STUDY OF STRUCTURES IN BLACK COTTON SOIL

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Abstract— In Civil Engineering aspects Black Cotton Soil is giving hazardous Problems to engineers. With the rapid development in Soil improvement, construction technique and social need various constructions of structure are taking place. The possibility of good construction sites to build structures on Black Cotton Soils is difficult due to their poor strength and deformation characteristics. This study discussed Black Cotton Soil problems their remedies, precaution taken and covers the guidelines to construct the structure in Black Cotton Soil.

Index Terms— Montmorinolite kaolinite, hydrated cations, Black Cotton Soil, Liquid Limit, Plastic Limit, Free swell index, Specific gravity, C.B.R,

I. INTRODUCTION

In India deposition of Black cotton soil is very good and prosperous for farmers. All the basic amenities of life i.e. food, clothes and house have been fulfilled by the soil, without soil It is just next to impossible to think about life on the earth. But on the other side in Civil Engineering aspects 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 depostis in nature exist in a extremely erratic manner producing there by a infinite variety of possible combination which will affect the strength of the soil and the procedure to make it purposeful. So in the particular case of Black cotton soil with wide range of challenges associated with the construction.

All the Black cotton soils are not expansive soils and all the expansive soil are not Black in colour. These soils possessed high strength in summer and decreased rapidly in winter. Swelling and shrinkage of expansive soil cause deferential settlement resulting in severe damage to the foundation, buildings, roads, retaining structures and canal linings.

This study deals with the formation of black cotton soil, Characteristics of black cotton soil, obstacles to construct structures in Black cotton soil, causes of structures failed in Black cotton soil, Remedial measures to construct the structures in Black cotton soils.

II. FORMATION OF BLACK COTTON SOIL:

2.1 Due to disintegration of a black lava i.e. Basalt Rock by Sun, wind and rain formation of Black cotton soil occurs, It is importnat to discuss the characteristics of black cotton soil because of which the troubles comes in the construction of different projects, mainly in Maharashtra, Gujrat, South Uttar Pradesh, East area of Madhya Pradesh and some of the part of Andhra pradesh and Karnataka posses the black cotton soil in more area. Which is about 20 % of land area of India? The average depth of this Black cotton soil is 3.7 mtrs. approximately.

2.2 Black cotton soils are made of varying Properties of minerals like Montmorinolite and kaolinite, chemicals like Iron Oxide and Calcium Carbonate and organic matter like humus.

Montmorinolite is a predominant mineral of black cotton soils. The swelling and Shrinkage behavior of black cotton soils originate mainly from this mineral.Clay minerals are hydra silicate of aluminium and magnesium. They are made of sheets of silica and aluminium stacked are above the other forming sheet like structure with expanding lattice. The structure of some aluminium is by magnesium ions and the minerals becomes chemically active. They attract water molecules(dipoles)and various types of hydrated cations to the surface causing the soil to increase the volume. Abundance of calcium in black cotton soils has another feature ,it may be present in the form of saturating ions or as molecules of CaCo3 (kankar). Treatment with the Sodium about base exchange and the soils becomes softer and more plastic. Organic matter in the form of humus makes these soils more plastic and compressible .The dark colour of the black cotton soils is believed to be either due to humus or titanium oxide.

III. PROPERTIES OF BLACK COTTON SOIL:

3.1 Physical properties

Sr No	Properties	Values.
1	Liquid Limit (L.L.) %	40 – 120 %
2	Plastic Limit (P.L.) %	20 – 60 %
3	Optimum water content(OMC) %	20 – 35 %
	Free swell index (DFS) %	40 – 180 %
5	Specific gravity (G)	2.60 – 2.75
6	Swelling pressure	50 – 800 KN/m2
7	C.B.R. (soaked)	1.2 – 4.0
8	Fines (<75 μ)	70 – 100 %
9	2 μ Fraction	20 – 60 %
10	Soil classification IS 1498 – 1970	CH or MH Clay /Silt of High plasticity
11	Procter Density	1350 – 1600 Kg/m3

