

Stabilization of Fine Sand through Sanitary Ware Waste as Admixture for Construction of Embankments for Roads

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ABSTRACT : According to Indian Standard Classification System of soils, the fine sand has nil cohesion and thus has a very low compressive strength and high permeability. Fine sand is not readily suitable for construction of embankments for roads which are supposed to bear heavy loads. This study discusses the possibility of fine sand stabilization using Sanitary Ware Waste as admixture. Present work has been taken up by addition of 4.75 mm sieve passed and 2.36 mm sieve retained Sanitary Ware Waste as admixture. The varying percentage 2%, 4%, 8% and 12% of sanitary ware waste were mixed with fine sand of different densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc (M.D.D). All the Direct Shear Tests were conducted at different mix compositions of sanitary ware 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 sanitary ware waste as admixture improves the strength characteristics of the fine sand so that it becomes usable as a suitable material for construction of embankments for roads.

KEYWORDS: Direct shear, fine sand, permeability, sanitary wares.

I. INTRODUCTION

In the Western Rajasthan (India), fine sand is found in abundance. Fine sand is scarcely suitable for construction of embankments for roads due to poor bearing capacity and higher compressibility; necessitate either improving available fine sand or importing good quality admixture. The improvement of soil at a site is essential due to rising cost of the land. In that case the properties of soil can be improved by soil stabilization.

Soil stabilization in a broad sense incorporates the various methods employed for modifying the properties of a soil to improve its engineering performance. Stabilization is being used for a variety of engineering works, the most common application being in the construction of embankments for roads, where the main objective is to increase the strength, stability, durability and to reduce the construction cost by making best use of locally available materials.

There is a great scope of stabilization of fine sand with the admixture of sanitary ware waste for construction of embankments for roads. The aim of present work is the beneficial and economical utilization of such wastes for improving properties of fine sand. Utilization of sanitary ware waste for improvement of soil properties is a sustainable and cost-effective technique. Since sanitary ware wastes can be easily available in huge quantity from different manufacturing units every year due to warping and braking of sanitary wares. Hence it was thought to be utilized as an admixture with fine sand. The problem of the disposal of warped and braked sanitary ware waste can also be overcome by using it for stabilization of fine sand. The laboratory studies have been done on fine sand by direct mixing of sanitary ware waste. Many researchers like Ameta et al. (2008), Awad ALKarni et al. (2012), Jain O.P. et al. (1979), Kevin M. (1978) and Woyal A.S. et al. (2012) have worked on stabilization of soils.

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II. MATERIALS USED FOR PRESENT STUDY

2.1 Fine Sand

Fine sand is spread in huge areas throughout the Western Rajasthan (India). The sand used in current study was brought from location near Dangiyawas-Banar villages, about 30-35 km away from Jodhpur on Jodhpur-Jaipur Road. Fine sand is uniform clean sand as per Unified Soil Classification System. Particles size ranges between 75 μ to 1.0 mm i.e. fine coarse sand, round to angular in particle shape as per Indian Standard Classification System.

2.2 Sanitary Ware Waste

Sanitary ware is the generic term used to describe items which traditionally were made from pottery. Materials used to manufacture sanitary ware are vitreous china clay, fireclay and high impact plastic. Vitreous china clay is the most common material used for the manufacturing of sanitary ware. Vitreous china clay is made from a mixture of fired white clays and finely ground minerals. A lot of sanitary ware waste is produced during formation of sanitary wares. The sanitary wares used in present work were of *Sonalika* Company. The sanitary ware waste was brought from a manufacturing unit near Bhuj, Gujarat (India). Fig.1 shows the sanitary ware waste admixture which is used for present investigation. Physical and engineering properties of sanitary ware waste material are shown in table 1.



