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Research Article

Influence of Clay Mineralogy on the Index and Strength Properties of Soil

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Abstract – The California Bearing Ratio (CBR) test is an important method used in civil engineering to evaluate soil strength and bearing capacity, specifically for the design of flexible pavements. Soil strength and stiffness are influenced by the type and amount of clay minerals present in the soil matrix, including illite, kaolinite, montmorillonite, vermiculite, and quartz. In this study, the influence of clay mineralogy, strength and index parameters (CBR and Atterberg Limits) was investigated through laboratory tests on soil samples. Results showed that the amount of clay minerals present in the soil is an important factor in determining soil strength and bearing capacity. Soils with high illite content demonstrated higher CBR and Atterberg Limits values compared to soils with higher amounts of other minerals, which tend to have a higher water-holding capacity and lower values, while soil having higher montmorillonite content tends to have lower CBR and Atterberg Limits due to its swelling and expansive characteristics. Understanding the effect of clay mineralogy on soil properties, particularly CBR and index properties is vital for constructing safe and cost-effective roads. Further research is needed to explore the influence of different types of clay minerals, soil strength and index properties.

Keywords – California Bearing Ratio Maximum Dry Density, Optimum Moisture, Soil Index Properties, X-Ray Diffraction

I. INTRODUCTION

Clay mineralogy is a fundamental aspect of geology and soil science, encompassing the study of clay minerals, which are essential components of soils, sediments, and rocks.

Most of the road network in the country is consisting of flexible pavement. The thickness of sub-grade mainly depends on CBR value, if the CBR value is higher, then designed thickness of the sub-grade is thinner and vice versa[1]. The higher the CBR value, the greater the soil's load-bearing capacity, which is essential for ensuring the stability and durability of engineered structures[2].

If the natural moisture content of soil is higher than liquid limit, the soil can be considered as soft and if the moisture content is lesser than liquid limit, the soil is brittle and stiffer[3]. The value of liquid limit is used in classification of the soil, and it gives an idea about plasticity of the soil[4].

The mineral composition of clay minerals, including kaolinite, illite, montmorillonite, quartz and vermiculite significantly influences these parameters[5]. This research aims to understand the influence of clay mineral composition and CBR and Atterberg Limits values, providing insights into how specific clay minerals shape a soil's engineering characteristics[6]. This knowledge will help engineers and geologists make informed decisions in civil engineering projects, contributing to safer and sustainable infrastructure[7].

II. MATERIAL AND METHOD

Experiments were conducted in the Soil Mechanics lab of the Civil Engineering Department at the University of Engineering and Technology (UET) Taxila and University of Peshawar. Atterberg limit tests were performed according to the recommendations in ASTMD4318-00[8]. The liquid limit and plastic limit of the soil were then determined and these values were used in the AASHTO soil classification system to categorize soils[9]. The Casagrande method was used to conduct the liquid limit test[10].

For the plastic limit test, soil samples were formed into thread-like shapes by rolling them on glass plates. This process was continued until visible surface cracks appeared on the threads.


Figure 1. Liquid Liquid Test


Figure 2. Plastic Limit Test

In the laboratory, we conducted modified AASHTO benchmark tests to determine the maximum dry density (MDD) of soil samples for two different soil types[11]. We then measure the total weight of the compacted soil and mold to calculate the maximum dry density (MDD). Optimum moisture content (OMC) refers to the moisture content at which the soil reaches its maximum dry density during compaction[12]. This critical value is determined using a modified control test.

AASHTO T-193-2007 is the State of California standard test method for California Bearing Ratio (CBR)[13]. The first step was to prepare soil samples A-4 and A-6. A total of six soil samples were taken and examined. Soil samples were carefully selected to have the maximum possible dry density (MDD) and maximum possible moisture content (OMC), previously evaluated using AASHTO T-180 2004 guidelines[14]. For several CBR samples, the compaction process required 10, 30, and 65 blows per layer. Five layers of material were compressed to achieve uniformity and regularity to create the CBR pattern[15].

