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Effect of Water treatment plant sludge on the Geotechnical Properties of an Expansive Soil

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ABSTRACT
Expansive soils are soils that expand when water is added, and shrink when they dry out. This continuous change in soil volume can cause damage to houses, other buildings, roads, pipelines, and other structures. Therefore it is essential to stabilize the expansive soil by suitable additives. The conventional Water treatment plant involves the process of coagulation, flocculation, sedimentation, filtration and disinfection. Large volumes of sludge or residues are generated during the processing of raw water to make it fit for drinking purpose. In general, this sludge is discharged directly into nearby water bodies or dumped in the landfills after dewatering. It may cause contamination of water bodies and soil from the chemical products used in the treatment. The review of published literature reveals that water treatment plant sludge or alum sludge can be utilized as a binding material due its pozzolanic properties. Hence A study was made on the effects of variation of geotechnical properties of soil treated with 2%, 4%, 6%,9% ,10% of water treatment plant sludge. It was found that there was an improvement of compaction parameters, CBR, Unconfined Compressive Strength and swelling characteristics when compared to untreated soil. From this investigation it was found that alum sludge can be utilized as an expansive soil stabilizer.
Keywords- Expansive soil. Alum sludge, Compaction parameters, unconfined compressive strength, Swelling pressure

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I. INTRODUCTION

1.1. Expansive Soil

Expansive soils contain minerals such as smectite clays that are capable of absorbing water. When they absorb water, they increase in volume. The more water they absorb, the more their volume increases. This change in volume can exert enough force on a building or other structure to cause damage. Cracked foundations, floors, and basement walls are typical types of damage done by swelling soils. Damage to the upper floors of the building can occur when motion in the structure is significant. Expansive soils will also shrink when they dry out. This shrinkage can remove support from buildings or other structures and result in damaging subsidence. Fissures in the soil can also develop. These fissures can facilitate the deep penetration of water when moist conditions or runoff occurs. This cycle of shrinkage and swelling places repetitive stress on structures, and damage worsens over time. Therefore it is essential to stabilize the expansive soil by suitable additives. Masoumeh Mokhtari. Masoud Dehghani et al (2012)

1.2. Water treatment Sludge/Alum Sludge

All water treatment plants (WTPs) produce waste/residue known as water treatment sludge (WTS) or Alum Sludge during the purification of raw water. Discharging alum sludge into river, streams, ponds, lakes, drains etc. or land filling the dewatered water treatment plant sludge is not environment friendly disposal option. Based on the characteristics, sustainable and profitable disposal through recycling and reuse have been reviewed. Utilization of alum sludge in brick making, in ceramics making, in the manufacture of cement and cementitious materials and as a substitute to building materials could provide safe disposal route. Reuse in wastewater treatment, in removal of heavy metals from aqueous solutions and in nutrient reduction from laden soils and runoffs are also some of the possible alternatives. The review of published literature reveals that alum sludge can be utilized as a binding material due its pozzolanic properties. Ahmad et al (2016)

1.3. Literature Review

Muhammad Aamir et al (2019) investigated and reported that addition of alum sludge to soil improved the soil bearing ratio significantly from 6.53% to 16.86% at the optimum level of an 8% addition of alum sludge. Furthermore, the artificial neural networks (ANNs) technique was applied to study the correlations between the CBR and the physical properties of soil, which showed that, at 8% optimum alum sludge, maximum dry density, optimum moisture content, and plasticity index were also improved.

Syyed Adnan Raheel Shah et al (2020) studied the relation of compaction energy with the strength of soil before and after addition of alum sludge as a soil stabilizer. It was found that soil strength can be improved even at a low compaction energy level of 600KN-m/m^3 by the addition of optimum percentage of 8% alum sludge as a soil stabilizer. So, roller compaction effort can also be reduced by addition of this soil stabilizer to save compaction cost i.e. saving of roller fuel consumption and rental cost as well.

