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Effect on Settlement of Dune Sand Reinforced With Porcelain Particles

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ABSTRACT: The soundness of a foundation and superstructure depends on the subsoil on which it is supported. The poor subsoil may not be able to support the structure safely. But sometimes due to unavoidable reasons, one is forced to construct superstructure on such a poor soil. In such conditions, no alternative is available other than imparting the artificial strength to soil.

This paper gives the knowledge on the effect on the settlement of dune sand when it is reinforced with porcelain insulators. The porcelain insulators were broken into particles and with help of standard sieves the size of particles were taken and then mixed with soil in a predefined percentage and the soil were tested for bearing capacity.

KEYWORDS: Footing; dune sand; settlement; insulators

I. INTRODUCTION

Dune sand consists about 60% of the area of Rajasthan. Utilization of this immense reserve of dune sand, the huge mass remained unnoticed, untouched from centuries, where life itself requires courage to move ahead to survive, in the absolute scarcity of basic needs. The motive of this study was to explore the possibilities of utilization of dune sand, as a low cost building material with some limitations like may be quasi- permanent in nature etc. This can be achieved by its stabilization. Soil stabilization is the alteration of one or more soil properties, by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties. Soils may be stabilized to increase strength and durability or to prevent erosion and dust generation. The properties of a soil may be altered in many ways among which a few are chemical, thermal, mechanical and other means. It must be realized however that because of the large variability of soils & engineering requirement, no one particular method is even adequate in more than a limited number of soils. Stabilization is being used for a variety of engineering works such as construction of all- weather roads and air field pavements including helipads, where the main aim is to increase the strength or stability of soil by making best use of the locally available materials. Engineers are responsible for selecting or specifying the correct stabilizing method, technique, and quantity of material required.

II. MATERIAL FOR STUDY

Jodhpur district is a part of Thar Desert. The Dune Sand used in the present study was brought from location near Jajiwai- Banar villages, at about 20- 25 kms away from Jodhpur on Jodhpur- Jaipur road. Dune sand has nil cohesion and has poor compressive strength and hence need stabilization. Dune sand is coarse grained, uniform clean sand as per unified soil classification system. Particle 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. The coefficient of permeability of dune sand is 2.0×10^{-4} cm/s. The different properties of the dune sand such as effective particle size, mean diameter, coefficient of uniformity, and coefficient of curvature, specific gravity and maximum dry density as found by laboratory tests are summarized in Table 1. The model footing was made of aluminum alloy. Three model footings were used in study, they were square in shape having sides' equal o 6.5 cm, 4.5 cm and 2.5 cm. The base of footing was made rough by pasting sand paper of

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zero grades. The footings were given a semi circular groove in the centre for resting a steel ball. The footings are shown in figure 1 and particle size distribution curve of sand is shown in figure 3. A true insulator is a material that does not respond to an electric field and completely resists the flow of electric charge. In practice, however, perfect insulators do not exist. Therefore, dielectric materials with high dielectric constants are considered insulators. The insulators are used on electric poles abundantly. But after any breakage or malfunctioning they become waste. Although there is no official data for the estimation for such a waste but the guesstimate can be given that millions and millions tonnes of such waste is available in India. Although this waste is not hazardous still the bulky shape of it makes it a difficult waste to manage. Pieces of such wastes for study were collected from a 33 kV electric station, Pratap Nagar, Jodhpur and one piece was weighing about 6 to 10 kg. One such piece of Porcelain insulator is shown in figure 2. There are hundreds of kilograms of broken insulators which are lying at every Electric station of India so one can guess the total load of waste of such insulators in whole India.

Table 1 Properties of Dune Sand Used

Effective Particle Size (D_{10})	Mean Particle Size (D_{50})	Coefficient of Uniformity (C_u)	Coefficient of Curvature (C_c)	Specific Gravity (G)	Maximum Dry Density (γ_{dmax})
0.12 mm	0.177 mm	1.73	1.23	2.67	1.62 g/cc



