A Study on the Use of Vitrified Tile Sludge (VTS), Cement & Treated Coir Fibre in Stabilizing Expansive Soil

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Abstract. Expansive soils tend to swell and shrink with the variation in moisture content. As a result, significant distress in the soil occurs, causing severe damage to the overlying structure. These types of soils are generally found in arid and semi-arid regions of the world and may cause severe damage to the structures built upon them if not treated properly. Soils containing the clay mineral, montmorillonite generally exhibit high swelling and shrinkage characteristics due to high specific surface area. Stabilization using industrial by-products is one of the different techniques to improve the engineering properties of expansive soils and make them suitable for various engineering applications. This study investigates the effect of industrial waste, vitrified tile sludge (VTS) in combination with cement in improving the strength characteristics of the expansive soil. Further, the study was extended to assess the influence of treated coir fiber (TCF), an abundantly available local material on the strength characteristics. At the cessation, the experimental investigation resulted two-fold solution by improving a problematic expansive soil and gainful utilization of the industrial waste.

Keywords: Expansive soil, Vitrified Tile Sludge (VTS), Treated Coir Fiber (TCF)First Section

1 Introduction

Expansive soils are highly problematic and cause severe damage to the structures founded in them because of their potential to react to changes in moisture regime. They swell when they imbibe water and shrink when water evaporates from them. The specific characteristics of problem soils, however, vary from region to region. It is a well-known fact that expansive soils pose considerable problems in civil engineering constructions. In India, predominantly expansive soils found in Deccan trap region of Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, Gujarat, and Tamilnadu.

Expansive soil shows the property of high plasticity and water receptivity which makes them highly problematic due to the presence of clay mineral called montmorillonite. More the clay mineral more will be the absorbed water and more will be the volume change. Due to this volume changes, severe distress and excessive settlement will take place in the structure. About 20% of the Indian subcontinent is covered with expansive soils. Expansive soil is considered as a potentially hazardous soil which if not treated well can cause extensive damages to not only to the structures built upon them but also can cause loss of human life. India is among those countries that competing in the race of globalization for the development of the country. Structures built on such soils show distress which is often detrimental and lead to structural damage. Damage caused by these soils is evidenced in many costly ways and is particularly obvious in buildings and pavements.

Several methods are suggested as solutions to prevent damage to buildings in expansive soil areas, namely: soil replacement, prewetting, compaction control, and chemical treatment. Some of these have been used in this country over the last decade. The selection of an appropriate method depends on ground characteristics, effectiveness, and applicability of the preferred technique, installation and maintenance costs. Among these methods, soil stabilization is a widely accepted technique that process by changing the behavior and properties of soil under certain conditions. Soil stabilization involves changes in properties like strength, density, swelling behavior, etc. Soil stabilization techniques can considerably increase the profiles of the low strength expansive soils to the desired extent. Further, these techniques are very economical and reduce the overall cost of a project.

Industrial waste management is one of the major environmental concerns worldwide. The exponentially growing industrial waste needs to recycle or to be utilized in an eco-friendly manner. Coir is a versatile natural fiber extracted from the fibrous husk that surrounds the coconut. The fibers are tough, strong and extremely resistant to fungal and bacterial decomposition. Vitrified tile is a ceramic tile with low porosity. Vitrified tile is obtained by hydraulic pressing a mixture of clay, quartz, feldspar, and silica, which make a vitreous surface. Thus, creating a single mass making them hard with low porosity. Different clay bodies reach vitrification at different temperatures. Vitrified tiles are the latest and largest growing industry alternate for many tiling requirements. India and China are the largest regions to contribute to the 6900 million square meters of production every year. With the increase in production of vitrified tiles in India, there is growing concern about the huge generation of tile polishing dust. This led to the dumping of large quantities of this polish waste in the factory premises causing environment pollution. The raw material composition of Vitrified tiles are 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. The vitrified tile is a successful waste material in stabilization strategy which enhances the composition qualities, subgrade characteristics, swelling characteristics, compressibility characteristics. The present study mainly focuses on the use of vitrified tile sludge (VTS), cement and treated coir fiber in stabilizing expansive soil.

