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Laboratory Protocol

Soil compaction and Stiffness testing with Terrasil

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Contents

1. Introduction:

Compaction of the soil is tested using Modified Proctor Method and stiffness of the soil is determined using CBR (California Bearing Ratio) method. This procedure is marginally modified procedure to accommodate requirement of Terrasil soil waterproofing nanotechnology.

1.1. Determination of OMC (Optimum Moisture Content)

1.1.1. **Step 1:** Obtain 2,500.0 g of oven dry soil passed through the #4 sieve.

1.1.2. **Step 2:** Weigh 1 "bread pan" moisture content container and record the weight on the data sheet.

1.1.3. **Step 3:** Weigh a 4.0 inch diameter compaction mould.

1.1.4. **Step 4:** Add enough water to your sample to obtain 6.0 % moisture content (remember water content is Ww/Ws).

1.1.5. **Step 5:** Compact the soil into the mould in five layers using a 4.5 Kg hammer and 25 blows per layer. Make sure that on the last layer, your compacted sample is just above (1/4" or so) the top of the mould so it can be trimmed and weighed.

1.1.6. **Step 6:** Weigh the mould and the sample and record on your data sheet.

1.1.7. **Step 7:** Take a representative sample of the soil (about half of it evenly distributed from the entire sample) and place in a "bread pan" moisture content container. Weigh the sample, record the data and place in the oven. Work quickly because water is being lost as time progresses.

1.1.8. Repeat steps 1 through 7 twice, increasing the moisture content to 9.0 % for the second step and then 12.0 % for the third step and 15.0% for the fourth step.

1.1.9. If the soil is expansive lateritic, then you may have to start at 9.0 % and measurement is done in 4.0 % increments.

1.1.10. Obtain all weights and plot moisture content vs. dry unit weight to scale on graph paper and indicate optimum moisture and maximum dry unit weight (Optimum Density).

2. Analysis:

2.1. Calculate the moisture content of each compacted soil specimen by using the average of the two water contents.

2.2. Compute the wet density in grams per cm^3 of the compacted soil sample by dividing the wet mass by the volume of the mould used.

2.3. Compute the dry density using the wet density and the water content determined in step 1. Use the following formula:

$$\rho_{dry} = \rho_{wet}/(1+w)$$

Where: w = moisture content in percent divided by 100, and ρ = wet density in grams per cm3.

2.4. Plot the dry density values on the y-axis and the moisture contents on the x-axis. Draw a smooth curve connecting the plotted points. Optimum Moisture Content (OMC) and Optimum Dry Density (ODD) is determined from the maxima of the curve.

3. Terrasil Containing samples

3.1. Terrasil solution used is 1:300-600 dilution (depending on soil type). Take same soil oven dry and prepare a compacted sample with OMC using similar procedure.

3.2. In this case use Terrasil solution is used instead of water. Determine Dry Density as described in previous section using OMC equivalent Terrasil solution.

3.3. Also determine Dry Density using 5.0, 10.0 and 15.0 % less moisture for typical soil and 10.0, 20.0 or 30.0 % for expansive soil. Terrasil will possibly have Optimum Dry Density at a lower value than OMC. The dry Density also expected higher than using plain water.

4. California Bearing Ratio (CBR) Test:

4.1. Objective: To determine the California bearing ratio by conducting a load penetration test in the laboratory.

4.2. Need and Scope:

4.2.1. The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

4.2.2. This instruction sheet covers the laboratory method for the determination of CBR. of undisturbed and remoulded /compacted soil specimens, both in soaked as well as un-soaked state.

4.3. Equipments and Tools required

4.3.1. **Cylindrical mould:** with inside diameter 150 mm and height 175 mm, provided with a detachable extension collar 50 mm height and a detachable perforated base plate 10 mm thick.

4.3.2. **Spacer disc:** 148 mm in diameter and 47.7 mm in height along with handle.

4.3.3. **Metal rammers:** Weight 4.89 kg a drop 450 mm.

4.3.4. **Weights:** One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in diameter, with a central hole 53 mm in diameter.

4.3.5. **Loading machine:** With a capacity of at least 5000 kg and equipped with a movable head or base that travels at an uniform rate of 1.25 mm/min. Complete with load indicating device.

4.3.6. **Metal penetration piston:** 50 mm diameter and minimum of 100 mm in length.

4.3.7. **Two dial gauges:** reading to 0.01 mm.

4.3.8. **Sieves:** 4.75 mm and 20 mm I.S. Sieves.

4.3.9. **Miscellaneous apparatus:** such as a mixing bowl, straight edge, scales soaking tank or pan, drying oven, filter paper and containers.

4.4. CBR Definition:

4.4.1. CBR is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.

$$\text{CBR} = \text{Test load/Standard load} \div 100$$

4.4.2. Following table gives the standard loads adopted for different penetrations for the standard material with a CBR value of 100.0 %.

Plunger Penetration (mm)	Standard Load (Kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

4.4.3. The test may be performed on undisturbed specimens and on remoulded specimens which may be compacted either statically or dynamically.

