Journal of
Geotechnical Studies
www.matjournals.com

e-ISSN: 2581-9763
Volume-6, Issue-1 (January-April, 2021)

Effect of Fineness of Soil on California Bearing Ratio Value

M. Ali[1], R. I. Islam[1], S. A. Chowdhury[2*], M. A. Sobhan[3]
[1]Research Student, [3]Professor
Department of Civil Engineering, Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh
[2]Lecturer, Department of Building Engineering & Construction Management, Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh

*Corresponding Author: showaib@becm.ruet.ac.bd

ABSTRACT

Being the bottom-most layer of a road, the sub-grade soil acts as one of the most important load-bearing strata on which the performance and design of a pavement depend essentially. The grain size of soil particles plays a significant role in strength characteristics of the sub-grade as working recommendations vary significantly respecting varying particle sizes. Generally, California Bearing Ratio (CBR) value is widely used for the evaluation of subgrade strengths. Since this test is an expansive and time-consuming one, it is much needed to establish an alternative approach to determine the CBR value from some other physical properties of soils, which are easy, cheap, and low time consuming with limited facilities for laboratory experiments. To confront this, an attempt has been conducted in this study to correlate CBR value of sub-grade with some physical properties of soils, such as Fineness Modulus (FM) along with grain sizes. Six types of fine sands were collected from six notable sites, i.e bed of River Payera in Borguna, River Katcha in Pirojpur, River Shayendha in Barisal, River Kapotakkha in Khulna, River Bhairab in Bagerhat, and one sample was collected from subsoil in Jessore. At the initial stage, the necessary engineering properties of soils, like fineness modulus, grain size distribution, unit weight, dry density, and optimum moisture content, were determined, followed by thirty CBR samples with different FM values at optimum moisture content. After that, a correlation was established in the form of an equation to express CBR value as a function of fineness modulus using regression analysis. From field and laboratory test results, it was found that the six sands are uniformly graded non-plastic fine sand with FM 0.13 to 0.26 and their PI is less than 5 and LL is less than 30. CBR of sands lies in between 11.44% to 12.09% and their swelling is in between 0.58% to 0.69%. The equation of co-relation is y = 0.0496x + 0.1081, where y refers to CBR (%) and x refers to Fineness modulus. From which one can ascertain the probable CBR value of find sand corresponding its FM value. With the help of this study, the CBR value of soil sample can be predicted in an easier, cheap, and less time-consuming manner to classify and evaluate the soil sub-grade rather than conventional CBR test.

Keywords-- California bearing ratio, Fineness modulus, Effect of fineness, Regression analysis

INTRODUCTION

A strong transportation system, consisting of a well-developed network of well-developed roadways, railways, waterways, and airways, is very important for any country's rapid economic, manufacturing, and cultural development. Among these four modes of transportation system, highways are one of the most economical and easiest modes for transportation. A road pavement is a comparatively durable layer of a highway built over natural soil with the primary purpose of sustaining and spreading heavy wheel loads of vehicles over a vast region of the underlying

e-ISSN: 2581-9763
Volume-6, Issue-1 (January-April, 2021)

subgrade soil, allowing deformations within an elastic or permissible range, and having an acceptable surface. The subtle art of road pavement construction is highly technical. Again, one of the most important parameters in the construction of road pavement is the California Bearing Ratio (CBR). The CBR value of the subgrade soil determines the thickness of component layers and the overall thickness of flexible pavement. Since this test is an expansive and time-consuming one, it is much needed to establish an alternative approach to determine the CBR value from some other physical properties of soils. In order to correlate CBR value with sieve analysis and compaction characteristics, an empirical formulae was developed as: $CBR = -8.214\ MDD^2 + 41.68\ MDD - 42.36$ (Rakaraddi and Vijay, 2001). Naveen and Santosh (2014) studied twenty samples of plastic and non-plastic soil to perform multiple linear regression analysis using index properties and soaked CBR value whose significant results were $CBR = -4.8353 - 1.56856 * OMC + 4.6351 * MDD$. NCHRP (2004) proposed as a best-fitted equation for correlated CBR value with clean, coarse-grained soil which is described as: CBR = 5 for (60 ≤ 0.01mm); CBR = 28.09 (D60)0.35 for (0.01 < D60 < 30); CBR = 95 for (D60 ≥ 30mm). To establish a correlation between CBR and soil parameters, soil samples (CL-ML) were mixed with varied sand content to perform a simple and multiple linear regression as: $CBR = 16.5235 + 0.1314 * \%\ sand - 8.3923 * MDD$ (Siddhartha et al. 2015). In this context, the aims of this study is to determine the physical properties of fine sand and to establish a relation between Fineness modulus and California bearing ratio value of fine sand, from which one can easily ascertain the probable CBR value of find sand corresponding its FM value.

