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Compaction Effect on CBR Values in Different Types of Soils

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A B S T R A C T

As per Indian Road Congress (IRC) guidelines, flexible pavements are designed for California Bearing Ratio (CBR) value of a subgrade soil, at maximum dry density (MDD) under saturated condition. From practical considerations, it is not always possible to achieve maximum dry density in the field at each and every location, especially near the edges where space is congested, not sufficient for the movements of the rollers. In the present study effect of partial compaction on CBR value of different types of the subgrade soil is studied. Maximum dry density is taken as full compaction i.e., 100% and 98%, 95% and 90% of MDD are the partial compaction levels at which CBR values are assessed. CBR value decreases by as much as 50% in case of clayey soil and by around 30% in case of Silty and sandy soil at 90% of MDD as compared to CBR at MDD. From the test results it is observed that the effect of degree of compaction is more in clay as compared to sand and silt.

Keywords: Keywords: California Bearing Ratio, Maximum Dry Density, Flexible Pavement

1. Introduction

Indian roads (flexible pavement) are designed as per IRC guidelines, according to which the flexible pavement is designed for CBR of subgrade soil. This CBR value of subgrade is obtained at MDD under saturated conditions. Top 500 mm thickness of naturally occurring local soil is generally termed as subgrade. It is just beneath the pavement crust, providing a suitable foundation for the pavement. The loads on pavement are ultimately transmitted to the ground below through the subgrade. The current MoRTH specifications require that the subgrade should be compacted to 97% of Maximum Dry density (MDD) achieved by the Modification Proctor Test (IS 2720 – Part 8). For the purpose of flexible pavement design, subgrade soil is characterized on the basis of CBR. Better subgrade means higher CBR which results in lower thickness requirement for a particular traffic. Generally, it is observed that while designing a flexible pavement the CBR value of subgrade soil is calculated at 100% of MDD achieved through Heavy Proctor compaction test. In field the heavy compaction is provided with the help of rollers. But sometimes it is not possible to obtain 100% compaction throughout the length of road mostly at edges and corners and also in some times of soils the required amount of compactive efforts are very high for achieving 100%. So, the present study is designed to study the CBR value of subgrade soil at 90%, 95%, 98% and 100% of MDD for different types of soils (i.e., clayey, sandy and silty soil). This will provide useful information regarding effect of compactive efforts on CBR in different types of subgrade soils.

2. Objective of the Study

The objective of the present study is to evaluate the compaction effect on different types of soils i.e., clayey soil, silty soil and sandy soil. Further, in this study the CBR value of subgrade soil at different degree of compaction are computed.

3. Material Used

Regarding the objective of present study three different types of soil namely Sand, Silt and Clay are selected to perform the tests. These soils are classified as per their nature. Sand are course materials with particles size less than 2.36 mm with little or no fines contributing to cohension of materials. Silts are finer than sand and exhibit little cohesion as compared to clay, these are brighter in colour. Another property of the silt is dilatancy i.e., a lump of silty soil when mixed with water, it squeezed and tapped a shiny surface makes its appearance. Clays are finer materials. These kinds of soils possess stickiness, high strength when dry, and show no dilatancy. Soils like black cotton and other expansive clays show swelling and shrinkage properties.

4. Tests Conducted

Initially experiments were conducted to find out gradation, liquid limit, plastic limit and plastic index of all three types of soil. Specific gravity is calculated for all types of soils. Later on, compaction tests were conducted to find out the OMC and corresponding MDD. Then CBR were conducted to evaluate the behavior of different soil types.

4.1 Evaluation of Index Properties of soil

Atterberg's Limit Test is referred to ASTM D 4318 and IS 2720: Part 5, Year-1985. These tests are performed to determine liquid limit, plastic limit and the plastic index of clayey soil in order to characterize its physical state with water content. The result of index properties such as Liquid Limit, Plastic Limit, PI value are presented in Table 1.

Table 1 Experimental values of Index Properties for Soil Samples

Sr. No.	Type of soil sample	Index properties of soil Liquid Limit	Plastic Limit	Plastic Index
1	clayey	43.30%	29.32%	13.98%
2	Silty soil	23.83%	19.65%	4.18%
3	Sandy soil	-	-	-

4.2 Wet Sieve Analysis of Soil Samples

Wet sieve analysis is carried out on 200gm of the collected subgrade sample as per IS 2720: Part 4 (1985). Soil retained and percentage of soil passing is calculated. The result of the experiment is given below.

