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Fine Sand Stabilization Using Sanitary Ware Waste as Admixture for Design of Flexible Pavement in Construction of Roads

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ABSTRACT: *When designing and constructing highways or more generally any road on fine sands type of soil, it is essential to make sure that the foundation soil is providing a stable, non-yielding surface for the movement of heavy vehicles. Fine sand is found in abundance in Western Rajasthan (India) in which hundreds of kilometers of new roads and highways are being constructed and maintained every year. As per Indian Standard Classification System of soils, the fine sand has nil cohesion. Due to very low compressive strength and high permeability, fine sand is not readily suitable for supporting flexible pavements as sub grade. This study discusses the possibility of stabilization of fine sand 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 California Bearing Ratio 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 base material for flexible pavement in construction of roads.*
Keywords : *C.B.R., fine sand, permeability, sanitary wares*

I. INTRODUCTION

All the works which are related to civil engineering such as the construction of highway, building structure, embankment and other structure have a strong relationship with soil. All these structures need a strong base of soil to make sure that the structure are stable and strong. Due to weakness and failure of soil which is supporting the structures, the structures become weak and collapse or fail. Therefore, the proper investigation of soil is necessary to ensure that these structures remain safe, free from settling and collapse. Soil conditions vary from one location to another location. Hence it is difficult to predict the behavior of soil. Hence soil conditions at every site must be thoroughly investigated for proper design.

Fine sand is scarcely suitable for sub grade which supports the sub base or base coarse in the pavement due to high compressibility. The properties of soil can be improved by soil stabilization. Stabilization is being used for a variety of civil engineering works, the most common application being in the construction of flexible pavements and airfield pavements, where the main objective is to increase the strength, erosion of soil and reduce the construction cost by making best use of locally available materials.

There is a wide scope of stabilization of fine sand with sanitary ware waste as admixture for design of flexible pavements in road construction. The aim of present work is the economical and beneficial utilization of such wastes for improving geotechnical properties of fine sand which is to be used as a base material for flexible pavement construction. Utilization of sanitary ware waste for improvement of fine sand properties is a cost effective and sustainable technique. Since sanitary ware wastes can be easily available in huge quantity from different manufacturing unites 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 disposal of warped and broken sanitary ware 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.

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. As per Unified Soil Classification System, fine sand is uniform clean sand. Particles size ranges between 75µ 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).

Figure 1 : Sanitary Ware Waste Admixture

Table 1 : Summary of the Physical Properties of the Tested Sanitary Ware Waste Material

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

III. EXPERIMENTAL 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 CBR values of fine sand of different dry densities by mixing sanitary ware waste in different proportions in unsoaked and soaked conditions.
3. To study the changes in permeability of fine sand by mixing with sanitary ware waste in different proportions.

3.1 Experimental 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. CBR Test to determine CBR value for fine sand and mix compositions with sanitary ware waste.
4. Permeability by Variable Head Permeability Test of fine sand and mix composition with sanitary ware 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	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.

$$\text{Percentage (\%) Retained} = \frac{\text{Wsieve}}{\text{Wtotal}} \times 100\%$$

where Wsieve is the weight of aggregate in the sieve in gm
Wtotal 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 RetainedThe 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	0.0

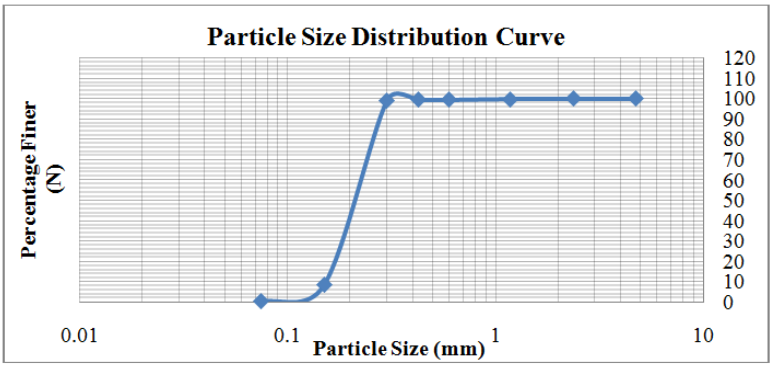

Figure 2 : Particle Size Distribution Curve

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 shows that on increment of moisture content, dry density first decrease and then increase. This phenomenon occurs due to bulking of sand. After reaching maximum dry density on optimum moisture content, dry density again 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 (M.D.D.) for the experiments occur at 4%, 12% and 18% moisture content.

