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Stabilization of Fine Sand with Ceramic Tiles Waste as Admixture for Construction of Embankment

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ABSTRACT: *This paper deals with the stabilization of fine sand with Ceramic Tiles waste as admixture. As the fine sand has very low bearing capacity and compressive strength along with nil cohesion, thus the construction of any structure on fine soil required stabilization. This study discusses the possibility of fine sand stabilization using Ceramic Tile Waste as admixture. Present work has been taken up by addition of 4.75 mm sieve passed and 2.36 mm sieve retained Ceramic Tile Waste as admixture. The varying percentage 2%, 4%, 8% and 12% of ceramic tile waste were mixed with fine sand of different densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc. All the Direct Shear Tests were conducted at different mix compositions of ceramic tile waste and fine sand of different dry densities as arrived from Standard Proctor Test. Falling-Head Permeability Tests were also performed on different mix compositions. On the basis of the experiments performed, it is determined that the stabilization of fine sand using ceramic tile waste as admixture improves the strength characteristics of the fine sand so that it becomes usable as construction of embankment.*

Keywords: *Direct shear, fine sand, permeability, ceramic tiles*

I. INTRODUCTION

Soil stabilization is the process of improving the Engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for the intended purpose. In its broadest senses, stabilization includes compaction, preconsolidation, drainage and many other such processes. Stabilization is being used for a variety of engineering works, where the main objective is to increase the strength, durability or to prevent dust generation and erosion of soil and to reduce the construction cost by making best use of locally available materials. In western Rajasthan, fine sand is available in abundance, which is scarcely suitable for construction of embankment and necessitate either improving available fine sand or importing good quality mineral aggregate.

Fine sand stabilization with the use of ceramic tiles as admixture has great scope for the construction of embankment. The aim of present work is the beneficial and economical utilization of such wastages for improving properties of fine sand. Utilization of ceramic tiles waste for improvement of soil properties is a sustainable and cost-effective technique. Due to warping, a huge amount of broken ceramic tile waste is produce every year from manufacturing unites. Hence it was thought to be utilized of ceramic tile waste as an admixture with which fine sand can be stabilized. On the other hand, the problem of the disposal of Ceramic tiles waste can be overcome by using it for stabilization of fine sand.

II. MATERIALS USED FOR PRESENT STUDY

2.1 Fine Sand

Fine sand is found in abundance in Western Rajasthan. The fine sand has similar characteristics which are found in various Towns of Jodhpur. Hence the sand used in present study was brought location near Dangiyawas-Banar villages, at about 30-35 kms away from Jodhpur on Jodhpur-Jaipur Road. Fine sand has nil cohesion and poor compressive strength and hence need stabilization. Fine sand is uniform clean sand as per Unified Soil Classification System. Particles size ranges between 75µ to 1 mm that is fine coarse sand, round to angular in particle shape as per Indian Standard Classification System.

2.2 Ceramic Tile Waste

A Ceramic Tile is an inorganic, nonmetallic solid prepared by the action of heat and subsequent cooling. Ceramic material may have crystalline or partly crystalline structure, or may be amorphous, because most common ceramics are crystalline materials. The earlier ceramics were pottery objects made from clay either by itself or mixed with other materials, hardened in fire. Later ceramics were glazed and fired to create a colored, smooth surface. The ceramic tiles used in present work were of Kajaria Company. The ceramic tile waste was bought from a manufacturing unit from Bikaner, Rajasthan (India).

Figure 1: Ceramic Tile Admixture

Table 1 : Summary of the physical properties of the tested ceramic tile waste material

Physical and Engineering Properties	
Density	2.27 gm/cc
Water Absorption in 24 hours	4% by dry weight

III. TEST PROGRAM AND PROCEDURE

The laboratory investigation on fine sand stabilization with ceramic tile waste as admixture was performed. This work is done for beneficial utilization of ceramic tile waste and a mix proportion that can be mixed with fine sand as a best stabilizer with limited detrimental effects.

The objective of the present study is to evaluate the use of fine sand as a construction material after stabilizing it with ceramic tile waste as admixture. The present study has been undertaken with the following objectives:

1. To study the effect of moisture content on dry density of fine sand.
2. To study the changes in shear stress of fine sand of different dry densities mixed with ceramic tile waste in different proportions.
3. To study the changes in permeability of fine sand by mixing with ceramic tile waste in different proportions.