Fig. 1. Sanitary Ware Waste Admixture

Table 1. Summary of the Physical and Engineering Properties of the Tested Sanitary Ware Waste Material

Physical and Engineering Properties of sanitary ware waste material	
Density	2.35 gm/cc
Water Absorption (For 24 hours)	3% by dry weight

III. TEST PROGRAM AND PROCEDURE

The laboratory investigation on fine sand stabilization with sanitary ware waste as admixture was performed. This work is done for beneficial utilization of sanitary ware 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 sanitary ware waste as admixture. The objectives of present study are given below:

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 sanitary ware waste in different proportions.
3. To study the changes in permeability of fine sand by mixing with sanitary ware waste in different proportions.

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3.1 Test Program

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

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

Table 2 shows the variables which are investigated in present study.

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.	Sanitary ware waste on different properties of sand	Size passing sieve size	4.75 mm Passing and 2.36 mm retaining
3.	Mix sanitary ware 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.

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

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

Results of particle size distribution of fine sand are shown in table 3 and fig. 2. A comparative study of results of particle size distribution of desert sand and test media (fines sand) is given in table 4.

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

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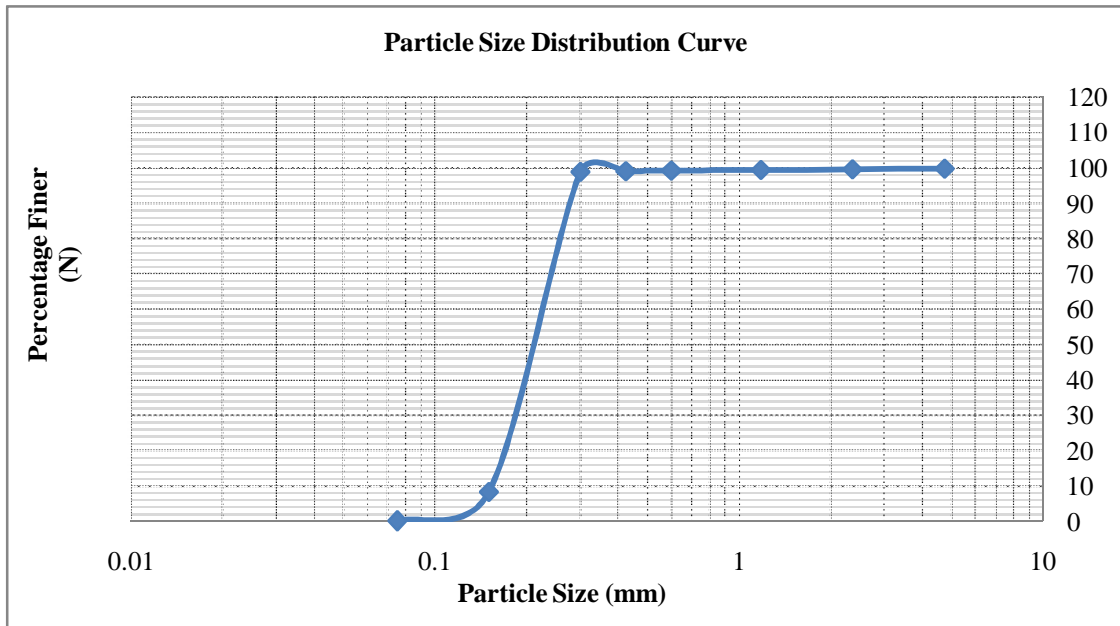


Fig. 2. Particle Size Distribution Curve

Table 4. Results of Particle Size Distribution

S. No.	Property	Desert Sand	Test Media (Fine Sand)
1.	Coefficient of Uniformity (C_u)	1.25-1.90	1.31
2.	Coefficient of Curvature (C_c)	0.90-1.40	1.08
3.	Mean Diameter (D_{50}) mm	0.11-0.18	0.20
4.	Effective Size (D_{10}) mm	0.08-0.12	0.16
5.	Fine Soil Fraction (75μ)	2-5%	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.

