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Efficiency of Calcium Chloride and Vitrified Tiles Sludge on the Strength Characteristics of Expansive Soil

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Abstract
Expansive soil is a term generally applied to any soil or rock material that has a potential for shrinking or swell-ing under changing moisture conditions. Severe damages occur to structures like light building, pavements, retaining walls, canal beds and linings etc. founded on the expansive soils. Soil stabilization may be defined as any process by which a soil material is improved and made more stable resulting in improved bearing capacity, increase in soil strength, and durability under adverse moisture and stress conditions. Stabilization using solid wastes is one of the different techniques to improve the engineering properties of expansive soils to make them suitable for construction. The use of vitrified tiles sludge (VTS) in combination with calcium chloride (Cacl2) as stabilizing materials for expansive soil can be checked for efficiency by con-ducting various strength tests. Objectives of study 1) To use the new potential industrial waste, vitrified tile sludge as a sta-bilized material and to solve the problem of waste disposal. 2) To evaluate the strength characteristics of expansive soil for different properties of vitrified tile sludge in replacement and calcium chloride as binder.

Keywords
Calcium Chloride, Engineering properties, Expansive soil, Stabilization, Vitrified Tile Sludge.

I. Introduction

Black cotton soils are the most problematic clays due to their peculiar swell shrink behavior with fluctuations in moisture content. Considerable surface area of most of the world nations is covered by the Black cotton soil and huge damages caused by them are also reported. India is one among these countries where expansive soils cover as much as one–fifth of the total land area. It has been investigated that the presence of expanding lattice type clay minerals like Montomorillonite induces the swell-shrink behavior to these soils.
For any country, transport and communication are the major influencing factors of its development. Importantly for highly populated countries like India, road transport is the major dependent aspect for accessibility and connectivity of different locations. During the process of network development, the alignment of roads may have to be finalized, though the soils en-route may not be suitable to bear the traffic loads with adequate strength.

Fig. 1: Swell & Shrink behavior of Expansive soils

II. Review of Literature

Expansive clay is one of the most abundant problems faced soil in geotechnical engineering applications. With Smectite clay minerals, such as Montomorillonite, exhibit the most profound swelling properties. The deposits of expansive soils occupy about 20% of the India's surface area. In India these soils are predominant in the states of Gujarat, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamilnadu. Expansive soils are frequently overlooked as a major problem because they take years to cause extensive damage.
Expansive soils cause heavy damages in structures, especially in water conveyance canals, lined reservoirs, highways, and airport runways etc., unless appropriate measures are taken. This behavior is attributed to the present of clay minerals with expanding lattice structure. Among them Montomorillonite clay mineral is very popular and absorbs water significantly. The soil is hard as long as it is dry but loses its strength (stability) almost completely on wetting. On drying, the soil cracks very badly and in worst cases, the width of cracks is almost 150mm and travel down to 3m below ground level. Indian black cotton soils are found to be formed by weathering of Basalts and traps of Deccan plateau. However, their occurrence on limestone gneiss, shales, sandstones, slates and limestone is also recognized. These soils are usually found near the surface with the layer thickness varying from 0.5m to about 3m. The distinct black color of this soil is due to the presence of Titanium in small quantity and cotton grows in these soils commonly.
Extensive studies have been carried out on the stabilization of problematic soil (such as marine clay and swelling soil, etc.) using various additives such as lime, fly ash, and Fiber.P. R. Modak et al. [1] studied stabilization of black cotton soil by using lime and Fly ash. BC soils are highly clayey soils.
Lime and Fly ash. R. Vinothkumar and P. D. Arumairaj [2] added Polypropylene Fibre for enhance the performance of Clay - Quarry dust, Clay - Fly ash, Clay - Waste Paper Sludge Ash. Modification of BC soil by chemical admixture is a common method for stabilizing the swell-shrink tendency of expansive soil [3]. Calcium chloride is known to be more easily made into calcium charged supernatant than lime an helps in ready cation exchange reactions [4]. The CaCl2 might be effective in soils with expanding lattice clays [5]. The laboratory tests reveals that the swelling characteristics of expansive soils can be improved by means of flooding at a given site with proper choice of electrolyte solution more so using chloride of divalent or multivalent cations

[6]. The bibliography on stabilization of soil and calcium chloride giving its wide use in highways[7].[8],[9], [10] has stated that CaCl2 enjoyed its wide use as dust palliative and frost control of subgrade soil. Recent studies ([11],[12]), indicated that CaCl2 could be an effective alternative to conventional lime used due to its ready dissolvability in water and to supply adequate calcium ions for exchange reactions.

III. Methodology

Materials Used

Expansive Soil

The Clay that has been used in this study was a typical BC soil collected from Odalarevu near Amalapuram, East Godavari District. The soil used for the investigation was dried, pulverized and then sieved through 4.75mm size sieve. The properties of black cotton soil experimented, based on relevant I.S. code provisions are given in the Table 1 below.

