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A Study of Physical Properties and Strength Parameters of Sand and Bentonite Mix

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Abstract*: In past decades, one of the major problems faced by geotechnical engineers is to improve the engineering properties of clayey soil, so that the improved engineering properties of clayey soil meet the requirement of civil engineering construction. The technique of improving engineering properties of soil is termed as soil stabilization or modification. In present study, sand procured from the bank of River Gaula at Kathgodam, district. Nainital, (Uttarakhand) was mixed with different proportions of sodium bentonite. Physical properties of Gaula sand and bentonite were determined in the laboratory. Specific gravity, optimum moisture content (OMC), maximum dry density (MDD), porosity and void ratio were determined at different proportion of sand bentonite mix. The present paper discusses the results obtained from the test conducted.*

1. INTRODUCTION

Soil stabilization refers to the process of changing soil properties to improve strength and durability. There are many techniques for soil stabilization, including compaction, dewatering and by adding certain material's to the soil. Periodic swelling and shrinkage occurs in the clayey soils during the alternate wet and dry seasons. Such cyclic swell shrink movements of the ground causes considerable damage to the structures constructed on these soils. As the clay percentage in soil increases the optimum water content (OMC) is also increases, shrinkage limit and strength and reduced the swelling potential, liquid limit, plasticity index and maximum dry density (MDD). Expensive soil shows very unpredictable results on soft soil. A study was done on different percentage of gaula sand and bentonite mix. A number of test were conducted at various percentages bentonite mix with sand such as S100%B0%, S95%B5%, S85%B15%, S75%B25%, and S65%B35%. Pycnometer test, atterberg limits, standard proctor test and strength parameters were studied.

2. Model Material

2.1 Gaula River Sand

The sample of Gaula River Sand was from the river Gaula near Kathgodam, Nainital, Uttarakhand. It was grey in colour and has been oven dried before conducting further laboratory tests.

Table-1: properties of sand.

Parameter	Value
Specific gravity (G)	2.68
Bulk Density (γ), g/cc	1.67
Plasticity Index	Non-Plastic
Maximum dry density ($\gamma_{d\,max}$), g/cc (Standard Proctor Test)	1.59
Optimum moisture content (OMC), %	4.70
Angle of internal friction (ϕ), degree	17.22
Cohesion (c), kPa	Negligible
Grain size distribution Sand size fraction (%) Silt size fraction (%)	 98.00 2.00
Soil type as per IS: 1498-1970	SP

2.2 Bentonite

Bentonite was used in the present study. Bentonite is an absorbent aluminium phyllosilicate, impure clay consisting mostly of montmorillonite. Bentonite usually forms from weathering of volcanic ash, most often in the presence of water. There are different types of Bentonite, each named after the respective dominant element, such as potassium (K), sodium (Na), calcium (Ca), and aluminium (Al).

Table-2: properties of bentonite.

Parameter	Value
Specific gravity (G)	1.63
Liquid Limit (%)	132.76
Plastic limit (%)	68.62
Plasticity Index (%)	64.14
Angle of internal friction (ϕ), degree	0
Cohesion (c), kPa	1.3
Soil type as per IS: 1498-1970	CH

2.3 Literature Review

On the basis of past researches it had been observed that inclusion of fibers significantly improves the engineering properties of soil. The use of reinforcements in subgrades can help in improving the safety coefficient of road embankment load carrying capacity and also decrease displacements of soil subgrade. Furthermore, if the weak subgrade is improved or reinforced, the crust thickness of the pavement will be less, which results in less repairs and overall economy.

Naeini et al. (2007), studied the variation of atterberg limit on mixing of bentonite in soft soil. On increasing the bentonite in soft soil liquid limit, plastic limit and plasticity index increases. The study showed that on increasing the bentonite percentage by 10% the liquid limit increased approximately by 36%, plastic limit increased approximately by 22% and plasticity index increased approximately by 60%. If further increase in the bentonite percentage by 10% the liquid limit increased approximately by 32%, plastic limit increased approximately by 22% and plasticity index increased approximately by 43%. Maximum dry density decreased approximately by 3.1% and 3.2% on addition of 10% and 20% bentonite in the soft soil respectively. Optimum moisture content increased approximately by 7.0% and 13.0% on addition of 10% and 20% bentonite in the soft soil respectively

Naeini S. A. et al. (2011) study was undertaken to investigate the effect of plasticity index on the shear strength parameters (c and φ). The initial stiffness at the same normal stress for reinforced and unreinforced soils remains practically the same. The percentage of fiber content played an important role in the development of shear strength parameters c and φ of the fiber reinforced soil. When the soil is reinforced with the waste polymer fiber, it reduced the dry density of the soil due to a low specific gravity and unit weight of polymer fiber. The increase in the fiber content also reduced the optimum moisture content (OMC) of the soil. The variation is linear for both cases.