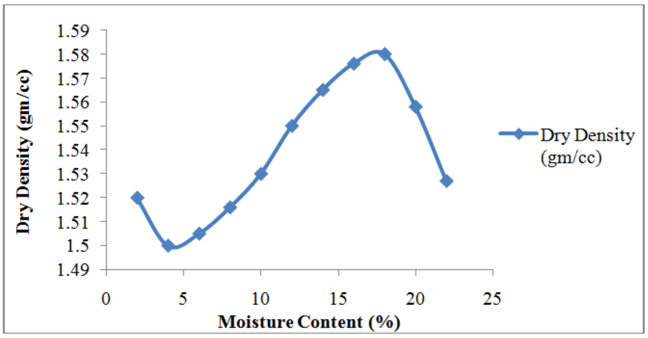

Figure 3 : Dry Density v/s Moisture Content Curve

3.1.3 California Bearing Ratio (C.B.R.) Test

In CBR test, 5 kg of soil was taken and mixed with water corresponding to required dry density and proportion of sanitary ware waste. The mix was compacted in 2250 ml CBR (150 mm diameter and 127.3 mm height) using light compaction. The mix was compacted in three equal layers; each layer being given 56 uniformly distributed blows of 2.6 kg hammer. Top surface of the specimen was finished properly to make it for even loading test. For the soaked condition, the samples were tested for the determination of CBR values on the next day. For obtaining the CBR values of unsoaked and soaked samples, penetration tests were done. The mould, containing the specimen was mounted on the testing machine and a surcharge weight equal to 5 kg (two spacer discs) was placed on the top of specimen before starting the penetration test. After setting the plunger on the surface of specimen, setting the load and penetration measuring dial gauge to read zero, the load was applied. Load readings at every 0.5 mm penetration were noted and a graph was drawn between the actual load (ordinate) and penetration (abscissa). In most of the tests the curve was either straight or convex upwards in the initial portion. In such cases the test load corresponding to 2.5 mm and 5.0 mm were read from the curve. In the case of the initial upward concavity, the corrected zero is obtained by drawing a tangent to the curve at the point of the greatest curvature. The corresponding to 2.5 mm and 5.0 mm penetration are measured from the corrected zero. Test results obtained show that CBR value increases with increase in dry density of sand. The CBR value also increases with increase in percentage of sanitary ware waste for same dry density sand. The test results are shown in tables and graph.

3.1.3.1 Comparative Study

The variation in CBR values have been tabulated and graphically represented in table 4., figure 4. for unsoaked condition and in table 4. and figure 4. for soaked condition. On the graph, at abscissa (X-axis) dry density of fine sand varying 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc has been marked and on ordinate (Y-axis) CBR values in % have been plotted for mix compositions of sanitary ware waste of different percentage 2%, 4%, 8% and 12%. It can be seen that on increment of dry density, the CBR value of the mix composition increases. The CBR value of the mix composition also increases as the percentage of admixture increases for both unsoaked and soaked conditions. Hence it can be concluded that to use the mix compositions in base and sub base construction, the CBR values can be increased or decreased as needed.The variations in CBR values at 1.58 gm/cc dry density and different percentage of mix compositions also show that increase in CBR values is more at unsoaked condition than that compared with soaked condition.

Table 5 : CBR Value Variation in Mix Compositions in Unsoaked Conditions

Dry Density (gm/cc)	CBR (%)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
1.50	2.146	3.577	3.934	5.007	5.723
1.55	2.504	3.934	4.649	5.723	6.438
1.58	2.861	4.292	5.007	6.08	6.796