3.1 Test Program

The test program included the preliminary tests for fine sand and mix compositions of fine sand with ceramic tile waste. Following tests were carried out:

1. Determination of particle size distribution of fine sand.
2. Standard Proctor Test (Proctor Compaction Test) for determining different dry densities for fine sand.
3. Direct Shear Test to determine shear stress of fine sand and mix compositions with ceramic tile waste.
4. Permeability by Variable Head Permeability Test of fine sand and mix composition with ceramic tile waste.

Table 2: Variables Investigated

S. No.	Effect of	Variables	Range Investigated
1	Moisture content in sand	Dry density	1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc
2	Ceramic tile waste on different properties of sand	Size passing sieve size	4.75 mm Passing and 2.36 mm retaining
3	Mix ceramic tile waste by dry weight of sand	Proportion percentage	2%, 4%, 8% and 12%

3.1.1 Particle Size Distribution or Gradation Test of Fine Sand

The particle size distribution test or gradation test was carried out with Indian Standard Sieve size 4.75 mm, 2.36 mm, 1.18 mm, 600 μ, 425 μ, 300 μ, 150μ, 75μ, pan and weigh balance in the laboratory.

A typical sieve analysis involves a nested column of sieve with wire mesh cloth (screen). A representative sample of 1000 gm is poured into the top sieve which has the largest screen opening of 4.75 mm. Each lower sieve in the column has smaller opening than the one above. The base is a round pan, called the receiver. The sample was shaken vigorously for 10 minutes on sieve shaker. After the shaking, the weight of material retained on each sieve was weighed. Percentage passing through each sieve was calculated and plotted against particle size. Since percentage passing 75 μ is within 1% only, hydrometer analysis was not done.

$$\text{Percentage (\%) Retained} = \frac{W_{sieve}}{W_{total}} \times 100\%$$

Where W_{sieve} is the weight of aggregate in the sieve in gm

W_{total} is the total weight of the aggregate in gm

The cumulative percentage passing of the aggregate is found by subtracting the percent retained from 100%.

Percentage (%) Cumulative Passing = 100% - Percentage (%) Cumulative Retained

The results of particle size distribution have been shown in table 3, table 4 and figure 2.

Table 3 : Particle Size Distribution of Fine Sand

S.No.	Sieve Size	Weight Retained (gm)	% Weight Retained	Cumulative % Weight Retained	Cumulative % Weight Passing	% Finer
1.	4.75 mm	2.0	0.2	0.2	99.8	99.8
2.	2.36 mm	2.0	0.2	0.4	99.6	99.6
3.	1.18 mm	2.0	0.2	0.6	99.4	99.4
4.	600 μ	1.0	0.1	0.7	99.3	99.3
5.	425 μ	2.0	0.2	0.9	99.1	99.1
6.	300 μ	2.0	0.2	1.1	98.9	98.9
7.	150 μ	904.0	90.4	91.5	8.5	8.5
8.	75 μ	82.0	8.2	99.7	0.3	0.3
9.	Pan	3.0	0.3	100	0	0