FIG. 1. Footings used



FIG. 2. Insulators used

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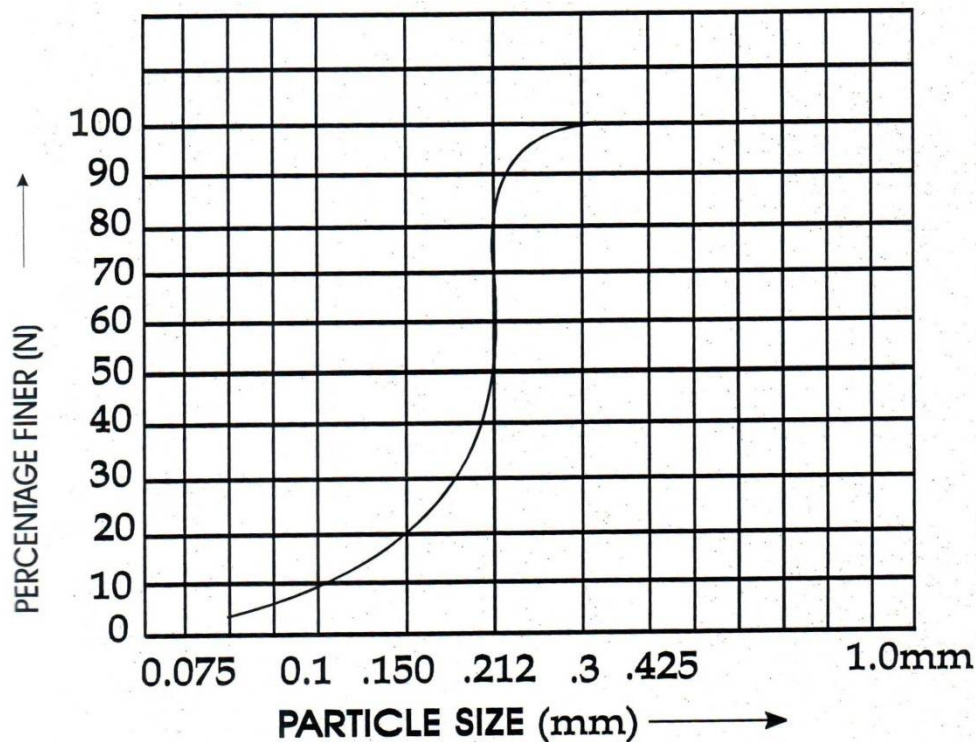


FIG. 3. Particle size distribution curve

III. EXPERIMENTAL SETUP

The Porcelain insulators were broken and turned into small pieces then with help of standard sieves three different sizes were taken. The apparatus used in the study was a tank, circular in plan. The tank was made of sufficiently thick steel sheet to withstand lateral expansion under loads. The diameter of tank was kept more than five times the diameter of largest footing so that it may not induce boundary effects. The present investigation deals with the laboratory studies on the feasibility of using particles of porcelain insulators as a means to enhance the bearing capacity of dune sand. The parameters investigated include:

- (1) Size of footings
- (2) Size of the particles of insulators
- (3) Percentage of reinforcement
- (4) Pattern of placement of reinforcement.

A series of load tests were conducted. Each test was repeated at least two times or more to ensure the reproducibility of test results. Tests were conducted on reinforced sands. 108 laboratory tests with different combinations were conducted. Table 2 summarizes the outline of test programme. The density of reinforced/unreinforced sand was kept constant equal to 1.65 g/cc throughout the test program. For placing the reinforcements, the

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quantity of sand required with a certain percentage of reinforcements to maintain density of reinforced/ unreinforced sand as 1.65 g/cc was calculated from the following equation:

Density of reinforced sand = Total mass of reinforced sand/ Volume of reinforced sand

$$\text{or } 1.65 = (M_s + M_p) / V \quad \dots\dots\dots(1)$$

where M_s = mass of sand in reinforced zone

M_p = mass of porcelain insulators in reinforced zone

V = volume of reinforced zone

Table 2 Test Program

Side of the square footing (S)	2.5 cm, 4.5 cm and 6.5 cm
Particle sizes of the reinforcement	4.75 mm- 2 mm, 2 mm - 1.18 mm and 1.18 mm – 425 μ
Percentage of reinforcement (by volume)	2%, 4%, 8% and 10%
Placement of reinforcement	In single layer at H = 0.5 S, at H = 1.0 S and at H = 1.5 S

