FOUNDATIONS ON EXPANSIVE SOILS

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Abstract—**Analysis and assessment of expansive soils is of utmost importance while founding the structures, as these soils undergo large volumetric changes even due to small fluctuations in water content. The volumetric changes are very large in magnitude and they are responsible for distress of structures. The amount of damage caused by expansive soils is alarming. Estimated average annual loss in the world, attributed to expansive soil movement is approximately 1, 05,988 millions of rupees, which exceeds the combined average of annual damages from floods, hurricanes, earthquakes and tornados. [1] In this paper various types of damages caused by expansive soils are given.**

Thorough understanding of engineering properties of soils are essential not only for using current methods in the design of earth structures, but also to provide a key to further progress in the field of geotechnical engineering. According to the characteristics and properties of swelling soils, various important techniques, that have to be adopted, while constructing a foundation on expansive soils are discussed in the present paper.

Keywords— expansive; swelling; CNS; MAT foundation

I. INTRODUCTION

Soil engineers did not recognize the problem of expansive soils until 1930. The increasingly extensive use of concrete slab on ground construction after 1940 has further increased the damage to the structure caused by expansive soils. Potentially expansive soils can be found almost anywhere in the world. The countries in which expansive soils have been reported as follows: Argentina, Cuba, India, Spain, Australia, Ethiopia, Ghana, South Africa, Burma, Israel, Mexico, Turkey, Canada, Iran, Rhodesia and U.S.A. In India, the expansive soil is called Black Cotton Soil, which covers 3, 00,000 sq.km widely. [2]

II. BEHAVIOUR & DAMAGES OF EXPANSIVE SOILS

Expansive soils are having inherent property of shrinking when it is dried and swelling when water is absorbed. When water is absorbed by a clayey soil which had shrunk by evaporation of pore water, the compression forces between soil particles reduces considerably and elastic expansion occurs and this cause swelling.

Following damages may be caused by expansive soils:

- Horizontal cracks in interior corner of main walls due to sinking of foundation.
- Diagonal cracks in exterior arched walls supported by piers and from footings because of swelling and shrinkage.
- Vertical cracks in the wall bottoms occur due to the lateral moments.
- The hearting of the earthen dam made of clay core exhibits even a small swelling pressure, due to change in water content may initiate shear cracks and these may cause instability to earthen dam.
- When the side slopes at the canal are subjected to change in water content, these slopes are likely to get damaged if they are made up of the expansive soils.
- The roads that pass through expansive sub grade are subjected to heaving and settlement of treacherous soils. No full proof solution yet obtained and a major research effort in India has been directed to find a solution to the roads passing through black cotton soil areas.[3]

III. INFLUENCING PROPERTIES

FIG 1 VERTICAL & DIAGONAL CRACKS

The important factor which influences the expansive soil is swelling pressure. It indicates the capacity of the soil. The following table gives the swelling potential of soil as low, medium, high and very high from which we can identify the soil as swelling type or not.

TABLE I. SWELLING POTENTIAL

S. No.	Soil Propoerty	LOW	MEDIUM	HIGH	V. HIGH
1.	Liquid limit	<35	35-50	50-70	>70
2.	Plastic index	<15	10-35	20-55	>55
3.	Shrinkage limit	>18	8-14	6-12	<10
4.	Colloidal content	<12	12-27	18-38	>27
5.	(< 1 micron	<20	20-30	30-60	>60
6.	fraction)	<20	20-35	25-50	>50
7.	Shrinkage index	<20	20-40	40-90	>90
	Free swell index				
	Clay content				
	(2 micron clay %)				

IV. METHODS OF FOUNDATION PRACTICES

The following are the important methods to adopt, while constructing foundations on expansive soils.

(1) Footings with special cushions
(2) CNS – MSM Technologies
(3) Granular pile anchor
(4) Strip footing
(5) Stiffened mat foundation
(6) Chemical stabilization
(7) Moisture control

(1) FOOTINGS WITH SPECIAL CUSHIONS

In this method the excavation is carried out up to a depth of greater than depth of foundation and freely draining soil such as a mixture of sand and gravel, is filled up and compacted up to base level of the foundation. Reinforced concrete footing is constructed at this level and over this brick wall may be constructed. Mixture of sand and gravel is filled up loosely over the footing. A cushion of granular soil below the foundation absorbs the effect of swelling and so its effect on foundation will considerably reduce. [4]