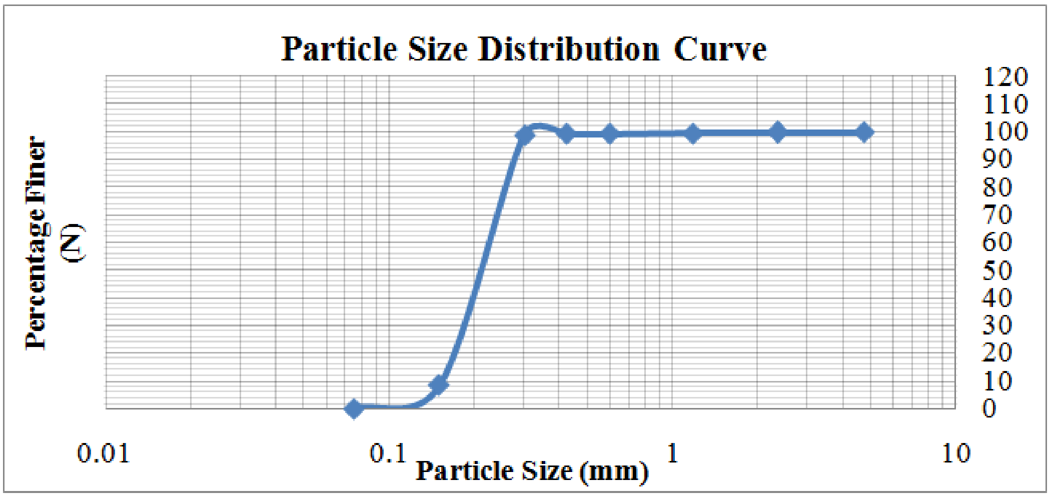

Figure 2: Particle Size Distribution Curve

Table 4: Results of Particle Size Distribution

S. No.	Property	Test Media (Fine Sand)
1.	Coefficient of Uniformity (C_u)	1.31
2.	Coefficient of Curvature (C_c)	1.08
3.	Mean Diameter (D_{50}) mm	0.20
4.	Effective Size (D_{10}) mm	0.16
5.	Fine Soil Fraction (75 μ)	0.10%

3.1.2 STANDARD PROCTOR TEST

Standard proctor covers the determination of the relationship between the moisture content and density of soils. The standard proctor test was performed in accordance with IS 2720 (Part VII) on fine sand. In this test, a standard mould of 100 mm internal diameter and an effective height of 127.3 mm, with a capacity of 1000 ml are used. The mould had a detachable base plate and a removable collar of 50 mm height at its top. The soil was compacted in the mould in 3 equal layers; each layer was given 25 blows of 2.6 kg rammer falling through a height of 310 mm.

The result tabulated in figure 3 shows that on increment of moisture content, dry density first decrease and then increase. In the curve dry density first decrease due to bulking of sand. After reaching maximum dry density on optimum moisture content, dry density decreases. The variation of dry density with moisture content shows that the required dry densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc for the experiments occur at 4%, 12% and 18% moisture content.

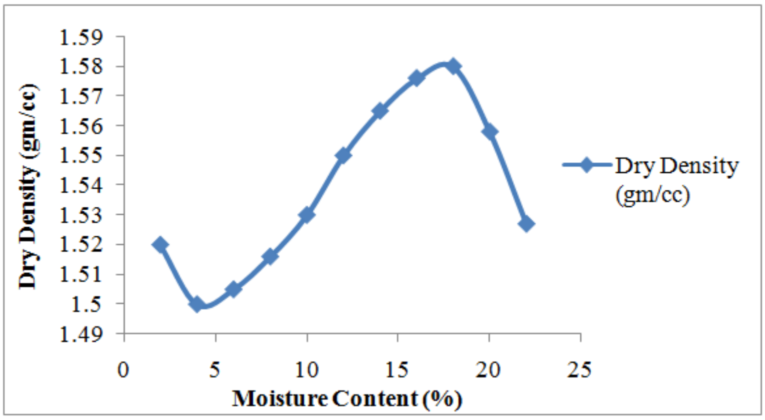

Figure 3: Dry Density v/s Moisture Content Curve

3.1.3 Direct Shear Test

The Direct Shear Test is used to determine the shearing strength of the fine sand using the direct shear apparatus. Direct shear tests were performed on mix composition of fine sand of 1.50 gm/cc, 1.55gm/cc and 1.58 gm/cc density with ceramic tile waste of 2%, 4%, 8% and 12% by dry weight of sand. Tests were carried out with a strain controlled shear apparatus at rate of 1.25 mm/min to determine failure stress and angle of internal friction (ϕ) of different mix composition in accordance with ID 2720 (Part XIII).

3.1.3.1 Comparative Study

A comparative study of variation of stresses has been made from the test results. The variation of shear stress graphs, showing on X-axis corresponding normal stress 0.1 kg/cm^2, 0.2 kg/cm^2, 0.3 kg/cm^2 and Y-axis corresponding shear stress at 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc dry density sand mixed with 2%, 4%, 8% and 12% admixture have been tabulated in following tables and figures.

The value of shear stress linearly increases for different dry density, different percentage of admixture and different normal stress. It has been found from the study that on keeping dry density as constant, the shear stress value of the mix composition increases as the normal stress increases. Also for the same normal stress, as the quantity of the admixture increase, the shear stress value of the mix composition increases as the dry density increases.

From the results obtained it can be concluded that angle of internal friction (ϕ) increases with increase in dry density in mix composition. For the same dry density, the angle of internal friction ϕ increases with increase in percentage or quantity of ceramic tile waste.