Table 1 Physical properties of Black Cotton Soil

Laboratory Experimentation	Value
Specific gravity	2.72
Grain size distribution	
Sand(%)	3
Silt (%)	35
Clay(%)	62
Compaction Parameters	
Maximum Dry Density(g/cc)	1.52
O.M.C. (%)	28.8
Atterberg's limits	
Liquid limit (%)	66.4
Plastic limit (%)	23.5
Plasticity index(%)	42.9
IS classification CH	
Differential Free Swell (%)	105
CBR- Unsoaked	3.4
Soaked	1.6

Vitrified Tile Sludge –VTS

Vitrified Tiles are the latest and largest growing industry alternate for many tiling requirements across the globe with far superior properties compared to natural stones and other manmade tiles. India and China are the largest regions to contribute to the 6900 million square meters of production every year. With an annual growth rate of 20% worldwide and 25% in India, Vitrified tile is the fastest growing segment in the tile industry. Vitrified tiles own 12% share of the overall tile production across the world. With the increase in production of vitrified tiles in India, there is growing concern about the huge generation of tile polishing dust.. The raw material composition of Vitrified tiles is

- Quartz of 99% Silica,
- Potash Feldspar of 12% to 14% Alkalis,
- Soda Feldspar of 12% to 14% Alkalis,
- Strengthening agent, China clay, body stains for producing in various colors.

VTS is used as a stabilizing material which was collected from the RAK Ceramics, Samalkota. The physical properties of Vitrified Tile Sludge (VTS) are given in the Table 2 below.

Table 2 Physical properties of Vitrified Tile Sludge (VTS)

Laboratory Experimentation	Value
Specific gravity	2.46
Grain size distribution	
Medium sand (%)	1.43
Fine sand (%)	97.5
Silt &clay(%)	1.07
Compaction properties	
MDD (g/cc)	1.58
OMC (%)	19.4

Calcium Chloride – $CaCl_2$

Calcium chloride (chemical formula $CaCl_2$) is the ionic compound of calcium and chlorine. It is a salt that behaves as a typical ionic halide, being solid at room temperature and highly soluble in water. Common applications include brine for refrigeration plants, ice and dust control on roads, and desiccation. Because of its hygroscopic nature, anhydrous calcium chloride must be kept in tightly sealed, airtight containers.

Calcium chloride can serve as a source of calcium ions in an aqueous solution, as calcium chloride is soluble in water. This property can be useful for displacing ions from solution. For example, phosphate is displaced from solution by calcium:

$$3\,CaCl_{2(aq)} + 2\,K_3PO_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)} + 6\,KCl_{(aq)}$$

Molten calcium chloride can be electrolysed to give calcium metal and chlorine gas:

$$CaCl_{2(l)} \rightarrow Ca_{(s)} + Cl_{2(g)}$$

Calcium chloride has a very high enthalpy change of solution. A considerable temperature rise accompanies its dissolution in water. The properties of Calcium chloride $CaCl_2$ are given in the Table 4 below.

Table 3 Properties of Calcium chloride $CaCl_2$

Molar Mass	110.98 $g \cdot mol^{-1}$
Appearance	White Powder
Odor	Odorless
Density	2.15 g/cm^3 (anhydrous) 2.24 g/cm^3 (monohydrate) 1.85 g/cm^3 (dihydrate) 1.83 g/cm^3 (tetrahydrate) 1.71 g/cm^3 (hexahydrate)
Melting Point	772–775 °C anhydrous 260 °C monohydrate 175 °C dihydrate 45.5 °C tetrahydrate 30 °C hexahydrate
Boiling Point	1,935 °C

IV. Results and Discussions

In the laboratory, various experiments were conducted by replacing different percentages of Vitrified Tile Sludge (VTS) in the expansive soil and also further stabilizing it with Calcium Chloride as a binder. Compaction, Strength and CBR tests were conducted with a view to determine the optimum combination of Vitrified Tile Sludge (VTS) as replacement in expansive soil and Calcium Chloride as a binder.

EFFECT OF % VITRIFIED TILE SLUDGE (VTS) AS REPLACEMENT ON THE STRENGTH CHARACTERISTICS OF EXPANSIVE SOIL

The individual influence of Vitrified Tile Sludge (VTS) on the Compaction and Strength characteristics of expansive soil are clearly presented in Figures below. The percentage of Vitrified

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Tile Sludge (VTS) was varied from 0%, to 25% with an increment of 5%. From the graphs, it was observed that the treatment as individually with 25% VTS has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual increase in maximum dry density with an increment in the % replacement of VTS up to 15% for strength characteristics. The addition of VTS had mobilized little amount of friction to the pure Clayey soil without friction.

