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RESEARCH ARTICLE OPEN ACCESS

A STUDY ON THE EFFECTS OF BENTONITE SLURRY ON THE COHESIVE PROPERTIES OF FINE SAND

Sahil Nur Rahman[1], Suhrit Kashyap[2], Uday Bhaskar Buragohain[3], Bhargov Hazarika[4], Abhash Moran [5], Mustakur Rahman[6], Rituparna Goswami[7]

1, 2, 3, 4, 5, 6 (B. Tech Student, Department of Civil Engineering, Jorhat Engineering College, Garmur, Jorhat, Email: sahilnurrahman9@gmail.com)

7 (Assistant Professor, Department of Civil Engineering, Jorhat Engineering College, Garmur, Jorhat, Email: goswami_rituparna@rediffmail.com)

Abstract:

This study evaluates the influence of Bentonite slurry on the Cohesive behaviour of Fine Sand for Soil Stabilization applications. Fine Sand was mixed with Bentonite contents of 3%, 6%, 9%, 12%, and 15% by dry weight using 4% and 8% Water–Bentonite slurry. Laboratory investigations included Particle Size Distribution, Specific gravity, Atterberg Limits, Unconfined Compression (UCT), and Direct Shear Tests. The results indicate a marked increase in Cohesion with increasing Bentonite content, while the Angle Of Internal Friction showed variable responses. The findings demonstrate the potential of Bentonite-treated sand for improving Soil Strength, Stability, and Permeability characteristics.

Keywords: *Fine sand, Bentonite slurry, Soil stabilization, Cohesion, Direct Shear Test, Unconfined Compression Test, Atterberg Limits, Internal Friction Angle.*

I. INTRODUCTION

Fine sand is a granular soil with particle sizes ranging from 0.075 mm to 0.425 mm and is widely used in construction, landscaping, and foundation engineering due to its uniform grading and ease of compaction. However, its cohesionless nature results in low shear strength, poor load-bearing capacity, high permeability, and vulnerability to erosion, settlement, and slope failure, which can adversely affect the stability of engineering structures. Bentonite, a naturally occurring clay mineral rich in montmorillonite, possesses high swelling, water absorption, plasticity, and cohesive properties. When combined with sand and water, Bentonite forms a binding matrix around sand particles, thereby increasing cohesion, reducing permeability, and improving overall soil stability. Owing to these characteristics, Sand–Bentonite mixtures are commonly used in soil stabilization, trench support, diaphragm walls, groundwater control, foundation backfilling, and pile drilling.

This study evaluates the effectiveness of Bentonite slurry in enhancing the engineering behavior of Fine Sand; with particular emphasis on Cohesion, Shear Strength, Stability, and the identification of an optimum bentonite content for practical geotechnical applications.

II. LABORATORY INVESTIGATIONS AND RESULTS

Laboratory investigations involves performing Grain Size Distribution, Atterberg's Limit test, Unconfined Compressive Strength test and Direct Shear Test as follows:

A. Grain Size Distribution Test

The procedure of the test has been followed as per IS 2720 (Part 4): 1985. In the Grain Size Distribution Test, Fine Sand is separated out from the available soil.

Table-1: Grain Size Distribution of the Soil Sample

Sieve Size (mm)	Weight Retained (gm)	Cumulative weight Retained	Cumulative % Retained	% Passing
0.6	27	27	2.07	97.93
0.425	124	151	11.61	88.32
0.3	693	844	64.92	35.08
0.15	434	1278	98.3	1.7
0.075	6	1284	98.76	1.24
0	0	1284	98.76	1.24

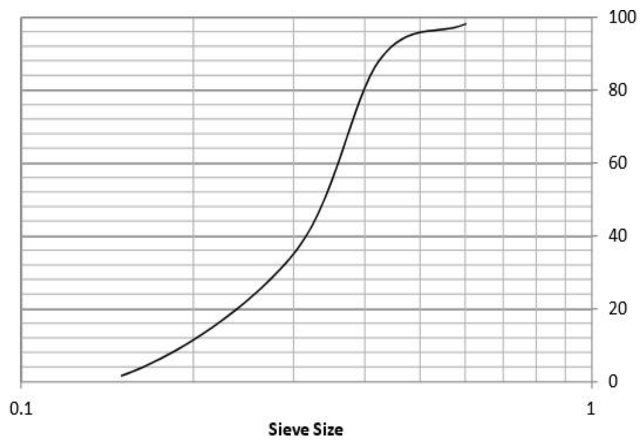

Fig-1: Particle Size Distribution Curve of the Soil Sample

B. Atterberg's Limit test

The procedure for determining Liquid Limit (W_L) and Plastic Limit (W_P) has been followed as per IS 2720 (Part 5): 1985.