METHODOLOGY

Materials and Sources

The coverage areas of this research are located mainly at coastal and tidal area of Bangladesh i.e. Borguna, Pirojpur, Barisal, Khunla and Bagerhat as well as non-tidal area Jessore. In these areas, the construction agencies normally collect local sand belonging FM below 0.5 from local river bed or from local underground layer for improved subgrade soil instead of scheduled sand of FM ≥ 0.5 because of unavailability and higher cost of this sand on order to save time without any approved specifications.

Table 1: *List of Samples with Designation and Name of Sources.*

Sr. No.	Sources Name	Sample Designation
1	Payera river, Borguna,	Type-A
2	Katcha river, pirojpur	Type-B
3	Shayendha river, Barisal	Type-C
4	Kapotakho river, Khulna	Type-D
5	Bhairab river, Bagerhat	Type-E
6	Underground Sample, Jessore	Type-F

e-ISSN: 2581-9763
Volume-6, Issue-1 (January-April, 2021)

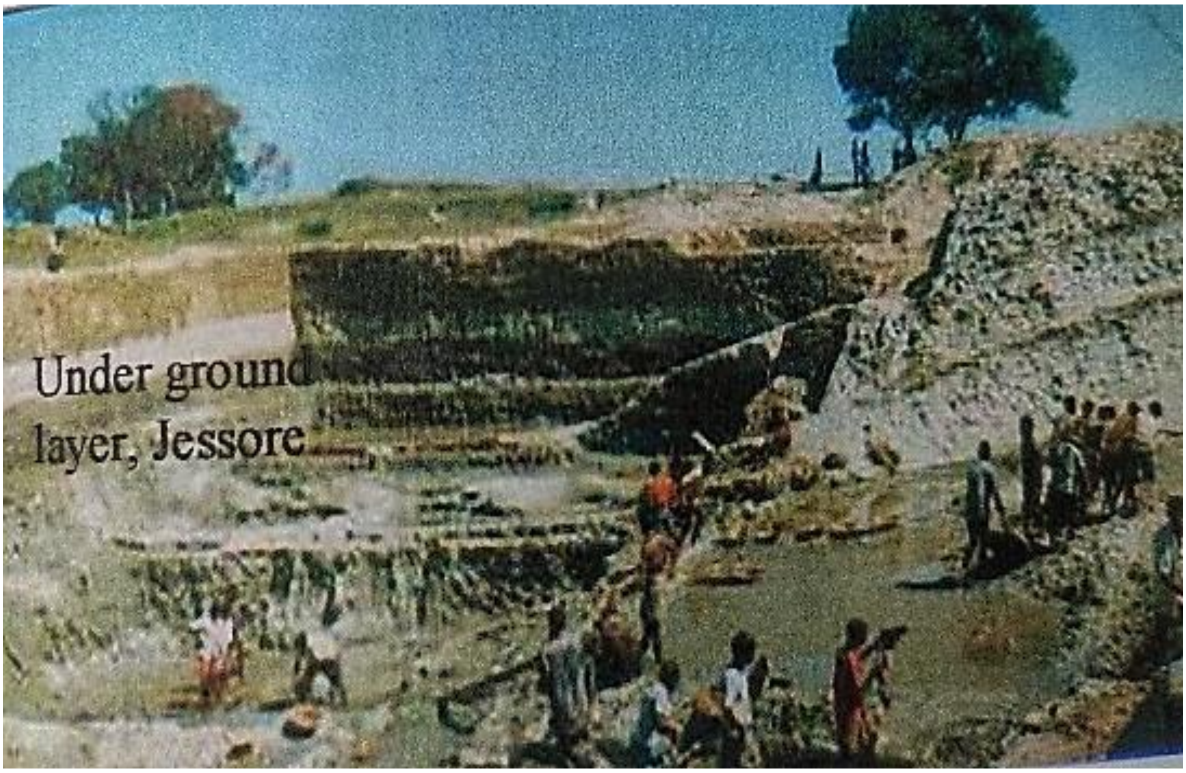

Figure 1: *Photographic view of tidal (above) and Non-Tidal (bottom) sources for local sands.*

Determination of Geotechnical Properties of Soil

Soils are granular and cohesive. Granular soil is generally an excellent foundation material for supporting structures and roads. Cohesive soil is often possesses low shear strength and plastic behavior. In a broad sense, the soil is an exceedingly complex system containing a significant number of properties. Fortunately, the properties of soil are functionally interrelated. Moreover, pavement construction is solely affected by the engineering and geotechnical properties of soil. There are four major factors that influence the engineering properties of soils: the prevailing size of mineral particles, the form of mineral particles, the grain size distribution, and the relative amounts of mineral particles.

Specific Gravity

The specific gravity of the soil is used to determine the composition of the soil solids, and is used to determine phase relationships in soils such as the void ratio and degree of saturation. The ratio of a substance's density (weight of air) to the mass of the same volume of water at a given temperature is known as its specific gravity. The volume of solid matter and internal pores is generally considered to be the volume of the mass particle. A pycnometer was used to assess bulk specific gravity, SSD specific gravity, and apparent specific gravity using ASTM C 128 (1997) and or AASHTO T 84 (2004) research methods. Table 2 summarizes the test findings.

