Compaction and Strength Characteristics of Black Cotton Soil In The Presence of Hydroxides

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Abstract— The environment is being polluted by humans and in doing so not only air and water but soil is also being contaminated. But increased industrialization, high population growth and uncontrolled exploration of natural resources have resulted in environmental degradation by polluting soil. Geotechnical engineer must concern about the impact of soil due to soil contamination. The industrial foundations and their structure are exposed to a hazardous environment hence their behavior must be considered in the design and execution. Soil pollution results in modification of the physical, chemical and biological properties of soil. There are number of mechanisms through which individual contaminants affect the engineering properties. Including chemical reactions such as dissolution or precipitation and physic-chemical phenomena, affecting intermolecular forces of water solutions. In this paper the behavior of black cotton soil is investigated, essentially containing montomorillonites as principal clay minerals in the presence of inorganic chemical fluids such as pore fluids.
Key words: Expansive, plasticity, distressed, silica fumes, Mine Tailings.

I. INTRODUCTION

Waste generated due to human activities pose a threat to the environment, and it is necessary to protect the environment against the pollution. Industrialization is necessary for socio-economic progress of a country. On the other hand it generates large amounts of solid and liquid waste also. Soils often get contaminated with a variety of chemicals due to improper disposal of waste or inadequate design of waste containment facilities. Soil pollution results in modification of the physical, chemical and biological properties of soil. Understanding the mechanism and effects of soil, water, pollution on the behavior of soil are important, from the point of assessing the changes in the soil properties and to avoid/minimize the failures due to soil contamination.

Leachate is generated in landfill sites by hydrolysis processes and also by water penetration. It is composed of large amounts of both organic and inorganic compounds hugely. Leachate from an improperly constructed landfill results an extensive contamination of soil beneath and adjacent to the dumping area contaminated sites depends on different site specific conditions like-geology and hydrology of the site, climate, type of waste material, type of contamination.

Expansive soils are commonly found in arid and semi aired regions. In India, about 20% of the soil is expansive soils commonly known as black cotton soil such soils contain montomorillite as main clay mineral and they exhibit high swelling and shrinkage with the seasonal moisture fluctuations.

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In this thesis the behaviour of black cotton soils, essentially containing montomorillonite as principal clay mineral and having clay fraction in different proportions is investigated, with specific reference to its compaction and shear strength in the presence of inorganic chemical fluids as pore fluids.

II. LITERATURE REVIEW

Recent studies have shown that several major processes can occur in clay as result contaminants however, the degree to which each of them may affected the geotechnical properties of soil greatly depends on the mineralogy of clay fraction.

According to Olphen when the environment becomes slightly acidic, hydrogen ions (H^+) engage in the exchange process with the cations from the diffuse double layer of clay particles. Due to its superior position in the Hofmeister series H^+ ions would likely replace the commonly found ex changed cations such as Na^+, Ca^{2+}, Al^{3+}, or Fe^{3+}From clay colloid chemistry known that this process would lead to an increase in double-layer thickness, resulting in a greater compressibility of soil. Results of compression tests conducted by Sridharan et al.on bentonite prepared in water with a specific type of ions lend support to this hypothesis. The investigators reported that bentonite "homonized" with ions of smaller valence had a higher compressibility.

The results obtained for the Kawasaki mud, a soil that contains montmorillonite, can be interpreted on the basis of the double-layer theory. It is believed that, in acidic medium, due to high concentration of H^+ ions, the diffused double layer becomes suppressed, causing a decreased in voids ratio.

The data from most of the sites considered were assembled including the results for shallow marine deposits, it was seen that the various sedimentation curves all lie in a well defined continuous band when plotted on a graph of I_{vo} versus log $_{vo}$. A regression line was fitted to the data and was called the sedimentation compression line (SCL). Further it was shown that the sedimentation compression curves for most, not all, natural clays lie well above the corresponding intrinsic compression curves. The location of the natural sedimentation curve relative to the intrinsic one was shown to depend on depositional conditions and on post depositional processes such as leaching. Further for over consolidated natural clays, it was shown, to provide a useful means of assessing the degree of over consolidation.