Fig. 3 plotted after experiment shows that on increment in moisture content, dry density first decrease and then increase. The dry density decreases due to capillary tension in pore water. The capillary tension resists the tendency of soil particles to take a dense state and hence the volume increases. This phenomenon is known as bulking of sand. After reaching maximum dry density on optimum moisture content, dry density again decreases. The required dry densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc (M.D.D.) for the investigation occur at 4%, 12% and 18% moisture content.

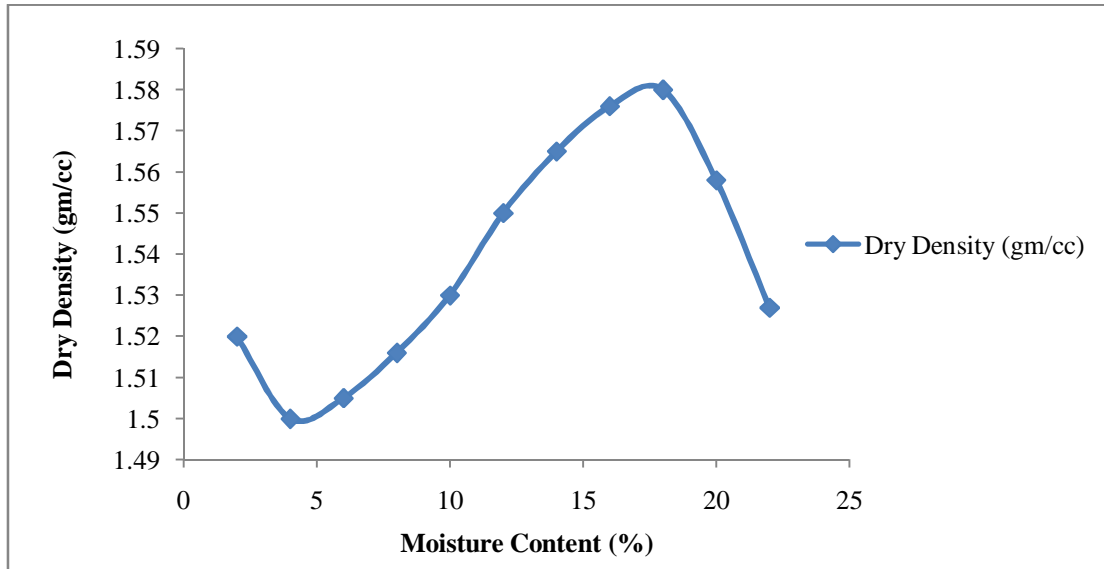


Fig. 3. Dry Density v/s Moisture Content Curve

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 sanitary ware 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/cm², 0.2 kg/cm², 0.3 kg/cm² 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 given in tables 5, 6, 7 and figs. 4, 5, 6.

The value of shear stress linearly increases with increase in dry density, percentage of admixture and 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 which are given in table 8 and fig. 7, it can be concluded that angle of internal friction (ϕ) increases with increase in dry density in mix composition. On the other hand, for the same dry density, the angle of internal friction ϕ increases with increase in percentage or quantity of sanitary ware 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/cm ²)	Shear Stress (kg/cm ²)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
0.1	0.1188	0.1452	0.1716	0.1914	0.2112
0.2	0.1782	0.2178	0.2508	0.2772	0.3102
0.3	0.2310	0.2904	0.3300	0.3630	0.4026

