A Critical Review on Foundations in Expansive Soils

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Abstract: **In India, the percent of the black cotton soil found in total soil deposition is almost 15%.This type of land is found in many other countries of the world. Black cotton soil is very troublesome and problematic and hazardous due to its characteristics. Because of its high swelling and shrinkage characteristics, the black cotton soil has been a challenge to the Engineers. The black cotton soil is very hard when dry but loses its strength completely when in wet condition. Soil deposits in nature exist in an extremely erratic manner producing there by an infinite variety of possible combination which will affect the strength of the soil and the procedure to make it purposeful. Swelling and shrinkage of expansive soil cause deferential settlement resulting in severe damage to the foundation, buildings, roads, retaining structures and canal linings.**

If the building settles more, then it may become the reason for the failure of a building or a house more particularly in case of load bearing structures. Hence it is necessary in such soils, either to place the foundation at such a depth where the effects of seasonal changes are not important or to make the foundation capable of eliminating the undesirable effects due to relative movement by either providing flexible type of construction or rigid foundations. Adequate load counteraction swelling pressures also provide satisfactory foundation. Thus, resting the foundations of the building on the black cotton soil is a very challenging job. Swelling creates upwards pressure on the structure and shrinkage creates downward pull. It results into cracks in foundations wall and roof. Hence foundation in black cotton soil need special care. This paper will discuss on study about soil type, study about types of foundations, study about suitability of foundations, comparison of foundations.

Keywords: **Expansive soils, Foundations**

I. INTRODUCTION:

Expansive soil is a worldwide problematic soil that causes extensive damage to civil engineering structures. Expansive soil, also called shrink-swell soil, is a very common cause of foundation problems. Foundation soils which are expansive will "heave" and can cause lifting of a building or other structure during periods of high moisture. Conversely during periods of falling soil moisture, expansive soil will "collapse" and can result in building settlement. Either way, damage can be extensive. Expansive soil will also exert pressure on the vertical face of a foundation, basement or retaining wall resulting in lateral movement.

Foundation:

The basic strategies for building on expansive soils: Design a foundation system that is strong and rigid enough to withstand the anticipated soil movement, or isolate the structure from the expansive soils environment. It swells excessively when wet and shrinks excessively when dry resulting terrible cracks in soil without any warning. It has a great affinity to water. This tendency of soil is on account of the presence of fine clay particles. Cracks are formed due to movement of the ground on account of alternate swelling and shrinkage. The cracks thus formed are sometimes 15 to 20 cm wide and 2.5 to 4 m deep.

Objectives:
1. To study about soil type
2. To study about types of foundations
3. To study about suitability of foundations
4. Comparison of foundations.

II. LITERATURE REVIEW:

Research done by Vinayank Kaushal and S.P.Guleria conducted (2015)research on Geotechnical investigation of black cotton soil founded that The mineralogy of expansive soil is dominated by the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa. The various tests like grain size analysis, specific gravity, atterberg's limits, standard proctor compaction, consolidation and direct shear test were conducted on the soil specimens. Further, results were compared with the Indian Standard Code.

An expansive black cotton soil occurs in the arid and semi-arid regions of the world. These soils are residually derived from genesis, basalt, basic volcanic ash, calcareous alluvium and sedimentary rocks containing calcareous shale, lime stone, slates and sand stones. Hot climate and poor drainage conditions are usually associated with the formation of expansive montmorillonite soils.

U.G.Fulzele, V.R.Ghane, D.D.Parkhe (2016)in their research in study on structures in black cotton soils founded that the stuability of different types of foundations base upon the construction and conditions of effecting types of foundations and importance of foundations.

"Department of the Army USA, Technical Manual TM 5-818-7, Foundations in Expansive Soils, 1 September 1983."Has discussed about the importance of foundations in expansive soils.
B.A.Mir(2015) in his research has discussed about challenges associated with expansive soils and remedial measures.

As mentioned, Civil engineering structures experience large scale damage due to heaving accompanied by loss of strength of these soils during rainy seasons and shrinkage during summer. Buildings crack, canal linings slide, beds of canals heave, roads get rutted and retaining structures etc. These deposits are predominant in the states of Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Tamilnadu and Madhya Pradesh.

