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ANALYSIS OF CBR VALUE OF SANDY SUB-GRADE MIXED WITH DIFFERENT PERCENTAGE OF COARSE AGGREGATES

Md. Siddik Riyad*[1], Quazi Sazzad Hossain[2] and MD Niamot Alahi[3]

[1] *Former Student, Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh, e-mail: riyad.ce64.kuet@gmail.com*
[2] *Professor, Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh, e-mail: sazzad@ce.kuet.ac.bd*
[3] *Former Student, Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh, e-mail: iraj.kuet@gmail.com*

*** Corresponding Author**

ABSTRACT

Pavement construction tends to be relatively costly in areas where subgrade soil is affected. Remodeling in soil properties by replacement of the poor subgrade soil may not always be an economical solution. Increasing the CBR value of the subgrade to decrease the thickness of that layer is an effective strategy. Considering this, an experimental study was carried out on sandy soil to demonstrate an economical solution by mechanical stabilizing the subgrade soil with stabilizers such as a coarse aggregate of 10 mm size and 20 mm size. The effect of mechanical stabilization on Maximum Dry Density (MDD), Optimum Moisture Content (OMC), and California Bearing Ratio (CBR) was investigated. The study exhibited that adding the stabilizers with subgrade soil enhanced the CBR value and MDD while OMC decreased. The desired CBR values of coarse aggregates of sizes 10mm and 20mm is obtained with the addition of 30% under soaked and unsoaked condition. For 10mm and 20mm coarse aggregates, it is estimated that OMC can improve CBR values by 1.75% to 145% and 15.8% to 117.74%, respectively. Using soaked coarse aggregates, this improvement varies from 5.2% to 155.6% and 21.3% to 194%, respectively, for 10mm and 20mm aggregates.

Keywords: *CBR, coarse aggregates, subgrade, soaked, unsoaked conditions*

1. INTRODUCTION

The majority of pavement design recommendations are predicated on the premise that aggregates are necessary components of pavement systems. However, the availability of acceptable quality aggregates may be a constraint in many instances in construction and may not be economically feasible, even when availability and transportation are taken into account. Due to the high investment and maintenance expenses of infrastructure development, studies have attempted to recommend optimal design methodologies and building materials for cost-effective infrastructure development. To satisfy the design requirements of the proposed project, soil properties can sometimes be modified using locally accessible admixtures. Because of rising industrialization and the need to improve the economy, great emphasis is being placed on the building of infrastructure for the safe and efficient transportation of raw materials and industrial output. As a result, the expansion of road networks is viewed as an indicator of a country's economic, social, and commercial advancement. Highways are a vital piece of transportation infrastructure. In this regard, precise soil sub-grade information can help to achieve sustainable and cost-effective highway building. The California Bearing Ratio (CBR) value can be viewed as an important metric in the strength assessment of the pavement sub-grade in highway pavement design. The California bearing ratio (CBR) test was originally developed by the California Division of Highways This test has been further developed by others and is the most commonly used strength test for evaluating the subgrade quality of soils (ASTM D 1883 and AASHTO T193-81).

Materials used in pavement construction must be examined to ensure proper and cost-effective design. The chosen materials must be added to assure quality and compaction. Laterites are vital to soil resources in civil engineering; they are utilized as building materials and to support various superstructures. They are employed as sub-grade, sub-base, and base materials beneath roadway and airport pavements.

The current study tried to uncover the relationships between CBR and soil index features. These correlations can assist the designer in selecting appropriate CBR values as well as cross-checking the CBR value acquired from laboratory testing. Some of the existing correlations, in addition to the soil test results, are employed for further enhancement. Existing CBR correlations are used to validate the laboratory CBR values. CBR can be measured in the laboratory and in the field, as is customary. For a road project, many soil samples must be analysed; calculating the soaked CBR of the soils is a difficult and time-consuming procedure. As a result, numerous researches have suggested simple methods for determining CBR of soils using readily determinable soil properties. (Deepak et al., 2014).