Table 5: Variation of Shear Stress for 1.50 gm/cc Dry Density Sand with 2%, 4%, 8% and 12% Admixture

Normal Stress (kg/cm²)	Shear Stress (kg/cm²)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
0.1	0.1188	0.1518	0.1848	0.198	0.2178
0.2	0.1782	0.2244	0.2574	0.2904	0.3168
0.3	0.2310	0.3036	0.3366	0.3762	0.4092

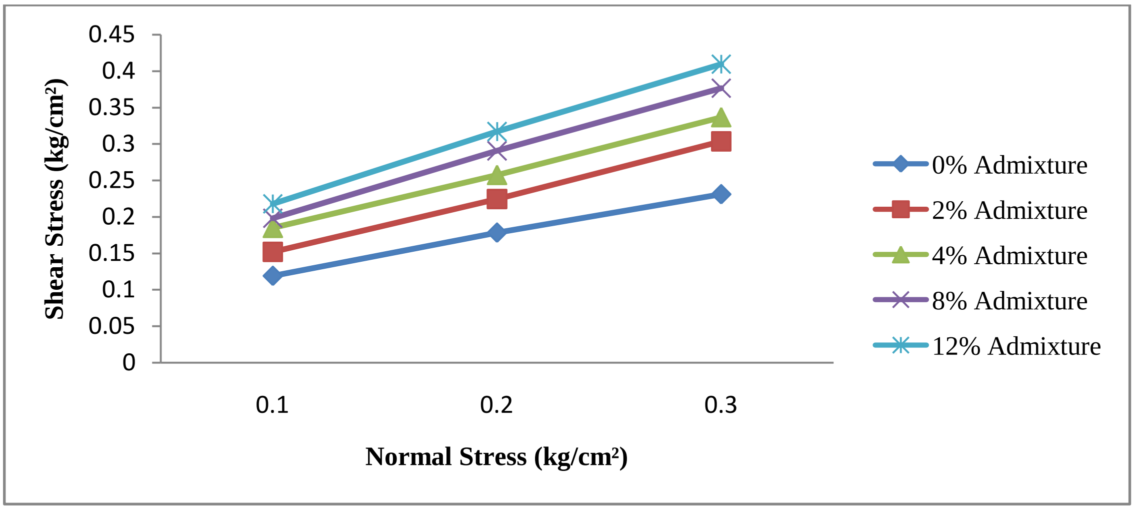

Figure 4: Variation of Shear Stress for 1.50 gm/cc Dry Density Sand with 2%, 4%, 8% and 12% Admixture

Table 6: Variation of Shear Stress for 1.55 gm/cc Dry Density Sand with 2%, 4%, 8% and 12% Admixture

Normal Stress (kg/cm²)	Shear Stress (kg/cm²)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
0.1	0.1320	0.1782	0.1980	0.2310	0.2640
0.2	0.1980	0.2574	0.2904	0.3366	0.3696
0.3	0.2574	0.3366	0.3762	0.4290	0.4752

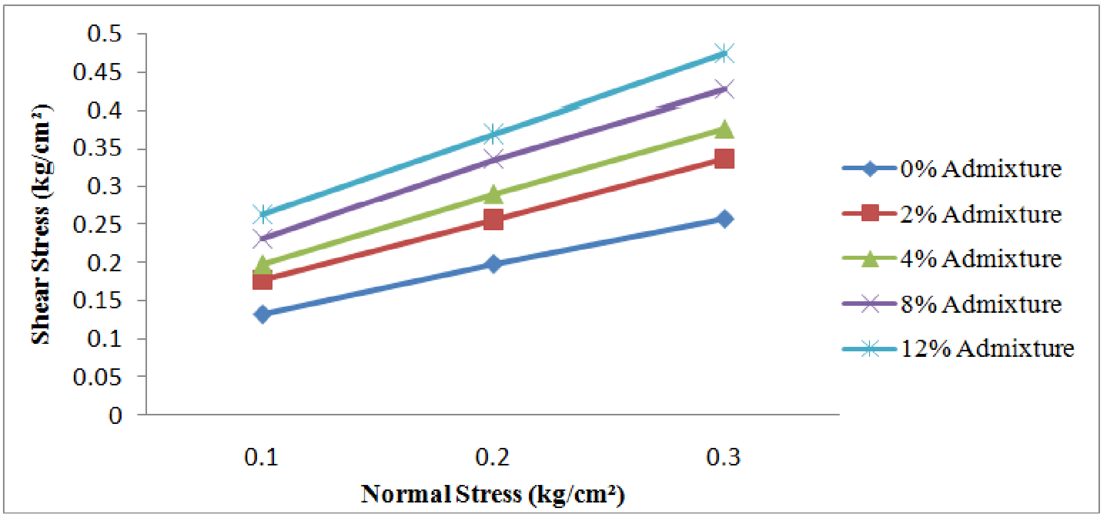

Figure 5: Variation of Shear Stress for 1.55 gm/cc Dry Density Sand with 2%, 4%, 8% and 12% Admixture