III. METHODOLOGY:

3.1. Study about the soil:

Field identification of soil type is typically limited to determining basic characteristics of soil like colour, texture, plasticity without much requirement of major equipment. The properties of the black cotton soil may be altered in many ways viz, mechanical thermal, chemical and other means. Therefore, it becomes very important to investigate the physical and engineering properties associated with the black cotton soil especially involved as a construction material and for foundation purposes. Study is done by the following properties.

3.2. Properties of soil:

Physical and geotechnical properties of the soil samples were studied in the laboratory.

Table 1:

S.NO.	PROPERTIES	LIMIT	IS CODE
1.	Liquid Limit	40% to 100%	IS 2720 PART-V (1985)
2.	Plastic limit	20% to 65%	IS 2720 PART-V (1985)
3.	Plasticity Index	20% to 40%	IS 2720 PART-V (1985)
4.	Shrinkage limit	9% to 14%	IS 2720 Part VI(1985)
5.	OMC	20 to 30%	IS 2720 Part VII
6.	MDD	1.8	IS 2720 Part VII
7.	Free Swell Index	>50%	IS 2720 Part XI
8.	Specific Gravity	2.6 to 2.7	IS 2720 Part III
9.	Grain size analysis	Cc = 1.137 Cu = 3.722	IS 2720 PART-IV(1985)

3.3. Types of foundation:

Foundations are of two types, there are Shallow foundations (D≤B) and Deep foundations(D>B).

1. Shallow foundation

1. Individual footing or isolated footing
2. Combined footing
3. Strip foundation
4. Raft or mat foundation

2. Deep Foundation

1. Pile foundation
2. Drilled Shafts or caissons
3. COFFER DAMS

3.4. Suitability of foundations:

Spread Footings:

Spread Footings foundations base is more wider than a typical load bearing wall . These footings are used where the bearing soil layer is within 3 m (10 feet) from the ground surface. The soil bearing capacity must be sufficient to support the weight

of the structure over the base area of the structure. These foundations should not be used on soils where there is any possibility of ground flow of water above bearing layer of soil which may result in Scour.

Combined footing:

Combined footing Supports two columns the two columns are so close to each other that their individual footings would overlap one column is placed right at the property line C.G. of column load and centroid of the footing should coincide. It is provided under following conditions:

When the bearing capacity of soil is less, requiring under more area under individual footing.

Strip footing:

Strip footing is suitable when the soil, through expansive, little swelling pressure. When the soil swells, the sand grains would yield by moving up, thus reliving the swelling pressure. These type of foundations are mostly used for medium loads. Strip foundations can be used for most sub soils, but are most suitable for soil which is of relatively good bearing capacity. They are particularly suited to light structural loadings such as those found in many low-to-medium rise domestic buildings - where mass concrete strip foundations can be used. In other situations, reinforced concrete may be required.

Mat foundation:

Mat Foundations are those which are spread across the entire area of the buildings to support heavy structural loads from column and walls. The use of mat foundation is for columns and walls foundations. This is generally recommended for high rise buildings. For low rise building, it would be very costly. This type of foundation is suitable for expansive soils whose bearing capacity is less for suitability of spread footings and wall footings. This foundation should not be used where the ground water table is above the bearing surface of the soil. Use of foundation in such conditions may lead to scour and liquefaction.

Pile foundation:

Pile Foundation is a type of deep foundation which is used to transfer heavy loads from the structure to a hard rock strata much deep below the ground level. Pile foundations are used to transfer heavy loads of structures through columns to hard soil strata which is much below ground level and where shallow foundations such as spread footings and mat footings cannot be used. This type of foundation is also used to prevent up lift of structure due to lateral loads such as earthquake and wind forces. The pile foundations resist the loads from structure by skin friction and by end bearing. Use of Pile foundations also prevents settlements of foundations.