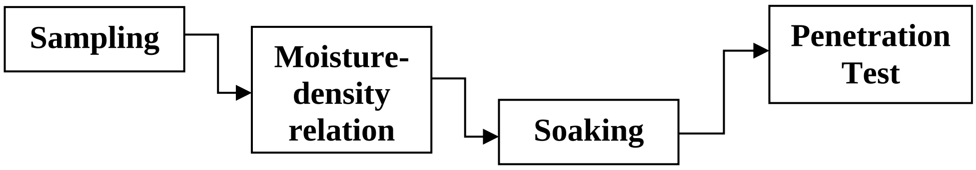
Civil engineers generally use CBR as a test value, especially those working on pavements, to determine the subgrade's stiffness modulus and shear force. Crushed rock strength is expressed as a percentage number in this indirect measure. Pavement engineers commonly use CBR values to determine the thickness of the pavement to be installed on the subgrade. The asphalt depth will be more significant for subgrades with a lower CBR value and the other way around. To put it another way, the pavement's specified thickness is determined by the CBR value of the sub-grade soil. Burnt brick dust can be used to improve subgrade soil. The clayey soil is combined with burnt brick dust.

As a result, the soil's swelling and optimal moisture content are reduced. (Pundir & Trivedi, 2017) on the other hand, boost the dry density and CBR value. Different soils produce varied CBR values even when compacted to the equivalent force and degree of penetration. There are numerous methods adopted to enhance the durability of the subgrade soil. Different approaches like thermal and mechanical stabilization are considered, including compaction to improve the quality of the subgrade. Besides, it has been observed that fly ash or randomly categorized fibers can also increase the endurance of subgrade.

The addition of coarse particles produces a change in the CBR rate of subgrade strength of soil in the current investigation. The coarse aggregates are rock fragments that are usually spherical or sub-rounded in shape. A literature review is carried to increase the CBR value using various strategies.

2. METHODOLOGY

According to an analysis of relevant literature, most studies have used fly ash/limestone or ashes collected from rice husk as a strengthening element to bolster the CBR value of the subgrade. Only a few types of research are done applying coarse aggregates as a reinforcing material to improve the soil properties. As a result, research is needed to assess this element because in places where coarse aggregates are abundant and acquiring other reinforcing materials is uneconomical, adding coarse aggregate will be a viable choice. CBR test will be conducted as per the following steps:



2.1 Materials

2.1.1 Sandy Soil

The soil for this investigation was derived from a river basin near Fulbarigate that was transported by stream. Particle size distribution curves were created based on laboratory testing conducted per AASHTO T88, T180, and T265.

2.1.2 Coarse Aggregates

The coarse aggregates used in this investigation are the same as those utilized in the manufacture of plain cement concrete. Local stone crushing factories near Noapara, Jessore, provided the coarse aggregates. The physical parameters of the sample were determined using lab tests under BS 812.

2.1.3 Water

The CBR tests used in the report were conducted in the laboratory. As a result, the water used to combine the samples is drawn from the laboratory's supply, which is regular tap water. The various physical characteristics of water were determined using ASTM D512 laboratory tests.

2.2 Sampling

The sample was obtained, and the specimen for compaction was prepared according to the standard for compaction in a 6 inch mold, with the exceptions listed below. The full gradation was employed to prepare the specimen for compression throughout alteration if all samples passed a 19mm sieve. If any materials were held on the 19.00mm sieve, they were removed and replaced with an equal number of materials that passed the 19.00mm sieve and were retained on the 4.75mm sieve, which was obtained by separating portions of the sample not otherwise used for testing. The coarse aggregate of 20 mm and 10 mm diameters is mixed with the sand in varied proportions (10% to 30% by weight), and the CBR values of each mix were obtained under damp and unsoaked conditions.

2.3 Moisture-Density Relation

The sand was subjected to the Modified Proctor compaction test to establish its optimum moisture content and maximum dry density. This test was conducted to determine the maximum dry density at optimum moisture content, as CBR was conducted in two states: optimum moisture content (OMC) and soaked condition. To execute at OMC conditions, the OMC and MDD values for each sample must be determined. For this test, an 8 kg prepared sample was placed in the specimen in five layers with 25 blows at each layer. Weigh the samples after finishing five layers with 25 blows at each layer. This experiment was conducted with various water mixing percentages. Initially, combining 4% of water and then adding an additional 3% of water to this sample to account for the access percentage of water may obstruct determining the true OMC and MDD. Following that, each compaction test gathered a sample to estimate the moisture content, and the sample was oven-dried for 24 hours at 1100c. The moisture content of this oven-dried sample was determined using this oven-dried sample. All data were entered into a data table, and a graph of moisture content vs maximum dry density was created. This graph illustrates the optimal dry density and moisture content.