Sambhandharaksa and Moh studied the effect of sodium chloride (NaCl) on the thixotropic characteristics of clay soil. They reported an increase in the dry unit weight as well as the thioxotropic strength of the treated clay with higher NaCl content. Water-soluble calcium chloride (CaCl2) has been used simultaneously with cement to stabilize clay soils containing appreciable amounts of organic matter. It was also indicated that the salt generally satisfies the absorption capacity of the organic matter for calcium ions, thus permitting the calcium from OPC to complete its reaction with the other components in the normal way.

The variation in the Liquid limit and plastic limit of black cotton soils with the chemical solutions having chloride, carbonate and sulphate and hydroxide has been investigated and reported by V.G Mutalikdesai. According to him the liquid limit and plastic limit values reduce in the presence of pore fluids having chlorides as anion, irrespective of cation present in the solution. Compression index varies linearly with the liquid limit for all of the pore fluids and soil under consideration.

III. Materials and Methods

A. *Materials Used:*

For the present study, Expansive black cotton soil, Sodium Hydroxide (NaOH), Calcium Hydroxide (CaOH) have been used. Their physical and chemical properties have been determined.

B. *Black Cotton Soil:*

Black Cotton soils are most characteristic of the Deccan Trap (Basalt) region, spread over the north-west Deccan plateau and they cover the plateaus of Maharashtra, Malwa and southern Madhya Pradesh continue eastwards in the south, along the Godavari and Krishna Valleys. Owing to the high proportion of clay Black Cotton soils are Well-known for their ability to retain moisture. They develop thick fissures in the field during hot weather. This soil is viscous and unmanageable to work, unless they are treated without delay. These soils develop under semi-arid conditions specifically in the areas that are covered with basalt. In the southern region of Tamil Nadu, granites and gneisses with iron content also form black cotton soils under the required semi-arid climatic conditions.

In India 20% of surface deposits are covered with expansive soils. The black cotton soil swells when it comes in contact with water and shrinks on drying. These soils are characterized by inherent swelling and shrinkage characteristics due to presence of Montmorillonite clay mineral, which exhibits volume change behaviour under changes of moisture content. Due to characterizes swelling and shrinkage behaviour of expansive soils leads to the severe damages to the Civil Engineering structures such as cracking in buildings or total distractions of the structure, foundations and pavements.

For the present investigation the Black Cotton soil was obtained from Bhalki, Bidar Dist. Karnataka State, India. It is collected from an open excavation at a depth of 0.6 m below the natural ground surface. The soil was air dried and pulverized after separating the pebbles. This pulverized soil passed through 425 micron IS sieve has been used for this investigation.

The physical properties and chemical composition of oven dried Black Cotton soil was analyzed as per the standard methods and are presented in *table 1*.

Properties		**BC Soil**
Colour		Black
Specific Gravity		2.70
Grain Size Distribution		
Fine Sand Fraction	(%)	7.00
Silt Size	(%)	17.0
Clay Size	(%)	76.0
Atterberg's Limit		
Liquid Limit	(%)	59
Plastic Limit	(%)	29.75
Plasticity Limit	(%)	29.25
Shrinkage Limit	(%)	8.2
Unified Classification		MH-OH
Compaction Characteristics		
MDD	(kN/m^3)	16.28
OMC	(%)	27.5

Table 1: Physical Properties of Black Cotton Soil

IV. Experimental programme

The black cotton soil from Bhalki in Bidar district as was used in this study. Manual labour method was used for the procurement of the soil. Top vegetation and dry soil crust was removed to a depth of 20cm with crow bars. Bigger size lumps were down with pick axes and rammers. The soil was pulverized with wooden mallet to break the lumps and then air dried. Further before usage, this was oven dried for 24 hours at a temperature of 110˚C.