2 Literature Review

In the present economic and environmental ambiance, high pressures are laid on engineers to identify suitable methods wherever possible to re-use any locally available waste materials to minimize the costs of a project and its impacts on the environment. Chemical stabilization has been discussed by many authors (Little and Nair, 2009; Al-Rawas and Goosen, 2006). Chemical stabilizers result in improving the CBR and UCS values of the sub-grade soil. The liquid limit and plastic limit of the stabilized soil are improved, especially in the cases of highly plastic clays and silts. The hydration process results in a stabilized soil which exhibits greater shear strength, stiffness, and bearing capacity. Waste materials such as coir fibre, vitrified tile sludge offers a viable alternative to economical, technical and environmental standpoints. They showed good potential for stabilizing soils by blending. It has been estimated that about 30% of daily production in the ceramic industry goes to waste (Binici, 2007). The disposal of which creates soil, water and air pollution.

Koyuncu et al. (2004) had added ceramic tile dust wastes up to 40% to study its effect on swelling pressure and swelling potential of Na–bentonite and found that swelling pressure and swelling potential decreased by 86% and 57% respectively at 40% addition of ceramic tile dust waste.Sabat and Nanda(2011)carried out a study on effect of marble dust on strength and durability of rice husk ash stabilized expansive soil and reported that the optimum percentage of RHA in stabilization of expansive soil is found out be 10 percent. The UCS and CBR of the rice husk ash stabilized expansive soil increased up to 20% addition of marble dust. He concluded that for beat stabilization effect, the optimum proportion of soil, rice husk ash, marble dust was found to be as 70: 10: 20 respectively.

Mathew and Ramesan (2016) studied the effect of the addition of coir fiber and polypropylene fiber on the clayey soil. In their findings it has been reported that addition of fibers improves the strength parameters. Jairaj and Prathap Kumar (2015), studied the effect of length of coir fiber on the strength of black cotton soil treated with lime. It was concluded that increase in length of fiber increases peak deviator stress for a given percentage of fiber content. However, when the length of fiber exceeds 20mm, there is marginal reduction in peak deviator stress. Singh and Mittal (2014) conducted an experimental study on clayey soil mixed with coir fibers in varying percentage. The test results indicate that both unsoaked and soaked values of CBR of soil increase with the increase in fiber content.

From the available literature, it can be perceived that limited research has been done to study the effects of waste ceramic dust in improving the geotechnical properties of expansive soil. Therefore, the present study has been undertaken to investigate the effects of vitrified tile sludge on cement & treated coir fiber in stabilizing the expansive soil.

3 Methodology

3.1 Materials Used

The different variables and their respective contents used in the present study are listed in Table 1 and the properties of collected soil are presented n Table 2.

Soil: The soil samples were collected from Komarigiripatnam (Odalarevu) in East Godavari District, A.P. The soil excavated from 3ft depth below the ground level. The geotechnical properties of the expansive soil are presented in Table 2.

Vitrified Tile Sludge: VTS is used as a stabilizing material which was collected from the RAK Ceramics, Samalkota.

Coir Fibre: Coir is a versatile natural fiber extracted from the fibrous husk that surrounds the coconut. It is available abundantly in India, particularly in Konaseema region of East Godavari of AP. Extraction of fiber and making ropes in two different units and the demand remains the same for both products, 150 units are running in Konaseema.

Cement: Used as a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together.