2.4 Soaking

There are two conditions of CBR test:

(a) Un-soaked condition / At OMC condition.
(b) Soaked condition.

The test on the soaked sample is a precautionary measure to account for increased moisture content caused by a lift in the water table or flooding in the area. The surcharge weight mimics the impact of the thickness of the road pavement that covers the base course.

At this point, the swell plate with an adjustable stem was placed on the soil sample in the mold, and sufficient weight was provided to meet the code requirements. The tripod was set on top of the mold, and the first dial was taken. Following that, the mold was placed in water and soaked for 96 hours, with dial readings collected every 24 hours. A final dial reading on the soaking specimen was recorded after 96 hours, and the swell was estimated as a percentage of the initial sample length. Calculation of swell percentage is shown in equation (1),

$$\%Swell = \frac{change\ in\ length\ in\ mm\ during\ soaking}{initial\ soil\ length} * 100\% \quad (1)$$

The sample was removed from the soaking tank and left to drain for 30 minutes after the water was drained from the top. Surcharge weights and perforated plates were removed after draining.

2.5 Penetration Test

The California Bearing Ratio (CBR) is a penetration test used to assess road subgrade strength. The results of these tests are used with curves to determine pavement and layer thickness. The most standard way for designing flexible pavement. It is a penetration test in which a 50 mm (1.969 in) diameter piston is used to penetrate the soil at 1.25 mm/minute. The CBR is the pressure up to a 2.5 mm penetration and its relation to the bearing value of a normal crushed rock. The CBR of a material is calculated for both the dry and saturated conditions. After determining the % swell, the penetration test is performed on the opposite side.

Surcharge the specimens with annular and slotted weights equal to the soaking weights. To prevent soft materials from entering the surcharge weight seat, use the penetration piston with a 10lb force after placing one surcharge weight on the sample. After seating the penetration piston, wrap the surcharge weight around it. Set the penetration piston to 10lb, then zero the penetration dial and load indicators. Apply the stresses to the penetration piston for 1.3mm/min penetration. Record the load at 0mm, 0.25mm, 0.50mm, 1mm, 1.25mm, 2.0mm, 2.5mm, 3.00mm, 3.5mm, 3.75mm, 4.00mm, 4.5mm, 5.00mm, 6.00mm, 7.5mm, 10.00mm, 12.50mm.

3. RESULTS AND DISCUSSIONS

3.1 Geotechnical Properties of Sand

The soil contains about 97.79 % particles passing through a 4.75mm sieve, according to the sieve analysis results. This curve indicates sand soil. Because the uniformity coefficient (C_u) is 1.82 and the curvature coefficient (C_c) is 0.82, the soil is classed as SP (sandy soil poor graded). The standard compaction test found that for 0% coarse aggregates, 14.25 % moisture content and 1721.54 kg/m3 maximum dry density.

Quantitative analysis of the slope and shape of the particle size distribution curve was done by means of the geometric values termed as the co-efficient of uniformity (C_u) and the coefficient of curvature (C_c) and shown in Figure 1:

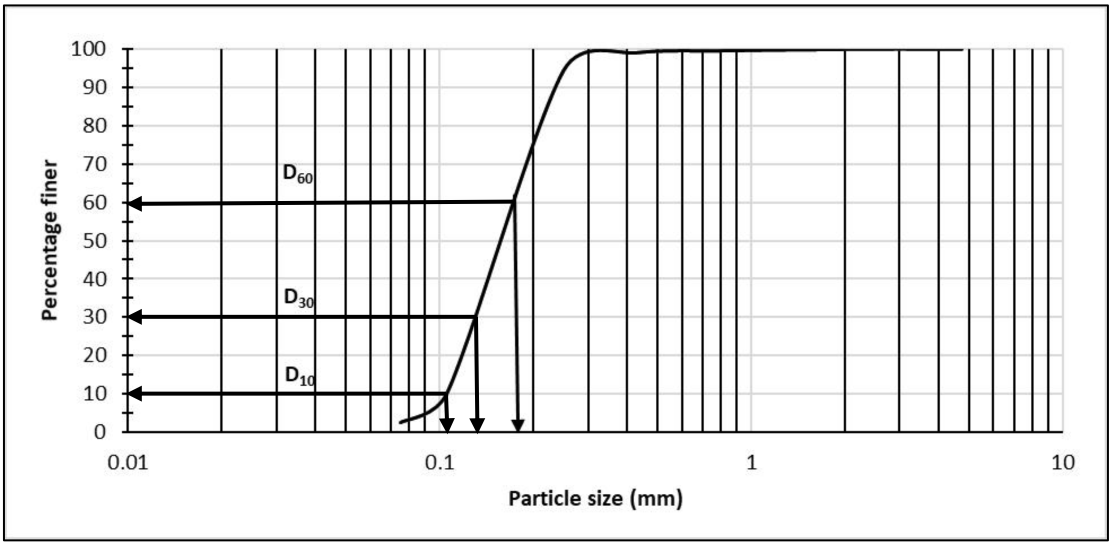


Figure 1: Particle size distribution curve

The co-efficient of uniformity (C_u) and the coefficient of curvature (C_c) can be expressed mathematically as:

$$C_u = \frac{D_{60}}{D_{10}} \quad (2)$$

$$C_c = \frac{(D_{30})^2}{(D_{60} * D_{10})} \quad (3)$$

In the mentioned equation D_{10}, D_{30} and D_{60} are the grain diameter (mm) corresponding to 10%, 30% and 60% passing on the particle size distribution curve, respectively.

3.2 Physical Properties of Coarse Aggregates

Coarse aggregates with a nominal size of 10mm and 20mm were tested. 10% of the aggregates have impact value, while 18% of the aggregates have crushing value. Table 1 represents the physical properties of coarse aggregates found after the test,

Table 1: Material attributes of coarse aggregates

Properties	Value
Aggregates Crushing Value (%)	18
Aggregates Impact Value (%)	10
Specific Gravity	2.53
Water Absorption(%)	2.21
Fineness Modulus	7.55

3.3 Physical and Chemical Properties of Water

Ordinary tap water is used during the fabrication of the sample. The physical and chemical parameters of that water are determined in the lab using regular tests. The pH of the water in the experiment was 7.11, which is slightly higher than 7.00, indicating that the water is alkaline. The sulphate concentration was 35 mg/L, which might impact the soil mix's durability and strength, and the chloride concentration was 720 mg/L, which was too high in this water and could cause efflorescence. Thus, the permitted limit of chloride and sulphate for this test is 1000 and 400 mg/L, respectively. The physical and chemical qualities of water indicate that it is drinkable and suitable for drinking, as well as appropriate for the purposes of this test.

3.4 Optimum Moisture Content

At its ideal moisture content, soil compaction achieves its dry density. Since there are two ways for determining CBR, OMC and MDD are crucial in determining the sandy subgrade's CBR value. OMC and MDD were determined using a compaction test with varying percentages of coarse aggregates mixed with sand by weight ranging from 10% to 30% for both 10mm and 20mm samples with a 10% increment and shown in Figure 2.