3.2 Chemical properties-

PH Value> 7 (Alkaline)
Organic Content 0.4 to 2.4 %
CaCo3 1 – 15 %
SiO2 50 – 55 %
SiO2 / Al2O3 3 – 5 %
Montmorrilonite Minerals 30 – 50 %

3.3 General properties-

3.3.1. The swelling and shrinkage behavior of a soil would largely depend upon clay minerals (like Montmorrilonite) present in soil.
3.3.2. Montmorrilonite is predominant mineral of B.C. soils.
3.3.3. Organic matter in the form of humes makes this soil more plastic and compressible.
3.3.4. It swells excessively when wet and shrinks excessively when its dry.
3.3.5. It has great affinity to water.

IV. TESTS FOR BLACK COTTON SOIL:

Before construction at site some properties of BC soil like swelling pressure, swelling index consolidation test and shear strength should be known in laboratory. It helps to ascertain the suitability of soil for civil engineering structures.

4.1 Swelling Pressure:-

Swelling pressure is the pressure which an expansive soil exerts, if the soil is not allowed to swell or volume change of the soil is arrested.
Two methods are used to determine the Swelling pressure.
4.1.1) Consolidometer method in which the volume change of the soil is permited and the corresponding pressure requires to bring back the soil of its original volume is measured.
4.1.2) Constant volume method in which the volume is prevented is measured. The equilibrium swelling is normally reached over a period of 6 to 70 days in general for all expansive soils.

4.2 Free swell Index:

It is the test conducted to measure the degree of expansive range of given soils. The degree of Expansiveness and possible damage to lightly loaded structure may be qualitatively address table given below. The sample is taken in two containers. One containers is filled with water and another is filled with kerosene and it is kept of 24 hrs. for observation. We see the expansive in water with this degree of Expansiveness is determined.

Degree of Expansiveness	DFS, Percent.
Low	less than 20
Moderate	20 to 35
High	35 to 50
Very high	50 and more

4.3 Consolidation Test:

The consolidation test is a laboratory test to study the compressibility of a soil. It consist of a loading device and a cylindrical container called consolidation cell. The consolidometer has arrangements for the application of the desired load increment, Saturation of sample and measure of change in thickness of the sample at every stage of consolidation process.
The ring containing the sample is then placed on the bottom porous stone. Filter paper is kept on the top of the sample and then top porous stone is placed. The loading pad is placed on the top porous stone and then the consolidation cell is kept under the loading unit. The dial gauge reading are noted at the initial petting pressure after primary consolidation etc. These readings are noted by an increment of load. After the consolidation under the final wad increment is cuple,. the load is reduced and swelling is allowed and the readings are noted.
If the consolidation settlement is very high, then that ground may consist of clayey soils which assumed unsuitable for Civil Engineering structure.

4.4 Triaxial Test:

The test conducted to find the Shear parameters of the soil i.e. Cohesion (c) and Shear resistance (Φ). For these type of soils consolidated – undrained test is dare. In this test the sample is enclosed in a rubber membrance, which is solid over the specimen with the help of a membrane stretcher. The specimen is placed in a triaxial cell and filled with water by connecting it to the pressure supply. The drainage valve is closed.
The sample is sheared by applying deviator stage by the loading machine. The specimen is recovered after removing the loading cap and the top porous stone. From the observations noted the mohr -circle is drawn. It gives the mohr's columb failure line. We can get the engineering behavior of expansive soil.

V. TYPES OF FOUNDATION IN BLACK COTTON SOIL:

There are mainly 3 types of structures like Buildings, Roads and canals mostly construct in Black cotton soil.