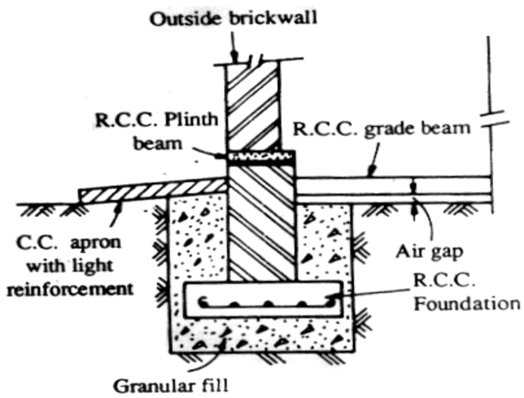

FIG 2 FOOTING WITH SPECIAL CUSHIONS

(2) CNS – MSM Technologies

- CNS Technology: - In this technology we intercept Cohesive Non-Swelling soil layer below the shallow foundations on expansive soils. Thus CNS concept is based on self equilibrating phenomenon with a difference that clay minerals present in CNS are non-expanding such as kaonite, chlorite etc., The thickness of CNS needed to prevent transmission of swelling pressure and heave to the foundation. Thickness depends upon swelling pressure, heave, index properties, density, and compression index of under laying expansive soil and also on the index properties, density, and compression index of CNS material. CNS can be obtained as a natural material or can be made produced by blending two or more materials.
- MSM Technology: - In this technology we intercept the layer of Mechanically Stabilized Mix over CNS intercepting layer, to improve the bearing capacity of the system. Normally MSM consists of graded aggregate, sand and fines with more plasticity, similar to that allowed in water bond macadam mix if possible better compaction may be adopted.

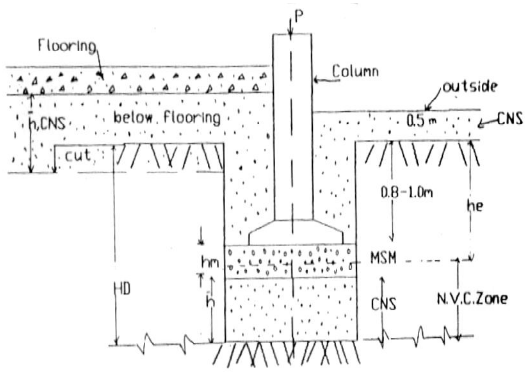

FIG 3 SHALLOW FOUNDATION WITH CNS & MSM INTERCEPTING LAYERS

(2) GRANULAR PILE_ANCHOR METHOD

Granular Anchor pile is one which the foundation is anchored at the bottom of Granular pile, to a mild steel plate through a central mild steel rod. This serves to hold the particulate granular medium and prevents the Granular pile from being sweared away by the swelling soil and thus instrumental in mobilizing frictional resistance to uplift force on the foundation. [5] So the uplift force caused on the foundation is resisted by

(i) Weight of the Granular _ anchor pile

(ii) Frictional resistance along the pile.

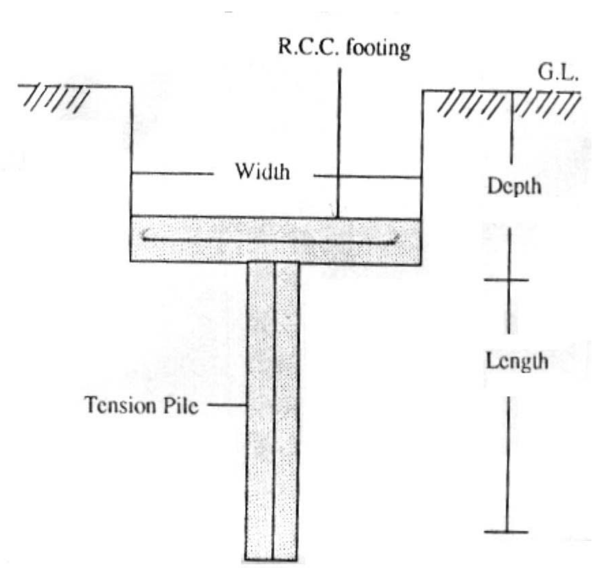

FIG 4 FOOTING WITH A PILE ANCHORAGE

(4) STRIP FOOTING

The design procedure used presently for strip footings does not consider the distortion mode of hogging when perimeter shrinkage causes corner down subsidence. It was realized that conventional strip foundations with sand cushions were inadequate reinforcing the shallow strip footings was then tried and inverted **'T'** foundations is now commonly used. [6] The common types of strip footings that have been used for light buildings are:

(i) Unreinforced with plinth band.
(ii) Nominally reinforced with plinth band.
(iii) Nominally reinforced inverted T.