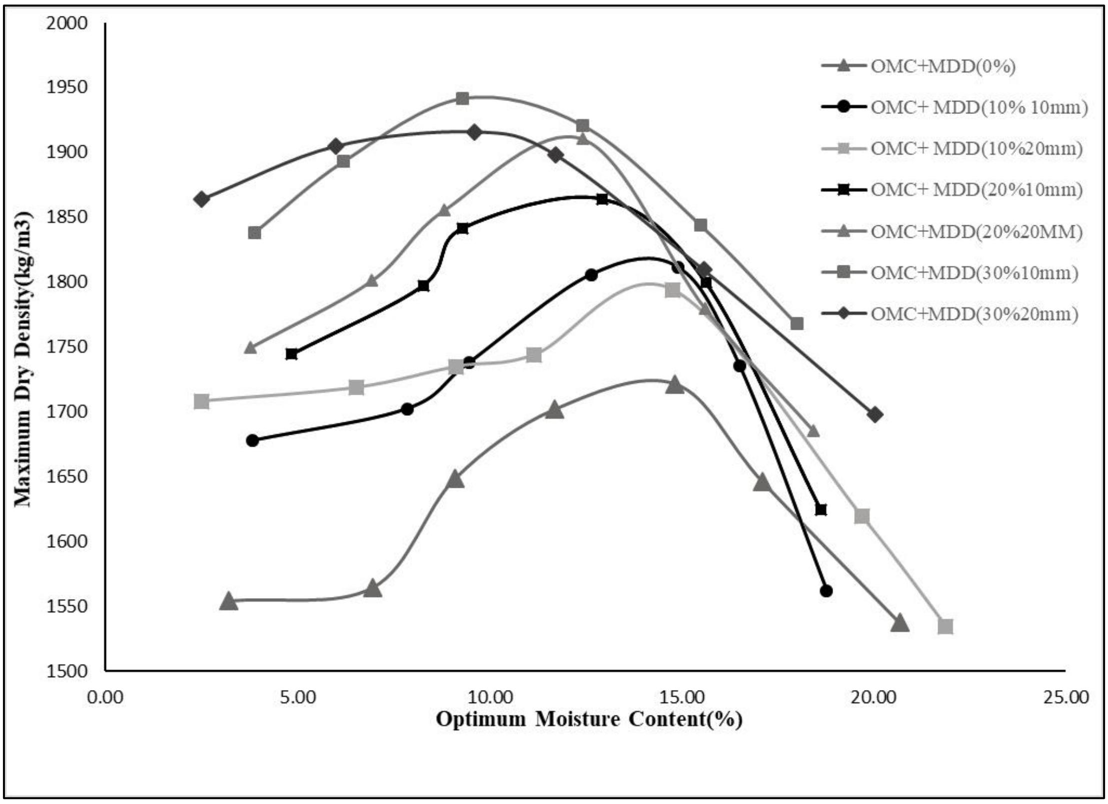


Figure 2: Compaction curve for 0% to 30% coarse aggregates both for 10 & 20 mm in size

3.5 Load Penetration Curves Analysis

Resistance to penetration is determined by penetrating the sample with a standard size piston at various penetration depths. The penetration resistance of a particular sample increases as the number of blows per layer increases. As a result, the mold compacted with 65 blows per layer has more excellent penetration resistance. As the quantity of coarse aggregates mixed with sand increases, so does the resistance to penetration. As a result, adding coarse particles to sand enhances its strength. The CBR value of sand without coarse particles was 16.07% at OMC and 12.5% in soaked conditions, respectively.

Figures 3, 4, 5 and 6 show the load penetration curve of mixed soil with 0%, 10%, 20% and 30% coarse aggregates. The adjusted load was calculated using the stress-strain curve for 2.5mm and 5mm penetration depths. The standard load was 6.9 MPa for 2.5 mm and 10.3 MPa for 5 mm depth of penetration, respectively. The CBR value was the corrected load to standard load ratio.

