# Utilization of Industrial Waste for Stabilization of Dune Sand

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*Abstract*— Rajasthan is a state which covers 10.4% of India and its western part is almost covered by Sand Dunes, hills of Dune sand created by wind. When designing and constructing highways or more generally any super structures on dune sands type of soil, it is essential to make sure that the foundation soil is stable and provides good support to the applied loads. It can be achieved by stabilization of Dune sand by mechanical means changing its gradation economically. Lime, cement, bitumen, ceramic granules, etc. are used to stabilize the Dune Sand in earlier attempts. In the present work Iron Dust of passing 2.36mm size which is an industrial waste and which creates a problem for disposal is utilized. Iron Dust of size 2.36mm is mixed with Dune Sand by weight in varying percentages i.e. 5%, 7.5%, 10%, 12.5% and15%. California Bearing ratio, Standard Proctor, Permeability and Shear Strength Tests are conducted for each mix composition.

***Key words:*** Dune Sand, Iron Dust, Stabilization, CBR Test, Shear Test

## I. INTRODUCTION

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 road and airfield pavements, where the main objective is to increase the strength or stability of soil and to reduce the construction cost by making best use of locally available materials.

### *A. Scope of Present Work*

In western Rajasthan, dune sand is available in abundance, which is scarcely suitable for construction of roads and necessitate either improving available dune sand or importing good quality mineral aggregates. And the industrial by-products are considered wastes, costing handling and disposing expenses, in addition to the environmental hazards. The aim of present work is the beneficial utilization of such wastes for improving dune sand to be used as a base material for roads construction and proper foundation material for other types of super structures. Iron dust obtained as industrial waste is considered within this category.

Utilization of industrial waste i.e. Iron dust for improvement of soil is a sustainable and cost-effective technique. Engineering properties studied in this investigation includes compaction, C.B.R permeability and Shear strength characteristics of soil with and without replacement of various proportions of Iron dust. Soil is replaced with Iron dust sieved in 2.36mm sieve in 5%, 7.5%, 10%, 12.5% and 15% to dry weight of soil.

Dry bulk density of dune sand with varying moisture contents 6%, 8%, 10% and 12% were observed by Proctor test. A curve is plotted between maximum dry density and water content for optimum moisture content. The composite mixture is prepared based on this optimum moisture content, is placed in mould and is compacted in 3 layers. C.B.R specimen thus prepared is tested and values are noted for unsoaked condition and soaked condition, in which specimen is soaked for 24 hours. Similarly specimens are prepared for permeability and shear strength tests of all mix compositions and results are tabulated.

It is observed that the dune sand which is loose in nature has transformed into rigid mass after stabilization with respect to the experiments conducted. Conclusions and Recommendations are drawn from the analysis of test results.

## II. SCOPE AND OBJECTIVE

The following are the objectives of the present study:

- To study the effects of iron dust of varying mix composition on Proctor density and OMC of sand.
- To study the CBR values of Dune sand mixed with iron dust in different proportions in soaked and unsoaked condition.
- To study the variation in coefficient of permeability of dune sand mixed with iron dust in different proportions.
- To study the change in shear stress of dune sand mixed with iron dust in different proportions.

## III. MATERIALS AND THEIR PROPERTIES

### *A. Dune Sand*

The soil used in present study was dune sand located between Jajiwal – Banwar villages, at about 20 – 25 km away from Jodhpur on Jodhpur – Jaipur roads. Dune sand is cohesion less, uniform clean and loose in its natural state. Particle size ranges between 75μ to 1.0mm i.e., fine to coarse sand, round to angular in particle shape as per Indian Standard Classification system. Dune sand is found in abundance in western Rajasthan.

### *B. Iron Dust (Industrial Waste)*

Iron dust is mostly a by-product of the grinding, filing, or milling of finished iron products, so their history largely tracks the development of iron. For the most part, they have been a waste product and will be creating disposal problem and pollution Hazard. Iron dust used in this present work is collected from the dump yard at Bhiwadi, Rajasthan.

Chemical Analysis of Iron dust has been conducted and the results are given in the table 3.1.

| Sl. No. | Chemical | Availability in (%) |
|---|---|---|
| 1 | $Fe_2O_3$ | 97.50% |
| 2 | $SiO_2$ | 2.50% |
| 3 | MgO | 0.50% |

Table 1: Results

Fig. 1: Iron dust (Industrial waste)

 

## IV. TEST PROGRAMME

The test programme included the preliminary tests for dune sand and mix composition of dune sand with ceramic granules. Following tests were carried out:

- Determination of particle size distribution of dune sand.
- Light Compaction Test (Standard Proctor Test) for determining maximum dry density and optimum moisture content. (For dune sand and mix composition with Iron dust).
- Permeability by variable head test of dune sand and mix composition with iron dust.
- CBR Test to determine CBR values for dune sand and mix composition with Iron dust.
- Direct shear test to determine shear stress of dune sand mix composition with Iron dust.