4.5. Preparation of Test Specimen

4.5.1. **Undisturbed specimen:** Attach the cutting edge to the mould and push it gently into the ground. Remove the soil from the outside of the mould which is pushed in. When the mould is full of soil, remove it from weighing the soil with the mould or by any field method near the spot.

4.5.2. Remoulded specimen: Prepare the remoulded specimen at Proctors maximum dry density or any other density at which CBR is required. Maintain the specimen at optimum moisture content or the field moisture as required. The material used should pass 20 mm I.S sieve but it should be retained on 4.75 mm I.S. sieve. Prepare the specimen either by dynamic compaction or by static compaction.

4.6. Dynamic Compaction

4.6.1. Take about 4.5 to 5.5 kg of soil and mix thoroughly with the required water.

4.6.2. Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base. Place the filter paper on the top of the spacer disc.

4.6.3. Compact the mix soil in the mould using a heavy compaction (4.5 Kg rammer). For heavy compaction compact the soil in 5 layers, 56 blows to

each layer by the 4.89 kg rammer.

4.6.4. Remove the collar and trim off soil.

4.6.5. Turn the mould upside down and remove the base plate and the displacer disc.

4.6.6. Weigh the mould with compacted soil and determine the bulk density and dry density.

4.6.7. Put filter paper on the top of the compacted soil (collar side) and clamp the perforated base plate on to it.

4.6.8. Similarly prepare compacted soil sample using Terrasil. Use Optimum Terrasil solution determined by proctor density test described earlier.

4.6.9. Measure the CBR as described below for the unsoaked samples.

4.6.10. Prepare two additional samples (one control with water and other with Terrasil/ solution) for determination of the CBR of the soaked samples.

4.6.11. Put both the sample for air drying (for 2-3 days) and oven drying (100 ^{0}C) for 2-3 hours. This drying step is the modification of the existing method to accommodate Terrasil/ technology requirement.

4.6.12. Then reassemble sample in the mould assembly and immerse in a tank of water and soak it for 96 hours. Remove the mould from tank.

4.6.13. It is also possible to test the soil sample by surface treatment. In this case the additional control sample is made. This sample is sprayed with 1:100-300 Terrasil solution (depending on soil type) over all side of the sample. The surface should be saturated with Terrasil solution. The sample air dry (2-3 days) and oven dry (100 ^{0}C) for 2-3 hours.

4.6.14. Then reassemble sample in the mould assembly and immerse in a tank of water and soak it for 96 hours. Remove the mould from tank.

4.7. Procedure for Penetration Test

4.7.1. Place the mould assembly with on the penetration test machine.

4.7.2. Seat the penetration piston at the center of the specimen with the smallest possible load but in no case in excess of 4 kg so that full contact of the piston on the sample is established.

4.7.3. Set the stress and strain dial gauge to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.

4.7.4. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm. Note the maximum load and corresponding penetration if it occurs for a penetration less than 12.5 mm.

4.7.5. Detach the mould from the loading equipment. Take about 20 to 50 g of soil from the top 3 cm layer and determine the moisture content.

4.8. Observation and Recording

4.8.1. Optimum water content (%)
4.8.2. Weight of mould + compacted specimen g
4.8.3. Weight of empty mould g
4.8.4. Weight of compacted specimen g
4.8.5. Volume of specimen cm3
4.8.6. Bulk density g/cc
4.8.7. Dry density g/cc
4.8.8. Period of soaking: 96 hrs. (4days).

4.9. For penetration Test

4.9.1. If the initial portion of the curve is concave upwards, apply correction by drawing a tangent to the curve at the point of greatest slope and shift the origin. Find and record the correct load reading corresponding to each penetration.

$$CBR = (PT/PS) \times 100$$

Where:

PT = Corrected test load corresponding to the chosen penetration from the load penetration curve.

PS = Standard load for the same penetration taken from the Table given earlier.

4.10. Interpretation and recording

4.10.1. CBR of specimen at 2.5 mm penetration

4.10.2. CBR of specimen at 5.0 mm penetration

4.10.3. CBR of specimen at 2.5 mm penetration

4.10.4. CBR values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the CBR value at 2.5 mm will be greater that at 5 mm and in such a case/the former shall be taken as CBR for design purpose. If CBR for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the CBR corresponding to 5 mm penetration should be taken for design.

General Soil Type	USC Soil Type	CBR Range
Coarse-grained soils	GW Clean gravels	40 - 80
	GP Clean gravels	30 - 60
	GM Gravels with fines	20 - 60
	GC Gravels with fines	20 - 40
	SW Clean sands	20 - 40
	SP Clean sands	10 - 40
	SM Sands with fines	10 - 40
Fine-grained soils	ML	15 or less
	CL LL < 50%	15 or less
	OL LL > 50%	5 or less
	MH	10 or less
	CH	
	15	or less
	OH	5 or less

Typical CBR Ranges

4.10.5. Standard CBR test methods are:

- ASHTO T193: The California Bearing Ratio
- ASTM D 1883: Bearing Ratio of Laboratory Compacted Soils