KOTESWARA RAO P.V. et al. (2012) study the effects on the properties of locally available Black cotton soil on the addition of polymer fibers on the with and without admixture modification. This study revealed that the fiber reinforcement improves the soil properties in terms of improved stress-strain patterns and progressive failure in place of quick post peak failure of plain samples.

3. Results and Discussion

3.1. Specific Gravity

Specific gravity of sand bentonite mix is determined by pycnometer method. The results below shows that specific gravity decreases on addition of bentonite in the sand.

Table-3: Specific gravity of sand bentonite mix

Description	Specific gravity (G)
Sand 100% Bentonite 0%	2.70
Sand 95% Bentonite 5%	2.67
Sand 85% Bentonite 15%	2.61
Sand 75% Bentonite 25%	2.55
Sand 65% Bentonite 35%	2.47

3.2. Standard Proctor Test

The compaction characteristics optimum moisture content and maximum dry density of the sand and Bentonite mixes were studied using Standard Proctor Test. Standard Proctor tests were conducted were conducted at various percentages bentonite mix with sand as per IS: 2720 (Part 7)-1980. The results are given below.

Table-4: OMC & MDD of sand bentonite mix

Description	MDD (g/cc)	OMC %
Sand 100% Bentonite 0%	1.594	4.70
Sand 95% Bentonite 5%	1.601	6.90
Sand 85% Bentonite 15%	1.614	8.50
Sand 75% Bentonite 25%	1.629	9.90
Sand 65% Bentonite 35%	1.691	12.20

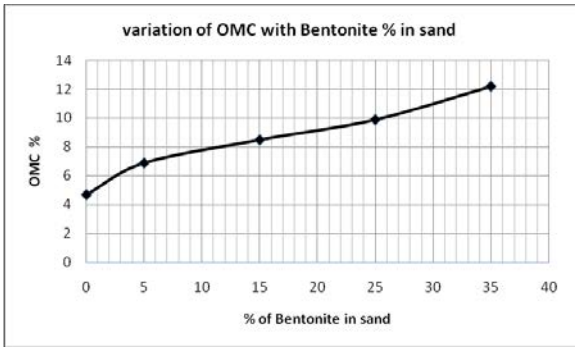

Figure 1 plot between OMC and % of Bentonite in sand

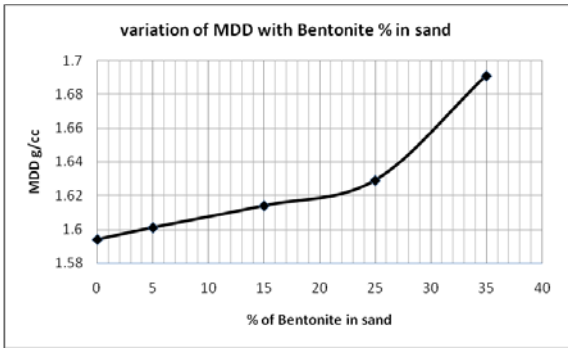

Figure 2 plot between MDD and % of Bentonite in sand

Void ratio and porosity were also determined for different mix proportions. Table 5 represents the variation of void ratio and porosity.

Table-5: void ratio & porosity of sand bentonite mix

Description	Void ratio (e)	Porosity (n)
Sand 100% Bentonite 0%	0.69	0.41
Sand 95% Bentonite 5%	0.67	0.40
Sand 85% Bentonite 15%	0.62	0.38
Sand 75% Bentonite 25%	0.56	0.36
Sand 65% Bentonite 35%	0.46	0.32

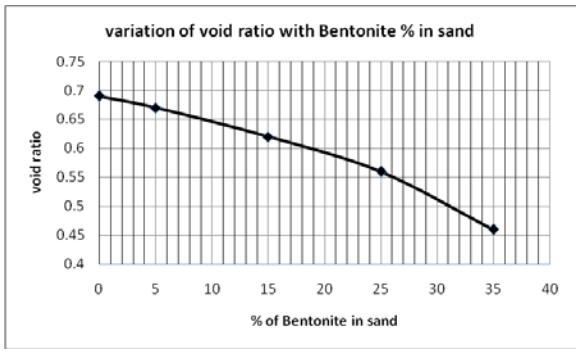

Figure 3 plot between void ratio and % of Bentonite in sand

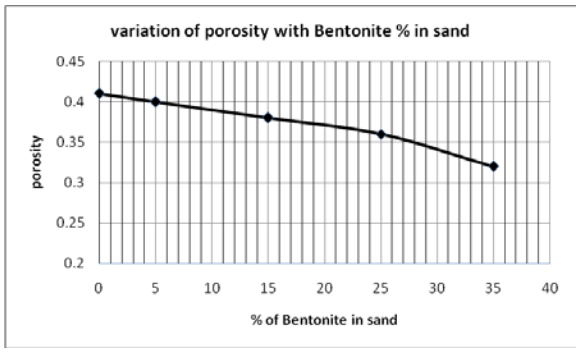

Figure 4 plot between porosity and % of Bentonite in sand

3.3 Unconfined Compressive Strength

A number of Unconfined Compressive Strength test were conducted at various percentages bentonite mix with sand. Samples were prepared at optimum moisture content for Unconfined Compressive Strength test. Following are the test results of the test.

