Stabilization of Soil using Chemical Additives

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Abstract

Searching for the best soil stabilizers to overcome the problem occurs by the clayey soils and sandy soils are still being the main concern, not only to achieve the required soil engineering properties but also by considering the cost and the effect to the environment. This research work presents the efficiency of sodium based alkaline activators as an additive in improving the engineering characteristics of cohesive and cohesion less soil. Investigations have been done in order to evaluate the effectiveness as soil stabilizer which involved the use of sodium hydroxide as chemical additive and concentrations of 1,2,4,8 molar were used. These materials were discussed in this paper and their effectiveness for stabilizing the soil were observed from the obtained results only in terms of strength and shear parameters like cohesion and angle of friction by conducting unconfined compressive test, California bearing test and direct shear test. The strengths of soil and their shear parameters were significantly increased with the use of sodium hydroxide as chemical additive and supposed they have the potential as effective soil stabilizers in field application.

Keywords- Soil Stabilization, Chemical additives, Sodium Hydroxide

I. INTRODUCTION

Dealing with soft sub grade soil or clayey soils is one of the major problems. The situation probably might occur in road ways or in highway constructions. Since there is reduction in sites for construction development it is crucial to find ways for soil improvement techniques to respond to the demands. There are many techniques for the improvement of soil and one of them is soil stabilization. Stabilization is the process of blending and mixing materials with a soil to improve the soil's strength and durability. The process may include blending soils to achieve a desired gradation or mixing commercial available additives that may alter the gradation, change the strength and durability or act as a binder to cement the soil. Soil stabilization is commonly used for better soil gradation, reduction of the Plastic Index or swelling potential and increased durability and strength. A soil layer's tensile strength and stiffness can be improved by using additives and can thereby reduce the thickness of the stabilized layer and overlying layers within the pavement systems. Soil stabilization can be accomplished by many methods all these fall into two main categories namely:

1) Mechanical stabilization.
2) Chemical stabilization.

The development of any country depends on the transportation facilities and construction projects. For the projects to be successful the foundation beds must be strong which requires better soil properties. Expansive soils have the tendency to swell when they come in contact with moisture and to shrink if moisture is removed from them. These volume changes in swelling soils are the cause of many problems in structures. The expanding nature of such soils covering different parts of Indian subcontinent has been greatly influenced by the genetic conditions under which these soils are formed. It has been investigated that the presence of expanding lattice type clay materials like montmorillonite induces the characteristics of swelling and shrinkage to these soils. These soils on imbibition of moisture expand considerably, associated with large reduction in shear strength. On the other hand these soils shrink on drying and regain the shear strength lost on wetting.

The cycle of alternate swelling and shrinkage will cause large distress to the structure resting on these soils. The annual cost of damage to the civil engineering structures caused by these soils are estimated to be £ 150 million in the U.K, $ 1000 million dollars in U.S.A and many billions of dollars worldwide. Expansive soils are also called as black soils black cotton soils and regular soils are mainly found over the Deccan lava tract (Deccan trap) including Maharashtra, Madhya Pradesh, Gujarat, and Andhra Pradesh and in some parts of Odisha and in the Indian sub-continent. Black cotton soils are also found in river valley of Tapi, Krishna, Godavari and Narmada. In the north western part of Deccan Plateau and in the upper parts of Krishna and Godavari, the depth of black soil is very large. Basically these soils are residual soils left at the place of their formation after chemical decomposition of the rocks such as basalt and trap. Also these types of soils are formed due to the weathering of igneous rocks and the cooling of lava after a volcanic eruption. These soils are rich in lime, iron, magnesia and alumina but lack in the phosphorus, nitrogen and organic matter.

Attempts have been made by many researchers to suggest remedial measures to these problems based on different concepts. The techniques that may prove to be successful for laying foundation on expansive soils are:

1) Mechanically replacing the expansive soil with non-expansive soil.
2) By increasing the structural load intensity (to counteract the swell pressure.)

3) By providing under-reamed piles etc.

Out of many methods available soil stabilization is found to be one of the best method for the increase of shear strength of a soil and control the shrinkage and swelling properties of soil and thereby improving the load bearing capacity of a soil and helps in supporting pavements and foundations. Soil stabilization aims at improving soil strengths and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two. Usually the technology provides an alternative provision to a practical problem. The simplest stabilization processes are compaction and drainage (if water drains of wet soils it becomes stronger). The other process is by increasing the gradation of particle size and further improvement can be achieved by adding binders to the weak soils. The mechanical and physical techniques of soil stabilization are based on decreasing the void rate by compacting or physically altering the grain size fractions involving the adjustments of the particle size composition of soil. The chemical technique is also a common stabilization approach since it produces a better quality soil with high strength and durability than mechanical and physical techniques. Coming to this study it is completely based on chemical stabilization using sodium hydroxide as a chemical additive.