Suchand et al (2020) carried out the compressive strength and splitting tensile strength tests to assess the effect of partial replacement of cement on the hardened properties of concrete. The results indicated that alum sludge is a reactive pozzolanic material; hence it can be used as a pozzolanic material in concrete.

Due to its pozzolanic properties alum has the potential to enhance the geotechnical properties of soil. Hence an attempt is made to study the effect of water treatment plant sludge on some Geotechnical properties of an expansive soil.

II. EXPERIMENTAL INVESTIGATIONS

2.1. Materials used

2.1.1Soil

The soil used for this investigation is obtained from Bakara pet near Tirupati. The dried and pulverized material passing through I.S.4.75 mm sieve is taken for the study. The properties of the soil are given in Table.1.

The soil is classified as “CH” as per I.S. Classification (IS 1498:1970) indicating that it is highly compressible clay. It is highly expansive in nature as the Differential Free Swell Index (DFSI) is

Table: 1 Properties of Untreated soil about 60%.`

Property	Value
Grain size distribution	
(a) Gravel (%)	5
(b) Sand (%)	12
(c) Silt+Clay (%)	83
Atterberg Limits	
(a)Liquid Limit (%)	65
(b)Plastic Limit (%)	30
(c) Plasticity Index (%)	35
Differential Free Swell Index (%)	60
Specific Gravity	2.72
Maximum Dry Unit Weight (kN/m^3)	15.2
Optimum moisture content (%)	21.2
California Bearing Ratio @ 2.5 mm(%)	5.3
Unconfined Compressive	207
Swelling Pressure(kN/m^2)	303

2.1.2,Water treatment sludge

The alum sludge is obtained from water treatment plant, Rangam pet near Tirupati. Alum sludge is basically a waste product produced by water treatment plants. The grey-colored alum sludge, which exists in slurry form, is used in dry and crushed form. Water treatment includes the removal of various compounds from water, particularly Al_2O_3, Fe_2O_3, SiO_2, CaO, MgO, Na_2O, K_2O, and other miscellaneous compounds in case of sludge. The alum sludge used for experiments was dried at 100^{0}C and then crushed and passed through sieve prior its addition to the soil sample.

III. PROCEDURE FOR MIXING

The soil from the site is dried and hand sorted to remove the pebbles and vegetative matter if any. It is further dried and pulverized and sieved through a sieve of 4.75mm to eliminate gravel fraction if any. The dried and sieved soil is sorted in air tight containers ready for use for mixing with additives. The soil mixed with water of chosen moisture content and stored of a day for uniform distribution of water in different containers. The soil sample so prepared is then mixed with water treatment plant sludge. The percentage weight varied from 3% to 15% in increment of 3%.The soil water treatment sludge mixtures are mixed thoroughly before testing.

IV. TESTS ON TREATED SOIL

4.1. Standard Proctor Test

Compaction characteristics of the soil have the great importance for practically achieving the desired strength, permeability and compressibility of soil during the construction. But these two parameters are influenced by water treatment plant sludge. Hence in this investigation Standard Proctor's compaction tests are carried out on expansive soil treated with water treatment plant sludge at various percentages of 3%, 6%, 9%, 12%, and 15% by dry weight of the soil.

The results of the Standard Proctor's compaction tests, conducted at different percentages of alum sludge are reported in Fig.1 and Fig.2.

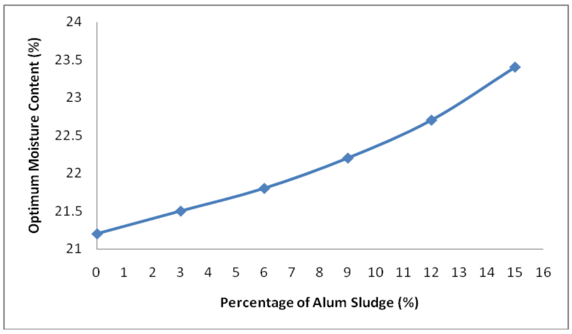

Fig.1: Variation in Optimum moisture Content with per cent Alum sudge

From the figure.1 it is observed that as the percentage of alum sludge increases the optimum moisture content increases due to better moisture holding capacity of alum sludge. The optimum moisture content of untreated soil is 21.2%.The optimum moisture content at 15% of alum sludge is 23.4%.