Table 1. Variables studied in the present work

S.No.	Stabilizing Agent	Variables
1	VTS as Replacement	0, 10, 20, 30
2	Cement	0, 0.5, 1.0
3	Treated Coir Fiber (TCF)	0, 0.5, 1, 2

Table 2. Properties of expansive soil

S.No.	Property	Value
1	Specific gravity	2.63
2	Differential free swell Index (%)	100
3	Liquid limit (%)	71.2
4	Plastic limit (%)	31.4
5	Plasticity index (%)	39.8
6	Sand Size Particles (%)	7.0
7	Silt & Clay Size Particles (%)	41&52
8	IS soil classification	CH
9	Max. Dry Density (g/cc)	1.45
10	Optimum Moisture Content (%)	27.5
11	CBR - Soaked (%)	1.3
12	Cohesion, C (kPa)	38.8
13	Angle of Internal Friction, Ø (degrees)	0

4. Results and Discussions

In the laboratory, various experiments were conducted by replacing different percentages of vitrified tile sludge in the expansive soil and also further stabilizing it with cement as a binder and further reinforced with treated coir fiber. Compaction, UCS and CBR tests were conducted to determine the optimum combination of vitrified tile sludge as a replacement in expansive soil and cement as a binder and further blended with treated coir fiber. The influence of the above said materials on the compaction and strength characteristics were discussed in following sections. All the tests were conducted per IS codes of practice.

4.1 Effect of VTS and Cement on the Compaction Properties

Figures1, 2, 5&6 shows the variation of compaction properties for replacement of VTS and to the optimum percentage of VTS, percentage addition of cement respectively. It can be observed that the treatment as individually with 20% VTS has moderately improved the expansive soil. Further, it can be inferred that there is a gradual increase in maximum dry density with an increment in the VTS up to 20% with an improvement of about 3.4 % and further addition of cement to the optimum percentage 1% of cement, a gradual increase in maximum dry density with an improvement of about 6.6 % is observed. As the density of VTS is comparatively higher than that of clay, replacing the clay with VTS would have improved the density. In addition, cement as auxiliary material provided further improvement in the MDD. This can be attributed to the development of a solid matrix of cement and VTS in the presence of OMC. The grain size distribution of VTS indicates 97.5% of fine sand (Prasad et al. 2015). This could be possible reason for the significant reduction in the OMC compared to VTS and cement mix.

4.2 Effect of VTS and Cement on the CBR

Figures 3&7, shows the variation of CBR values for replacement of VTS and to the optimum percentage of VTS, percentage addition of cement respectively. It can be observed that the treatment as individually with 20% VTS has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual increase in CBR values with an increment in VTS up to 20% with an improvement of about 207 % soaked CBR and further addition of cement to the optimum percentage 1% of cement that there is a gradual increase in CBR values with an improvement of about 82.5% for soaked CBR. Replacing the highly compressible material like clay with a sand-sized material can reduce the compressibility and improves the CBR. Further, the presence of china clay and other strengthening agents stiffens slowly in the presence of water and improves the CBR in the long term. It is clear that cement provides additional strength in the presence of water and significantly improves the CBR in soaked condition.

4.3 Effect of VTS and Cement on the Strength Characteristics

Figures 4& 8, shows the variation of UCS Values for replacement of VTS and to the optimum percentage of VTS, percentage addition of Cement respectively. From the figures, it was observed that the treatment as individually with 20% VTS has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual increase in UCS values with an increment in the % replacement of VTS up to 20% with an improvement of about 35.3 % further addition of cement to the optimum percentage 1% of cement that there is a gradual increase in UCS values with an improvement of about 58.09%.The VTS, a quantize based porus material has very minimal influence in improving the UCS when replaced. However, when added with auxiliary material cement, due to the formation high strength matrix as a result of pozzolanic reaction significantly improved the UCS.