II. CHEMICAL STABILIZATION

Under this category, soil stabilization depends mainly on chemical reactions between chemical additives and soil particles which then produce a strong network that bind the soil grains to achieve the desired effect. A chemical stabilization method is the fundamental of this review since it produces better quality soil with high strength and durability than mechanical and physical techniques and therefore, throughout the rest of this report, the term soil stabilization will mean chemical stabilization. In chemical stabilization soil is stabilized by adding different chemicals. The main advantage of chemical stabilization is that setting time and curing time can be controlled.

A. Advantages of Chemical Stabilization

1) In this stabilization method, setting time and curing time can be controlled.
2) It gives more strength to the soils.
3) The compacted density of the soil is increased.
4) Chemical stabilization increases the permeability of the soil

B. Development of New Chemicals for Stabilization

As technology advances and economic conditions change, many more chemical agents will be introduced into sub grades to improve their compact ability, durability, and strength. At the same time, more performance-based testing will be necessary to prove the effectiveness of these stabilization agents. In addition, there are chemicals being used today in the petrochemical industry whose use in soils is as yet unexplored. Another area for research is such processes as injection and spray-on techniques for more economical treatment. Out of many chemicals available we have selected sodium hydroxide as chemical additive as it provides a better results and cheaper than any other chemicals.

III. AIM & OBJECTIVE OF THE WORK

The present work is aimed at assessing the effects of sodium hydroxide (NaOH) in soil stabilization.

- To enhance the engineering properties of soil and Study the effects of chemical stabilizers on Cohesion less soil.
- To enhance the engineering properties of soil and Study the effects of chemical stabilizer on cohesive soil.

To fulfill the aim of this study, the following objectives have been framed.

A. Objectives

1) To procure the sandy soil and clayey soil samples.
2) To study the engineering properties of the procured samples.
3) To evaluate the performance of the soil when stabilized with sodium hydroxide as a chemical stabilizer.

IV. METHODOLOGY ADOPTED

This research work shows how to increase the soil properties by using sodium hydroxide as a chemical additive and we have done it on both cohesive soils (PART 1) and cohesion less soil (PART 2).

A. Part 1

- Firstly sandy soil have been collected from the Yeragattugutta Hillock, KITS Warangal premises and conducted various tests on the soil to find its physical properties of the soil.
- Firstly sieve analysis test is performed to determine the type of soil what we have taken.

- After that compaction test is performed to find out the optimum moisture content and Maximum dry density, and with obtained OMC and MDD, direct shear test and California bearing ratio test are carried to find out the shear parameters and strength of the soil without using any chemical.
- A certain concentration of sodium hydroxide is fixed and mixed with soil sample.
- The concentrations of sodium hydroxide have been prepared based on its molarities (1M, 2M, 3M, 4M…i.e. 40 grams of sodium hydroxide is added to 1000 ml of water to prepare a solution of 1M concentration).
- Then the use of sodium hydroxide and its behavior regarding soil stabilization is studied and conducted the same tests what we have done earlier and the changes in the soil properties are determined.
- The results are compared with addition and without addition of sodium additive.

B. Part 2

- In the second stage of the study cohesive soil from hasanparthy region is collected and free swell index is performed to find the expansiveness of soil and the same tests have performed to determine its engineering properties, which have done on sandy soils.
- In addition to that atterberg limits and unconfined compressive strength have performed to find its unconfined compressive strength of the soil. The concentrations of sodium hydroxide are fixed and added in the soil, as which have done earlier and the results are compared with and without chemical additives.

V. EXPECTED OUTCOME

It is expected that the soil is stabilized and its engineering properties are enhanced using sodium hydroxide as a chemical additive.