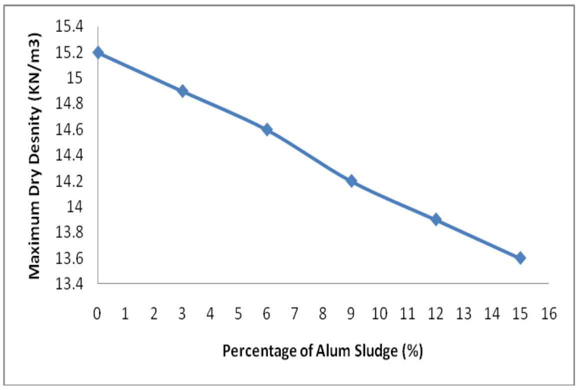

Fig.2: Variation in Maximum Dry Unit weight with per cent Alum sudge.

From the figure.2 it is observed that as the percentage of alum sludge increases the dry density decreases due to aggregation/flocculation and forms the cementitious products. The Maximum dry unit weight of untreated soil is 15.2 KN/m^3.The Maximum dry unit weight at 15% of alum sludge is 13.6KN/m^3.

4.2. California Bearing Ratio Test

The California bearing ratio test is penetration test meant for the evaluation of sub grade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement. California bearing ratio value used as an index of soil strength and its bearing capacity. It is the ratio expressed in percentage of force required to penetrate a test soil mass, to a specified depth, of a circular plunger of 50 mm diameter and the force that required for the same penetration in a standard material i.e crushed stone.

In this investigation California Bearing Ratio tests on Expansive soil treated with alum sludge varying from 3% to 15% in increment of 3% is carried out. The tests are conducted on remoulded soil specimens at their respective optimum moisture content and Maximum Dry Unit Weights and compacted according to I.S. Light compaction.

The variation of the CBR values with different percentages of alum sludge is shown in fig.3.From the figure. It is observed that as the percentage of alum sludge increases CBR values increases up to 9% then decreases. The increase in CBR value is due to increase in bond between soil and alum sludge and frictional resistance that has been worked out from alum sludge. The CBR value of untreated soil is 5.3%.The maximum increase in CBR values obtained at 9% and is equal to 11.2%.

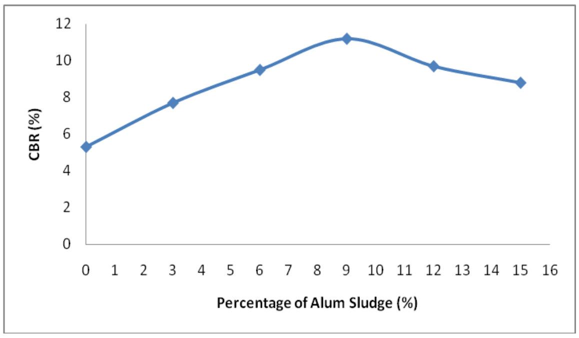

Fig.3: Variation in CBR Values with per cent Alum sludge

4.3. Unconfined Compressive Strength test (UCS)

The Unconfined Compression Test is a laboratory test used to derive the Unconfirmed Compressive Strength (UCS) of a soil specimen. Unconfirmed Compressive Strength (UCS) stands for the maximum axial compressive stress that a specimen can bear under zero confining stress. Due to the fact that stress is applied along the longitudinal axis, the Unconfined Compression Test is also known as Uniaxial Compression Test. UCS is a parameter widely used in geotechnical design, but may not represent the strength in-situ.