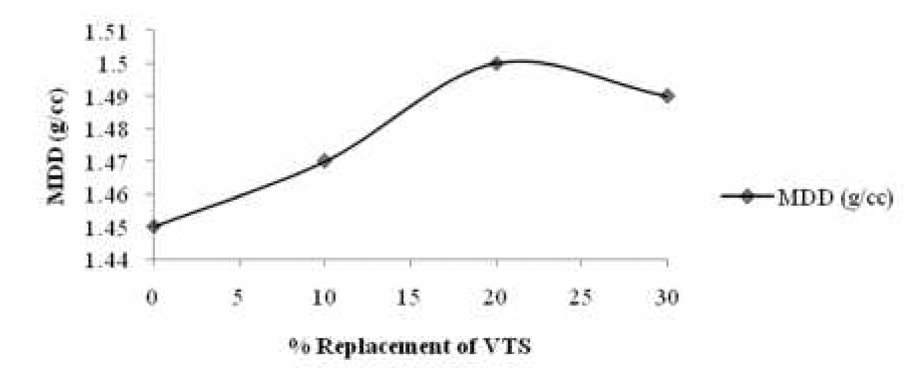

Fig. 1. Variation of MDD with % replacement of vitrified tile sludge (VTS)

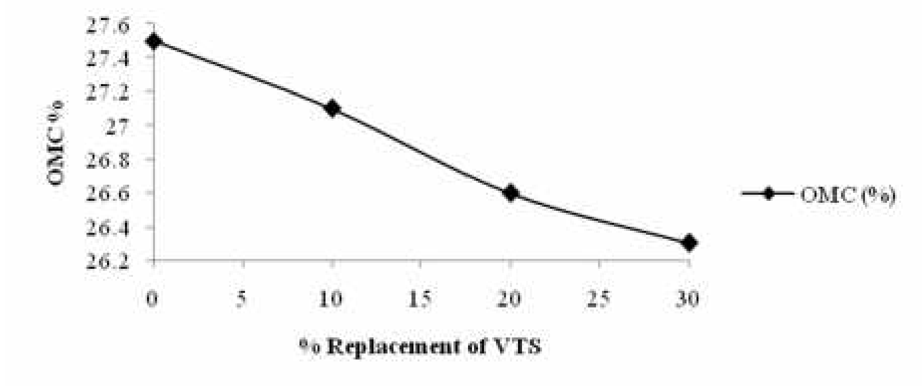

Fig. 2. Variation of OMC with % replacement of vitrified tile sludge (VTS)

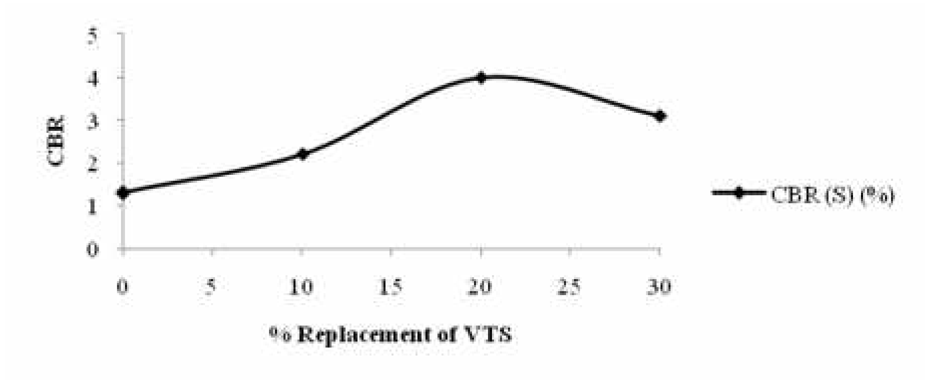

Fig. 3. Variation of CBR with % replacement of vitrified tile sludge (VTS)

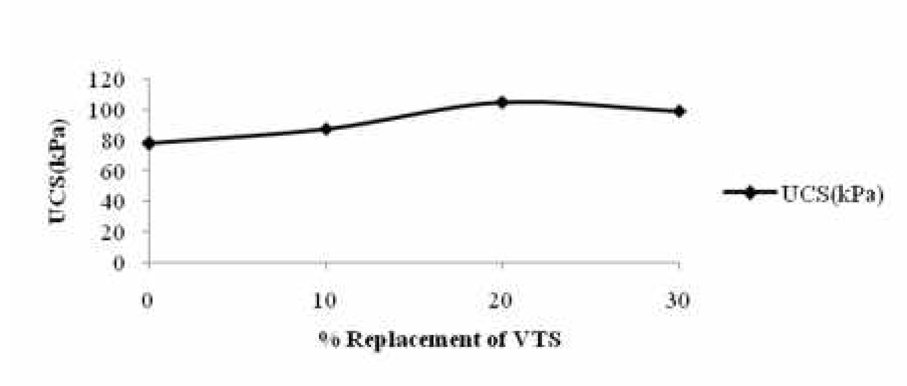

Fig. 4. Variation of UCS with % replacement of vitrified tile sludge (VTS)