The soil falls under CH category i.e. clay of high compressibility as per I.S classification system. The fine fraction has high liquid limit and plasticity index. The properties of black cotton soil procured from Bhalki were tested for various properties. They contain montmorillonite as the principal clay mineral. The black cotton soils found in different regions show a wide range in their clay contents and hence the activity. Their liquid limit is found to vary from 50% to 120% in different regions of Deccan plateau. Their behaviour, especially in the presence of different contaminant is not thoroughly investigated. Therefore the present investigation focuses on the behaviour of black cotton soils when they come in contact with different contaminants.

V. Results

Experimental results have clearly shown that the contaminants influence on the compaction and the unconfined compressive strength of soil. The relation between OMC with the soaking period and dry density with the soaking period for two hydroxide compounds (NaOH, $Ca(OH)_2$) with two concentrations of 0.1N and 1.0N are plotted in Fig.5.1 to 5.9. The addition of chemicals to the soil decreases the optimum moisture content and increases the dry density. Similar results were reported by Frydam et al and Wood [6]. They attributed this behaviour to the fact that at low moisture content the soil structure before compaction tends to change from edge-to-face type of flocculation to face-to face flocculation with the increase in concentration. Consequently under the influence of dynamic compaction, the clay particles become more oriented and the compacted dry unit weight increases with the increase in the concentration of the pore fluid. The decrease in the optimum moisture content as the concentration of the pore fluid increased may be explained due to the higher the face-to-face flocculation the lower is the amount of water required for lubrication.

The unconfined compressive strength with the soaking period for two hydroxide compounds (NaOH, $Ca(OH)_2$) with two concentrations of 0.1N and 1.0N are plotted in Fig.4.2.1 to 4.2.6. From the experimental study it can be seen that the increased in the concentration of the contaminants leads to an increase in the unconfined compressive strength. The addition of chemical to the soil causes an increase in the ion concentration of the pore water with reduction in the double layer thickness and this, causes a reduction in the antiparticles repulsion and an increase in the attraction, resulting in the increase in cohesion. The strength of the cohesive soil also depends on the compaction effort. The unconfined compressive strength increase with the increase in the compaction effort. The results indicate that maximum strength is found in the soil treated with calcium carbonate.

A. Effect Of Contaminants On Compaction Characteristics:

The effect of period of soaking on OMC and dry density with the soaking period for different contaminants (NaOH, Ca(OH)2) for the two concentrations (0.1N,1.0N) are plotted in from fig 5.1 to fig 5.6.

NaOH

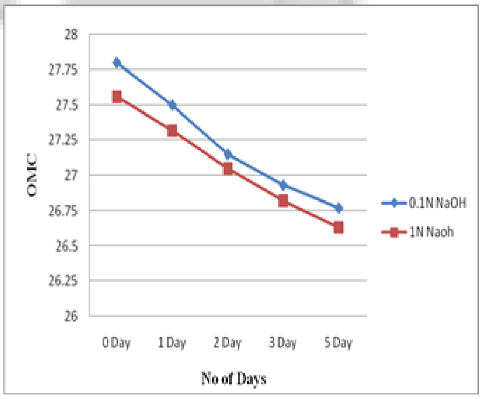

Fig.5.1: OMC vs. Number of days of pore fluid of NaOH

Fig.1.1shows the plot of OMC verses the soaking period for soil with the pore fluid of NaOH.

From the graph it is shown that as the soaking period of pore fluid increases the optimum moisture content of soil decreases. And also as the increases in the concentration of pore fluid, decreases the optimum moisture content.

$Ca(OH)_2$

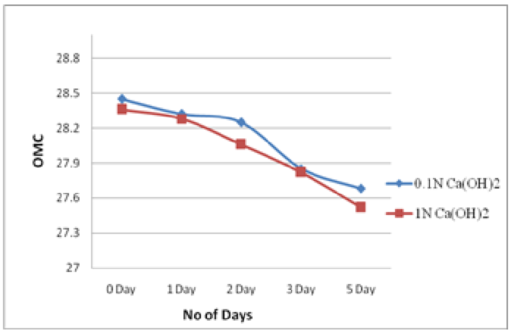

Fig.5.2: OMC vs. Number of days of pore fluid of $Ca(OH)_2$

Fig.5.2 shows the plot of OMC verses the soaking period for soil with the pore fluid of $Ca(OH)_2$.