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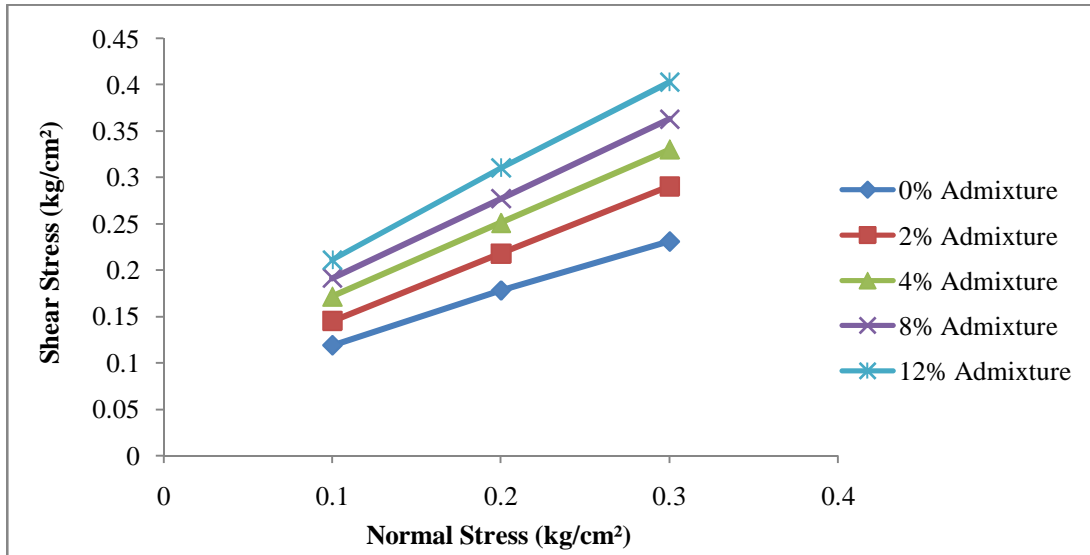


Fig. 4. Variation of Shear Stress for 1.50 gm/cc Dry Density Sand with 2%, 4%, 8% and 12% Admixture

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

Normal Stress (kg/cm ²)	Shear Stress (kg/cm ²)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
0.1	0.1320	0.1650	0.1914	0.2244	0.2508
0.2	0.1980	0.2508	0.2838	0.3300	0.3564
0.3	0.2574	0.3300	0.3762	0.4290	0.4686

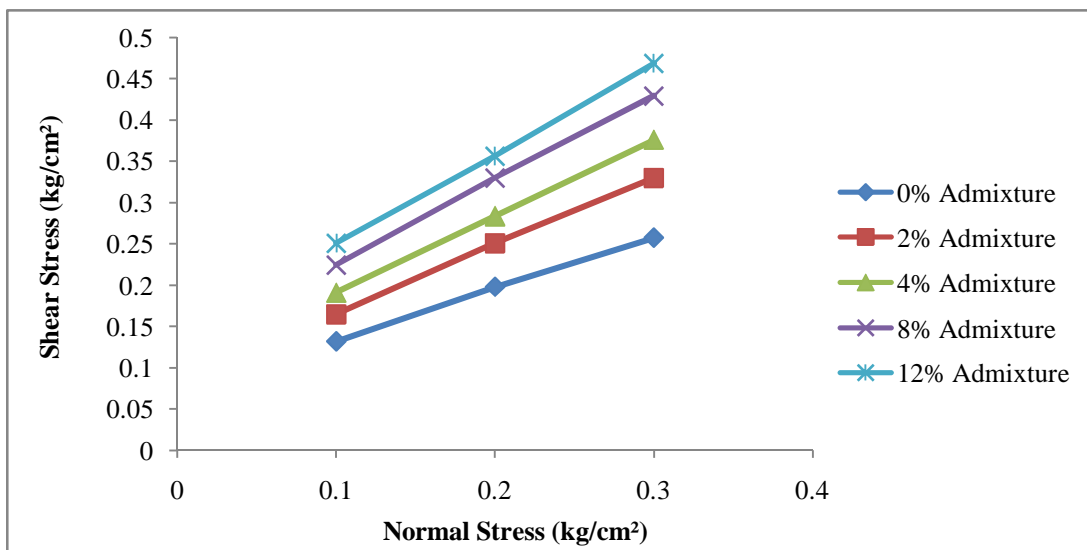


Fig. 5. Variation of Shear Stress for 1.55 gm/cc Dry Density Sand with 2%, 4%, 8% and 12% Admixture

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

Normal Stress (kg/cm ²)	Shear Stress (kg/cm ²)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
0.1	0.1386	0.1848	0.2112	0.2376	0.2640
0.2	0.2112	0.2772	0.3102	0.3432	0.3828
0.3	0.2772	0.3630	0.4092	0.4488	0.4950