The reinforcement was varied as percentage by volume of reinforced zone. From the analogy of pressure bulb, it is inferred that the soil is significantly affected to a depth of 2 to 2.5 times the width of footing, so the depth of reinforced zone was assumed to be 3 times the width of footing. Volume of reinforced zone was calculated for the three sizes of square footing having side equal to 2.5 cm, 4.5 cm and 6.5 cm. From the volume of reinforced zone, the volume of reinforcements V_p required for a given percentage of reinforcement was calculated. Mass of sand (M_s) required maintaining density of reinforced sand as 1.65 g/cc was calculated from equation (1). For placement of the reinforcements in a single layer, the calculated amount of dune sand was placed in tank in lifts and compacted so as it achieved a density of 1.65 g/cc. Each lift was of 5 cm thickness. The predetermined amount of reinforcement for particular reinforcement content was placed in tank in a single layer at desired depth below the footing. Three depths were chosen for the study, $H = 0.5 S$, $H = 1.0 S$ and $H = 1.5 S$, where H is the depth of single layer of reinforcements and S is the side of the square footing. Dune sand was again placed over layer of reinforcements and was compacted to achieve density of 1.65 g/cc. After filling the tank up to required depth, the top surface of sand was levelled. For the compaction of the reinforced sand, a steel rod with wider base was used as a temper. Before starting new test, the sand in tank was removed (from previous test) up to a depth of $3S$. The depth to which particular sand was to be compacted was already marked each time before starting the new test. After placing the sand and reinforcing particles of porcelain insulators in tank as explained above, the top surface of sand was levelled. The proving ring was suspended from the loading arrangement. Footing was placed on the levelled surface of sand. A steel ball was placed on the central groove of the footing. An adopter was attached to lower end of the proving ring. Footing was adjusted to such a position that steel ball placed on it just gets fitted into the groove of adopter, so that vertical load was applied centrally over the footing and no eccentricity was developed. A thick strip of iron was placed across the width of the tank to

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accommodate magnetic bases. Two dial gauges were mounted on the magnetic bases. Figure 4 shows the experimental setup of the apparatus. A seating load of 70 g/cm^2 was applied for about 10 minutes, which was released before the start of the test. The load was increased in an increment of about 10 percent of estimated ultimate load, and was recorded through proving ring. The resulting settlement was recorded through dial gauges. The readings of dial gauges were recorded, when rate of settlement was reduced to $0.01 \text{ mm}/10 \text{ minutes}$. The failure was assumed as that ultimate state at which settlement occurred continuously without application of further load.

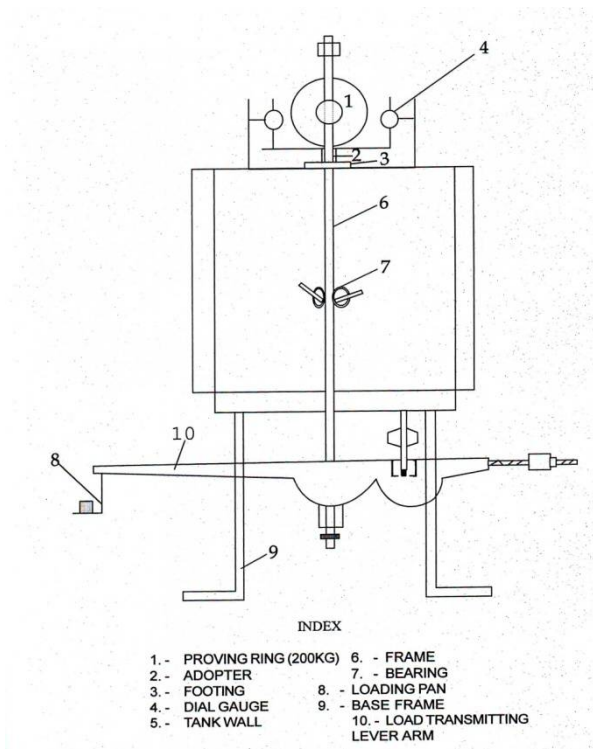


FIG. 4. Sectional view of testing tank

IV. GRAPHICAL PRESENTATION AND ANALYSIS OF TEST RESULTS

The results obtained from a series of load tests were analyzed to determine influence of various factors and the study has been done to understand the following aspects:

- (1) Effect of content of particles of porcelain insulators on bearing capacity
- (2) Effect of type of placement of reinforcement on bearing capacity
- (3) Effect of particle size of reinforcement on bearing capacity
- (4) Effect of different sizes of footing on bearing capacity

