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UTILIZATION OF BENTONITE TO REDUCE PERMEABILITY OF DUNE SAND

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Abstract:
The usefulness of bentonite in decreasing seeping losses from small canals & field channels built in Rajasthani sand dunes was tested through experiments. When adequately compacted at the ideal moisture content, adding two to six percent of bentonite to dune sand led to a reduction in permeability of seven to seventy-three times.

1 Introduction

The effective and economical use of available water for irrigation takes enormous importance in a growing nation like India, which places a lot of emphasis on the growth of agriculture. It is especially important in regions with minimal precipitation that experiences a certain season of the year. In such dry and semi-arid areas, irrigation potential may be considerably increased by conserving irrigation water by preventing seepage and evaporation losses from reservoirs, tanks, and irrigation canals. Although a significant amount of water is lost by seepage while in transit, estimates of the conveyance losses have varied, generally, depending on the kind of terrain, the wetted perimeter, the depth of water flow, and to a lesser extent, depending on the age of the canal. Kennedy demonstrated that the main, branch, and distributaries channels lost 26% of the water, whereas field channels lost 11%. The comparable losses for the Ganga Canal System's canals were discovered to be each 22 percent. The loss of water owing to seepage, etc. between diversion in the canal system and delivery to fields has been calculated at 38% in the semiarid and arid areas of Western USA. It is evident that much of the valuable irrigation water is wasted as canals pass through sandy soils, such as those in Western Rajasthan. Canal lining is the most efficient method of decreasing seepage loss from canals. For this aim, a variety of materials have been effectively employed. They include the more well-known concrete, tiles, asphalt, and compacted earth. With different degrees of effectiveness, novel materials such as fake butyl rubber, plastic films and soil stabilisers have recently been tested as canal linings. All, with the exception of compacted individual linings, are highly pricey and only appropriate for big canals. For small canals and field channels, which account for 30 to 40 percent of the total seepage loss from any canal system, inexpensive canal linings have to be constructed. Treatment options include adding cement or pulverised clay to the surface layers, which are fine enough to fill and seal the spaces in loose soil and make them somewhat impermeable, or covering the soil's top with a water-repellent substance like bitumen. For the latter, some finely ground materials, such bentonites, may be well suited. These are exceptionally fine-grained volcanic clayey materials that set them apart from more typical clays by their strong water absorption and high colloidal content.

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2 Materials & Methods

Bentonites can range in colour from white to creamy to yellowish to black. Western Rajasthan, Bihar, Jammu and Kashmir, and Punjab have large bentonite deposits. Rajasthan bentonites are dark in colour, ranging from light grey to chocolate brown. Most bentonite has conchoidal or sub-conchoidal fractures, and it may be readily cut into thin shavings with a knife. Newly cut surfaces have a wavering shine. The chemical make-up and physical-chemical characteristics of the bentonites from Rajasthan are shown in Tables 1 and 2, respectively. It is clear from the chemical analysis that these bentonites are abundant in alkalis.

Table 1. Chemical Composition of Some Rajasthan Bentonites

Source	Barmer	Jodhpur	Jaisalmer	Bikaner
Silica (SiO_2),%	51.40	55.80	51.40	52.40
Alumina (Al_2O_2), %	21.40	19.63	24.70	24.10
Iron oxide (Fe_2O_2) and Titenium oxide (TiO_2), %	6.80	8.25	5.20	6.60
Lime (CaO), %	0.70	0.61	0.60	0.40
Magnesia (MgO), %	1.90	2.63	1.50	0.40
Sodium oxide (Na_2O) and Potassium oxide (K_2O), %	3.10	3.36	2.20	0.70
Moisture at 110^0C, %	8.70	6.50	7.40	8.10
Loss on Ignition, %	6.00	9.61	7.00	8.30