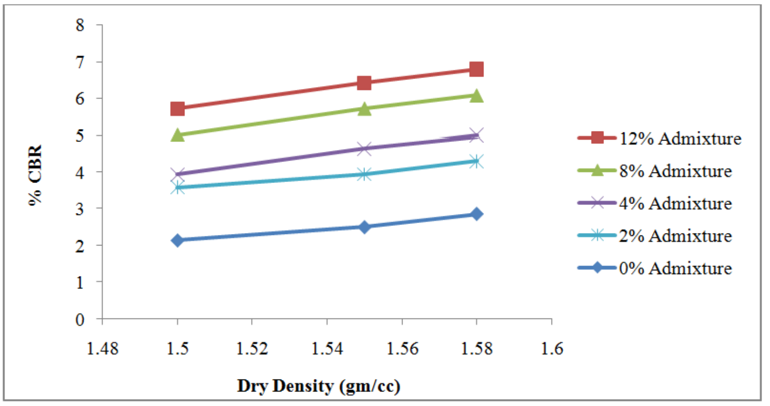

Figure 4 : CBR Value Variation in Mix Compositions in Unsoaked Conditions

Table 6 : CBR Value Variation in Mix Compositions in Soaked Conditions

S.No.	Mix Composition	CBR (%)
1.	1.58 gm/cc dry density sand mixed with 0% Admixture	1.073
2.	1.58 gm/cc dry density sand mixed with 2% Admixture	1.431
3.	1.58 gm/cc dry density sand mixed with 4% Admixture	2.146
4.	1.58 gm/cc dry density sand mixed with 8% Admixture	2.861
5.	1.58 gm/cc dry density sand mixed with 12% Admixture	3.219

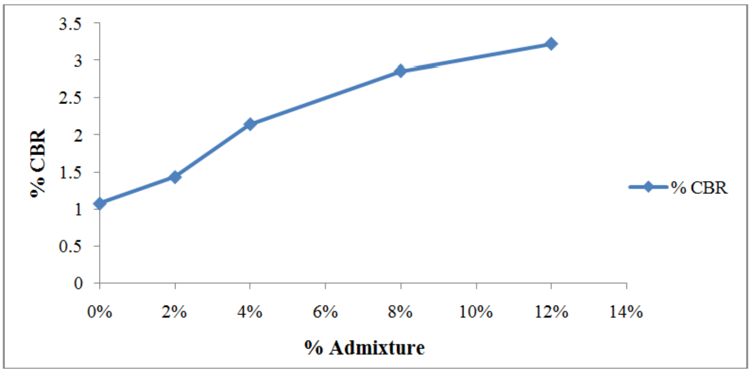

Figure 5 : CBR Value Variation in Mix Composition in Soaked Conditions

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 sanitary ware 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 sanitary ware waste.

Table 7 : 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}

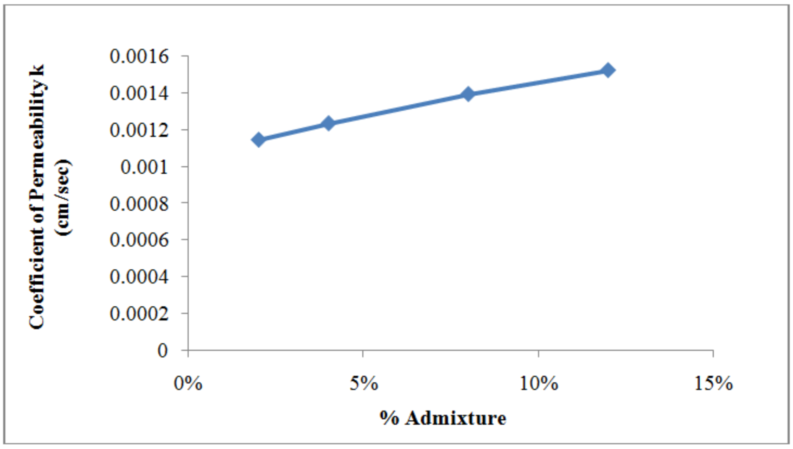

Figure 6 : Variation of Coefficient of Permeability k (cm/sec) with Mix Composition

IV. CONCLUSIONS

In present 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, CBR values for both unsoaked and soaked conditions 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. CBR tests were performed on mix compositions of fine sand and sanitary ware waste as admixture. Sanitary ware waste of varying percentage 2%, 4%, 8% and 12% were mixed with fine sand of different densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc. A linear increment was observed in CBR values in both unsoaked and soaked conditions. For unsoaked condition, CBR values are greater than that of soaked condition for same dry density of sand and same quantity of admixture. As the CBR value is increasing, the required thickness of flexible pavement 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 design of flexible pavement in road construction.

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