It can be inferred from the figures, that there is a gradual increase in the strength properties of the soil with percentage replacement of Vitrified tile sludge (VTS).From the above results, the 20% replacement of expansive soil with VTS can be considered as optimum.

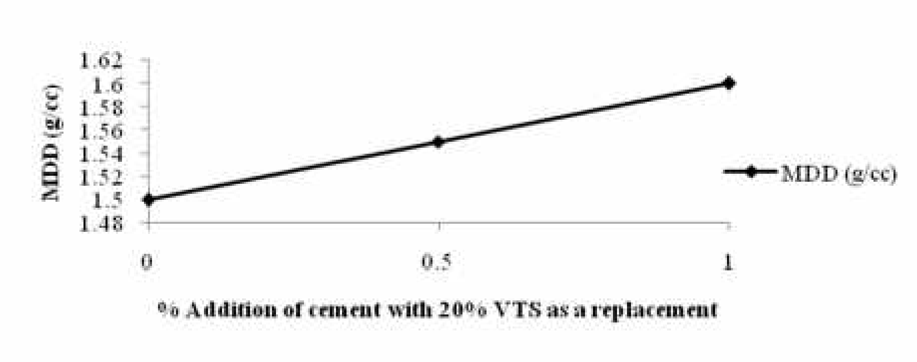

Fig. 5. Variation of MDD with % addition of cement

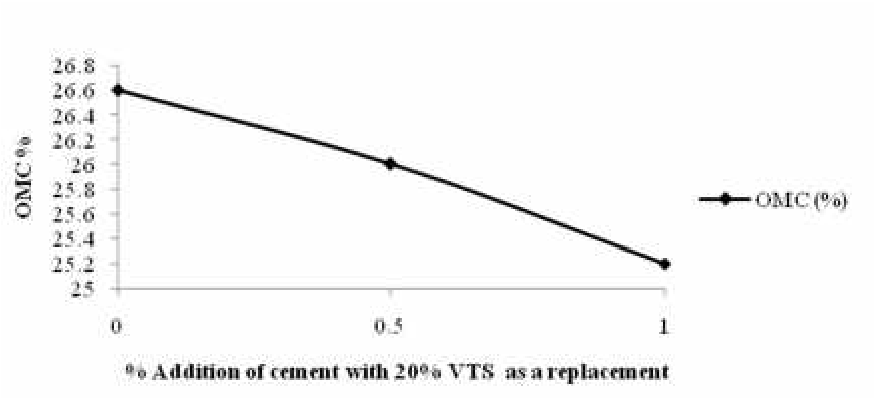

Fig. 6. Variation of OMC with % addition of cement

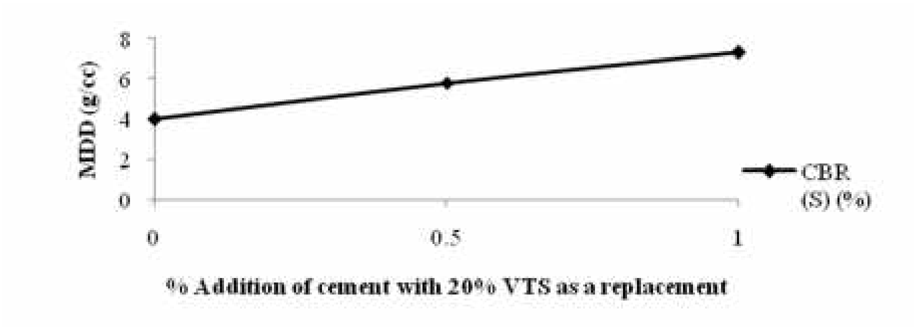

Fig.7. Variation of CBR with % addition of cement

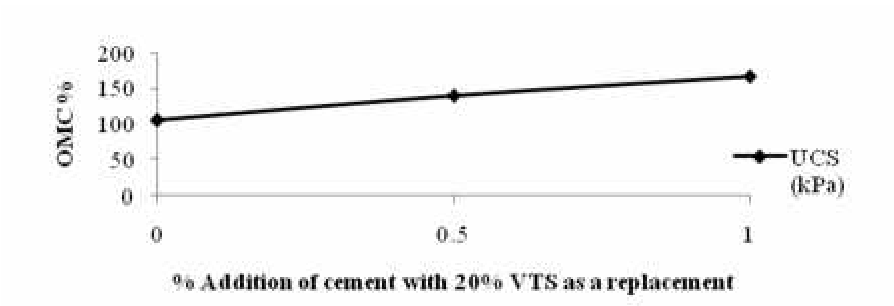

Fig.8. Variation of UCS with % addition of cement

It can be perceived that the improvement in the CBR values is significantly higher than compaction and UCS. Though the percent of admixtures were same for all the tests, the reaction time and strength achievement for the soil-VTS-cement matrix would be different. Since UCS and compaction properties are tested immediately after the sample preparation and soaked CBR is tested after 96 hours, the sample got much time to complete the pozzolanic reaction. This resulted in high strength profiles for soaked CBR compared to compaction and UCS.

From the results, the optimum content of cement with 20% vitrified tile sludge as replacement of expansive soil is determined as 1%.Further, tests were conducted for different percentages of Treated coir fibre by adding to the VTS treated expansive soil with an optimum percentage of cement i.e. 1%.

4.4 Effect of Treated coir fiber (TCF) on Expansive soil with 20% VTS as replacement + 1.0% CEMENT

For the soil-VTS-cement matrix maximum dry density value is 1.6 g/cc from the figure 9 it is found that with the addition of treated fibres to the soil-VTS-cement mix there was increase in dry density up to 1% of addition then decrease subsequently with further addition of fibre content. The increase in dry density may be due to better interaction of soil with fibre. From the figures 10 and 11 it was found that the CBR and UCS value increases with increase in fibre content. When the treated coir fibre content is varied, a fall in the CBR and unconfined compressive strength was observed with fibre content greater than 1.0% in case of coir fibre. Hence it is concluded that fibres at 1.0% yield a maximum value in terms of dry density, CBR and UCS. The increase in the values of MDD, CBR and UCS with addition of 1% TCF can attributed to the better orientation of fibres along with the soil particles. However, with further increase in the TCF, accumulation of fibre material is observed which eventually lead to the reduction in the strength of the soil matrix.