In this investigation, Unconfined Compressive Strength test is, carried out to study the strength behavior of soil treated with different percentages of alum sludge. The variation in Undrained Shear Strength with respect to different percentages of alum sludge is shown in Fig:4.

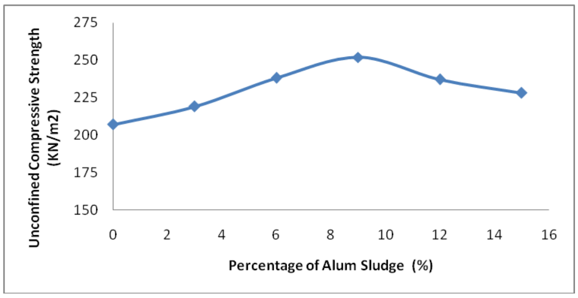

Fig.4: Variation in Unconfined Compressive Strength with per cent Alum sudge.

From the figure.4 it is observed that as the percentage of alum sludge increases unconfined compressive strength values increases up to 9% then decreases. The increase in UCS value is due to increase in bond between expansive soil and alum sludge. The unconfined compressive strength value of untreated soil is 207 kN/m^2. The maximum increase in UCS values obtained at 9% of alum sludge and is 252 kN/m^2.

4.4. Swelling Characteristics

Swelling pressure of clays is an important parameter required for the design of a variety of structures founded on expansive soils. This swelling pressure has serious consequences in the form of cracks and distress structures founded on expansive soil. Light weight structures are severely affected due to high swelling pressure exerted by these soils. But these parameters are influenced by addition of alum sludge. In this investigation the swelling pressure of soil is measured for 'no volume change' condition. The method requires continuous adjustment of pressure on the soil specimen taken in a consolidation cell, so that the soil volume at any time is equal to its initial volume.

In this investigation swelling pressure of an Expansive soil treated with alum sludge varying from 3% to 15% in increment of 3% is carried out. The variation of the swelling pressure values with different percentages of alum sludge is shown in Fig.5.From the figure.5 it is observed that as the percentage of alum sludge increases swelling pressure values decreases. The decrease in swelling pressure value is may be due to flocculation and cation replacement because alum sludge consists of calcium ions. The swelling pressure of untreated expansive soil is 303 kN/m^2.The swelling pressure at 15% alum sludge is 251kN/m^2.

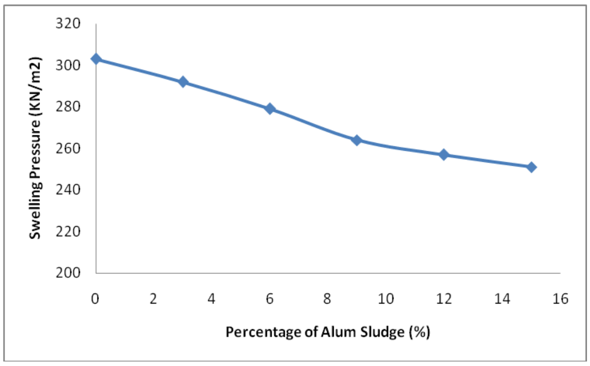

Fig.5: Variation in Swelling Pressure with per cent Alum Sudge.

V. SUMMARY AND CONCLUSIONS

Expansive soil or clay is considered to be one of the more problematic soils and it causes damage to various civil engineering structures because of its swelling and shrinking potential when it comes into contact with water. Hence Stabilization of expansive soil with suitable additives is essential. In this work, the performance of alum sludge in expansive soil stabilization was examined via laboratory investigation. Different tests like Compaction test, CBR UCS , and Swelling pressure test were conducted. Addition of alum sludge increases optimum moisture content and decreases the maximum dry density.CBR and UCS values improved up to 9% then decreases .It is suggested that alum sludge of 9% by weight of soil can be utilized as an effective soil stabilizer if available in abundant quantity. The results are based only on laboratory investigations and hence it is further recommended that the viability and long-term performance in the fled, of this material, should be determined in actual soil stabilization projects.

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