Figure 3. CBR Machine

The X-ray structure analysis was carried out using a modern X-ray diffractometer a high-precision instrument that can be used to determine the crystalline composition of materials[16]. When it comes to analysing clay soils, radiography can provide valuable information about the presence and abundance of various clay minerals such as montmorillonite, illite, kaolinite, vermiculite and quartz[17].

For this purpose, Match-2 software, a widely used tool in the field of X-ray diffraction analysis, was used. This software not only facilitates the creation of diagrams, but also allows the identification and quantification of various minerals present in the soil, thereby making a significant contribution to our understanding of the mineralogical composition of the soil[18].

III. RESULTS

The first step in studying the collected soil was to classify it. Soil samples A-4 and A-6 collected from KPK and Punjab were classified using AASHTO soil classification system (AASHTO M 145 2008). To do this, we determined the index properties and gradation of soil samples. The results of the index properties including liquid limit and plasticity index (ASTM D 145 2008) were summarized and presented in the Table 1 for A-4 soil and Table 2 for A-6 soil type.

The CBR test sample with and without soaking was prepared with a relative compaction of 95% based on the OMC and MDD obtained for each MPCT A-4 and A-6soil sample. The test results for CBR with and without impregnation are listed below in Table 3 and Table 4.

Table 1. L.L & P.I for 3 Soil Samples

Property (A-4)	S 01	S 02	S 03
Liquid Limit (%)	38	29.5	24.5
Plasticity Index (%)	4.7	6.5	8.4

Table 2. L.L & P.I for 3 Soil Samples

Property (A-6)	S 01	S 02	S 03
Liquid Limit (%)	32.8	34.5	38
Plasticity Index (%)	13.3	16.7	23.5

Table 3. CBR soaked &CBR unsoaked

SAMPLES	CBR soaked	CBR unsoaked
A-4	(%)	(%)
S 01	8.6	25.6
S 02	7.9	22.4
S 03	7.1	20.2

Table 4. CBR soaked and CBR unsoaked

SAMPLES	CBR soaked	CBR unsoaked
A-6	(%)	(%)
S 01	4.9	16.7
S 02	4.6	16.4
S 03	4.1	15.8

Table 5. Minerals Composition for 3 Soil Samples

Sample	Illite	Kaolinite	Quartz	Vermiculite	Montmorillonite
A-4	%	%	%	%	%
S 01	51.8	23.4	22.0	1.8	1.0
S 02	46.0	27.6	22.00	2.7	1.7
S 03	39.9	16.2	16.2	7.7	1.5