Table-6: UCS & cohesion values

Bentonite (%)	qu (kPa)	cu(kPa)
5	44.2	22.10
15	56.19	28.10
25	130.57	65.29
35	179.79	89.89

3.4 Direct shear test

The standard procedure for the 'Direct shear test' as explained in Indian Standard Code (IS: 2720, Part XIII-1986) was referred for the study to determine the shear parameters. Tests were conducted at various percentages bentonite mix with sand. Samples were prepared at optimum moisture content for Direct Shear test. Following are the test results of the test.

Table-6: cohesion & angle of internal friction values

Sand % + Bentonite %	Cohesion (c) kPa	Angle of internal friction (φ ˚)
Sand 100% Bentonite 0%	0.84	18.93
Sand 95% Bentonite 5%	2.94	18.06
Sand 85% Bentonite 15%	13.26	17.17
Sand 75% Bentonite 25%	24.21	15.43
Sand 65% Bentonite 35%	40.21	12.02

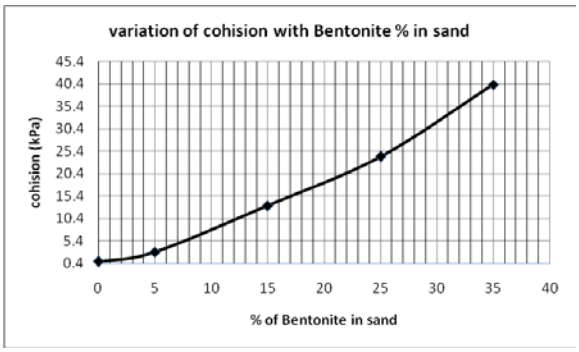

Figure 5 plot between cohesion and % of Bentonite in sand

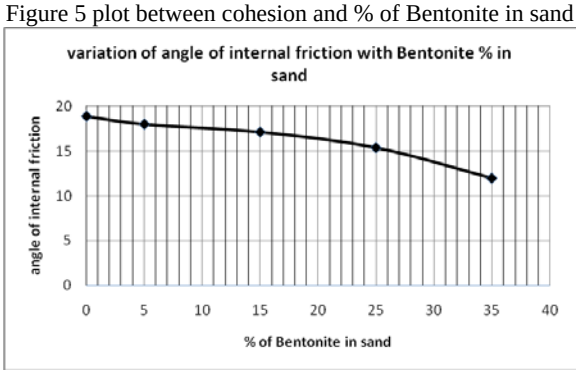

Figure 6 plot between angle of internal friction and % of Bentonite in sand

4. Conclusion

A study has been conducted to investigate the effect of increasing the plasticity of soft soil on the strength parameters. For this study a number of tests were conducted on model material sand and bentonite. At varying percentage of bentonite the following tests results are obtained.

i. Specific gravity of sand bentonite mix decreases from 2.70 to 2.47 with increase in bentonite percentage in sand.
ii. Optimum moisture content (OMC) of sand bentonite mix increases from 4.70% to 12.20% with increase in bentonite percentage in sand.
iii. Maximum dry density (MDD) of sand bentonite mix increases from 1.594 g/cc to 1.691 g/cc with increase in bentonite percentage in sand.
iv. Void ratio of sand bentonite mix decreases from 0.69 to 0.46 with increase in bentonite percentage in sand.
v. Porosity of sand bentonite mix decreases from 0.41 to 0.32 with increase in bentonite percentage in sand.
vi. Unconfined compressive strength (UCS) increases from 44.20 kPa to 179.79 kPa with increase in bentonite percentage in sand.
vii. Cohesion value of sand bentonite mix increases from 0.84kPa to 40.21kPa with increase in bentonite percentage in sand.
viii. Angle of internal friction of sand bentonite mix decreases from 18.93˚ to 12.02˚ with increase in bentonite percentage in sand.

It is clearly shown that the rate of increase of cohesion value increases rapidly when percentage of bentonite increase beyond 25 %. Similarly rate of decrease of angle of internal friction value decreases rapidly when percentage of bentonite increase beyond 25 %.

5. References

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