Table 7: Variation of Shear Stress for 1.58 gm/cc Dry Density Sand with 2%, 4%, 8% and 12% Admixture

Normal Stress (kg/cm²)	Shear Stress (kg/cm²)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
0.1	0.1386	0.198	0.231	0.264	0.297
0.2	0.2112	0.2838	0.33	0.3696	0.4092
0.3	0.2772	0.3828	0.4356	0.4752	0.5214

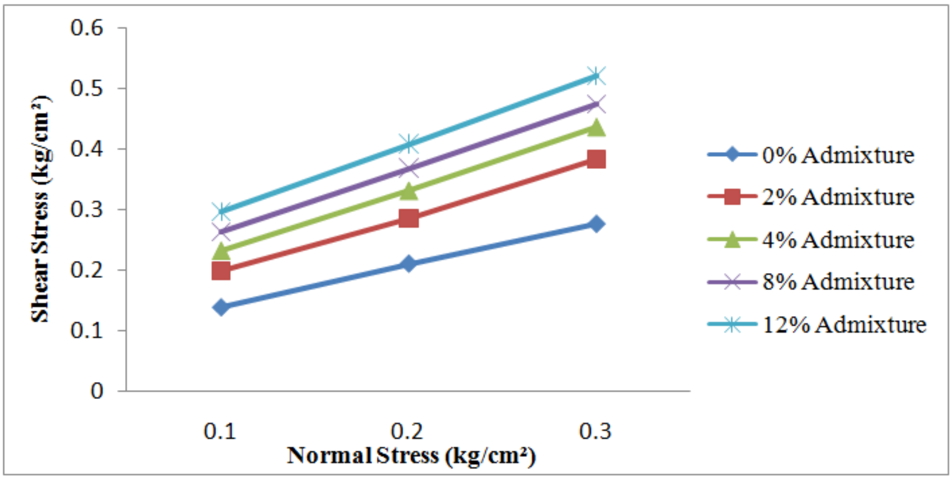

Figure 6: Variation of Shear Stress for 1.58 gm/cc Dry Density Sand with 2%, 4%, 8% and 12% Admixture

Table 8: Variation of ϕ with Dry Density of Sand and % Admixture

Dry Density (gm/cc)	Angle of Internal Friction ϕ (Degree)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
1.50	29°17'	35°58'	37°11'	41°42'	43°44'
1.55	32°05'	38°22'	41°42'	44°42'	46°33'
1.58	34°43'	42°44'	45°39'	47°26'	48°17'