The soil can be classified using plasticity chart and hence Plasticity Index (I_P) can be obtained as the difference between Liquid Limit (W_L) and Plastic Limit (W_P).

Table-2: Consistency Limit Test Results of Soil Sample

Penetration in mm	8	28	32
Wt. of wet soil + Container(gm)	46	49	42
Wt. of dry soil + Container(gm)	31	33	21
Wt. of water(gm)	15	16	21
Wt. of Container(gm)	27	27	12
Wt. of dry soil (gm)	4	6	9
Water Content	0.2667	0.375	0.4286
Water Content %	26.67	37.50	42.86

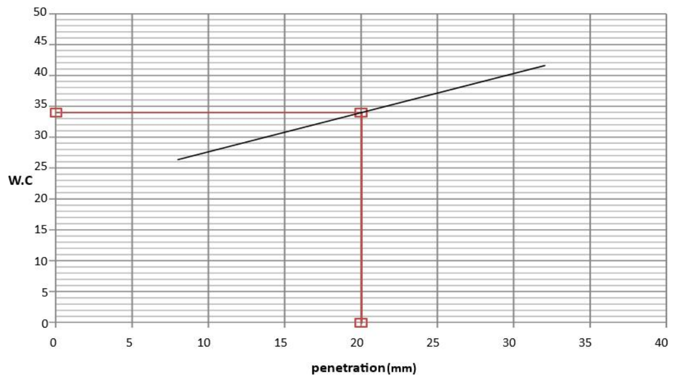

Fig-2: W.C. V/S Penetration

From the Fig-2, it is evident that the W_L of the soil is 34%. W_P for the soil is nil, hence soil cannot be classified using Plasticity Index Chart.

C. Unconfined Compressive Strength (UCS) Test

The procedures for performing the UCS test has been followed as per IS 2720 (Part 10): 1991.

Table-3: Results of Unconfined Compression Strength test

Dial Gauge Reading	Deformation (mm)	Proving Ring Reading	Normal Load	Strain	Strain (%)	Corrected Area	Compressive Strength
0	0	0	0.00	0.000	0.00	0.0011	0.00
50	0.5	8	0.02	0.007	0.66	0.0011	21.17
100	1	14	0.04	0.013	1.32	0.0011	36.81
150	1.5	16	0.05	0.020	1.97	0.0012	41.78
200	2	22	0.07	0.026	2.63	0.0012	57.07
250	2.5	24	0.07	0.033	3.29	0.0012	61.84
300	3	28	0.08	0.039	3.95	0.0012	71.65
350	3.5	32	0.10	0.046	4.61	0.0012	81.33
400	4	42	0.13	0.053	5.26	0.0012	106.00
450	4.5	46	0.14	0.059	5.92	0.0012	115.29
500	5	52	0.16	0.066	6.58	0.0012	129.42
550	5.5	54	0.16	0.072	7.24	0.0012	133.45
600	6	58	0.18	0.079	7.89	0.0012	142.32
650	6.5	56	0.17	0.086	8.55	0.0012	136.43
700	7	50	0.15	0.092	9.21	0.0012	120.94

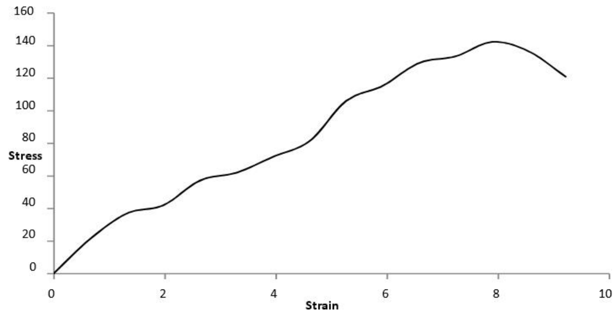

Fig-3: Stress v/s Strain Curve from the Results of Unconfined Compression Strength test

The cohesion of the tested Bentonite is obtained as 71.16 kpa from UCS test.

