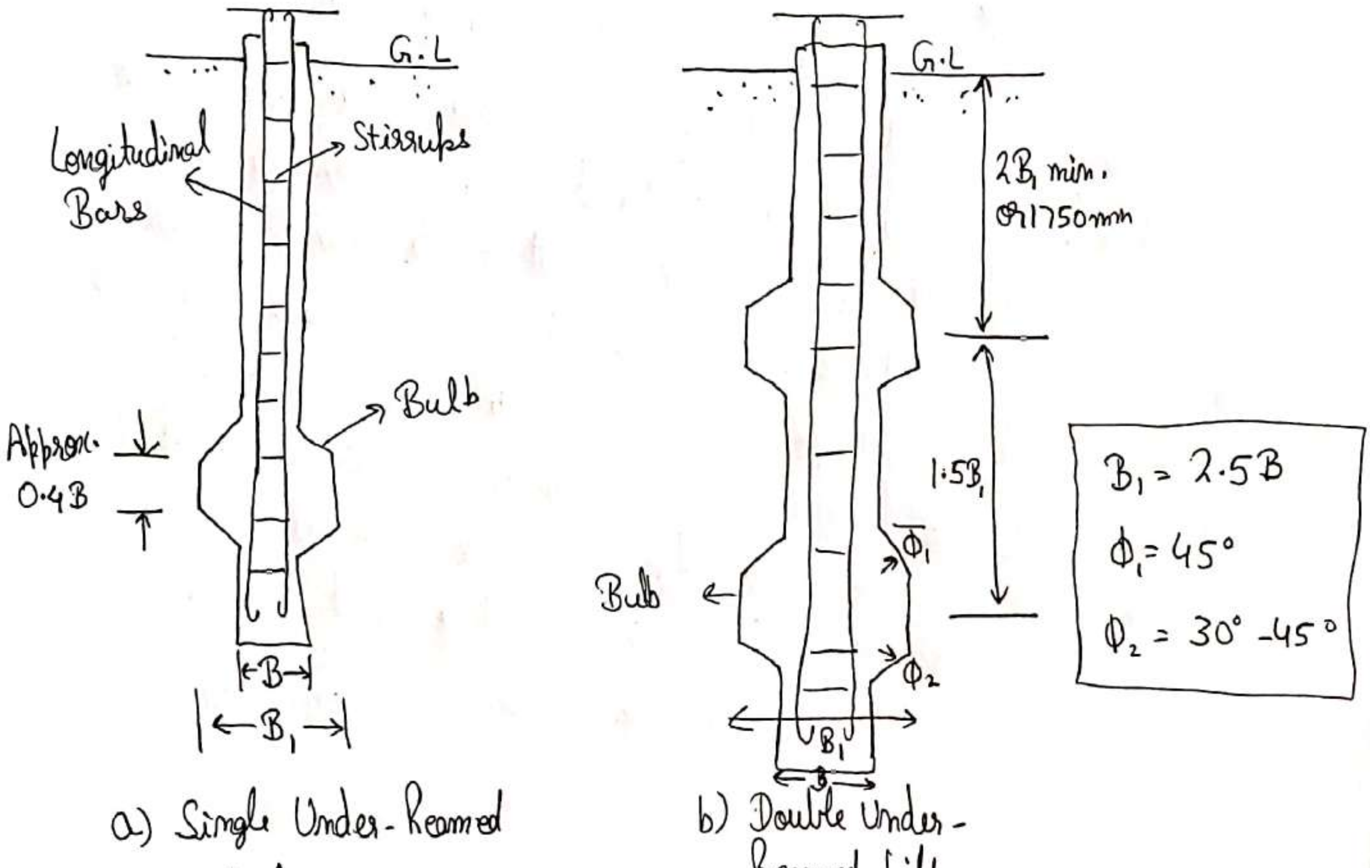
b) Flexible Structures: The structures are made flexible so that they change shape depending upon heave.

c) Isolating Foundations: Deep foundations such as drilled piers & under-reamed piles are constructed to isolate the foundation from swelling effect of soil.

The method of isolating foundation is commonly used.

UNDER-REAMED PILE:

- The under reamed piles are developed by CBRI, Roorkee and are commonly used in India for foundation in expansive soil.
- Under-reamed piles are quite suitable for expansive soils.
- Under-reamed piles anchor the structure to a stable soil mass well below unstable soil which is subjected to ground movement because of seasonal changes
- The unstable zone is same as active zone, defined earlier.
- The under-reamed piles are bored, cast-in situ concrete piles with a bulb or underream at its bottom.
- In a double under-reamed pile, there are two bulbs.
- IS: 2911- Part 3 recommends a maximum of two bulbs.



a) Single Under-Reamed pile

b) Double Under-Reamed pile

→ Basically the bulbs provides adequate bearing & anchorage to the piles.

→ Under-~~reed~~ reamed piles should satisfy the bearing capacity & settlement criteria like all other piles. In addition it should satisfy the following criteria:

1) Min. length of the pile in the deposit of expansive soil should be 3 to 5 m below the ground surface.
Top 1.2 m is usually neglected while calculating skin friction.

2) Diameter of Bulb is taken 2 to 3 times diameter of shaft (normally 2.5 times shaft diameter)
Diameter of shaft is 20 to 30 cm.
For heavier loads double bulbs may be used.