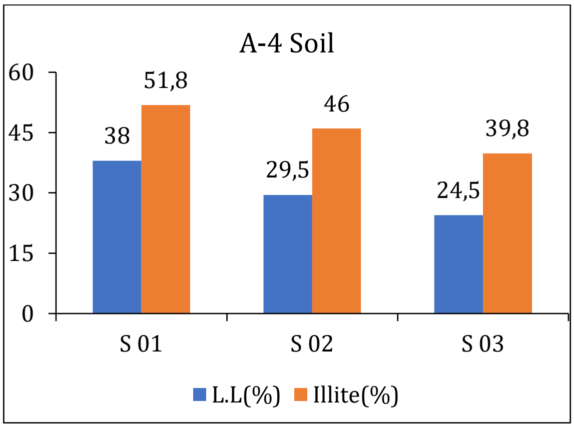

Figure 4. L.L & Illite

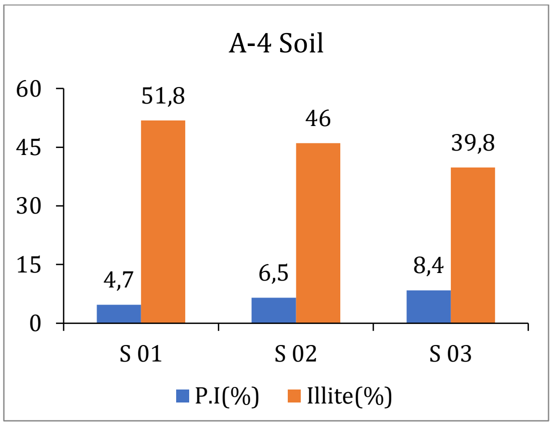

Figure 5. P.I & Illite

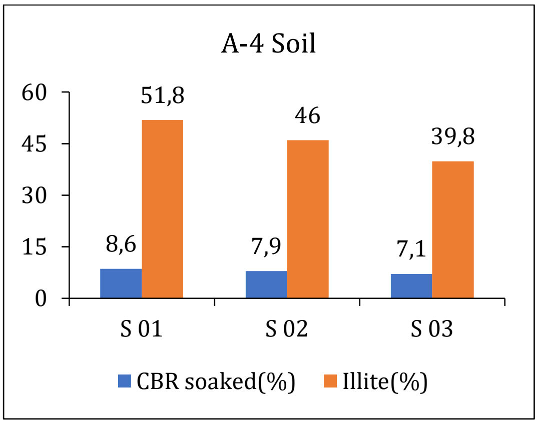

Figure 6. CBR soaked & Illite

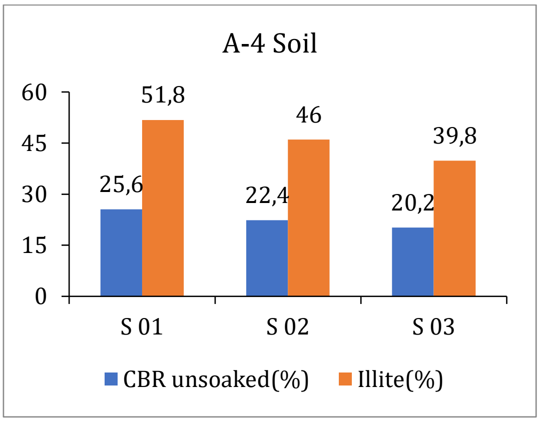

Figure 7. CBR unsoaked & Illite

Table 6. Minerals Composition for 3 Soil Samples

Sample	Illite	Kaolinite	Quartz	Vermiculite	Montmorillonite
A-6	%	%	%	%	%
S 01	59.6	15.6	17.9	6.2	0.7
S 02	48.6	17.3	25.4	6.3	2.4
S 03	48.7	20.3	25.9	1.9	3.1