D. Direct Shear Test

Direct Shear Tests were carried out to determine the Shear Strength Parameters of natural soil and soil mixed with 3%, 6%, 9%, 12%, and 15% Bentonite. Bentonite slurry prepared with 4% and 8% water content was thoroughly blended with the soil, and the mixtures were compacted in the Direct Shear Box without air voids. For each sample, normal stresses of 0.5 kg/cm², 1.0 kg/cm², and 2.0 kg/cm² were applied. The corresponding maximum shear stresses were obtained from Stress–Displacement Curves and plotted against the applied normal stresses. From the resulting linear relationship, the slope provided the Angle Of Internal Friction (φ), while the intercept on the Shear Stress Axis represented the Cohesion (c) of the soil mixture.

The results of Direct Shear Test at 4% and 8% of water is shown through Table-4 and Table-5.

Table-4: Results of the Direct Shear Test at 4% water

Bentonite Content	0	3	6	9	12	15
Cohesion	0	0.13	0.21	0.23	0.26	0.27
Angle of Internal friction	25.07	23.06	22	20.88	16.62	11.18

Table-5: Results of the Direct Shear Test at 8% water

Bentonite Content	0	3	6	9	12	15
Cohesion	0	0.19	0.22	0.25	0.27	0.31
Angle of Internal friction	25.07	23.15	20.54	16.71	12.61	9.74

III. INTERPRETATION OF TEST RESULTS

A. Changing Pattern of C And Φ at Different Bentonite Content

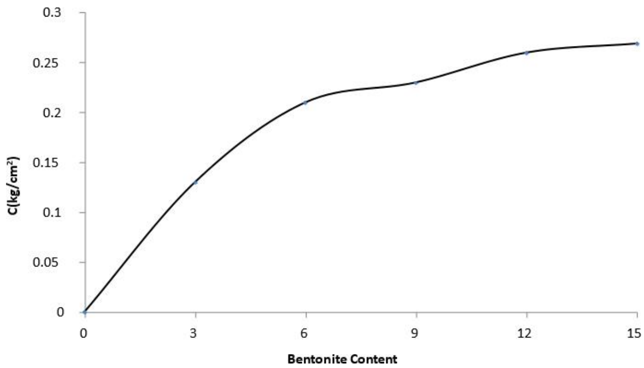

Fig-4: Variation of Cohesion at different Bentonite content for 4% water

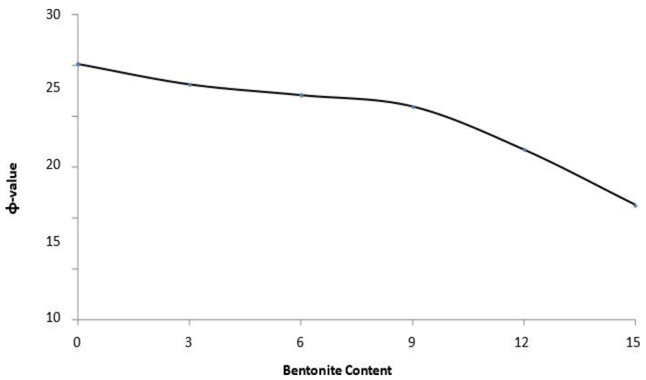

Fig-5: Variation of Angle Of Internal Friction at different Bentonite content for 4% water

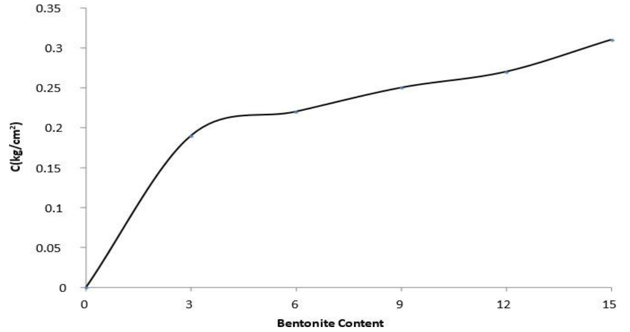

Fig-6: Variation of Cohesion at different Bentonite content for 8% water

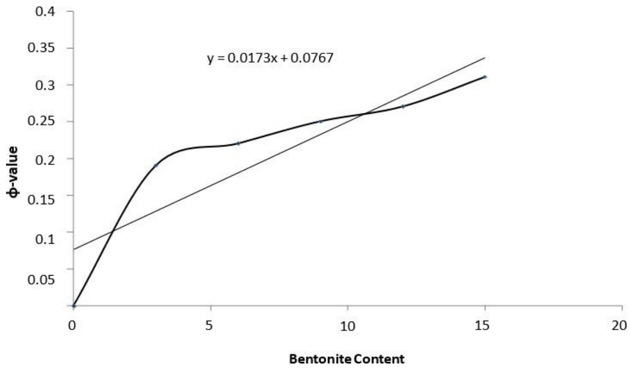

Fig-7: Variation of Angle Of Internal Friction at different Bentonite content for 8% water

