Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 4 (2023)

# Application of Bentonite on Dune Sand to Decrease its Permeability

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**Abstract:** Various Experiments were conducted to find the effectiveness of bentonites in reducing the losses, majorly seepage from the minor canals and the streams in the Rajasthan sand dunes region. When 1 to 5 percent bentonite was mixed in the dune sand available in western Rajasthan it resulted in the loss of 5 to 50 in permeability when it was compacted properly at the present optimum moisture content.

## 1. Introduction

In India, where agriculture is a leading sector. Proper utilization of water for the irrigation purpose is of great importance, to provide water to the crops in proper manner and also economic utilization of avaiable water is also of imprtance. In rajasthan area, there is low precipation and rainfall as compared to other parts of country is also very low in a year. So, in arid and semi arid region like rajasthan it is very important yo conserve water for the irrigation purpose, to reduce the seepage losses, evaporation losses from the canals, tanks and the reservoirs. Reduction of losses can increase the irrigation potential.

Kennedy gave the observation that 26-30 percentage of water is lost in the main and branches of the canal, 20-25 percent of water is lost in the field channels. There is large proprtion of water loss through seepage. Losses estiates varies with nature of terrain, depth of water flow, wetted perimeter and how much is the age of canal. It has been recommended to assume a canal seepage loss of 1.7-2.7 cu.m/109 sqm wetted area se for clay loam, silty soil or lava ash loam, and 5.1-6.0 cum 10 sq.m wetted area/sec for loose sandy soils (Kanwar Sain). It shows that the irrigation water is passing through sandy soils or lost there from the canals in the western rajasthan region.

**Table 1:** Properties of Dune Sand

| S No. | Properties | Approx value |
|---|---|---|
| 1 | Coefficient of Uniformity | 1.2 |
| 2 | Coefficient of Curvature | 0.9 |
| 3 | Specific Gravity | 2.66 |
| 4 | Mean Size Diameter | 0.15 |
| 5 | Effective Particle Size | 0.11 |
| 6 | Maximum Void Ratio | 0.9 |
| 7 | Minimum Void Ratio | 0.5 |
| 8 | Fine Soil Fraction | 2 |

## 2. Minimizing Seepage Loss

The most used and effective method till date to reduce seepage loss is from canal is lining. Materials like concrete, asphalt, tiles, films of plastic, rubber, soil stabilizers have been used or tries as canal lining with huge amount of success. But methos are quite expensive and are only suitable for major canals. Cheap canal linings are to be looked for minor canals and field channels which are responsible for seepage loss for any canal system.

Canal lining is done to prevent seepage by providing a sufficient impermeable membrane and good stability against and seepage pressure of infiltrating water. Concrete asphalt and tile linings fulfil these requirements when constructed with proper care, but are not suitable from the point of view of economy for minor canals and field channels. Cheaper treatment may include like coating the surface soil with bitumen or adding more surface layers i.e materials like cement or clay which can easily fill the seals and voids. Bentonites may be very useful for this purpose as these are very fine grained clayey material orignated from volcanoes and are different from normal clays. Bentonites have high absorption of water and have high colloidal content.

## 3. Bentonites Properties

Bentonite is a clay mineral having mainly 'montmorillonite'. Fundamental property of this clay is to absorb water and and expand. The level of hydrartion and swelling depends upon the ions, hydrophilic powder. When bentonite is disperesed in water very high coplloidal suspensions are formed. These swelling type bentonites, also known as sodium bentonites, have Na+ as the exchangeable ion. There is fromation of gel, the absorption of water proceeds with considerable increase in volume, creating an excellent gel and viscous material Low-swell bentonites containing C++ the exchangeable ion.

Bentonites are yellowish, creamy and are found in the western Rajasthan, Bihar, Jammu and Kashmir and Punjab. In Rajsthan bentonites are of dark yellowish colour varying from dark yellow to dark choclate brown. Bentonites are formed from the volcanic eruption , weathering of volcanic ash and most offten in presence of water. Clay minerals and clay deposits may vary in nature, two or more may not have same clay minerals and frequently different samples from same or different deposits. The physical and chemical properties i.e swelling, shrinkage, cation exchange , plasticity varies between the depositsdue difference in the chemical subsitution, structure, nature of exchangable ions present, amount of impurities present like quartz, mica, feldspar etc.

Bentonites can been used in controlling the seepage from the canals by lining of the bentonite membrane or by sediment lining using water bentonite system and lining of bentonite with the soil mixtures. The methods involve use of 5 to 25% of bentonites and is very economical and easy to use as compared to other types of canal linings.

As bentonite is readily available in western parts of Rajsthan and is cheap in rates, thus is easy to use material for the lining of canal. It can reduce seepage loss of the canal, an investigation was carried out to study the use of bentonite in reducing the permeability of dune sand which is a typical desert soil of Rajasthan. The scope was to determine an optimum quantity of bentonite to be mixed with dune sand which could yield a suitable memberane or surface lining for use in canals and field channels.

**Table 2:** Properties of Bentonite

| S No. | Properties | Approx Value |
|---|---|---|
| 1 | Soil Group | CH |
| 2 | Liquid Limit | 252 |
| 3 | Plastic Limit | 50 |
| 4 | Maximum Dry Density | 1.1 |
| 5 | Silt Percentage | 25 |
| 6 | Clay Percentage | 70 |
| 7 | Specific Gravity | 2.2 |
| 8 | Optimum Moisture Content | 20 – 25 |

**Table 3:** Chemical Compostion in Bentonite

| S No. | Chemical Composition | Composition (%) |
|---|---|---|
| 1 | CaO | 1.8 |
| 2 | MgO | 4.2 |
| 3 | $SiO_2$ | 55.6 |
| 4 | $Al_2O_3$ | 16.5 |
| 5 | $Na_2O$ | 1.5 |
| 6 | $SO_3$ | 0.05 |
| 7 | $K_2O$ | 0.1 |
| 8 | $Fe_2O_3$ | 9.1 |

## 4. Experimental Work

Dune Sand was collected from the Osiya region of Jodhpur situated in the western part of Rajasthan and was further investigated for its properties, various tests were perfromed on dune sand. It was found to contain 25 % silt and remaining be the fine sand. The particle size distribution was further investigated. Bentonite clay was from the barmer region, In Jodhpur there are various factories who deals in packed bentonites. Bentonite caly was directly collected from the factories of Jodhpur in basni area.