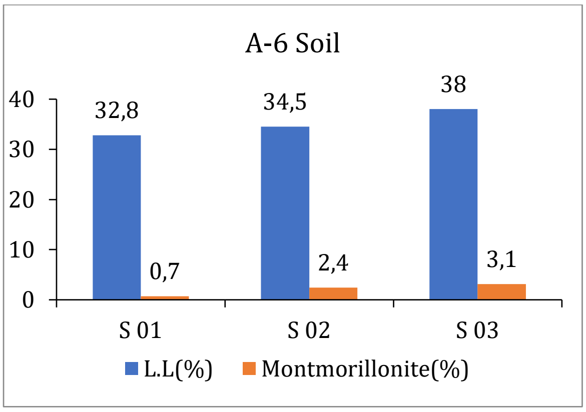

Figure 8. L.L & Montmorillonite

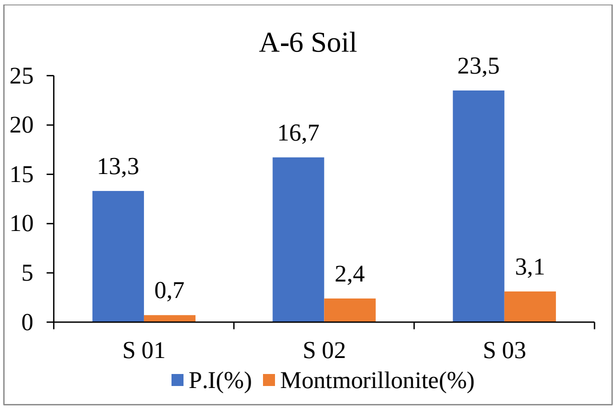

Figure 9. P.I & Montmorillonite

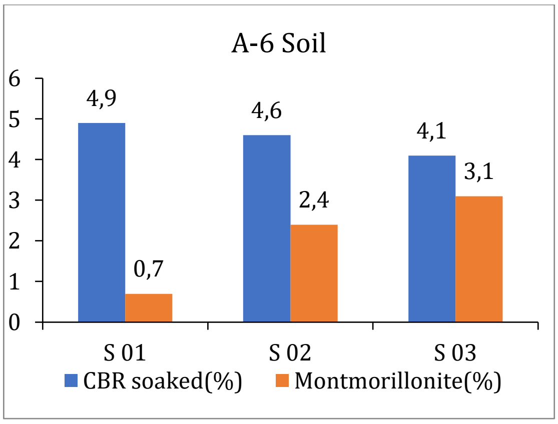

Figure 10: CBR soaked &Montmorillonite

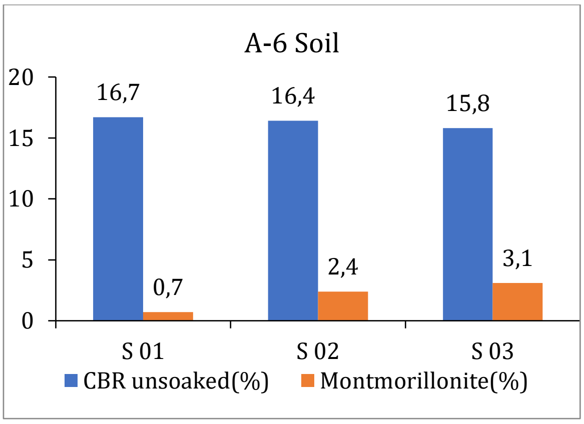

Figure 11: CBR unsoaked & Montmorillonite

IV. DISCUSSION

The previous chapter presented the results of tests conducted on two soil types A-4 and A-6 collected from six different locations in KPK and Punjab. The first step in studying the collected soil was to classify it. Soil samples A-4 and A-6 collected from KPK and Punjab were classified using AASHTO soil classification system (AASHTO M 145 2008). To do this, we determined the index properties and gradation of soil samples.

After classifying the soil samples collected from KPK and Punjab districts, the maximum dry density (MDD) of A-4 and A-6 soils was determined as per the guidelines laid down in AASHTO T-180 2004. AASHTO tests have been modified to achieve this purpose were carried out in the laboratory and samples with different moisture content were prepared.

AASHTO T-193-2007 is the State of California standard test method for Bearing Ratio (CBR). The first step was to prepare soil samples A-4 and A-6. A total of six soil samples were taken and examined. These samples were then subjected to a standard load of 4.54 kg.

Soil samples were carefully selected to have the maximum possible dry density (MDD) and maximum possible moisture content (OMC), previously evaluated using AASHTO T-180 2004 guidelines. The compaction levels of the CBR soil samples were between 95% and 100% MDD. For several CBR samples, the compaction process required 10, 30, and 65 blows per layer. Using a 10-pound hammer with an 18-inch drop, each sample was compacted into a 6-inch diameter mold. Five layers of material were compressed to achieve uniformity and regularity to create the CBR pattern.

XRD is a powerful technique for studying the crystallography and mineralogical composition of materials. When it comes to analysing clay soils, radiography can provide valuable information about the presence and abundance of various clay minerals such as montmorillonite, illite, kaolinite, vermiculite and quartz.

Once the XRD results were available, Match-2 software was used to analyse the XRD data, create graphs, and quantify the various minerals present in the soil. Based on the Match 2 software results, the clay soil sample contains varying amounts of these clay minerals. In particular, illite was found to be present in large quantities in the samples compared to other clay minerals. The Match 2 software detected higher amounts of illite in clay soils compared to other minerals. This might be indicated by more intense or broader peaks corresponding to Illite in the XRD pattern.