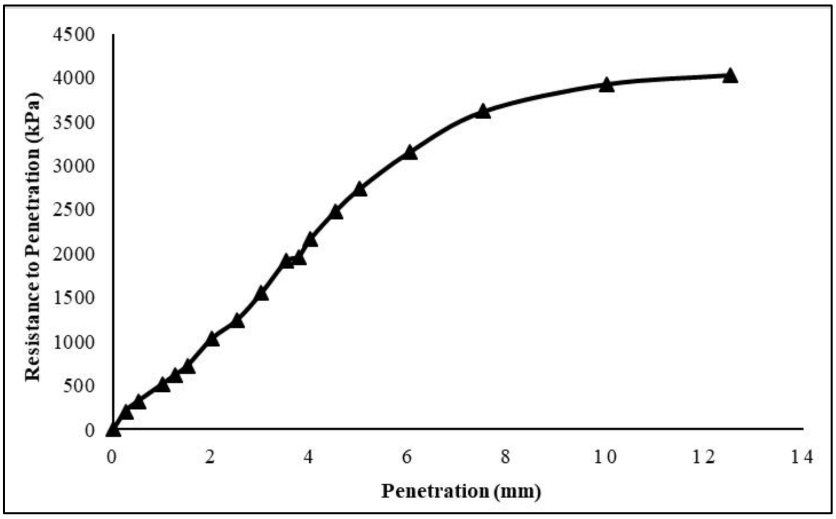


Figure 3: Load penetration curve for 0% coarse aggregates soil

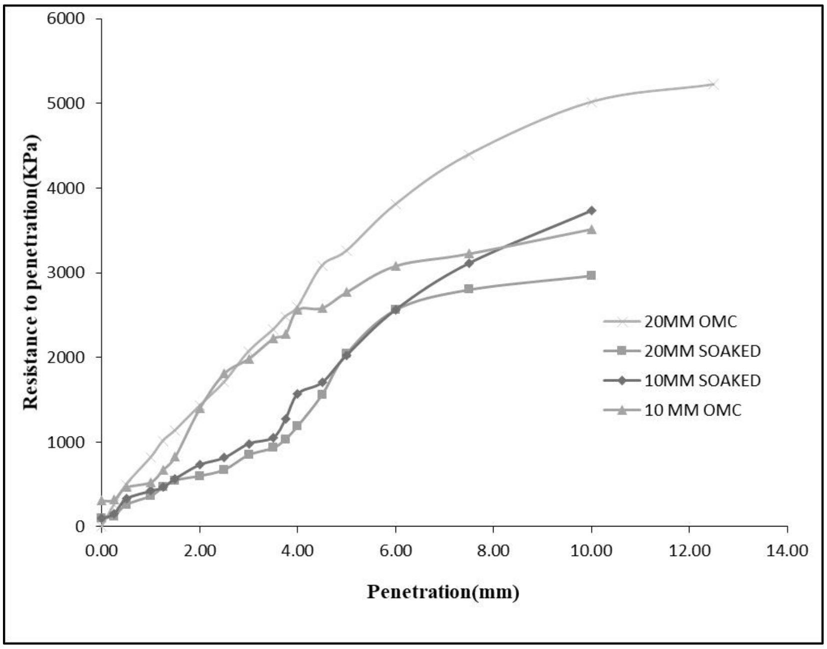


Figure 4: Load penetration curve for 10% coarse aggregate soil

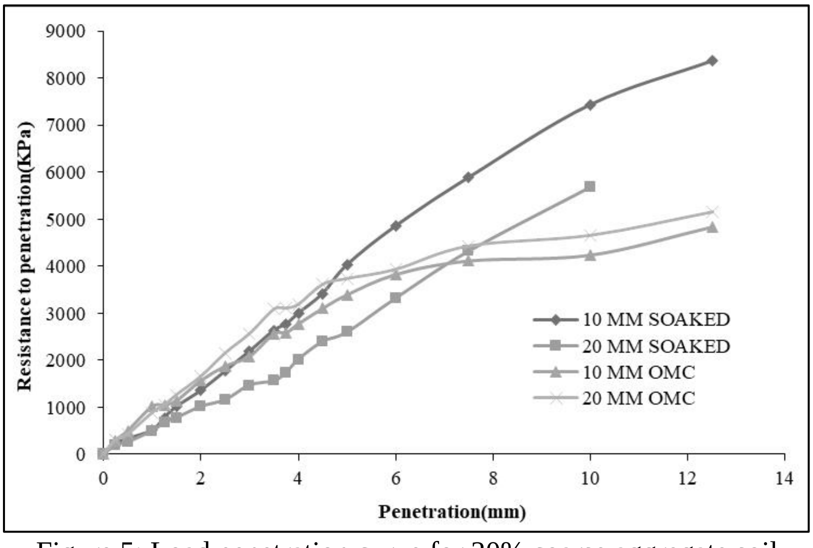


Figure 5: Load penetration curve for 20% coarse aggregate soil

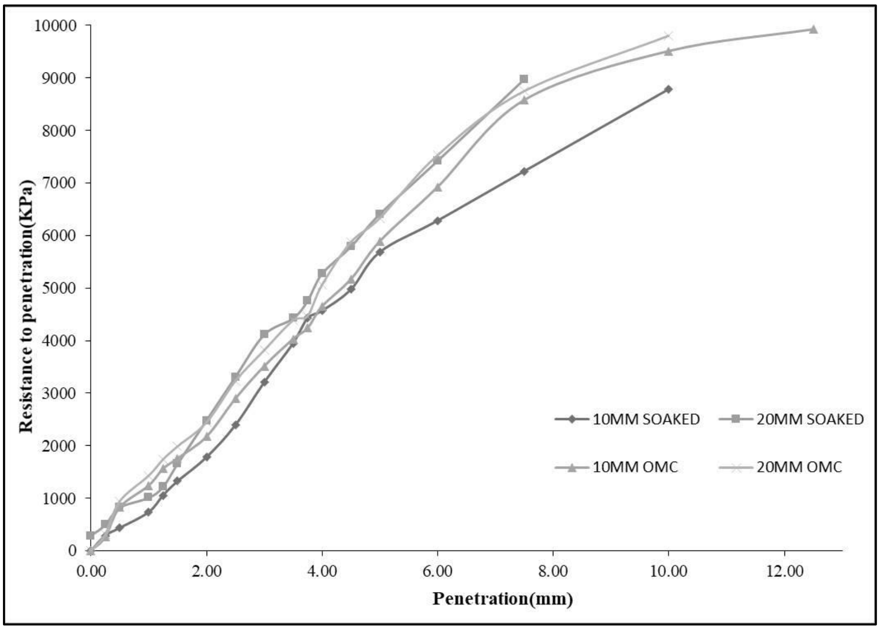


Figure 6: Load penetration curve for 30% coarse aggregate soil

3.6 CBR Values of Sand Mixed with Coarse Aggregates

CBR tests were performed on sand samples at OMC and in soaked conditions, initially without combining coarse aggregates and subsequently by mixing coarse aggregates in varied percentages ranging from 0% to 30% by weight of the dry sand with a 10% increment of coarse aggregates at optimal moisture content. Sand without coarse aggregates has a CBR value of 16.07% at OMC and 12.50% at soaked conditions.

After mixing and increasing the number of coarse aggregates, the CBR value of sand increases. This increase ranges from 16.35% to 18.61% at OMC. Coarse aggregates of 10mm and 20mm sizes change into 13.15% and 15.16% in wet conditions. More specifically, adding 10% CA with 10mm particles yields 39.37% and 34.99% at OMC, and when 30% CA is mixed with 20mm at the soaked condition, the outcomes are 36.95% and 31.8%.