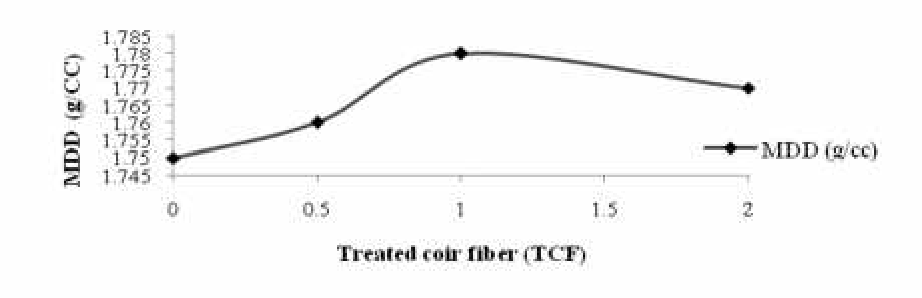

Fig.9. Variation of MDD with % of treated coir fiber

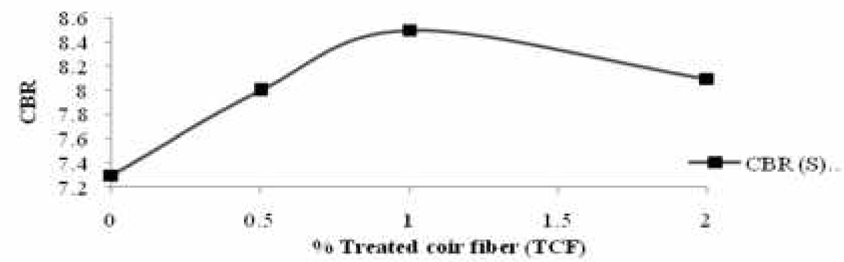

Fig.10. Variation of CBR with % of treated coir fiber

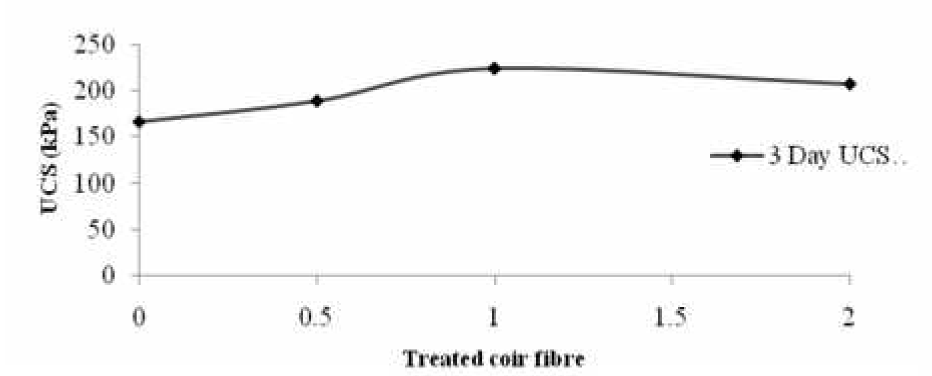

Fig.11. Variation of UCS with % of treated coir fiber

From the above discussions, the optimum content of TCF with 1.0% cement + 20% VTS as replacement of expansive soil is 1.0%. It is clear that there is an improvement in the behavior of expansive soil stabilized with 1.0% cement + 20% VTS+ 1% TCF.

It is evident that the addition of vitrified tile sludge to the virgin expansive soil showed an improvement in compaction and strength characteristics to some extent and on further addition of cement shows prominent results and further blending it with treated coir fiber, 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 VTS replacement in the expansive soil has improved its strength and upon further blending with Treated coir fiber, the strength has further improved and also these materials have imparted friction to the clayey soil. It can be summarized that the materials vitrified tile sludge (VTS), cement and TCF had shown promising influence on the Strength and Penetration properties of expansive soil.

5 Conclusions

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 expansive soil treated with vitrified tile sludge 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 30% with an improvement of about 10% and it is observed that for the replacement of 20% there is a gradual increase in Maximum dry density about 3.4 %.Further addition of cement content from 0% to 10% with an increment of 1%. For the cement content of 1%, MDD increases about 6.6%.
- There is an improvement in strength characteristics with a replacement of VTS from 0% to 30% with an increment of 10%.There is an improvement of 207% In CBR and 35.3% in UCS values. Further addition of cement content from 0% to

10% with an increment of 1%. For cement content of 1%, there is an improvement of 82.5% In CBR and 58.09% in UCS values

- Further blending with treated coir fiber with 0% to 2% with an increment of 0.5% there is an increment of CBR and UCS values is about 16.4% and 34.9% respectively.
- It is evident that the addition of Vitrified tile sludge (VTS) to the virgin Expansive soil showed an improvement in compaction, strength and penetration characteristics to some extent and on further blending it with cement and treated coir fiber the strength mobilization was more pronounced.
- Finally, it can be summarized that the materials Vitrified tile sludge (VTS) and cement and treated coir fiber had shown promising influence on the strength characteristics of expansive soil, thereby giving a two-fold advantage in improving problematic expansive soil and also solving a problem of waste disposal.

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