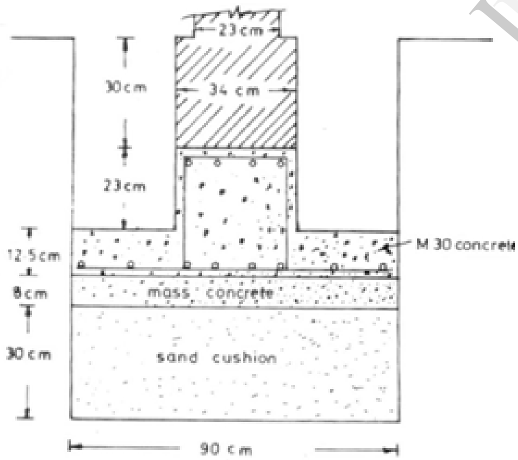

FIG 5 INVERTED TEE STRIP

(5) STIFFEND MAT FOUNDATION

The common method of stiffening consists of a slab cast beams 3 – 4 meters apart both longitudinally & laterally. The rigidity of mat minimise distortion of the superstructure from both horizontal and vertical movements of the foundation soil. Differential heave also reduced when stiffness of slab and superstructure is increased. [7]

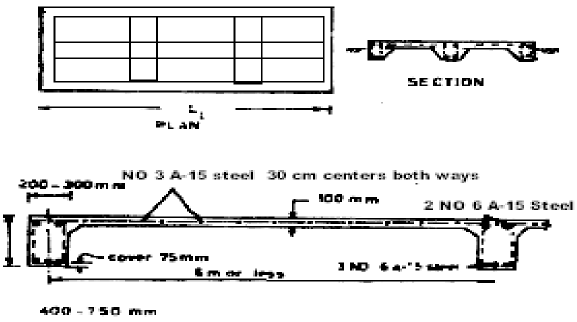

FIG 6 STIFFENED MAT FOUNDATION

(6) MOISTURE CONTROL

If the water is prevented from moving into the soil, under and near the building post construction, swell & shrinkage is reduced. For that moisture barriers are placed around the perimeter of the building. They efficiently reduce the variations in water content and differential heave. [8]

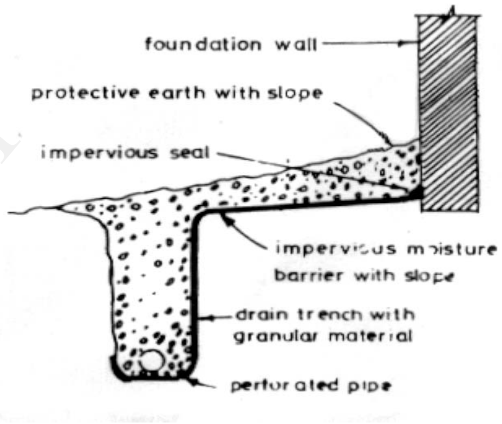

FIG 7 VERTICAL & HORIZONTAL MOISTURE BARRIERS

(7) CHEMICAL STABILIZATION

The soils treated with calcium carbide do not easily pickup water as it is deliquescent and hygroscopic. When sodium chloride is added to the soil crystallization occurs in the pores of the soil and it forms a dense hard-mat. So absorption of moisture is prevented. Phosphoric acid combined with wetting agent can be used for stabilization of expansive soils as it reacts with clay minerals and forms insoluble aluminum phosphate, which serves as moisture proof. Some agents such as sodium silicate, alkyl chloro silanes, siliconate amines, chrome lignin can be used for the water proofing of the soils.

V. CONCLUSIONS

Deeper foundations are much safer than shallow foundations as they offer more frictional resistance. Providing cushions under the foundations can reduce effect of swelling potential on foundation. Granular Pile concept is a new concept which is more effective and economically viable than the existing foundation practices, particularly under light structures. As moisture changes are responsible for the swelling of expansive soils, it is better to provide moisture barriers around the building area to prevent the percolation of moisture. Some chemicals form water proofing agents, when they are mixed with the soil and prevents the access of moisture.

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