Variables investigated and mix compositions used have been given in table 2.

| Sl. No. | Effect of | Variables | Range Investigated |
|---|---|---|---|
| 1 | Curing environment on C.B.R value | Type of curing | Soaked and Unsoaked. |
| 2 | Iron dust on different properties of sand | Size passing sieve size | Passing 2.36mm. |
| 3 | Mix Iron dust by weight of sand | Proportion percentage | 5%, 7.5%, 10%, 12.5% and 15%. |

Table 2: Variables Investigated

## V. RESULTS AND DISCUSSIONS

The tests were performed to investigate the behaviour of Iron dust with varying percentages mixed with dune sand as mentioned in previous chapter i.e. Particle size distribution of sand, Proctor's density, California Bearing Ratio, Coefficient of Permeability and Shear Strength Parameters. Results obtained from tests were as below:

| Sl. No. | Property | Desert Sand |
|---|---|---|
| 1 | Coefficient of Uniformity (Cu) | 1.76 |
| 2 | Coefficient of Curvature (Cc) | 0.9 |
| 3 | Mean Diameter (D50)mm | 0.17 |
| 4 | Effective Size (D10)mm | 0.11 |
| 5 | Fine Soil Fraction (75Ω) | 2% |
| 6 | Max Dry density | 1.65 |
| 7 | Optimum Moisture Content (OMC) | 12.56% |

Table 3: Properties of Sand

### *A. Particle size Distribution of Dune Sand*

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 75µ for dry dune sand is within 1% only, hydrometer analysis was not done for dry dune sand. Result has been presented in table 4 and 5.

| Sl. No. | Sieve Size | Weight retainer (g) | % Weight Retained | Cumulative % weight Retained | Cumulative % weight Passing | % Finer |
|---|---|---|---|---|---|---|
| 1 | 2.0mm | 0 | 0 | 0 | 100 | 100 |
| 2 | 1.0mm | 0 | 0 | 0 | 100 | 100 |
| 3 | 600µ | 0 | 0 | 0 | 100 | 100 |
| 4 | 425µ | 0 | 0 | 0 | 100 | 100 |
| 5 | 300µ | 0 | 0 | 0 | 100 | 100 |
| 6 | 150µ | 932.0 | 93.2 | 93.2 | 6.8 | 6.8 |
| 7 | 75µ | 60.0 | 6.0 | 99.2 | 0.8 | 0.8 |
| 8 | Pan | 4.0 | | | | |

Table 4: Particle Size Distribution of Dune Sand (Dry)

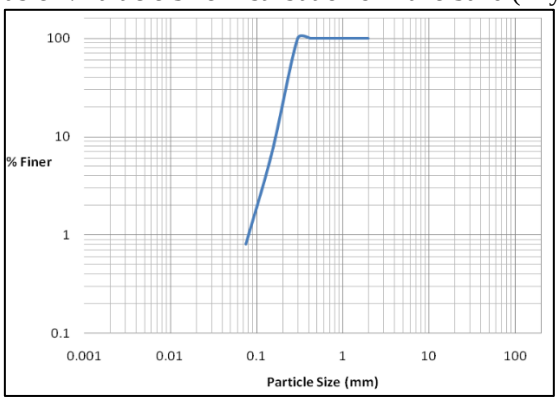


Fig. 2: Particle size distribution of Dune Sand (Dry)

| Sl. No. | Sieve Size | Weight retained (g) | % Weight Retained | Cumulative % weight Retained | Cumulative % weight Passing | % Finer |
|---|---|---|---|---|---|---|
| 1 | 2.0mm | 0 | 0 | 0 | 100 | 100 |
| 2 | 1.0mm | 0 | 0 | 0 | 100 | 100 |
| 3 | 600µ | 0 | 0 | 0 | 100 | 100 |
| 4 | 425µ | 0 | 0 | 0 | 100 | 100 |
| 5 | 300µ | 0 | 0 | 0 | 100 | 100 |
| 6 | 150µ | 466 | 46.6 | 46.6 | 53.4 | 53.4 |
| 7 | 75µ | 302 | 30.2 | 76.8 | 23.2 | 23.2 |
| 8 | Pan | 26 | | | | |

Table 5: Particle Size Distribution of Dune Sand (Wet)