Table 2: *Test results of Specific gravity of samples (Azad, 2010).*

Sample Designation	Avg. SP. Gravity
Type-A	2.68
Type-B	2.6
Type-C	2.64
Type-D	2.69
Type-E	2.65
Type-F	2.61

Particle Size Analysis and Fineness Modulus

The engineering properties of soil are affected by the distribution of different grain sizes, which is determined by determining the percentage of different grain sizes, gradation and FM, as well as soil classification. ASTM C 136 (2006) and or AASHTO T 27 (2006) for sieve analysis and ASTM D 422 (2002) and AASHTO T 88 (2002) for hydrometer analysis are the standard test methods has been followed in this research works for grain size analysis respectively. The fineness modulus (FM) is a calculation of the coarseness or fineness of a substance with a particle size greater than 75 microns. The fineness and coarseness of soil are also shown by the FM of the soil. Table 3 summarizes the test results used in this study.

Table 3: *Test results of Particle size analysis (Azad, 2010).*

Sample Designation	Fineness modulus (FM)
Type-A	0.13
Type-B	0.15
Type-C	0.17
Type-D	0.18
Type-E	0.22
Type-F	0.26

Atterberg Limits

To execute the experiments in accordance with ASTM D 4318, a multi-point liquid limit and plastic limit test protocol was used (2002). The samples have been allowed to dry before testing after pulverizing and then soil paste has been made adding required amount of water. Table 4 summarizes the test results used in this study.

Table 4: *Test results of Atterberg Limits (Azad, 2010).*

Sample Designation	Liquid Limit, LL (%)	Plasticity Index, PI (%)	Plasticity
Type-A	26.7	1.60	SP
Type-B	30.1	0.31	NP
Type-C	26.0	0.70	NP
Type-D	24.2	2.60	SP
Type-E	29.1	1.80	SP
Type-F	25.3	1.20	SP
Note:- SP-Slightly Plastic, NP- Non plastic			

Unit Weight and Relative Density

According to ASTM C 29 (2006) test procedures for unit wt. and ASTM D 4254 (2006) for relative density determination, the relative density has been found out. In addition, in-situ dry unit weight in field void condition was determined as per specification. Table 5 summarizes the test results used in this study.

