CE EN 341
Soil Mechanics Laboratory
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Section 6

The Standard Proctor Compaction Test

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I. Introduction

Objective of the Standard Proctor Compaction Test

As always, one of the main objectives in running the Proctor compaction test was for me to gain experience with the test. By gaining experience, I will be able to better tell whether a lab technician is performing the compaction test correctly. Also, I will be able to better tell whether the technician's results seem accurate for the soil tested.

But the main purpose of the proctor compaction test is to determine the maximum dry unit weight of a soil. The optimum moisture content at this dry unit weight can also be determined.

Proctor developed the compaction test in 1933. Since then, Proctor's test has since been modified to create a higher energy of compaction; but the standard Proctor compaction test is still widely used.

Purpose for Running the Test

The chief purpose of running the compaction test is to determine the maximum dry unit weight of a soil. After determining this maximum dry unit weight, specifications can be determined for field compaction of the soil.

Normally, the contractor performing the earth work is told to achieve a compacted field dry unit weight of 90-95% of the maximum dry unit weight determined in the laboratory. Compacted soils can be used in the construction of highways, landfills, foundations, and many other areas of construction.[1]

II. Test Procedure

We performed the standard Proctor compaction test using the following procedure:

1. First, we collected the equipment--the compaction mold, the standard Proctor hammer, the soil (about 8 pounds in a large pan), the water, and moisture cans.
2. Second, we broke up all the small soil lumps. The soil had already been run through the No. 4 sieve, so we added about 180 ml of water to the soil sample. The water brought the soil to its initial moisture content.
3. Third, we weighed the proctor mold and base plate without the extension.
4. Fourth, we attached the extension to the top of the mold and began to add moist the soil to the mold.
5. We then began to compact the soil in three equal layers, with 25 blows by the standard Proctor hammer in each layer.
6. After compacting the three layers and removing the top attachment from the mold, we trimmed off the excess soil from the mold. We then weighed the soil, base plate, and mold together to determine the dry unit weight of the soil.
7. We then extruded the soil from the mold by pounding the mold with a hammer. We collected a sample of moist soil and placed it into an evaporating dish. We then weighed the soil and placed the soil in the oven to dry. This data was used to determine the moisture content.

[1]in Das, 1994, p. 109.

8. Finally, we added 70 ml of water to the soil in the large pan to raise the moisture content by 2%. We thoroughly mixed the soil and went through the whole process again from start to finish.

III. Results

Graphs and Tables

Table 1: Dry Unit Weight and Zero Air Void Data and Calculations.

Test Number	Weight of mold (lb)	Weight of mold + moist soil (lb)	Weight of moist soil (lb)	Moist unit weight (lb/ft^3)	Moisture content (%)	Dry unit weight (lb/ft^3)	Zero-Air-Void unit weight (lb/ft^3)
1	9.42	13.69	4.27	128.10	8.29	118.30	135.58
2	9.42	13.94	4.52	135.72	9.96	123.43	130.84
3	9.42	13.96	4.54	136.05	11.76	121.73	126.07
4	9.42	13.85	4.43	132.99	13.56	117.11	121.64

Table 2: Moisture Content Calculations.

Test No:	1	2	3	4
Dish No:	k1	k2	k3	k4
Weight of Dish (g):	106.66	325.58	325.31	325.29
Weight of can + moist soil (g):	347.84	768.4	522.75	816.8
Weight of can + dry soil (g):	329.38	728.3	------------	758.1
Moisture content (%):	8.29	9.96	11.76	13.56