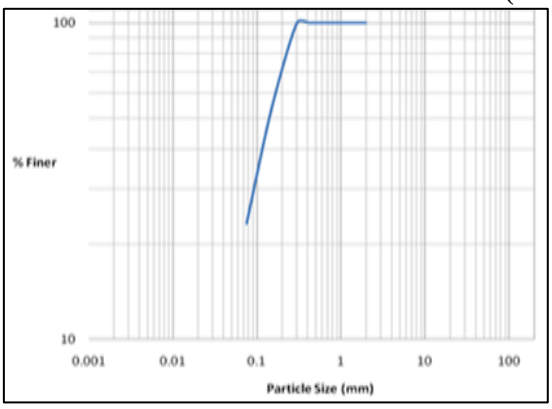


Fig. 3: Particle size distribution of Dune Sand (Wet)

### *B. Standard Proctor Test*

Standard Proctor Test as per IS 2720 (Part VII) performed on dune sand mixed with Iron dust in varying percentage, results shows that the M.D.D. with increase in percentage of mix composition increases i.e. at 5% it is 1.669 and at 15% it is 1.769. O.M.C also increases from 12.56% to 14.21%. The variation of M.D.D for different mix composition have been graphically represented and tabulated in table 6.

 

| Sl. No. | Mix Composition | M.D.D Values (gm/cc) |
|---|---|---|
| 1 | Dune Sand | 1.65 |
| 2 | 5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 1.669 |
| 3 | 7.5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 1.702 |
| 4 | 10% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 1.729 |
| 5 | 12.5% of Iron dust passing 2.36mmSieve by weight + Dune sand | 1.75 |
| 6 | 15% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 1.769 |

Table 6: M.D.D variation of Mix Composition

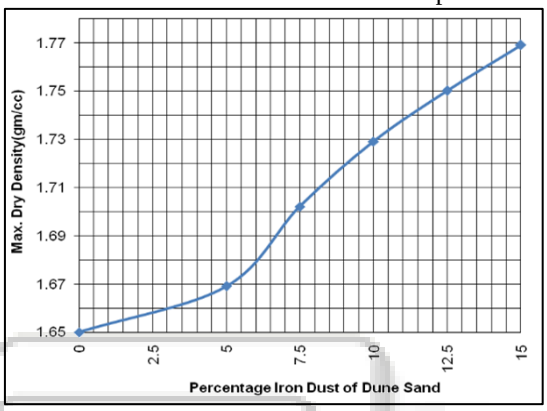


Fig. 4: M.D.D variation of Mix Composition

### *C. California Bearing Ratio (C.B.R) Test*

California Bearing test were conducted on Dune sand and Dune sand mixed with Iron dust passing sieve 2.36mm by 5% 7.5%, 10%, 12.5% and 15% of sand for Soaked and Unsoaked condition, as per IS 2720 (Part XVI).

The test results obtained shows that the value of C.B.R increases with increase in percentage of Iron dust as compared to C. B. R value of dune sand.

| Sl. No. | Mix Composition | C.B.R |
|---|---|---|
| 1 | Dune Sand | 18.98 |
| 2 | 5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 19.71 |
| 3 | 7.5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 20.68 |
| 4 | 10% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 24.33 |
| 5 | 12.5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 25.55 |
| 6 | 15% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 26.64 |

Table 7: Variation in CBR with Mixture of Dune Sand and % of Iron Dust in Unsoaked Condition

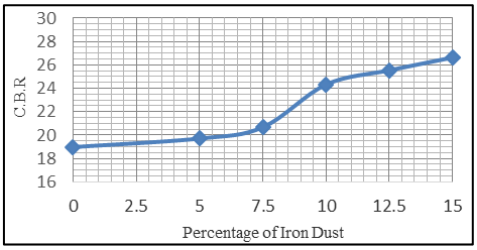


Fig. 5: Variation in CBR with Mixture of Dune Sand and % of Iron Dust in Unsoaked Condition

Obtained C.B.R values for unsoaked condition with different percentage of mix composition from the test results are tabulated in table and presented graphically. From the tabulated results it is observed that value of C.B.R increases with increase in percentage of Iron dust.