Table 5: *Test results of Loose and Dense Unit Weight (Azad, 2010).*

Sample Designation	Fineness modulus (FM)	Loose Unit Weight, (kg/m^3)	Dense Unit Weight, (kg/m^3)
Type-A	0.13	1214	1420
Type-B	0.15	1220	1426
Type-C	0.17	1212	1426
Type-D	0.18	1218	1446
Type-E	0.22	1228	1447
Type-F	0.26	1219	1427

e-ISSN: 2581-9763
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Dry Density and Moisture Content

Depending on the project specifications, the standard proctor test or the modified proctor test based on ASTM D 698 (2002) and ASTM D 1557 (2002) test methods are used in the laboratory to assess optimum dry density (MDD) along with optimum moisture content (OMC). Table 6 summarizes the test results density and moisture Content used in this study.

Table 6: *Test result of Density and Moisture Content (Azad, 2010).*

Sample Type	FM	OMC (%)	MDD (gm/cc)
Type-A	0.13	16.19	1.63
Type-B	0.15	17.55	1.632
Type-C	0.17	17.51	1.596
Type-D	0.18	17.15	1.63
Type-E	0.22	17.25	1.60
Type-F	0.26	17.80	1.609

California Bearing Ratio (CBR)

According to ASTM D 1883 (2007) and or AASHTO T 193 (1995), The CBR experiments were carried out in a lab on a prepared specimen based on MDD (modified) for 95-100% compaction. In this work, 1-point CBR tests have been performed in the laboratory for each sample subjected to standard surcharge load and after 96 hours soaking for soaked CBR and before soaking for unsoaked CBR. For both cases, the CBR values were calculated from average stress for respectively 2.50 mm penetration and 5.00 mm penetration taking from stress versus cumulative penetration curves. Table 7 shows the CBR (percent) values for penetrations of 2.50mm and 5.00mm.

Table 7: *CBR (%) Values for 2.5 mm and 5.0 mm penetration (Azad, 2010).*

Penetration (mm)	CBR, % (Soaked)					
	Type-A	Type-B	Type-C	Type-D	Type-E	Type-F
2.5	8.74	7.28	8.30	8.71	9.46	10.17
5.0	11.84	11.94	11.65	11.50	11.89	12.09

The CBR (%) values of the fine sand and their corresponding FM values are given in Table 8.

Table 8: *Soaked CBR Value for Different Sample Type (Azad, 2010).*

Sample Type	Fineness modulus	CBR Value (%)
Type-A	0.13	11.44
Type-B	0.15	11.54
Type-C	0.17	11.65
Type-D	0.18	11.75
Type-E	0.22	11.89
Type-F	0.26	12.09

Swelling or Expansion Ratio

The swell capacity of a laterally-confined specimen that had been surcharged and flooded for 96 hours was assessed. The prepared mould was submerged in water for 96 hours as per specification to assess the percent swell of the samples, and measurements were taken both before and after immersion from the same level. The test results of Expansion ratio are presented in Table 9.

e-ISSN: 2581-9763
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Table 9: *Test result of Expansion Ration for different Types (Azad, 2010).*

Sample Type	Fineness modulus	Expansion Ratio (%)
Type-A	0.13	0.66
Type-B	0.15	0.58
Type-C	0.17	0.63
Type-D	0.18	0.69
Type-E	0.22	0.62
Type-F	0.26	0.59

RESULTS

Test properties of selected sample types are summarized in Table 10.

Table 10: *Test properties of selected sample types.*

Sample Type	SP. Gravity	Loose Unit Weight, (kg/m^3)	PI (%)	OMC (%)	MDD (gm/cc)	Fineness Modulus, FM	Avg. CBR Value (%)
Type-A	2.68	1214	1.60	16.19	1.63	0.13	11.44
Type-B	2.6	1220	0.31	17.55	1.632	0.15	11.54
Type-C	2.64	1212	0.70	17.51	1.596	0.17	11.65
Type-D	2.69	1218	2.60	17.15	1.63	0.18	11.75
Type-E	2.65	1228	1.80	17.25	1.60	0.22	11.89
Type-F	2.61	1219	1.20	17.80	.609	0.26	12.09

The CBR values of selected six samples increases with an increase of their Fineness modulus value. The correlation between Fineness modulus values of selected fine sands corresponding to their CBR values is straight in nature as shown in Fig. 2.