VI. CHEMICAL

Sodium hydroxide as a chemical additive as it is found that it will act as a good compaction aid between the soil particles and it is very soluble in water. The following are the properties of sodium hydroxide:

Table 1: Properties of Sodium Hydroxide

S.NO	Properties	Range
1	Chemical formula	NaOH
2	Molar mass	39.9971 g/mol.
3	Melting point	318˚ C
4	Density in natural state	2.13 g/cc
5	Acidity	13
6	Type of bond	Ionic
7	Sodium content	57.48%
8	Oxygen content	40.00%
9	Hydrogen content	2.52%

VII. DETERMINATION OF PROPERTIES OF COHESION LESS SOIL

Table 2: Properties of cohesion less soil

S.NO	Properties	Confirming to IS code	Values
3	Maximum dry density	IS 2720: part 7:1980	1.82 g/cc
4	Optimum moisture content	IS 2720: part 7:1980	14.3 %
5	cohesion	IS 2720:part 13:1986	0
6	Angle of friction	IS 2720:part 13:1986	38˚
7	CBR value	IS 1969-1980	7.29

A. Properties of Cohesion less Soil using Various Concentrations of NaOH

1) Modified Compaction Test on Soil In Addition with Various Concentrations of NaOH

Table 3: Results obtained from compaction curve for various concentrations of NaOH added in the soil

S.NO	Concentrations Of NaOH	Maximum dry density (g/cc)	OMC (%)
1	4M concentration	1.829	13.8
2	6M concentration	1.86	13.9
3	8M concentration	1.87	13.9
4	10M concentration	1.80	12.2

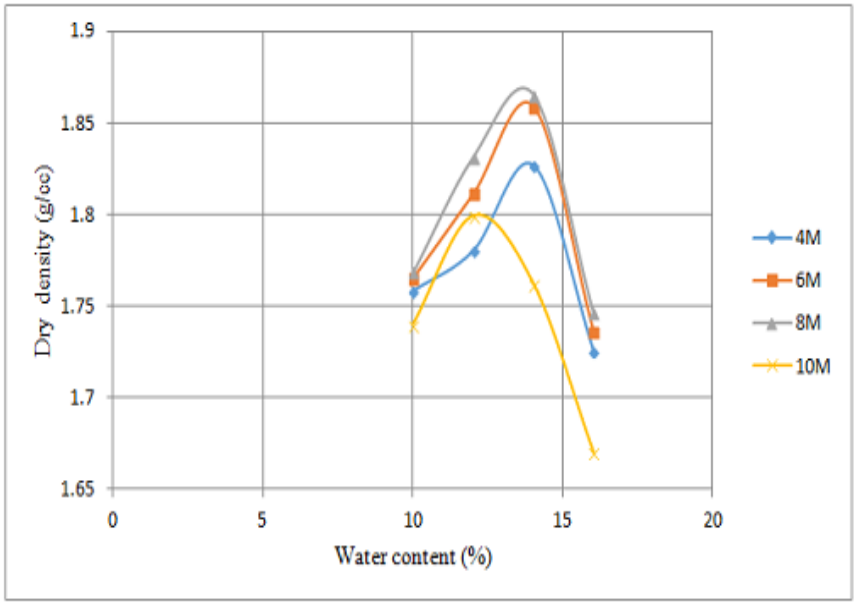

Fig. 1: Modified Compaction curves for various concentrations of NaOH

The variation of water content Vs Dry Density for varying concentrations of NaOH by weight of soil can be represented as shown above.

It can observe that at 4M, 6M, 10M concentrations there is a constant increase in the maximum dry density of soil. This indicates that at 6M concentration there is optimum moisture content that increases the properties of the soil so that it can be used in the field application. Upon increase in the concentration of NaOH there is a decrease in the optimum moisture content and dry density. Therefore it can be consider 6M concentration is adaptable and beyond that it becomes uneconomical.

2) Direct Shear Test on Soil in Addition with Various Concentrations of NaOH

This test is performed in order to determine the shear parameters like cohesion and angle of friction which will be obtained from the graph drawn for normal stress vs. shear strength.

Table 4: Results obtained from direct shear test for various concentrations of NaOH added in the soil

S.NO	*Concentration of NaOH*	*Cohesion (c) (kg/cm^2)*	*Angle Of Friction (Φ)*
1	*2 Molarity concentration.*	*0.17*	*46˚*
2	*4 Molarity concentration.*	*0.2*	*46.33˚*
3	*6 Molarity concentration.*	*0.22*	*47.38˚*
4	*8 Molarity concentration.*	*0.38*	*50.194˚*
5	*10 Molarity concentration.*	*0.11*	*49.18˚*

It is clear that the value of cohesion is increasing slightly from 2 molar concentrations to 6 molar concentrations and there is a sudden rise in the value of cohesion at 8 molar concentrations. That shows that at 8 molar concentration of NaOH is the optimum for increasing the shear parameters of soil and beyond that the values goes on decreasing.