C.B.R values for unsoaked condition increases with increase in mix composition i.e. at CA2 it is 19.71and at CA6 it is 26.64. Hence it can be concluded that C.B.R values for unsoaked condition increases with increase in mix composition.

| Sl. No. | Mix Composition | C.B.R |
|---|---|---|
| 1 | Dune Sand | 10.18 |
| 2 | 5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 12.61 |
| 3 | 7.5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 14.6 |
| 4 | 10% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 15.21 |
| 5 | 12.5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 15.82 |
| 6 | 15% of Iron dust passing 2.36mm Sieve by weight + Dune sand | 17.52 |

Table 8: Variation in CBR with Mixture of Dune Sand and % of Iron Dust in soaked Condition

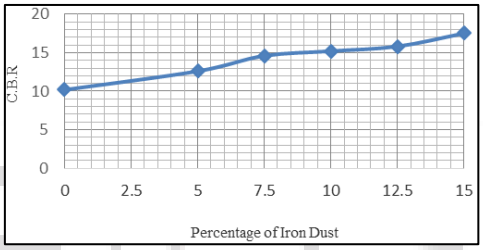


Fig. 6: Variation in CBR with Mixture of Dune Sand and % of Iron Dust in soaked Condition

Similar to Unsoaked condition C.B.R Values for soaked conditions with different percentage of mix composition obtained from test results are also tabulated in table 4.16 and represented graphically. From the table it is observed that similar to unsoaked condition C.B.R value increases with increase in percentage of mix composition for soaked condition also.

Under soaked condition the C.B.R value of dune sand is 10.18 whereas the C.B.R value of 5% mix composition is 12.61 and it increases with increase in percentage of mix composition i.e. at 15% it is 17.52. Thus it is concluded that increase in percentage of mix composition in soaked condition also increases the C.B.R value.

### *D. Variable Head Permeability Test*

Tests were performed on variable head permeameter as per IS 2720 (Part XVII). Mix composition of Iron Dust passing sieve 2.36mm in varying percentages of 0, 5, 7.5, 10, 12.5 and 15 of Dune Sand were tested. From the test results obtained, it can be concluded that coefficient of permeability increases with increase in percentage of mix composition up to 10% i.e. $5.776 \times 10^{-4}$ K cm/s to $6.241 \times 10^{-4}$ K cm/s and reduces with further increase in percentage of mix composition. The coefficient of Permeability decreases with 12.5 and 15 percentage of mix composition.

| Sl. No. | Mix Composition | Coefficient of |
|---|---|---|

 

| | | Permeability (K cm/s) |
|---|---|---|
| 1 | Dune Sand | $5.041 \times 10^{-4}$ |
| 2 | 5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | $7.056 \times 10^{-4}$ |
| 3 | 7.5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | $10 \times 10^{-4}$ |
| 4 | 10% of Iron dust passing 2.36mm Sieve by weight + Dune sand | $9.8 \times 10^{-4}$ |
| 5 | 12.5% of Iron dust passing 2.36mm Sieve by weight + Dune sand | $8.1 \times 10^{-4}$ |
| 6 | 15% of Iron dust passing 2.36mm Sieve by weight + Dune sand | $6.72 \times 10^{-4}$ |

Table 9: Variation of Coefficient of Permeability with Mix Composition

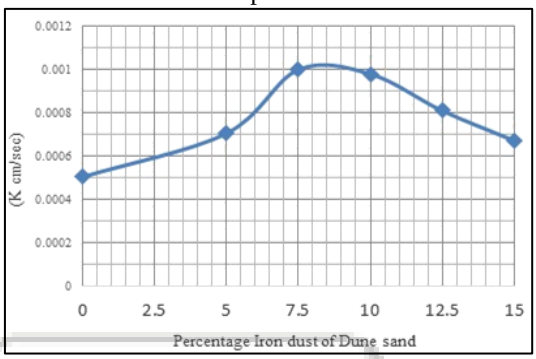


Fig. 7: Variation of Coefficient of Permeability with Mix Composition

### *E. Direct Shear Test*

Direct shear test as per IS 2720 (Part XIII) were performed on mix composition of Iron Dust passing sieve 2.36mm with 0, 5, 7.5, 10, 12.5 and 15% of Dune sand. Tests were carried out with a strain controlled shear apparatus at rate of strain of 1.25 mm/min to determine failure stress and angle of internal friction Φ of different mix composition.