Various graphs between different attributes were plotted for better understanding of the test observations. One such graph has been shown in figure 5 in which 2.5 cm size footing is reinforced with particle size 425 micron placed

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as a single layer at $H = 0.5 S$. The different curve shows different values at different percentages of reinforcement. Behaviour of square footing on dune sand reinforced with particles of porcelain insulators shows that the ultimate bearing capacity increases rapidly with increase in reinforcement content. It was observed from different graphs that amount of reinforcement in dune sand influences the load intensity- settlement curve pattern. Dune sand containing 10% of reinforcement tends to fail at much higher load than that of dune sand alone. In general, the greater amount of reinforcement in sand, the higher is the load taken by the footing at failure. For 2.5 cm square footing when the reinforcement is 10% with particle size as 425 micron and for the placing at $H = 0.5 S$, then the load intensity is 7.1 t/m^2 in compare to 6.6 t/m^2 when the sand is loaded with 8% of reinforcement. When the observations are taken for the 4.5 cm square footing the same pattern is observed. When loaded by 10% of 425 micron reinforcement as a single layer at $H = 0.5 S$ then the load intensity observed is 8.2 t/m^2 in compare to 7.5 t/m^2 when loaded by 8% of reinforcement. 8.9 t/m^2 is the load intensity observed when the sand is loaded by 10% of 425 micron reinforcement at single layer at $H = 0.5 S$ and the footing size used is 6.5 cm. Similarly the other readings are observed.

More graphs were plotted for observing the effect of placement of reinforcement at different depths. The maximum value of bearing capacity has been observed when the reinforcement is placed in a single layer at a depth of $0.5 S$ below the base of the footing. The increase in bearing capacity is not significant when reinforcement is placed at a depth equal to the side of the square footing. Also when the reinforcement is placed at a depth equal to 1.5 times the side of the footing, the bearing capacity has decreased. Ultimate bearing capacity of 7.1 t/m^2 is observed when the 2.5 cm square footing is used and 425 micron particle size of the reinforcement is placed as single layer at $H = 0.5 S$. When the reinforcement is placed at a depth equal to the side of the footing the ultimate bearing capacity decreases to 6.6 t/m^2 . The value of it further decreased when the reinforcement is placed at a depth 1.5 times the side of the footing. The value observed was 6.2 t/m^2 . When 4.5 cm footing was used and the reinforcement size was 2 mm then the value of ultimate bearing capacity was 9.2 t/m^2 when placed at $H = 0.5 S$. Value decreased to 8.6 t/m^2 when the reinforcement was placed at a depth equal to the side of the footing and the value further decreased to 8.1 t/m^2 when placed at $H = 1.5 S$. Same pattern was observed in other sets of readings.

Graphs were also plotted for understanding the effect of particle size of reinforcement on bearing capacity. The maximum value of bearing capacity has been observed when the reinforcement size is taken as 2 mm. The value of the ultimate bearing capacity is decreased when the reinforcement size is taken as 1.18 mm and the value is least when 425 micron size reinforcement was used. When 6.5 cm size footing is used and 425 micron reinforcement is placed as a single layer at $H = 0.5 S$, the value of ultimate bearing capacity observed is 8.9 t/m^2 . The value increased to 9.1 t/m^2 when the sand was reinforced by 1.18 mm particle size. When 2 mm particle size of reinforcement was used then the value of ultimate bearing capacity observed was 9.5 t/m^2 . Similarly when 4.5 cm size footing is used and 425 micron reinforcement is placed as a single layer at $H = 0.5 S$, the value of ultimate bearing capacity observed is 8.2 t/m^2 . The value increased to 8.6 t/m^2 when the sand was reinforced by 1.18 mm particle size. When 2 mm particle size of reinforcement was used then the value of ultimate bearing capacity observed was 9.2 t/m^2 .