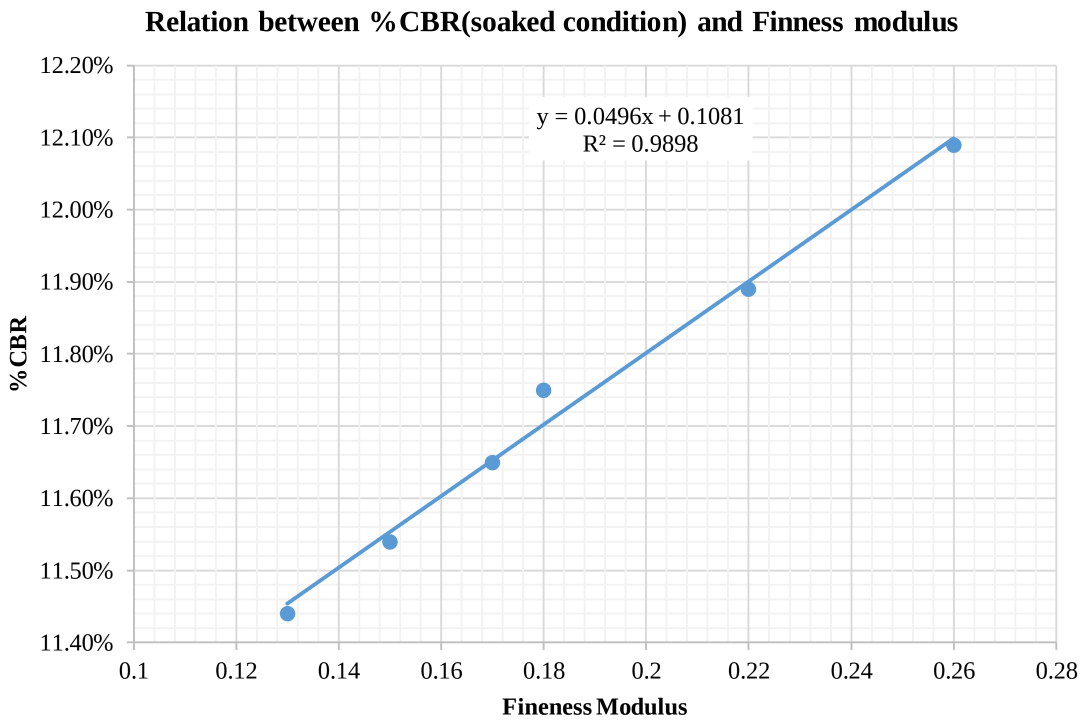

Figure 2: *Relation between Average % CBR value (Soaked Condition) and Fineness Modulus.*

The equation of this correlation is:

$$y = 0.0496x + 0.1081$$

Where, y = California Bearing Ratio CBR (%), x = Fineness Modulus (FM) of fine sand.

CONCLUSION

Fine sands collected from selected six rivers in coastal area that is from greater district Khulna and Barisal. The FM values of selected fine sands are in between 0.13 to 0.26. From the considerations of strength properties, the local fine sands having FM less than 0.50 may be used as subgrade or improved subgrade soil. The CBR values of selected six samples increases with an increase of their Fineness modulus value. The correlation between Fineness modulus values of selected fine sands corresponding to their CBR values is straight in nature. The equation of this correlation is $y = 0.0496x + 0.1081$. Where y is CBR (%) and x is FM. In remote area where fine sands are available, the probable CBR value of that fine sand one can be ascertained using this co-relation when FM values are known.

SUGGESTIONS

The Soil should be tested in field conditions to get CBR value in order to compare the CBR value of modified soil with different grain sizes. To know the nature of the relation between CBR% and Fineness modulus of sand, the sand should be fine with FM value < 0.50. Investigation may be performed by varying intrinsic properties of materials. The tests have been performed manually, but an accurate value can be obtained by using an automatic machine.

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e-ISSN: 2581-9763
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