Table 2 Grain size distribution of subgrade soil samples

Sr. No	Size of sieve	Clayey Subgrade soil		Silty subgrade soil		Sandy subgrade soil	
		Soil retained (gm)	Percentage of soil passing	Soil retained (gm)	Percentage of soil passing	Soil retained (gm)	Percentage of soil passing
1	4.75 mm	Nil	100	Nil	100	Nil	100
2	2.00 mm	Nil	100	Nil	100	Nil	100
3	425 microns	3.32	98.34	1	99.50	1.31	98.34
4	75 microns	12.17	92.75	71.68	63.66	174.70	12

4.3 Specific Gravity Test of Soil Samples

Specific gravity is dimension-less parameter. The Specific Gravity of solid particles is defined as the ratio of the mass of a given volume of solids to the mass of an equal volume of water at 4ºC. Specific Gravity of geological material lies in the range of 2.60 to 2.80. The specific gravity value is the average value of all the solid particles present in the soil mass. It is an important parameter used for determination of void ratio and particle size. Specific gravity is determined in the lab using Pycnometer bottle as per IS 2720: Part 3 (1980) are given in table 3.

Specific Gravity = (W2-W1) / [(W4 – W1) - (W3 – W2)]

1. Specific gravity for clayey subgrade soil = (909 – 705) / [(1619 – 705) – (1742.7 – 909.1)] = 2.64

2. Specific gravity for silty subgrade soil = (1125 – 705) / [(1619 – 705) – (1883 – 1125)] = 2.69

3. Specific gravity for clayey subgrade soil = (950 – 705) / [(1619 – 705) – (1774 – 950)] = 2.72

Table 3 Specific Gravity of subgrade soil samples

Sr. No.	Soil Sample Type	Weight of Pycnometer bottle (W1)	Weight of Pycnometer bottle + Sand (W2)	Weight of Pycnometer bottle + Half-filled soil + distilled water (W3)	Weight of Pycnometer bottle + distilled water (W4)
1.	Clayey	705 gm	909 gm	1742.7 gm	1619 gm
2.	Silty	705 gm	1125 gm	1883.7 gm	1619 gm
3.	Sand	705 gm	950 gm	1774 gm	1619 gm

4.4 Proctor Compaction Test

The relationship between the moisture content and dry density of the soil is obtained in the process. Compaction effort provided in this laboratory test is comparable with that obtained in the field. For a given soil, for a given amount of compaction effort, the density obtained depends on the moisture content as per IS 272A: Part-7 (1980). The water content corresponding to the maximum dry density (MDD) is known as the optimum moisture content (OMC). Hence the value of MDD and OMC for clayey, silty and sandy subgrade soil can be calculated from the graphs below. As per figure 1 the MDD and OMC for clayey subgrade soil are 1.92 g/cc & 15.8 % respectively. And thereof for silty subgrade soil MDD and OMC is 1.93 g/cc & 10.5 %and for sandy subgrade soil MDD and OMC is 1.89 g/cc & 8.5 % respectively.