Under reamed Pile Foundation:

Under reamed piles foundation are one more method of pile foundation. Under reamed piles are bored cast in situ concrete piles having bulk shaped enlargement near base. In this type of foundations, the building or a house is anchored to the ground at the depth where the ground movement due to changes in moisture content is negligible.

Drilled shafts or cassions:

A drilled cassion is largely a compressed member subjected to an axial load at the top and reaction at the bottom. Drilled cassions are generally drilled with the mechanical means. Drilled shafts foundations are not suitable when deep deposits of soft clays and loose water bearing granular soils exists. It is also not suitable where carving formations are difficult to stabilize, i.e. soil made up of boulders and artesian aquifer exit.

The word caissons derived from the French word caisse meaning a box. Box like structure, round or rectangular which sunk from the surface of either land or water to some desired depth. Used for placing foundation under water.

Coffer dam:

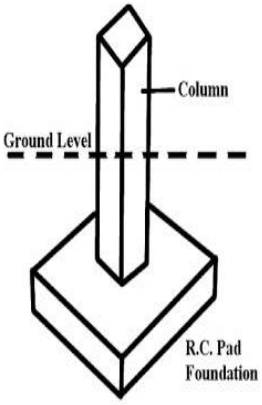
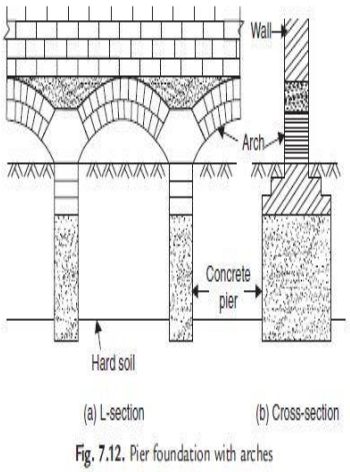
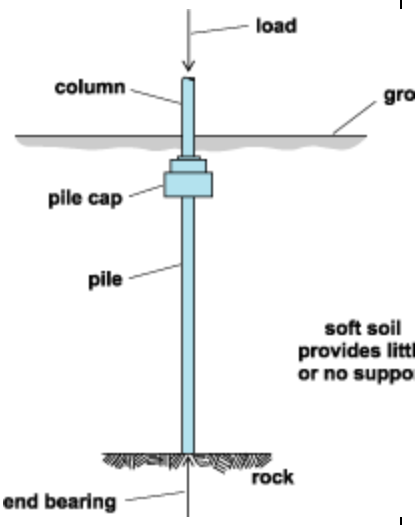
Cofferdam is a temporary structure which is built in a river, lake or dam to remove water from the area and make possible to construct Require in dams, docks and bridge and used where driving of sheet pile is easily possible.

3.5. Comparison of foundation:

Based on the stability of foundation following types of foundations are provided for construction purpose in black cotton or any expansive soil.

Pad foundation
Pier foundation
Under-reamed pile foundation.

Table 2:

S.No.	Pad foundation	Pier foundation	Pile foundation
1.	Diagrammatical reprenstation of pad foundation. 	Diagrammatical reprenstation of pier foundation.  Fig. 7.12. Pier foundation with arches	Diagrammatical representation of pile foundation. 
2.	In pad foundation the loads from the structure are simply distributed to the bearing layer of soil.	Pier foundation consists of cylindrical columns to support and transfer large superimposed loads to firm strata.	In pile foundation, the loads are transferred by means of vertical timber, concrete or steel.
3.	Pad foundation are driven mechanically.	Piers are drilled with the drill machine.	Piles are driven through the overburden soils into the load-bearing strata.
4.	Pad foundations are usually placed to transfer point loads from the column or framed structure and consists of a concrete block or concrete pad.	Pier foundations transfer load through bearing only.	Pile foundations transfer the load through friction (in case of friction piles) or through both friction and bearing (in case of combined end bearing and friction piles).
5.	Pad foundations are of shallow depth.	Pier foundations are of shallow depth.	Pile foundations are of great depth.
6.	These can be selected for high bearing capacity at a shallow depth with no change of differential settlement.	Pier foundation are used where top strata consist of decomposed rock, stiff clays.	Pile Foundation exists where there are no firm strata at reachable depth and the loading is uneven.
7.	Types of pile foundations are plain concrete, reinforced concrete, combined, continuous and pad foundations with ground beam.	The types of pier foundations are masonry or concrete piers and drilled caissons.	The types of pile foundation are end-bearing piles, friction piles, compaction piles, anchor piles, tension or uplift piles, sheet and batter piles etc.
8.	Pad foundations are required for medium size structures.	Pier foundations are required for small loading.	Pile foundation is required to resist greater loads like a load of bridge or flyover.