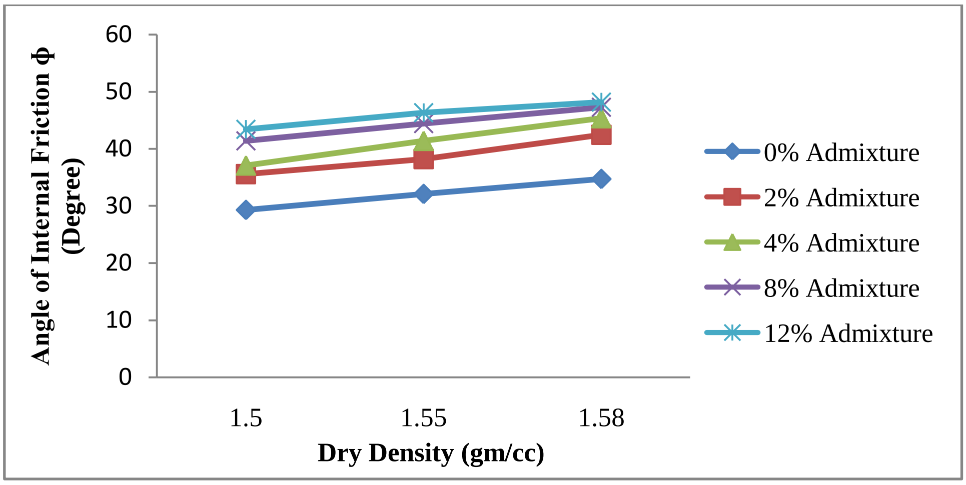

Figure 7: Variation of ϕ with Dry Density of Sand and % Admixture

3.1.4 Variable Head Permeability Test

Permeability is the measure of the ease with which water can flow through a soil sample. The tests were conducted in variable head permeameter according to IS 2720 (Part XVII).Test investigations were carried out on variable head permeameter with mix compositions of 1.58 gm/cc dry density fine sand and ceramic tile waste in varying percentages of 2%, 4%, 8% and 12%.

A conclusion from the test results obtained that coefficient of permeability (k) increases with increase in percentage of ceramic tile waste.

Table 9: Variation of Coefficient of Permeability k (cm/sec) with Mix Composition

S.No.	Percentage (%) Admixture	Coefficient of Permeability (cm/sec)
1.	2%	1.18×10^{-3}
2.	4%	1.24×10^{-3}
3.	8%	1.41×10^{-3}
4.	12%	1.54×10^{-3}

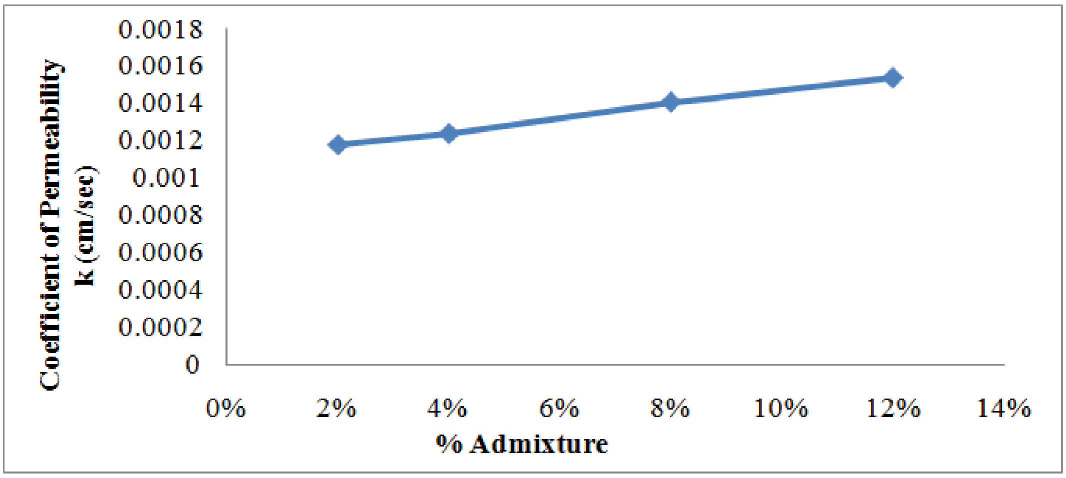

Figure 8: Variation of Coefficient of Permeability k (cm/sec) with Mix Composition

IV. CONCLUSIONS

In this investigation we have used ceramic tile in different proportions to study its effect on various geotechnical properties of fine sand of Western Rajasthan. The results of the testing program clearly show that the engineering properties of the fine sand improved considerably due to stabilizing with ceramic tile waste. In the present investigation, as we are increasing the quantity of admixture of ceramic tile waste, the angle of internal friction increases. So we have stopped the further increment of admixture. Further study can be done by addition of more amount of admixture.

A few generalized conclusions are summarized below:

1. The shear test were performed for mix compositions of fine sand of different dry densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc with ceramic tile waste of varying percentage 2%, 4%, 8% and 12%. The angle of internal friction (shearing resistance) ϕ increases with increase in dry density of fine sand and quantity of the ceramic tile waste. As the ϕ is increasing, the required section for embankment is reduced.
2. Permeability Tests were performed for mix composition of 2%, 4%, 8% and 12% of ceramic tile waste and fine sand of 1.58 gm/cc dry density. The coefficient of Permeability k (cm/sec) increases with increase in the percentage of ceramic tile waste mixed to fine sand. Greater the percentage of ceramic tile waste more was the mix composition permeable. Hence, the impermeable material should be used in the mix composition to reduce the permeability.
3. After this investigation we conclude that ceramic tile waste can successfully be used as admixture for fine sand stabilization. It can be used for the making embankment for construction of road.

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