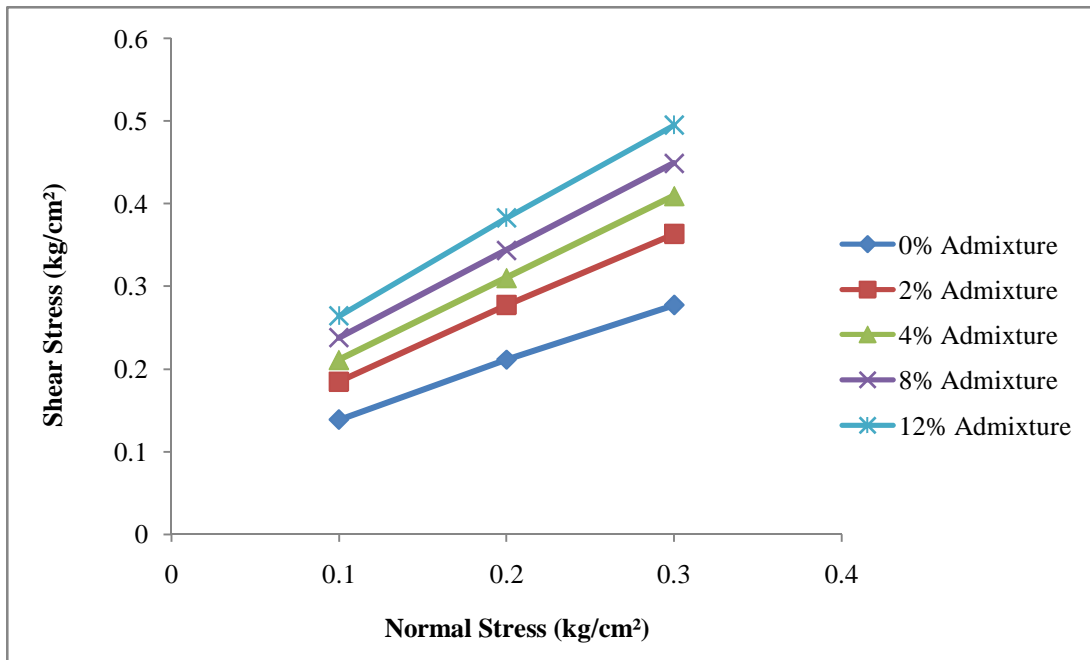


Fig. 6. Variation of Shear Stress for 1.58 gm/cc Dry Density Sand with 2%, 4%, 8% and 12% Admixture

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	29.29°	35.96°	38.36°	40.61°	43.73°
1.55	32.09°	39.52°	42.73°	45.65°	47.43°
1.58	34.72°	41.70°	44.70°	46.55°	49.10°