**Fig 1:** Proctor Test Apparatus

### 4.1 Permeability Tests

Permebaility Tests were performed in the benotine and dune sand soil mixtures at the different values and at the different dry densitites. The dry densitites and the water content realtionship were determined from the light copaction test which is part of standard proctor test. The bentonite content was varied from zero to 8% by weight of dry soil with interval of 2%. The maximum dry densities and the corresponding optimum water contents are given in Table. The permeability of bentonite with various sand mixes were determined at dry densities corresponding to 100, 95 and 90 percent of the maximum dry densities achieved in the light compaction test, the moulding water content being always maintained equal to the optimum water content for the concerned mix. In the falling head permeability method water flows through a soil sample, connected to a standpipe which provides the water head and allows the water to passing through sample. Test is started by allowing the water to flow through the sample until the water in stand pipe reaches the given lowe limit. Time is recorded i.e time required for water in the standpipe to drop from initial level to the final level (lower level) is recorded. Again stand pipe is filled with water and procedure is repeated several times. It was ensured that recorded time is same for the each test performed within an allowable variation of about 10 percentage, otherwise test is failed. Before starting the test it is ensured that the soil sample is fully saturated. If the soil sample is not fully saturated it will give erroneous results. Vacuum was applied to remove any entrapped air within the sample. With the formula coefficient of permeability is calculated in m/s.

**Fig 2:** Peremability Test Apparatus

**4.2Deterimination of Permeability**

**Sample Preparation**: The permeability of bentonite and various sand mixes were determined by the falling head method pemebaility test. Samples having a cross-section of 50 cm and height of 6 cm were prepared in the specimen mould by static compaction in a compression machine. The wet weight of the soil (Wwet) was calculated from the relationship Wwet-yd (I +W.) V where ya is the test dry density, w, the optimum water content and V is the volume of the specimen mould. Wet mix was kept for maturing for some time prior to compaction with a piece of cloth on it, to prevent the moisture losses.

**Saturation of Sample:** Most important part is that soil samples should be saturated fully proir to the testing Dessciators, vacuum pump, backfilling can be done to ensure proper saturation of soil sample. The degree of saturation achieved varied between 92 to 96%.

Permeability Tests: The permeability was determined under falling head. Two or three specimens were tested simultaneously, Permeameter was connected to a 0.74 cm diameter tube which was mounted on a wooden board further fixed to wall. Tube served as standing pipe for this set up.

**Table 4: Density -** Moisture Relationship for Dune Sand - Bentonite Mixtures

| Bentonite | 0% | 2% | 4% | 6% | 8% |
|---|---|---|---|---|---|
| Maxm. dry denisity (g/cm$_2$) | 1.51 | 1.55 | 1.61 | 1.63 | 1.65 |
| Optimum Moisture Content (%) | 12.90 | 13.40 | 14.29 | 15.10 | 15.5 |

## 5. Test Results

Dry Density-Water Content Relation : The maximum dry density variation 1.51 to 1.65 g/cm$^3$ and the optimum water content from 12.90 to 15.55 % for the different mixes, both were increasing with increase in bentonite content.

**Permeability Test Results:** Tests were performed with various mixes of dune sand and bentonite, It was obsereved that with various mix of bentonite content and soil permeability decreased considerably even when there was a little addition of 2 percent of bentonite. When more amount of bentonite was added to the dune sand there was faster decrease in permeability, almost there was a reduction of 25 times with four percent of bentonite was addded. It further increased to 75 percent times reduction when six percent of bentonite was added. There was futher reduction when 8 percent of bentionite was added to the soil mixture. It showed that permeability was decreasing with the addition of bentonite to the soil mix.

The ratio of permeability of soil to that of soil-bentonite mixes for various degrees of compaction are given in the below table.

It is evident that by the addition of small amounts of bentonites-4 to 8% by weight of soil, the permeability can be effectively reduced. Thus soil-bentonite mixe be used as membranes.

**Table 5:** Ratio of Permeability of Dune Sand-Bentonite mixes

| Bentonite content | Degree of Compaction (percent of maximum dry density) | | |
|---|---|---|---|
| | 100 | 95 | 90 |
| 2% | 9.5 | 9.4 | 9.9 |
| 4% | 25.1 | 20.4 | 12.4 |
| 6% | 75.3 | 75.8 | 52.2 |
| 8% | 80.12 | 80.45 | 62.1 |

Thus reduction in permeability proved that bentonite as a cheap and readily available material can be efficiently used as material for the lining of the canals and the field channels in western part of Rajasthan. Permeability was greatly affected with the addition of bentonite and reportedly reduced with maximum dry density at optimum moisture content.

## 6. Conclusions

The study conclude that by adding little amount of bentonite to the soil mixture, permeability decreases, Addition of bentonite can be effective in saving irrigation water from the canals and field channels which account for major seepage loss in system. Benotine mixed in quantity 2-8 percent by weigth with readily available dune sand can be cheap and be very useful in canal lining, further it can be used as membrane for the canals in western part of Rajasthan.

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