As far as the black cotton soil concern for single storey or double storeys buildings according to bearing capacity of soil, soil stabilization will be useful but the multi storeys, high rise building or super high rise buildings the mat foundation or pile foundation are useful. For the structures like Road & Canals in B C. soils the challenges are almost similar. There are four types of foundation (1). spread Footings and wall Footings, (2) Mat foundations, (3) Pile foundations and (4) Drilled shafts foundations and uses of these foundations depends on the soil condition and loads from the structures.

5.1 Spread Footings and wall footings:-

Spread Footings foundations base is more wider than a typical load bearing wall . The weight from the building structure spread over more area and provides better stability because of the wider base of this footing type. Spread footings and wall footings are generally used for individual columns, walls and bridge piers. 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.

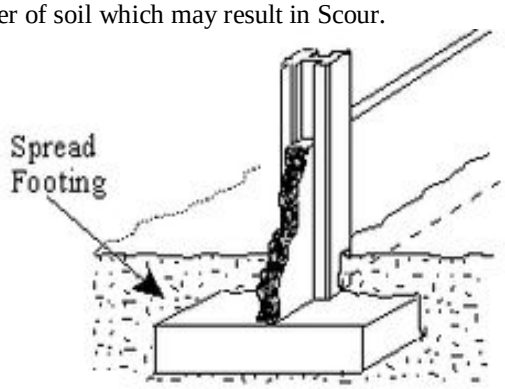

Fig. 1 Spread Fotting

5.2 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. Where the load from structure on columns and walls are very high and to prevent differential settlement of individual footings, thus designed as a single mat of all the load bearing elements of the structure. This type of foundation is suitable for expansive soils whose bearing capacity is less for suitability of spread footings and wall footings. This type of Footing is economical generally when one half area of the structure is covered with individual footings and wall footings is provided. 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.

Fig. 2 Mat Foundation.

5.3 Pile Foundations:

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. Generally this type of foundations is used for soils where soil conditions near the ground surface are not suitable for heavy loads. The depth of hard rock strata may be 5 m to 50 m (15 feet to 150 feet) deep from the ground surface. The pile foundations resist the loads from structure by skin friction and by end bearing. Use of Pile foundations also prevents settlements of foundations.

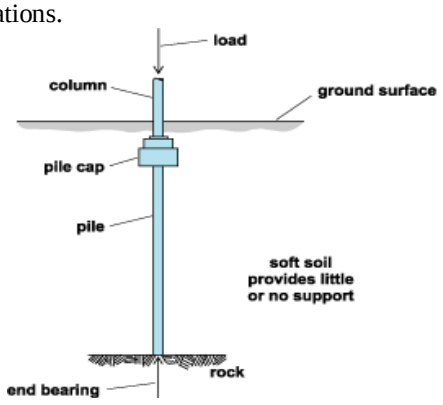

Fig. 3 Pile Foundation.

5.3.1 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.

These piles are commonly recommended for providing safe and economical foundation in expansive soils such as black cotton soil, filled up ground and other type of soils having poor bearing capacity. In these type of foundation the structure is anchored to the ground at a depth where ground movement due to changes in moisture content negligible. A pile having one bulk is known as single under reamed pile. It is seen that the load bearing capacity of the pile can be increased by increasing the number of bulk at the base. In such a case the pile is named as multi under reamed Pile. The increase in the bearing capacity of the pile can also be achieved by increasing the diameter and the length of the pile.

The method of construction of under reamed pile is very simple. The holes for casting piles in the ground may be bored by using hand augers. The auger should be rotate slowly with a constant downward pressure and should be taken out when it is just full. For deeper boring suitable extension rods are attached to the auger. In projects where the magnitude of pilling work is more, electric power which may be used for expediting boring operation. After boring is carried out the required depth the base of the bore hole is enlarged in the form of a bulb near the base by use of a tool known as under reamer. In case of double or multi under reamed piles, after the boring and under reaming of the bulk the boring is extended further for second under reaming and so on. In sites where the sub soil water table is high, bentonite slurry is used to retain the sides of the bore hole against collapse.