The addition of coarse particles raises the CBR values seen in Table 2. The CBR values of the sand mixes made with 10mm coarse aggregates are, as expected, lower than those made with 20mm coarse aggregates; this is not surprising. Because small coarse aggregates are less resilient than bigger particles, this is likely due to the strength of the coarse aggregates. As a result, the CBR of sand with coarse particles of 10mm is lower than that of 20mm. The graphical representation of CBR values and % of coarse aggregates added with sand is shown in Figure 7.

Table 2: Adding coarse aggregates increases CBR value %

% of Coarse Aggregates	CBR Value (%)			
	At OMC		In Soaked Condition	
	10mm	20mm	10mm	20mm
0	16.07	16.07	12.50	12.50
10	16.35	18.61	13.15	15.16
20	29.06	31.05	24.10	28.78
30	39.37	35.00	35.95	31.80

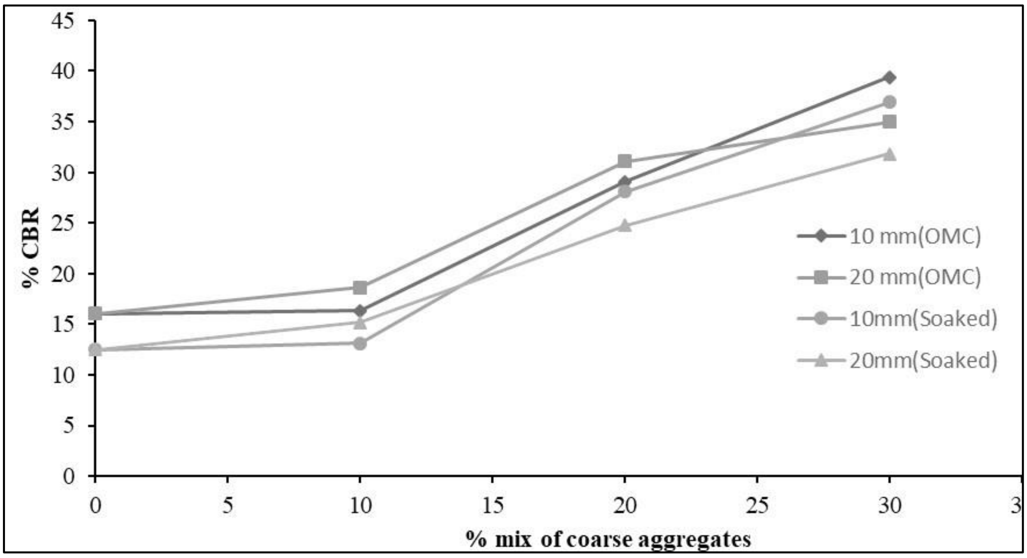


Figure 7: Variation of CBR values with percentage of coarse aggregates

Table 3: Percent improvement in CBR values of soil mixed with different % of CA

% of Coarse Aggregates	CBR Value (%)			
	At OMC		In Soaked Condition	
	10mm	20mm	10mm	20mm
10	1.75	15.81	5.2	21.3
20	80.84	93.22	98.8	124.2
30	145.0	117.74	155.6	194.0