Table 2. Physico-Chemical Properties of Some Rajasthan Bentonites

Source	Barmer	Jodhpur	Jaisalmer	Bikaner
Sp. gravity	2.45	2.23	2.51	2.44
Total Exchangeable Base in milliequivalents per 100 gm at pH 7	48.0	90.0	47.5	47.5
Base Saturation capacity in milliequivalents per 100 gm	80.0	92.0	65.0	74.0
pH values 2% Suspension	8.37	7.48	7.91	7.57
6% Suspension	8.23	7.83	8.31	7.88
Swelling water absorbed per gm of oven dried Bentonite, in c.c.	2.52	5.01	2.79	2.79
Thixotropy for 6% suspension	1 min	Instl.	3 min	5 min
Sand content, %	0.40	0.24	-	-
Liquid limit, %	162.2	341.0	-	-
Plastic limit, %	41.2	40.4	-	-
Plastic Index, %	121.0	300.6	-	-

3 Experimental Work

Dune sand of Bikaner was selected as the representative soil for this investigation. The soil was put through the usual preliminary tests for its classification. It was found to contain 11% silt, the rest being fine sand. The particle size distribution curve of the soil is given in Fig. 1.

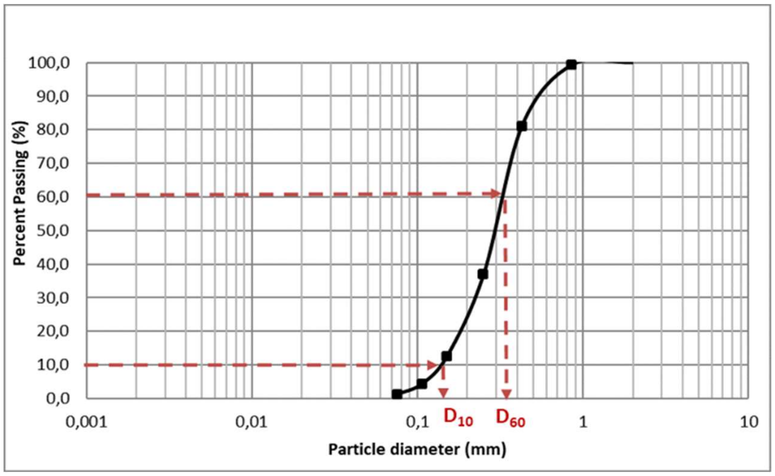

Fig 1: Grain Size Distribution Curve

It was considered desirable to determine the permeability of bentonite-soil mixture at different values of dry density. The dry density-water content relationships for various mixes of sand-bentonite were determined by standard compaction apparatus. The bentonite content was varied from zero to 6% by weight of dry soil with an interval of 2%. The maximum dry densities and the corresponding optimum water contents are given in Table 3. The permeability of bentonite-sand mixtures was determined at dry densities corresponding to 100, 95 and 90 percent of the maximum dry densities achieved in the compaction test, the moulding water content being always maintained equal to the optimum water content for the concerned mix.

Permeability was determined under falling head set up. Two or three specimens were tested simultaneously, each permeameter being connected to a 0.74 cm diameter tube mounted on a wooden board fixed to wall. The tube served as the standpipe for the falling head set-up. Coefficient of permeability was calculated by the usual falling head formula and reduced to 27°C.

Table 3. Density-Moisture Relationship for Sand-Bentonite Mixtures

Bentonite	0%	2%	4%	6%
Max Dry Density (g/cm^3)	1.670	1.690	1.718	1.730
Optimum Moisture Content (%)	13.90	14.40	15.29	15.80

4 Test Results

The results of compaction tests for the various bentonite soil mixes are shown in Fig. 2. The maximum dry density (Υ_{dmax}) varies from 1.67 to 1.73 g/cm^3 and the optimum water content varies from 13.9% to 15.80% for the different mixes, both increasing with increase in bentonite content.