After the pile hoes are ready for concreting, reinforcement cage are lowered in the holes and concrete is poured by use of a funnel. The piles should be cast at least 200 to 400 mm above the cut off level. Later on when the concrete is hardened the extra length of each pile is broken and the pile top is brought to the desired level. Following diagram shows under reamed pile foundation.

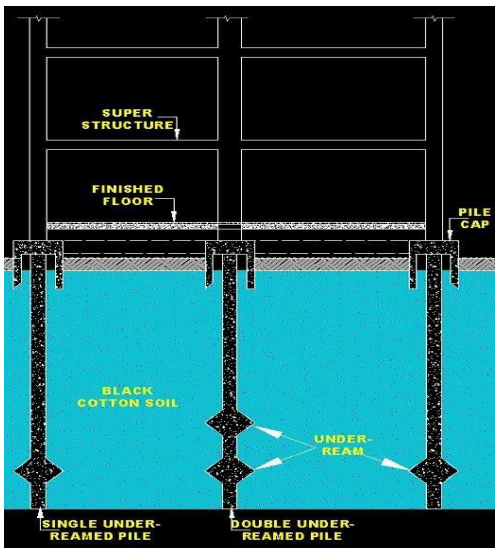

Fig. 4 Under reamed pile foundation.

5.4 Drilled Shafts:

Drilled shafts is also a type of deep foundation and has action similar to Pile foundations. But are high capacity cast in situ foundations. It is also called as caissons. It resists loads from structure through shaft resistance, toe resistance or combination of both of them. The construction of drilled or caissons are done using an auger. This foundation can transfer column loads larger than Pile foundations. It is used where depth of hard strata below ground level is (location) within 10 m to 100 m (25 feet to 300 feet). This foundation is not suitable when deep deposists of soft clays and loose water bearing granular soils exists. It is also not suitable for soils where caving formations are difficult to stabilize, soils made up of boulders and artesian aquifer exists.

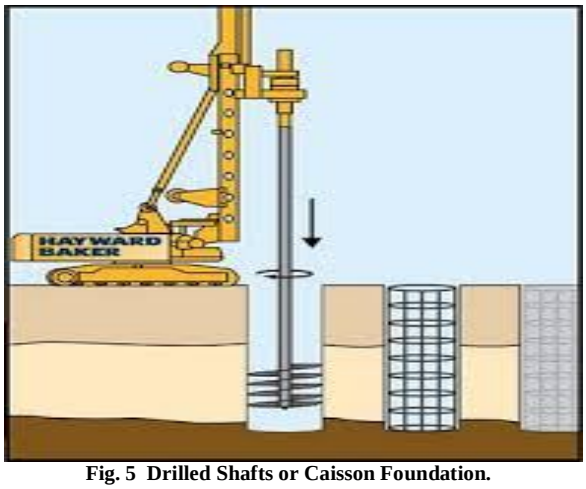

Fig. 5 Drilled Shafts or Caisson Foundation.

VI. SAFET Y PRECAUTIONS OF FOUNDATIONS IN BLACK COTTON SOIL

The property of volumetric changes with the change of atmospheric conditions makes black cotton soil dangerous to founded buildings. 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 an account of the Pressure 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 .To avoid this following precautions are generally adopted while building structures on black cotton soil.

6.1) To limit the load on the soil to 5.5 tonnes/ sqr.m.

If water is liable to find an access to the foundations, the limit of loading should be restricted to (4900 kg/sqr.m.) 4.9 Tonnes / sqr.m

6.2) To take the Foundation to such depth where the cracks cease to extend. The minimum depth of foundation should be at least 1.5 m.

6.3) To provide reinforced concrete ties or bonds all around the main walls of the building. The R.C.C. ties or bonds which may be 10 cm to 15 cm thick should be placed at plinth level, lintel level and eaves

level. In case of Flat roof, R.C.C. slab it self acts as a tie and as such no extra bond needed to be provide near the roof in such cases.