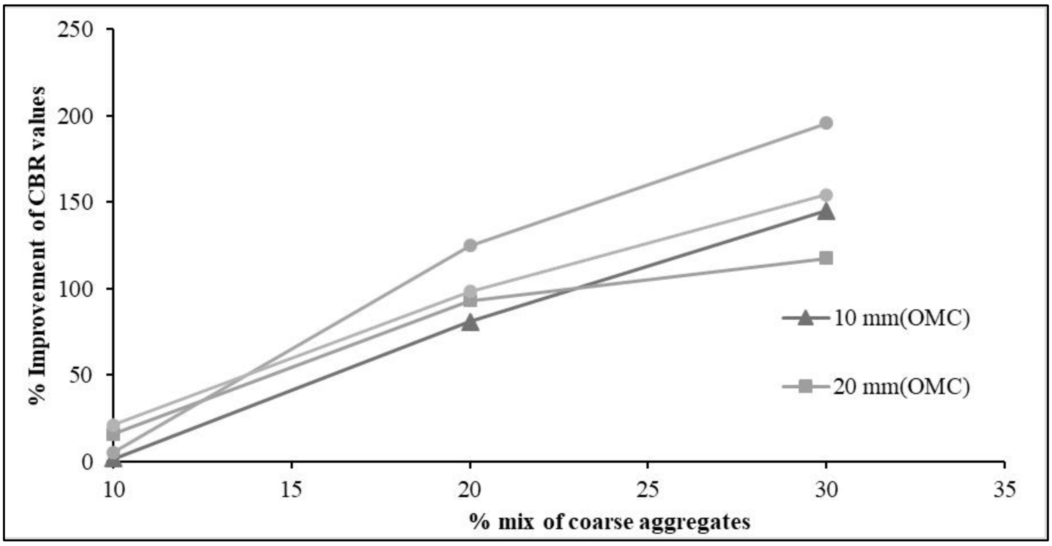


Figure 8: Percent improvement in CBR values for various mix of coarse aggregates

It is apparent from Figures 7 to 8 and Tables 2 to 3 that soaking of the sample induces a reduction in the CBR value of the sand. Both with and without mixing coarse aggregates. Still, the rise in the percentage of added coarse aggregates has a similar effect on CBR in wet conditions and at OMC. The decrease in CBR value is attributable to an increase in the moisture content of the mixes above OMC during the soaking phase, which softens the soil and reduces effective stresses. Furthermore, because the particles are mobilized, the load-carrying ability is diminished as a result of soaking.

4. CONCLUSIONS

This study aims to see if the addition of coarse aggregates changes the CBR value of sandy soil. The results reveal that adding coarse aggregates by weight from 0% to 30% considerably varies the OMC, MDD, and CBR. Maximum Dry Density increased steadily with increasing percentage of coarse aggregates, from 1721.54 kg/m3 to 1915.91 kg/m3. The optimal moisture level declined significantly as the fraction of coarse particles increased, from 14.25% to 9.61%. The CBR value was 16.07% with 0% coarse aggregates, which was changed to 39.37% when 30% coarse aggregates replaced the sample by weight at OMC conditions. The CBR was 12.50% without any coarse aggregates and 36.95% with 30% coarse aggregates in soaked conditions.

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REFERENCES

ASTM D-422. (1998). Standard Test Method for Particle-Size Analysis of Soils. ASTM International, 63. https://doi.org/10.1520/D0422-63R07E01.2.

ASTM D 1557. (2012). Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort. ASTM International, 3, 1–10. https://doi.org/10.1520/D155712.1.

ASTM D 854. (2002). ASTM D854 Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer. ASTM International, 04, 1–9.

ASTM D2216. (1998). ASTM D 2216 Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. ASTM International, (January), 1– 5. https://doi.org/10.1109/WiCom.2008.1574.

Deepak Yadav, P.K. Jain and Rakesh Kumar (2014), "Prediction of Soaked CBR of Fine Grained Soils from Classification and Compaction Parameters", *International Journal of Advanced Engineering Research and Studies* E-ISSN2249–8974 Int. J. Adv. Engg., Res. Studies/III/IV/April-June, 2014/119-121.

Neha, P., & Trivedi, M. K. (2017). Improvement of pavement soil subgrade by using Burnt Brick Dust. *International Journal for Research in Applied Science and Engineering Technology*, *5*(5), 218-221.