Table 4 : showing the test results conducted on expansive soil replaced with different % of vitrified tile sludge

ES+VTS	MDD	OMC	DFS	C	Ø
100+0	1.50	30.4	160	52	00
95+5	1.51	30.6	136	58	00
90+10	1.53	30.3	115	67	10
85+15	1.56	29.8	101	81	30
80+20	1.55	29.6	84	80	30
75+25	1.54	29.4	59	77	20

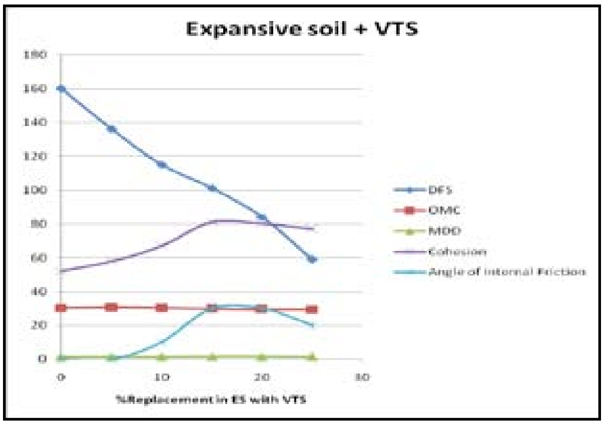

Fig. 2 : Plot showing the variation of Various Properties with % of Vitrified Tile Sludge as replacement in Expansive soil.

EFFECT OF CALICUM CHLORIDE CONTENT ON THE STRENGTH CHARACTERISTICS OF EXPANSIVE SOIL + VITRIFIED TILE SLUDGE (VTS) MIXES

The influence of lime as binder on the Compaction and Strength characteristics of expansive soil + Vitrified Tile Sludge (VTS) mixes are clearly presented in Figures for different percentages of $Cacl_2$ respectively. The percentage of $Cacl_2$ was varied from 0%, to 4% with an increment of 0.5%. In the laboratory, tests were conducted by blending different percentages of$Cacl_2$ to expansive soil + Vitrified Tile Sludge mixes with a view to determine its optimum blend.

It is observed from the graphs, that there is an improvement in maximum dry density and also corresponding strength characteristics with an increase in the $Cacl_2$ content. From the above results it is evident that the addition of $Cacl_2$ to the VTS – Expansive soil mix had improved its Compaction and Strength characteristics.

Finally from the above discussions, it is clear that there is improvement in the behaviour of Expansive soil stabilized with Vitrified Tile Sludge (VTS) + $Cacl_2$. It is evident that the addition of Vitrified Tile Sludge (VTS) to the virgin Expansive soil showed an improvement in Compaction and Strength characteristics to some extent and on further blending it with $Cacl_2$, the improvement was more pronounced. This made the problematic expansive soil which if not stabilized is a discarded material, a useful fill material with better properties. The Vitrified Tile Sludge (VTS) replacement in the expansive soil has improved its strength and upon further blending with $Cacl_2$, the strength has further improved and also these materials has imparted friction to the clayey soil. It can be summarized that the materials Vitrified Tile Sludge (VTS) and $Cacl_2$ had shown promising influence on the Strength and Penetration properties of expansive soil, thereby giving a two-fold advantage in improving problematic expansive soil and also solving a problem of waste disposal.

Table 5 : Showing the results of the tests conducted on calcium chloride inclusions in optimum mix of expansive soil & vitrified tile sludge.

ES+ VTS + $Cacl_2$	MDD	OMC	C	Ø	UnSoaked	Soaked
0	1.56	29.8	81	3^0	3.61	2.75
1	1.57	29.8	89	3^0	3.92	2.88
2	1.58	29.2	96	4^0	5.10	3.74
4	1.58	29.0	93	3^0	4.96	3.56

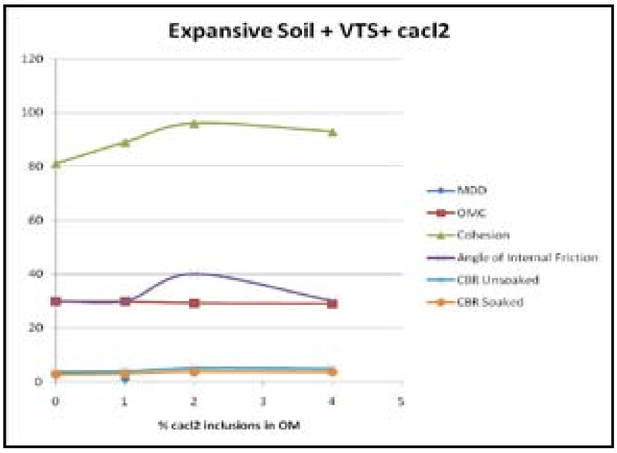

Fig. 3 : Plot showing the variation of Various Properties with % of calcium chloride in optimum mix of expansive soil & vitrified tile sludge. .

V. Conclusion

The following conclusions are made based on the laboratory experiments carried out in this investigation. From the laboratory studies, it is observed that the Expansive Soil chosen was a problematic soil having high swelling, and high plasticity characteristics. It was observed that the treatment as individually with 15% VTS has moderately improved the expansive soil. There is a gradual increase in maximum dry density with an increment in the % replacement of VTS up to 15% with an improvement of about 2% and it was about 15% for strength characteristics.

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