3) The vertical spacing between the two ~~bulbs bulbs~~ bulbs should not be less than 1.5 times the bulb diameter for 30 cm diameter piles. For large diameter piles its 1.25 times the bulb diameter.
The spacing between bulbs is usually 1.5 m to 3 m.

4) Minimum horizontal spacing of piles should be 2 times the bulb diameter. The max. spacing should not exceed 2.5 m to avoid pile cap problems.

5) Depth of top most bulb from ground surface should be at least 2 times bulb diameter. This depth should not be less than 1.75 m.

6) Piles are connected at their top by a RCC plinth beam
→ There should be air gap of about 8 cm between lower surface of plinth beam & ground surface; to prevent swelling of soil.

Load Carrying Capacity of Under-Reamed Pile :

Load Carrying Capacity or ultimate load and safe load for under-reamed pile can be determined by static analysis.

→ The ultimate load for a single bulb :

$$Q_u = Q_p + Q_s$$

$$Q_u = \left[q_{sh} A_{sh} + q_b (A_b - A_{sh})\right] + f A_{sh}$$

q_b = bearing capacity of soil at under reamed section

q_{sh} = bearing capacity of soil at bulb

A_b = Cross sectional area of bulb ($= \pi/4 B_1^2$)

A_{sh} = Cross sectional area of shaft ($= \pi/4 B^2$)

f = unit skin friction (adhesion) on shaft above and below bulb

A_s = surface area of shaft of pile above & below bulb

Taking $q_b = 9C$; i.e $N_c = 9.0$

$$Q_u = \left[\frac{\pi}{4} B^2 (9C) + \frac{\pi}{4}(B_1^2 - B^2)(9C')\right] + \alpha c_a A_s$$

C = unit cohesion at base

C' = unit cohesion at Bulb

c_a = avg. cohesion on shaft (average Cohesion)

α = adhesion factor.

$\alpha = 1.0, 0.7, 0.4, 0.3$ respectively for soft, medium, stiff & very stiff clays.

B = Diameter of shaft

B_1 = Diameter of Bulb

Note : Uplift force on pile is not considered separately, but the specifications given above are such that the under-reamed pile has an adequate resistance against uplift.

Double under-reamed pile :

$$Q_u = q_{sh} A_{sh} + q_b (A_b - A_{sh}) + f A_s + \bar{f} \bar{A}_{sb}$$

$\bar{A}_{sb}$ = Surface area of cylinder circumscribing the bulbs. Length of Cylinder is equal to distance b/w the centres of bulbs.

$\bar{f}$ = Unit skin friction between soil to soil along cylindrical surface A_{sb}.

$$Q_u = \frac{\pi}{4} B^2 (9C) + \frac{\pi}{4}(B_1^2 - B^2)(9C') + \alpha C_a A_s + C_a' \bar{A}_{sb}$$

C_a' = avg. unit cohesion on Area $\bar{A}_{sb}$

Q. A single under-reamed pile is installed in soft clay. The centre of under-ream is located at a depth of 15 m from G.S. The diameter of pile shaft & bulb are respectively 1.0 m & 2.5 m. Determine allowable load with F.O.S = 2.5

Undrained Shear Strength ⇒ Take $C_u = 65 + 7D$; D = depth in m ; $\alpha = 1.0$
C_u in kN/m^2

Soln : Taking $C = C' = 65 + 7D$
$= 65 + 7 \times 15 = 170 \; kN/m^2$

$$C_a = \frac{65 + 170}{2} = 117.5 \; kN/m^2$$

$$Q_u = \frac{\pi}{4} B^2 (9C) + \frac{\pi}{4} (B_1^2 - B^2) \times 9C' + \alpha C_a A_s$$

$$= \frac{\pi}{4} (1)^2 (9 \times 170) + \frac{\pi}{4} (2.5^2 - 1^2) \times (9 \times 170)$$

$$+ 1.0 \times 117.5 (\pi \times 1 \times 15)$$

$$= 1201.66 + 6308.71 + 5537.05$$

$$= 13047.43 \text{ kN}$$

$$Q_a = \frac{Q_u}{2.5} = \underline{\underline{5218.97 \text{ kN}}}$$

Q. In the last question, determine the allowable load if there is another bulb of same diameter below the first bulb. The spacing between the centres of bulb is 4m. All other data remains same.

Soln:

$$\text{Now } D = 15 + 4m = 19m$$

$$C = C' = 65 + 7 \times 19 = 198 \, kN/m^2$$

$$C_a = \frac{65 + 198}{2} = 131.5 \, kN/m^2$$

$$A_{sb} = \frac{\pi}{4}(2.5)^2 \times 4 = 19.63 \, m^2$$

$$C_a' = 65 + 7 \times 17 = 184 \, kN/m^2$$

$$Q_u = \frac{\pi}{4} B^2 (9C) + \frac{\pi}{4}(B_1^2 - B^2)(9C') + \alpha \, C_a A_s + C_a' A_{sb}$$

$$= \frac{\pi}{4} \times 1^2 \times 9 \times 198 + \frac{\pi}{4}(2.5^2 - 1^2)(9 \times 198)$$

$$+ 1.0 \times 131.5 (\pi \times 1.0 \times 15) + 184\left(\frac{\pi}{4} \times 2.5^2 \times 4\right)$$

$$= 1399.58 + 7347.79 + 6196.79 + 3612.83$$

$$Q_u = 18556.99 \, kN$$

$$Q_a = \frac{18556.99}{2.5} = 7422.796 \, kN$$

C_a' = Average Unit cohesion on area A_{sb}