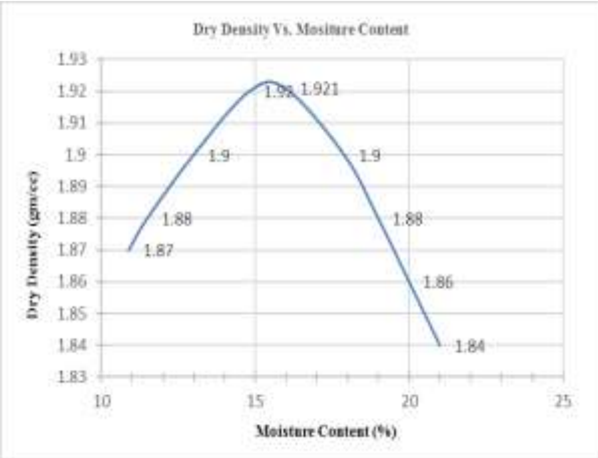

Figure 1. Proctor Compaction Test on Clayey Subgrade Soil

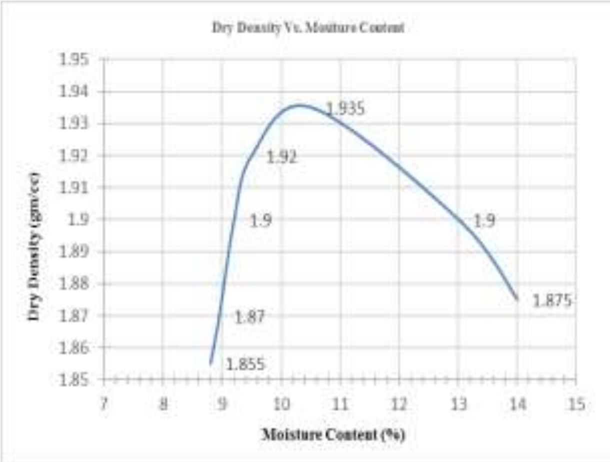

Figure 2. Proctor Compaction Test on Silty Subgrade Soil

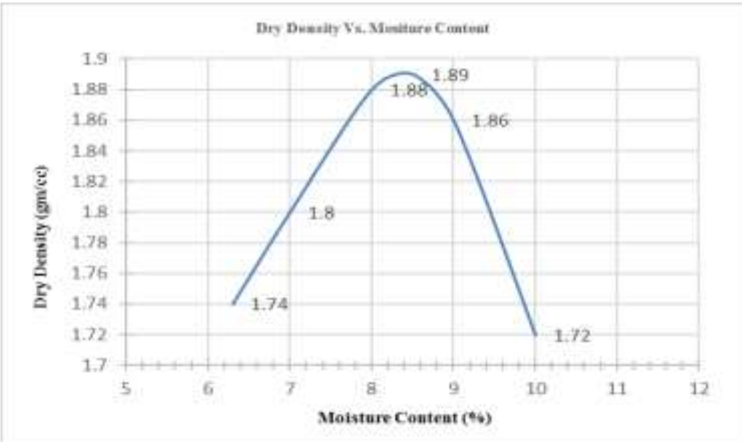

Figure 3. Proctor Compaction Test on Sandy Subgrade Soil

4.5 Effect of Degree of Compaction on CBR Value of different soil samples

The flexible pavements are generally designed on the basic of CBR value of subgrade soil at 97% of compaction. It is not possible to achieve full compaction throughout the length of road. Sometimes the compaction achieved through normal compactive efforts is not up to the required level and if we have to provide the high compaction, extra ordinary compactive efforts are required which results in uneconomical compaction. In the present study CBR value is calculated at different lever of compaction as per IS 2720: Part 16, (1987), so that judicious decision could be taken between input compactive efforts and the obtained CBR value. For the purpose of analysis, the graph below shows the variation in CBR values at different degree of compaction. The variation of CBR test result at 90%, 95%, 98%; and 100% compaction of MDD is given below in Figure 4, 5 and 6.