IV. RESULTS AND DISCUSSION:

Black cotton soil is characterized as medium to high compressibility and plasticity, high shrinkage and swelling properties. Black cotton soil is also referred as expansive soils with this reason; therefore its geotechnical properties are required to be investigated before allowing any construction above it. The mineralogy of this soil is dominated by the presence of montmorillonite which is characterized by large volume change from wet to dry seasons and vice versa. Physical and geotechnical properties of the soil samples were studied in the laboratory. The test conducted were grain size analysis, specific gravity, atterberg's limits, standard

Proctor compaction, consolidation and direct shear test. Results as obtained were compared with the Indian standard code. Empirical models with the help of regression analysis developed in this study can improve the understanding of parameters involved for describing the characteristics of black cotton soil having medium plasticity and its use as construction material in roads and foundation purpose for the site engineers.

Soil properties should be obtained for settlement determination.

The total settlement of a foundation comprises three parts as follows
S = Se+Sc+Ss
where,
S = total settlement
Se = elastic or immediate settlement
Sc = consolidation settlement
Ss = secondary settlement

- Immediate settlement, Se, is that part of the total settlement, S, which is supposed to take place during the application of loading.
Si=(1-μ2)If*qB/Es
q is the intensity of load,
B is the width of the footing,
Es is the young's modulus of the soil,
μ is the poisons ratio and
If is the factor depends on shape of the footing, size of the footing, type of the footing and point of calculation of settlement.

- The consolidation settlement is that part which is due to the expulsion of pore water from the voids and is time-dependent settlement.

$$S_{c(p)-\text{oed}} = \int \frac{\Delta e}{1+e_o} dz = \int m_v \Delta \sigma'_{(1)} dz$$

where
$\Delta\sigma'_{(1)}$ = effective vertical stress increase
m_v = volume coefficient of compressibility

- Secondary settlement normally starts with the completion of the consolidation.

$$S_{c(s)} = C'_\alpha H_c \log(t_2/t_1)$$

Where
C1a=Ca/(1+ep)
ep=void ratio
Hc=Thickness of clay layer

Settlement for the suitable foundations is determined and by this we can select the suitable foundation in black cotton soil.

The most important characteristic of the soil is, when dry, it shrinks and is hard like stone and has very high bearing capacity. But when the soil is moist it expands, becomes very soft and loses bearing capacity. Due to its expansive character, it increases in volume to the extent of 20% to 30% of original volume and exerts pressure. The upward pressure exerted becomes so high that it tends to lift the foundation upwards. This reverse pressure in the foundation causes cracks in the wall above. The cracks are narrow at the bottom and are wider as they go up. The unusual characteristics of the soil make it difficult to construct foundation in such soil. Thus it study about types and suitability of foundations in expansive soils and comparison of foundations is required.

V. CONCLUSION:

1. Due to peculiar characteristics of Black Cotton Soil, it forms a very poor foundation material for construction. The black cotton soils also possess low strength and undergo excessive volume changes, making their use in constructions very difficult. Hence it becomes to determine the laboratory tests reports to determine soil type before going to construction and the results where compared with Indian Standards Code.

2. The foundation should be constructed or taken to a depth to protect the structure against structural damage by swelling or shrinking soil. Furthermore, the foundation should transmit the loads the ground without causing settlements and other moments that are large enough to impair or damage the structure or reduce its overall usefulness, and hence the study about the types of foundations is required.

3. It is advisable to know the suitability of each type of foundations before selection of any construction Project.
4. Final selection of foundation should be done based on comparison of foundations.

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