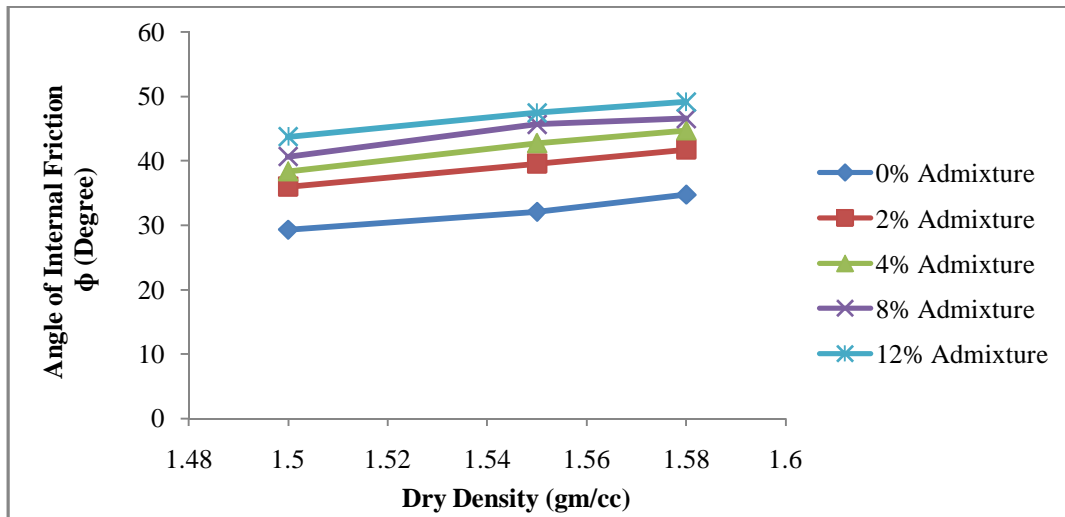


Fig. 7. Variation of ϕ with Dry Density of Sand and % Admixture

3.1.4 Variable Head Permeability Test

Permeability is the measure of the ease with which water can flow through a soil sample. Test investigations were carried out on variable head permeameter with mix compositions of 1.58 gm/cc dry density fine sand and sanitary ware waste in varying percentages of 2%, 4%, 8% and 12% according to IS 2720 (Part XVII). A conclusion from the test results obtained that coefficient of permeability (k) increases with increase in percentage of sanitary ware waste. The test results of variable head permeability tests are given in table 9 and fig. 8.

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

S. No.	Percentage (%) Admixture	Coefficient of Permeability (cm/sec)
1.	2%	1.14×10^{-3}
2.	4%	1.23×10^{-3}
3.	8%	1.39×10^{-3}
4.	12%	1.52×10^{-3}

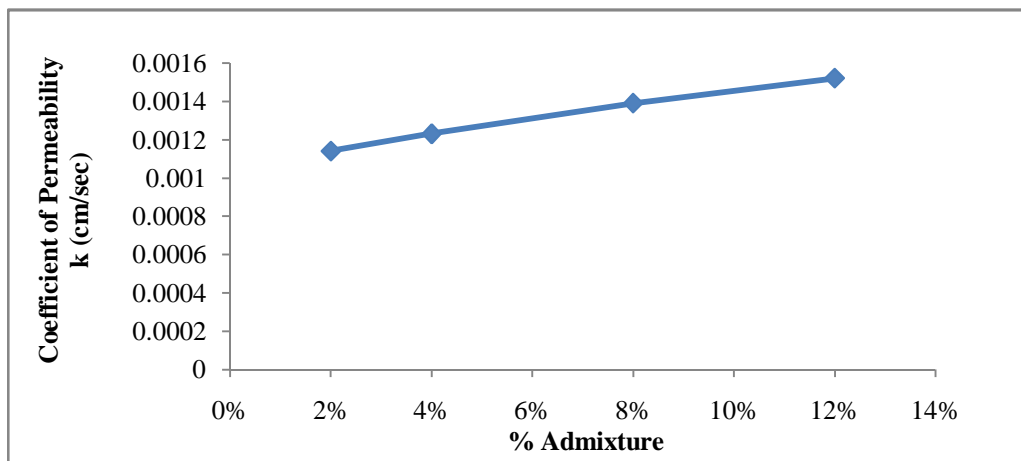


Fig. 8. Variation of Coefficient of Permeability k (cm/sec) with Mix Composition

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IV. CONCLUSIONS

In this investigation we have used sanitary ware waste 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 sanitary ware waste. In this investigation, as we increased the proportion of admixture, angle of internal friction (ϕ) also increased. So we have done our investigation upto 12% admixture. Further investigations can be done by adding more proportion of sanitary ware waste 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 sanitary ware 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 sanitary ware waste. As the angle of internal friction (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 sanitary ware 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 sanitary ware waste mixed to fine sand. Greater the percentage of sanitary ware waste more was the mix composition permeable.
3. After this investigation we conclude that sanitary ware waste can successfully be used as admixture for fine sand stabilization. Hence the mix composition of fine sand and sanitary ware waste can be used for the construction of embankments for roads.

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