3) CBR Test

Table 5: Results of CBR test for various concentrations of NaOH added in the soil

S.NO	*Particulars*	*Penetration at 2.5 mm*	*penetration at 5 mm*
1	*4 Molarity*	*7.29*	*6.08*
2	*6 Molarity*	*8.39*	*7.05*
3	*8 Molarity*	*9.48*	*7.688*
4	*10 Molarity*	*8.175*	*7.201*

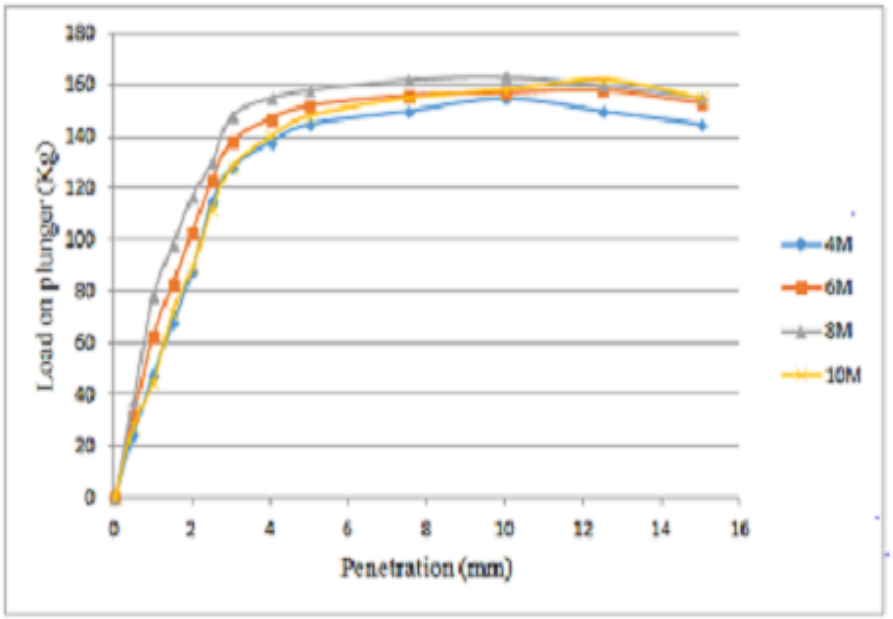

Fig. 2: CBR test for various concentrations of NaOH.

From the above obtained results it can be observed that there is an increase in the value from 4M to 6M and from 6M to 8M and then it gradually decreases after 8M concentration. Therefore it is optimum at 8M concentration to be used as an additive.

The result obtained from the above tests clearly infers that NaOH added as a chemical additive is optimum up to 8 Molarity, beyond which it is neither economical nor useful.

VIII. STABILIZATION OF COHESIVE SOIL USING NAOH

Table 6: Properties of cohesive soils

S.NO	Properties	Confirming to IS code	values
1	Liquid limit	IS 2720: part 5: 1985	66.03%
2	Plastic limit	IS 2720:part 5:1985	39.44%
3	Optimum moisture content	IS 2720:part 7:1980	14.2 %
4	Maximum dry density	IS2720:part 7:1980	1.905 g/cc
5	Cohesion (c)	IS 2720:part 13:1986	0.4 kg/cm^2
6	Angle of friction (Ø)	IS 2720:part 13:1986	21.26˚

A. Properties of Cohesive Soil for Various Concentrations of NaOH Added

1) Liquid Limit of Cohesive Soil for Various Concentrations of NaOH

Table 7: Liquid Limit for various concentrations of NaOH

S.NO	Concentrations of NaOH	Liquid Limit
1	2 Molarity	54 %
2	4 Molarity	52.1 %
3	6 Molarity	49.8%
4	8 Molarity	47.4 %
5	10 Molarity	47.3 %

The results in Table 7 clearly indicate that as the concentration of NaOH is increased the liquid limit of the soil is decreased, which means and increase in shear strength of the soil.