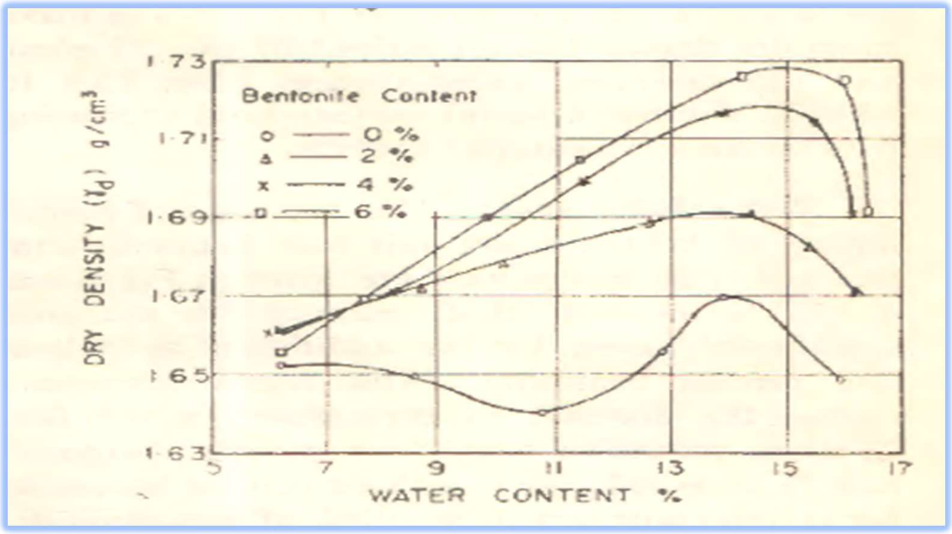

Fig 2: Dry Density Relationship

The variation of permeability of bentonite-soil mix with bentonite content and with compaction is given in Fig 3 and 4. It is evident that permeability decreases considerably even by the addition of as little as two percent bentonite. With higher bentonite content the decrease in permeability is very fast, 23 times reduction with four percent of bentonite and 73 times reduction with six percent of bentonite, for samples compacted to 100% of maximum dry density. The ratio of permeability of soil to that of soil-bentonite mixes for various degrees of compaction are given in the table 4.

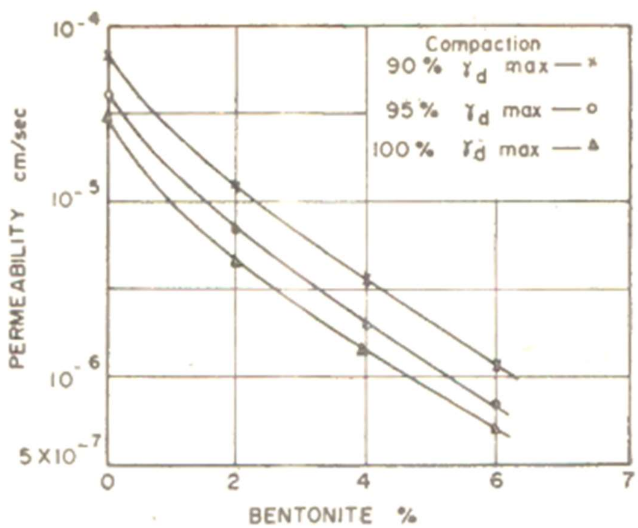

Fig 3: Variation of Permeability with Bentonite Content

Table 4. Ratio of Permeability of Soil and Soil-Bentonite mixes

Bentonite Content	Degree of Compaction (Percent of Maximum Dry Density)		
	100	95	90
2%	7.5	7.4	7.9
4%	23.1	18.4	10.4
6%	73.3	73.8	50.2

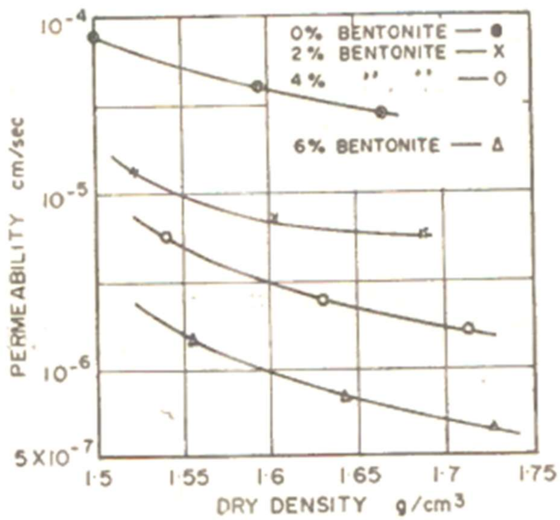

Fig 4: Variation of Permeability with Dry Density

5 Conclusion

The lining of small canals and field channels, which account for around 33 to 40% of the total seepage loss in a canal system, can result in significant savings in irrigation water. Bentonite can produce a cheap and efficient lining material that can be used as a buried membrane for small canals in desert regions when it is mixed in small quantities (2 to 6% by weight) with dune sand.

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