From the results obtained it can be concluded that the angle of internal friction Φ increase with increase in mix composition. Angle of internal friction Φ has varied from 29 to 42 for mix composition of iron dust.

| Normal Stress (Kg/ $cm^2$) | Mix Composition | | | | | |
|---|---|---|---|---|---|---|
| | 0% | 5% | 7.5% | 10% | 12.5% | 15% |
| 0.5 | 0.430 | 0.298 | 0.376 | 0.394 | 0.365 | 0.203 |
| 1.0 | 0.644 | 0.595 | 0.597 | 0.570 | 0.608 | 0.590 |
| 1.5 | 0.929 | 0.853 | 0.890 | 1.030 | 1.149 | 1.035 |

Table 10: Variation of Shear Stress for all mix composition

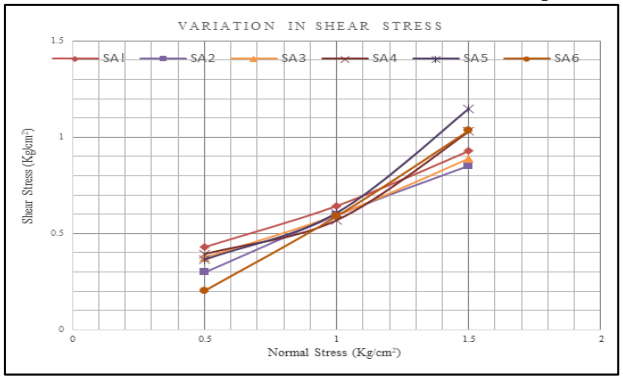


Fig. 8: Variation of Shear Stress for all mix composition

It is observed that Shear stress value increases with increase in mix composition. Hence it can be concluded that the shear test value increases with increase in admixture

| Mix Composition | Φ (Degrees) |
|---|---|
| 0% | 27 |
| 5% | 29 |
| 7.5% | 30 |
| 10% | 32 |
| 12.5% | 38 |
| 15% | 42 |

Table 11: Variation of Φ with % of Iron Dust with Dune Sand

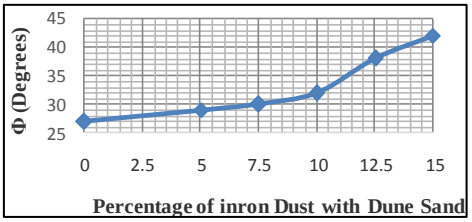


Fig. 9: Variation of Φ with % of Iron Dust with Dune Sand

It is observed that the angle of internal friction Φ of dune sand with different percentage of Iron dust increases with increase in percentage of Iron dust.

## VI. CONCLUSIONS AND RECOMMENDATIONS

### *A. Conclusions*

The results obtained from the various tests suggests that Iron dust passing sieve size 2.36mm may proves it is useful as stabilizing agent for dune sand. The details of experimental technique, method of analysis and the test results with their interpretations have been given in preceding chapters.

Following are the conclusions drawn from present investigations:

- Many industrial by-products like Iron dust are considered wastes costing handling and disposing expenses, in addition to the environmental hazards.
- The effect of Iron dust of size 2.36mm on Max dry density is that it increases the Max dry density with increase in percentage of Iron dust i.e. at 5% mix composition it is 1.669 gm/cc and at 15% mix composition it is 1.769 gm/cc. The Optimum moisture content also increases with increase in percentage of Iron dust mix composition.
- CBR values with different mix composition of Iron dust i.e. 5%, 7.5%, 10%, 12.5% and 15% increases with increases in percentage for both soaked and unsoaked condition. In unsoaked condition, C.B. R value increases with increase in percentage of Iron dust i.e at 5% mix composition it is 19.71 whereas for 15% mix composition it is 26.64. Similarly for soaked condition also the C.B.R value increases with increase in percentage of Iron dust i.e. for 5% mix composition it is 12.61 whereas for 15% mix composition it is 17.52. For unsoaked condition, C.B.R values are greater compared with the values of soaked condition.
- Coefficient of Permeability K (cm/s) increases with increase in percentage of Iron dust up to particular percentage i.e at 5% mix composition it is 7.056 x 10-4cm/sec whereas for 15% mix composition it is 10 x 10-4cm/sec. Further increase in percentage of Iron dust decreases the value.

 

– Shear test is performed for dune sand with mix composition 5%, 7.5%, 10%, 12.5 and 15% Iron dust of sand. Angle of internal friction Φ increases with increase in percentage of mix composition i.e. at 5% mix composition it is 29º and whereas for 15% mix composition it is 42º.

*B. Recommendations*

Based on this study following recommendations are made:

– Iron dust can be used in stabilization of dune sand and the stabilized sand can used in construction of roads in rural areas for economizing cost of construction.
– The usage of Iron dust in stabilizing the dune sand reduces the problem of disposal of Iron waste to large extent.
– From the study it is observed that C.B.R value for soaked condition are less than that of unsoaked conditions. In deserts as their will be active monsoon season for more than a week in a year further experimental work is required for the stabilization of dune sand using impermeable material.

*C. Future Work*

Study on stabilization of Clayey sand with industrial waste similar to the stabilization of Dune sand, can be carried out in future so that problems with construction on clayey soil can be solved.

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