Finally the graphs were drawn for understanding the effect of footing size on bearing capacity. The maximum value of bearing capacity has been observed when the size of footing is 6.5 cm. The value of the ultimate bearing capacity is decreased when the size of footing is taken as 4.5 cm and the value came least when 2.5 cm footing is used. When 1.18 mm particle size is used and placed as a single layer at $H = 0.5 S$, the value of ultimate bearing capacity observed as 8.1 t/m^2 for 2.5 cm size of footing. The value increased to 8.6 t/m^2 when the same size particle is used at the same placing but the size of footing is used 4.5 cm. When the 6.5 cm size of footing is used then the value increased to 9.1 t/m^2 . When 2 mm particle size is used and placed as a single layer at $H = 0.5 S$, the value of ultimate bearing capacity observed as 8.6 t/m^2 for 2.5 cm size of footing. The value increased to 9.2 t/m^2 when the same size particle is used at the same placing but the size of footing is used 4.5 cm. When the 6.5 cm size of footing is used then the value increased to 9.5 t/m^2 .

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LOAD INTENSITY v/s SETTLEMENT

2.5 cm SQUARE FOOTING

REINFORCEMENT PARTICLE SIZE = 425 μ

SINGLE LAYER AT H = 0.5 S

PERCENTAGE REINFORCEMENT

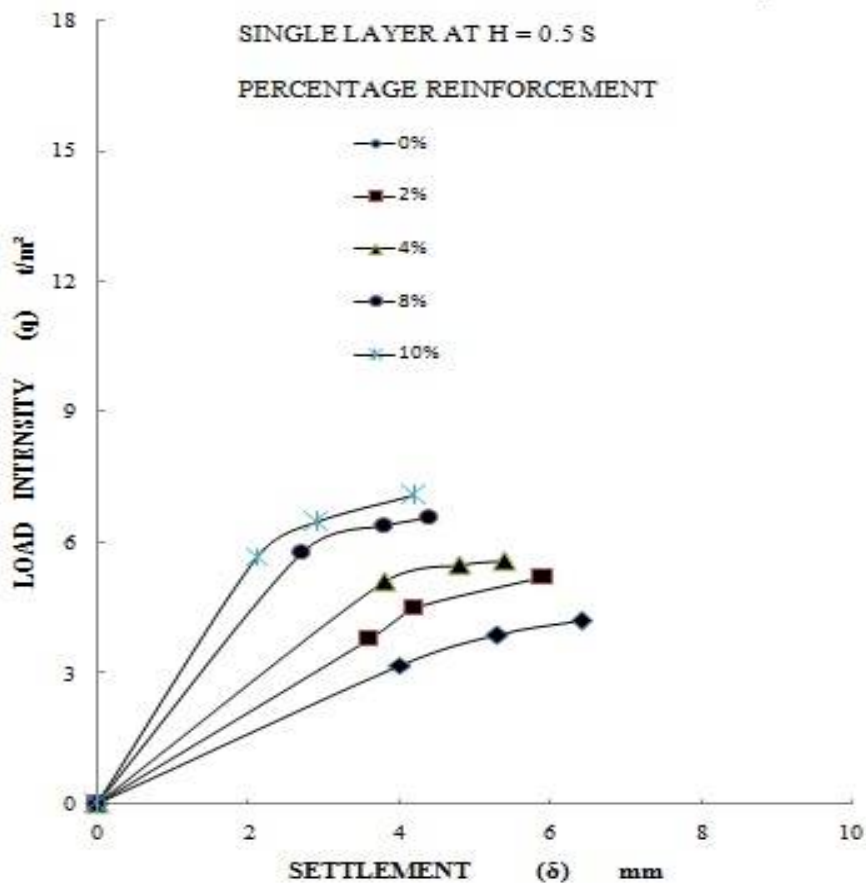


FIG. 5. Load-settlement curve

V. CONCLUSION

The bearing capacity of a square footing placed on dune sand reinforced with particles of porcelain insulators increases with increase in the reinforcement content. The maximum value of bearing capacity is obtained when the particles of porcelain insulators are placed in a single layer at depth equal to 0.5 times the side of the square footing. The bearing capacity of dune sand reinforced with particles of porcelain insulators increases as the size of the particles increases. The bearing capacity of dune sand increases as the size of the footing increases. Maximum bearing capacity reached when 6.5 cm sides' footing was placed on the dune sand and the reinforcement particle size was 2 mm. The settlement of a footing placed on dune sand reinforced with particles of porcelain insulators decreases with increase in

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reinforcement content. The settlement is minimum when the reinforcement content in sand is in the range of 0% to 4%. Settlement continues to decrease for 8% and 10% reinforcement content, but decrease is comparatively less.

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