6.4) If the depth of the black cotton soil at a given site is only 1 to 1.5 m the entire black cotton soil above the hard bed may be completely removed and the foundation may be laid on the hard bed below.

6.5) The swelling of soil in direct contact with the foundation material causes maximum damage. Hence it is necessary to prevent the direct contact of black cotton soil with masonary work below ground level. These can be achieved by making wides trenches for foundations and filling spaces on the either side of the foundation masonry with sand or moorum.

6.6) The bed of foundation trench should be made firm hard by ramming it well, On the rammed bed a 30 cm layer of a good hard moorum should be spread in layers of 15 cm, each layer being well watered and rammed before laying the next layer. On this layer either stone or sand bed should be provided to the desire height to place the foundation concrete bed block upon it.

6.7) In case of ordinary buildings the foundations should be taken at least 30 cm deeper than the depth where the crack stop.

6.8) In important structures raft foundation should be provided so as to float the building on the bed below the depth, quite independent of the surrounding soil.

6.9) For less important structures like compound walls etc. the foundation should be preferably taken at least 15 cm below the depth at which cracks in soil cease to occur.

6.10) Construction in black cotton soil should be undertaken during dry season.

6.11) The width of trench for main walls or load bearing walls of a building should be dug 40 cm wider than the width of foundation. This is necessary to ensure provision of at least 20 cm wide layer of coarse sand on either side of foundation masonry thereby separating the sub structure from having direct contact with black cotton soil.

In case of compound wall width of sand layer on either side of foundation masonry could be 15 cm.

VII. PRECAUTIONS FOR ROAD IN BLACK COTTON AREA:

7.1) Maximum dry density should not be less than 1.44 gm/cm3 for the filling of soil.

7.2) There should be 6 Passes of 8 to 10 Tonnes roller on the soil before filling the soil. In addition to this where the filling of soil is done for important road 60 cm black cotton soil should be removed and compaction should be done with good soil.

7.3) Filling soil side slope should not be more than 2: 1 but where the water percolation is more the slope should be 3:1

7.4) According to the C.B.R. value of soil the Pavement thickness should be decided.

7.5) In the water logging area deep nali should be dug and according to the need lateral drains should be provided.

7.6) Proper drains should be provided to roads so the water should not be logged on the roads or road side.

7.7) The road side drains should be cleaned before the mansoon to avoide the water logging which causes the failure.

CONCLUSIONS / RECOMMENDATIONS

8.1) Black cotton soils are inorganic clays and form a major soil group in India.

8.2) Since Black cotton soils have high swelling and shrinkage properties, it is found to be most troublesome for engineering considerations.

8.3) The black cotton soil is very hard when dry. But looses its strength when in wet condition.

8.4) The swelling and shrinkage behavior of black cotton soils originate mainly from montmorinolite and illite clay minerals.

8.5) Pile foundations and Drilled shafts always depend on the soil condition and load of the structure.

8.6) Mat foundation should not be used where the ground water table is above the bearing surface of soil.

8.7) Engineering properties of Black cotton soil should be check before construction of the site.

8.8) For short strata of Black cotton soil it is better to remove all Black cotton soil completely and foundation may be laid on the hard bed.

8.9) Care should be taken to prevent the direct contact of Black cotton soil with masonary work below ground level.

8.10) Construction in Black Cotton soil should be undertaken in dry season.

8.11) It is advisable to know the stability of each type of foundations before selection of any construction Project.

8.12) Due to water scarcity all the canals should be converted in to pipe canals Hence the water losses which is 60 to 70 % in canal will be avoided

8.13) Considering huge population of India, for food grain and vegetables land is very precious for production. So the permission should be given to construct the multi storied building in rural area, .with water harvesting and solar energy.

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