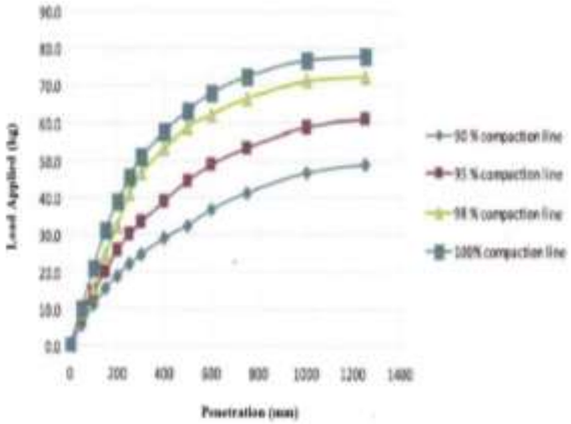

Figure 4. CBR value of clayey subgrade soil at different degree of compaction

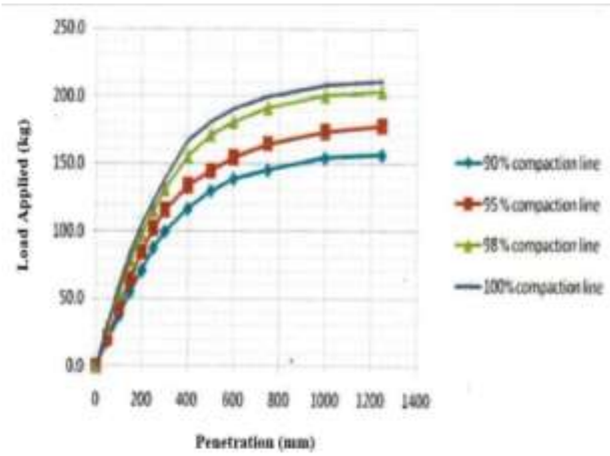

Figure 5. CBR value of Silty subgrade soil at different degree of compaction

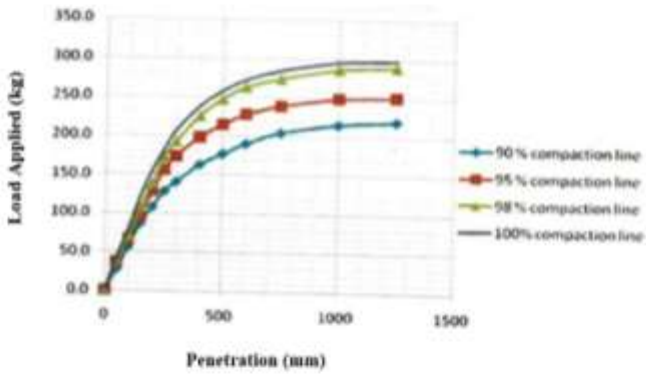

Figure 6. CBR value of Sandy subgrade soil at different degree of compaction

5. Results

Results from above graphs are summarized in tabular form as given below:

Table 4 CBR values for different soil sample at different degree of compaction

Subgrade Soil Sample Type	Penetration Depth (mm)	CBR values at different compaction percentage			
		90% compaction	95% compaction	98% compaction	100% compaction
Clayey soil	2.5 mm	1.6	2.2	3	3.3
	5.5 mm	1.5	2.2	3	3.1
Silty soil	2.5 mm	6.4	7.5	8.4	8.9
	5.5 mm	6.4	7	8.3	8.9
Sandy soil	2.5 mm	9.3	11.4	12.6	13.3
	5.5 mm	8.6	10.4	12.1	12.5

1. **Clayey subgrade soil:** The CBR value is calculated at 2.5 mm and 5 mm penetration and it is observed that CBR value corresponding to 2.5mm penetration is higher than the CBR value corresponding to 5.0mm in all the cases. From Table 4 it is observed that the CBR value is in the range of l.6 to 3.3 depending upon degree of compaction. The CBR value reduces to nearly 50% to its original value at 90% compaction.

At 98% compaction the reduction in CBR value is 10 %. The CBR value reduces by 35% at 95%o compaction of MDD in case of clayey subgrade soil.

2. **Silty subgrade soil:** The CBR value is calculated at 2.5 mm and 5 mm penetration and it is observed that CBR value corresponding to 2.5mm penetration is higher than the CBR value corresponding to 5.0mm in all the cases. From above Table 4 it is observed that the CBR value is in the range of 6.4 to 8.9 depending upon degree of compaction. The CBR value reduces to nearly 71 % to its original value at 90 % compaction. At 98% compaction the reduction in CBR value is 6%. The CBR value reduces by 83%o at 95% compaction of MDD in case of Silty subgrade soil.

3. **Sandy subgrade soil:** The CBR value is calculated at 2.5 mm and 5 mm penetration and it is observed that CBR value corresponding to 2.5mm penetration is mostly higher than the CBR value corresponding to 5.0mm. From above table it is observed that the CBR value is in the range of 9.3 to 13.3 depending upon degree of compaction. The CBR value reduces to nearly 70 % to its original value at 90 % compaction. At 98% compaction the reduction in CBR value is 6%. The CBR value reduces by 85%o at 95% compaction of MDD in case of Silty subgrade soil.

4. CBR value decreases by as much as 50% in case of clayey soil and by around 30% in case of silty and sandy soil at 90% of MDD as compared to CBR at MDD. From the test results it is observed that the effect of degree of compaction is more in clay as compared to sand and silt.

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