V. CONCLUSION

1. The research results show that illite content has a significant effect on the strength and index properties of soil samples in KPK and Punjab provinces, Pakistan.
2. The higher the illite content, the higher the strength and index properties of A-4 soils collected from different locations in KPK and Punjab, Pakistan. The reason is illite is a non-expanding clay mineral, meaning that its layers do not swell when wet. It is also a relatively hard and durable mineral.
3. Lower content of montmorillonite does not affect the values of strength and index properties, in our results of A-6 soil samples containing montmorillonite 0.7%, 2.4% and 3.1% respectively. If montmorillonite has higher quantity, then montmorillonite decreases strength and Index properties soil because it has higher expansion and lower mineral strength.
4. The presence of secondary clay minerals such as vermiculite, which was not frequently observed in this research, kaolinite and quartz fluctuated randomly and therefore not included in this research.
5. The results of this study can be used to determine the strength and stability of soil at construction sites.

REFERENCES

1. Nagaraj, H. and M. Suresh, *Influence of clay mineralogy on the relationship of CBR of fine-grained soils with their index and engineering properties.* Transportation Geotechnics, 2018. **15**: p. 29-38.
2. Zumrawi, M.M., *Prediction of CBR value from index properties of cohesive soils.* 2012.
3. Black, W., *The strength of clay subgrades: its measurement by a penetrometer.* 1979.
4. Nagaraj, H., *Prediction of engineering properties of fine-grained soils from their index properties.* 2006.
5. Prakash, K. and A. Sridharan, *Free swell ratio and clay mineralogy of fine-grained soils.* Geotechnical Testing Journal, 2004. **27**(2): p. 220-225.

6. Rakaraddi, P. and V. Gomarsi, *Establishing relationship between CBR with different soil properties.* International journal of research in engineering and technology, 2015. **4**(2): p. 182-188.
7. Witczak, M., W. Houston, and C. Zapata, *Correlation of CBR Values with Soil Index Properties.* Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures, Technical Report. NCHRP Project, 2001.
8. Uzundurukan, S., et al., *Suction and swell characteristics of compacted clayey soils.* Arabian Journal for Science and Engineering, 2014. **39**: p. 747-752.
9. Shirur, N.B. and S.G. Hiremath, *Establishing relationship between CBR value and physical properties of soil.* IOSR journal of mechanical and civil engineering, 2014. **11**(5): p. 26-30.
10. Talukdar, D.K., *A study of correlation between California Bearing Ratio (CBR) value with other properties of soil.* International Journal of Emerging Technology and Advanced Engineering, 2014. **4**(1): p. 559-562.
11. Yared, L., *Correlation of CBR value with soil index properties for Addis Ababa subgrade soils.* 2013.
12. Janjua, Z.S. and J. Chand, *Correlation of CBR with index properties of soil.* International Journal of Civil Engineering and Technology, 2016. **7**(5): p. 57-62.
13. Agarwal, K. and K. Ghanekar. *Prediction of CBR from plasticity characteristics of soil*. in *Proceeding of 2nd south-east Asian conference on soil engineering, Singapore*. 1970.
14. Chowdhury, S.R.M., et al., *Summary resilient modulus prediction model for unbound coarse materials.* Journal of Transportation Engineering, Part B: Pavements, 2021. **147**(3): p. 04021035.
15. Harini, H. and S. Naagesh, *Predicting CBR of fine-grained soils by artificial neural network and multiplelinear regression.* Internat. Jour. Civil Engg. Tech.(IJCIET), 2014. **5**(2): p. 119-126.
16. Segal, L., J.J. Creely, A. Martin Jr, and C. Conrad, *An empirical method for estimating the degree of crystallinity of native cellulose using the X-ray diffractometer.* Textile research journal, 1959. **29**(10): p. 786-794.
17. Vinod, P. and C. Reena, *Prediction of CBR value of lateritic soils using liquid limit and gradation characteristics data.* Highway Research Journal, IRC, 2008. **1**(1): p. 89-98.
18. Soewignjo Agus, N. and H. Andy, *Correlation Between Index properties And California Bearing Ratio Test of Penkababu Soils with and Without soaked.* Canadian Journal on Environmental, Construction and Civil Engineering, 2012. **3**: p. 1-11.