Table-6:C and φ value at different Bentonite content mixing at 4% and 8% water

Water Content	C						φ					
	0%	3%	6%	9%	12%	15%	0%	3%	6%	9%	12%	15%
4%	0	0.13	0.21	0.23	0.26	0.27	25.07	23.06	22.005	20.88	16.62	11.18
8%	0	0.19	0.22	0.25	0.27	0.31	25.07	23.15	20.54	16.71	12.61	9.74

B. Slope of Changing Pattern of C

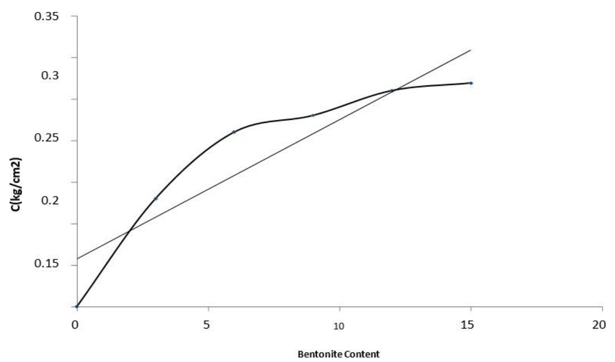

Fig-8: Increase of Cohesion at 4% water

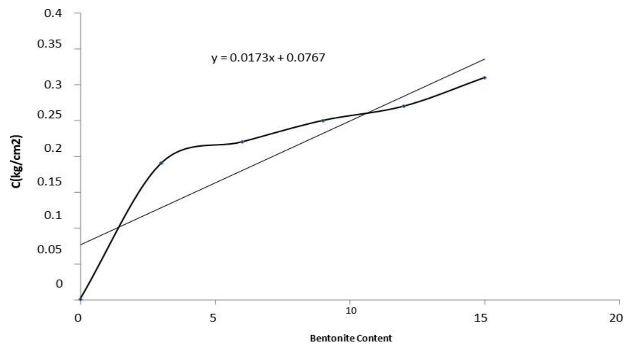

Fig-9: Increase of Cohesion at 8% water

From Fig-8 and Fig-9, Slope of the changing trends are obtained as 54.82° and 56.78° respectively.

C. INTERPRETATION

By Interpreting the above graphs, it can be concluded that:

(i) With increasing Bentonite content, C value of the soil increases.

(ii) With increasing Bentonite content φ value of the soil decreases.

(iii) From trend line and slope of the trend lines of graphs between Bentonite content and Shear Parameters it can be observed that, slope of the trend line at 8% water content slurry (56.78°) is more than that of slope of trend line at 4% water content (54.82°). So, with increasing water content cohesion of the sand increases.

This is matching with the general perception that bentonite increases cohesion.

IV. CONCLUSION

The results of this study demonstrate that Bentonite slurry significantly improves the Cohesive behavior of Fine Sand, thereby enhancing its suitability for a range of geotechnical and construction applications. As the water content of the mixture increases, Bentonite undergoes greater swelling, resulting in an increase in volume and improved interaction with surrounding soil particles. This process promotes stronger particle bonding and leads to a noticeable increase in Cohesion. The study further indicates that higher Bentonite content contributes to increased Cohesive Strength while reducing the Angle Of Internal Friction due to the coating of sand particles by Bentonite. The combined effect of enhanced Cohesion and reduced Intergranular Friction improves the overall stability and engineering performance of the Sand–Bentonite mixture. Moreover, the influence of Bentonite becomes more pronounced at higher water contents, where its swelling and binding characteristics are fully mobilized. Although the findings confirm the effectiveness of Bentonite in modifying fine sand properties, additional research is required to evaluate long-term durability, field performance, and potential environmental impacts under varying site conditions.

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