From the graph it is shown that the optimum moisture content of soil decreases marginally in the first two days, after that the optimum moisture content decreases rapidly as the soaking period increases.

Hydroxides

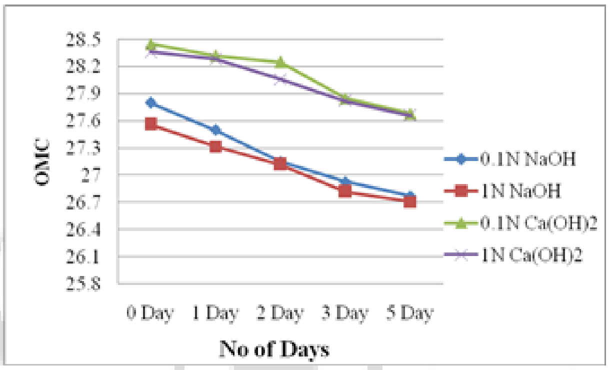

Fig.5.3: OMC vs. Number of days of both concentrations of pore fluids of Hydroxides

Fig.5.3 shows the plot of OMC verses soaking period for soil with pore fluids of NaOH and $Ca(OH)_2$ in both concentrations with the increase in the contact period the optimum moisture content decreases. For lower concentration of the pore fluid decreases in optimum moisture content is marginal during the initial period whereas for higher concentration of pore fluid decreases in optimum moisture content appears to be substantial.

This behaviour is due to at low concentration the cation of pore fluid available in the pore solution is low and it gradually increases with the increases in the concentration. Thus the activity of the clay reduces gradually with the increase the concentration of pore fluid reaches a stable state when enough cations are available for satisfy the negative charges on the surface of clay particles.

$Ca(OH)_2$

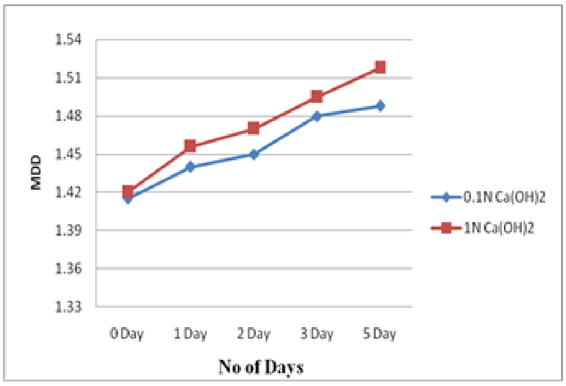

Fig.5.4: MDD vs. Number of days of pore fluid of $Ca(OH)_2$

Fig.5.4 shows the plot of MDD verses the soaking period for soil with pore fluid of $Ca(OH)_2$. With the increase in the contact period the MDD increases for both the concentrations of pore fluid of $Ca(OH)_2$. For lower concentration of pore fluid increases in MDD is marginal whereas for higher concentration of pore fluid, increases in MDD sharply.

NaOH

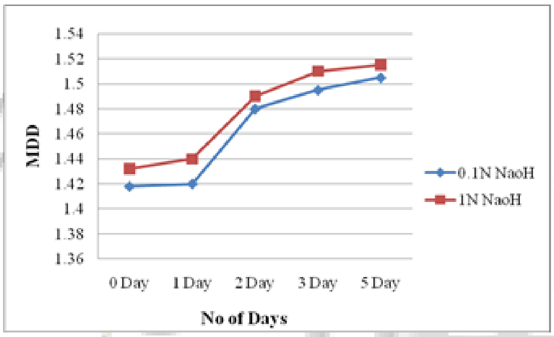

Fig5.5: MDD vs. Number of days of pore fluid of NaoH

Fig.5.5shows the plot of MDD verses the soaking period for soil with pore fluid of NaOH.

From the graph it is shown that the maximum dry density increases with increase in the concentration of the pore fluid. In the first two days that is 0-1 day the increase in the maximum dry density is negligible but after two days it increases sharply for both concentration of pore fluid.