Table 8: Shear Parameters for various concentrations of NaOH

S.NO	Particulars	Cohesion (c) (kg/cm^2)	Angle of friction (Ø)
1	2 Molarity concentration	0.43	24.62˚
2	4 Molarity concentration	0.50	29.24˚
3	6 Molarity concentration	0.51	30.57˚
4	8 Molarity concentration	0.55	30.79˚
5	10 Molarity concentration	0.63	31.0˚
6	12 Molarity concentration	0.50	29.87˚

2) Unconfined Compressive Strength Test on Soil with Addition of Various Concentration of NaOH

S.NO	Particulars	Shear strength ($S=\frac{qu}{2}$) (kg/cm^2)
1	For 2 Molarity concentration	2.6
2	For 4 Molarity concentration	2.675
3	For 6 Molarity concentration	2.825
4	For 8 Molarity concentration	2.875
5	For 10 Molarity concentration	3.00
6	For 12Molarity concentration	2.66

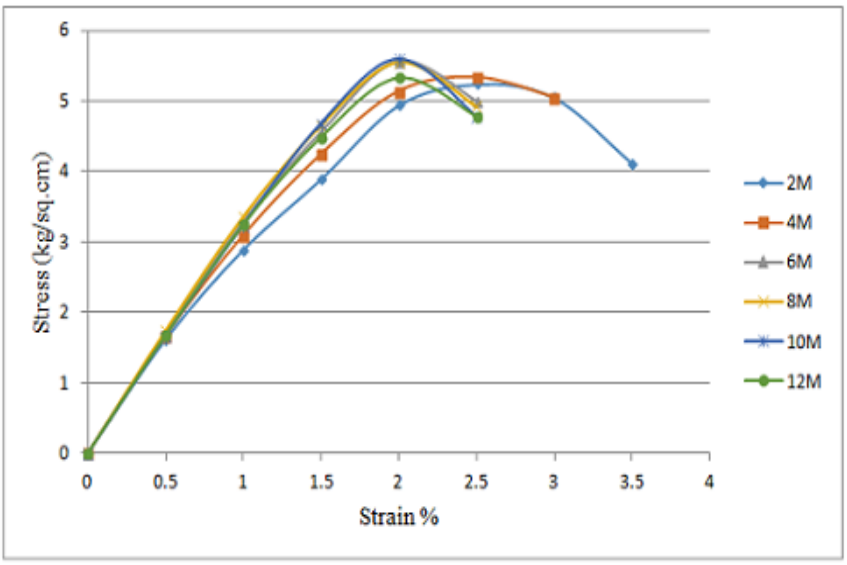

Fig. 3: Unconfined compressive test with varying concentration of NaOH.

The stabilization of cohesion less soil and cohesive soil has drawn attention to avoid its disastrous effect on infrastructural components like road, building etc. In this work a new idea of stabilizing the cohesion less soil and cohesive soil using sodium hydroxide as a chemical additive was discussed. The chemical was used at different concentrations like 1M, 2M, 3M, 4M…. etc. The method of sample preparation, proportion of chemical additive, curing of sample and changes in basic engineering properties of soil is discussed.

1) Based on the obtained results and discussions thereof following conclusions can be made in case of cohesion less soils.
- The maximum dry density is found to be gradually increased for the increase in the concentrations from 1 molar to 8 molar concentrations and beyond that it gets decreased and becomes uneconomical.
- The shear parameters also got increased in case of 8 Molarity and beyond that it becomes uneconomical.
- From the CBR test it can be concluded that the strength of the soil got increased from varying concentrations of sodium concentrations and it is also found that at 8 molar concentrations it gives maximum strength than at other concentrations.

2) Based on the obtained results and discussion thereof following conclusions can be made on cohesive soils.
- The unconfined compressive strength soil is found to vary with different concentrations of sodium hydroxide.
- It is evident that at 10 molar concentrations it gives better results and makes economical than other concentrations.
- Long term strength is more in case of 10 molar concentrations.
- It is evident that the shear parameters get increased from the results obtained from direct shear test till 10 molar concentrations. Beyond that it becomes uneconomical.
- From the results obtained from direct shear test it is evident that at 10M concentrations it gives better results compared to other.

IX. CONCLUSIONS

- From the results it is observed that Max. Dry density decreases after using 10Molar solution mix. Therefore, an optimum of 8M solution can be used for Cohesionless soil
- In case of cohesive soil Max dry density increases upto 10M and decreases after that, Hence an optimum of 10Molar solution can be used for Cohesive soil
- According to economical point of view an optimum of 8-10% chemical additive can be used, beyond which it becomes uneconomical.
- The soil engineering properties are thereby enhanced and it is successfully done using NaOH as chemical additive.

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