Hydroxides

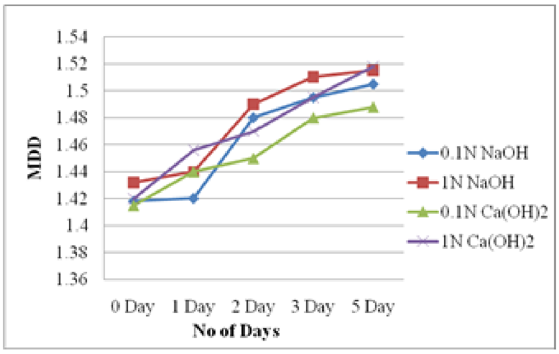

Fig.5.6: MDD vs. Number of days of both Concentration of pore fluids of Hydroxides

Fig.5.6 shows the plot of MDD verses the soaking period for soil with pore fluids of NaOH and $Ca(OH)_2$ of both concentrations. For a contact period up to 0-1 day increases in MDD negligible. But as the soaking period increases, it can be seen that between 1-3 days MDD increases sharply. After 3 days again steady change in MDD can be seen in pore fluids of NaOH and $Ca(OH)_2$ of both concentrations.

Pore fluid	No.of.days	O.M.C (%)		M.D.D(gm/cc)	
		0.1N	1N	0.1N	1N
NaoH	Immediate	27.8	27.56	1.418	1.432
	1 day	27.5	27.32	1.42	1.44
	2 day	27.15	27.12	1.48	1.49
	3 day	26.93	26.82	1.495	1.51
	5 day	26.77	26.71	1.505	1.515
$Ca(OH)_2$	Immediate	28.45	28.36	1.415	1.42
	1 day	28.32	28.28	1.44	1.456
	2 day	28.25	28.06	1.45	1.47
	3 day	27.85	27.82	1.48	1.495
	5 day	27.68	27.66	1.488	1.518

Table 5.1: Values of O.M.C and M.D.D of soil

B. Effect Of Contaminants On Unconfined Compressive Strength Characteristics:

The effect on unconfined compressive strength with the number of days soaking period for different contaminants NaOH, $Ca(OH)_2$) for the two concentrations (0.1N,1.0N) are plotted in from fig 5.7 to fig 5.9.

NaoH

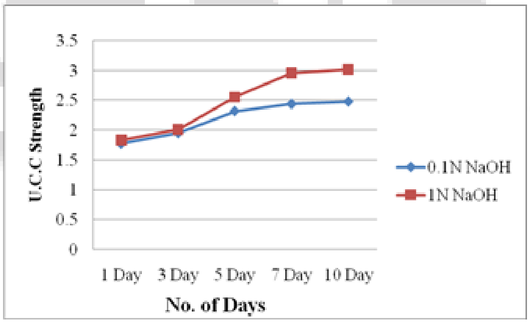

Fig.5.7: U.C.C Strength vs. Number of days of pore fluid of NaoH

Fig.5.7 shows the plot of unconfined compressive strength (U.C.C) verses the soaking period of soil with pore fluid of NaoH.

From the graph it is shown that unconfined compressive strength increases in both the concentration of pore fluid of NaoH. However the concentration of pore fluid is increases, the unconfined compressive strength also increases for any specified soaking periods.

Ca $(OH)_2$

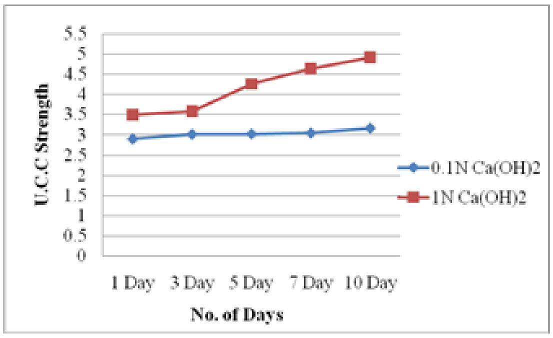

Fig.5.8: U.C.C Strength vs. Number of days of pore fluid of $Ca(OH)_2$

Fig.5.8 shows the plot of unconfined compressive strength (U.C.C) verses the soaking period of soil with pore fluid of Ca $(OH)_2$. It is observed that the U.C.C strength is increases and rate of increasing is different for both the concentrations of pore fluid of $Ca(OH)_2$.

Hydroxides

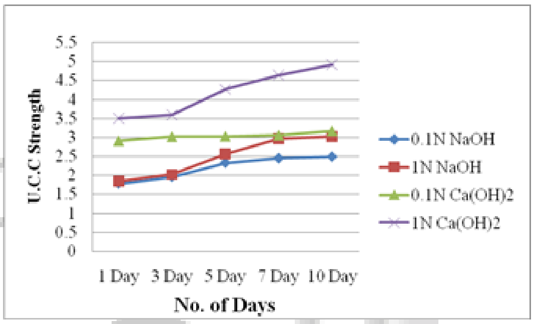

Fig.5.9: UCC Strength vs. Number of days of both concentrations of pore fluids of Hydroxides

Fig.5.9 shows the variation of U.C.C strength with the soaking period of soil and pore fluids of NaOH and $Ca(OH)_2$ of both concentrations with the increases in the contact period the unconfined compressive strength shows an increase in both the concentrations. Here higher concentration of pore fluids effect is more compare to the lower concentration pore fluids in both NaOH and $Ca(OH)_2$ pore fluids.

Pore fluid	No. of days	0.1N	1N
NaoH	1 day	1.773	1.832
	3 day	1.95	2.013
	55 5 day	2.32	2.556
	7 day	2.44	2.956
	10 day	2.48	3.018
$Ca(OH)_2$	1 day	2.901	3.49
	3 day	3.012	3.581
	5 day	3.021	4.258
	7 day	3.043	4.63

Table 5.2: Values of Unconfined compressive strength of soil

VI. CONCLUSIONS

In the earlier studies mainly focused on the liquid limit, plastic limit etc that is index properties of soil of higher activity clays exposed to a various contaminates, very limited study was focused on the engineering properties like compaction characteristics and compressive strength characteristics. Hence in the present study the experimental work is carried to understand the compaction characteristics and compressive strength characteristics of black cotton soil when exposed to different contaminants having different concentrations.

- The variations in the compaction and strength characteristics of black cotton in the presence of pore fluids having hydroxide as anions and sodium and calcium as cations for concentrations 0.1N and 1N are investigated.
- The optimum moisture content and maximum dry density of black cotton soil with respect to their clay frictions are sensitive to the changes in cations and anions present in the pore fluid.
- The optimum moisture content decreases and maximum dry density increases sharply of black cotton soil in the presence of pore fluids with NaOH, $Ca(OH)_2$ for a 0.1N and 1N concentration. Reduction in OMC and increases in MDD is more with divalent cations then the monovalent.
- As the contact period of pore fluid with the soil increases the optimum moisture content decreases.
- At low concentration the cations available in the pore solution is low and it gradually increases with the increases in the concentration therefore a decreasing OMC.
- The unconfined compressive strength of black cotton increases with the addition of pore fluids of different concentrations that is 0.1N and 1N.
- Unconfined compressive strength increases as the time duration increases.
- It can be seen that the increased in the concentration of the pore fluid increases the unconfined compression strength. This is due the increase in the ion concentration of the pore water with contaminate reduction in the double layer thickness and this causes a reduction in the antiparticles repulsion and an increase in the attraction, resulting in the increase in cohesion.
- The unconfined compressive strength increase with the increase in the compaction effort.

VII. FUTURE SCOPE OF WORK

Based on the current investigations, following details provides the scope for further studies.

In the present investigation the variations of optimum moisture content, dry density and unconfined compressive strength of black cotton soil is investigated with a Hydroxides anions as a pore fluid of different concentration that is 0.1N and 1N. In the further compaction and strength characteristics of the black cotton soil is investigated with a pore fluid containing Chlorides and

Sulphates as anions.And also increasing the concentration of the pore fluid may provide an interesting interference for both chemicals.

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