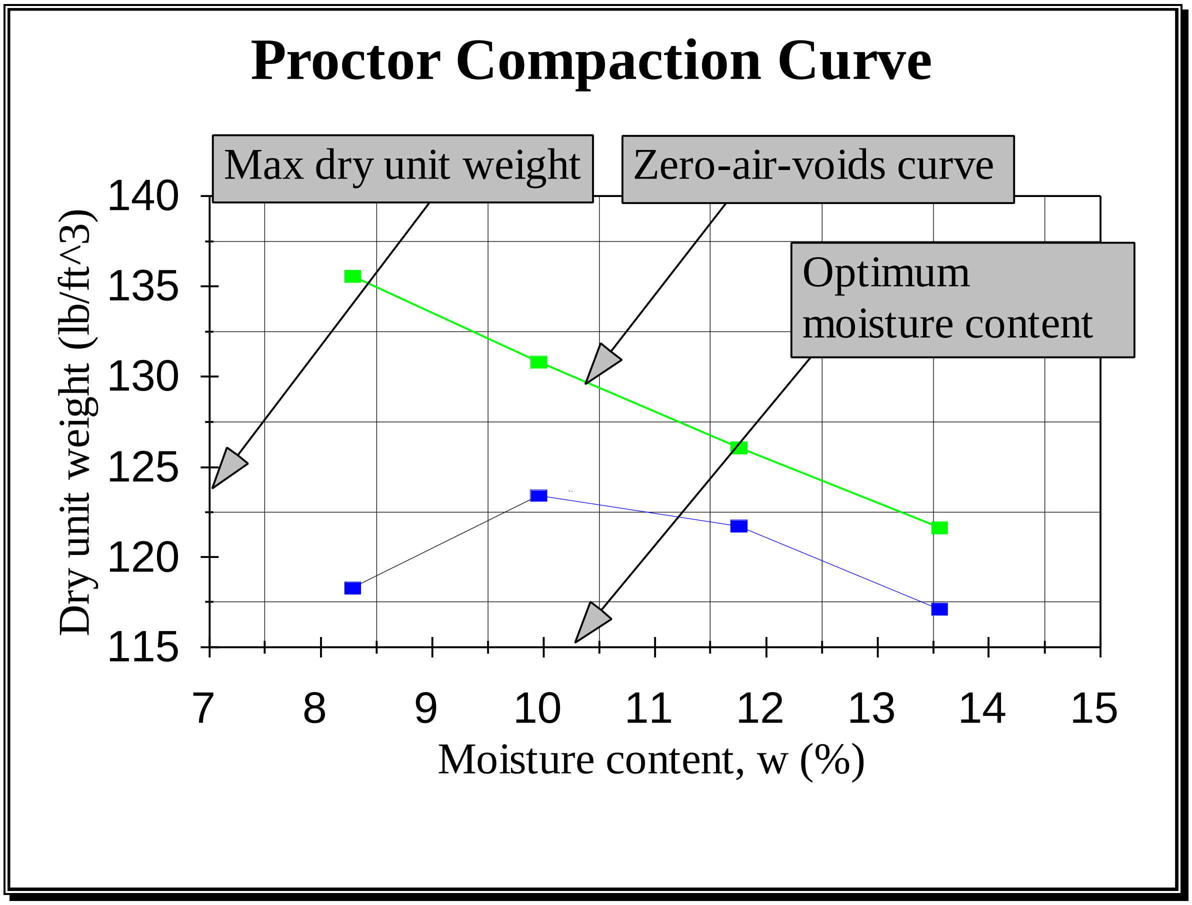

Figure 1: The Compaction Curve--Moisture Content v. Dry unit Weight.

$$w_{opt} = 10.25\%$$
$$g_{d(\max)} = 123.25\frac{lb}{ft^3}$$

Results From the Standard Proctor Compaction Test

The results from the standard Proctor compaction test are located in figure one and tables one and two. The compaction curve indicates that the soil tested had an optimum moisture content of 10.25% and a maximum lab dry density of 123.25 in the Proctor compaction test.

Determination of the Moist Unit Weight

The moist unit weight is simply the total weight of wet soil over the total volume. After determining the weight of soil in each sample, this weight was divided by the volume to determine the moist unit weight.

$$\gamma_{moist} = \frac{weight(measured)}{volume\left(\frac{1}{30}\ ft^3\right)}$$

Determining the moist unit weight of each soil sample was the first step in creating the compaction curve. Next, I determined the moisture content in each specimen.

Determination of the Moisture Content

The moisture content is defined as:

$$w = \frac{W_w}{W_s}$$

where w is the moisture content, W_w is the weight of water in the sample, and W_s is the weight of soil solids in the sample. We dumped one of the soil specimens in with the other soil before obtaining its dry weight (without water). Therefore, the moisture content of our sample #3 is bogus. We averaged the moisture contents of samples 2 and 3 to obtain the moisture content in sample #3.

The optimum moisture content, or the moisture content at maximum dry density, was determined graphically to be 10.25%.

Determination of the Dry Unit Weight

After determining the moisture content of each soil specimen, I determined the dry unit weight using the following equation:

$$\gamma_d = \frac{\gamma_{moist}}{1 + \frac{w(\%)}{100}}$$

I determined the dry unit weights and moisture contents for each soil specimen. Then, I plotted the compaction curve, γ_d vs. w (%). The maximum dry unit weight (see figure 1) was determined to be 123.25 lb/ft^3.

The Zero-Air-Void Curve

The zero-air-void curve shows the maximum possible dry unit weight of the soil specimen. In figure 1, you can see that I plotted the zero-air-void curve with the compaction curve. The values used in the zero-air-void curve are located in table 1. These values were calculated according to the equation:

$$\gamma_{zav} = \frac{\gamma_w}{\frac{w(\%)}{100} + \frac{1}{G_s}}$$

Where γ_{zav} is the maximum dry unit weight at a given moisture content, γ_w is the unit weight of water (62.4 lb/ft^3), *w* is the moisture content, and G_s is the specific gravity of the soil solids. I assumed the specific gravity to be 2.65 for all my calculations.

Summary

Below is a summary of the data obtained in the standard Proctor compaction test.

Table 3: Summary of Results.

Maximum Dry Density	Optimum Moisture Content
123.25 lb/ft^3	10.25%

IV. Discussion

What do the Results Mean?

Optimum moisture content. The optimum moisture content is the moisture content at which the maximum dry unit weight is attained. As the water content of a soil increases, the dry density also increases until this moisture content is reached. After the moisture content of a soil increases beyond the optimum, the dry density decreases. On the wet side of optimum moisture content, large changes in the soil's permeability, compressibility, and strength occur. The optimum moisture content of the soil we tested was found to be 10.25%.

Maximum dry density. The dry unit weight (or dry density) of a soil is defined as:

$$\gamma_d = \frac{W_s}{V}$$

Where γ_d is the dry unit weight, W_s is the weight of the soil solids, and V is the total volume of soil. The maximum dry unit weight is when the soil solids are packed closest together. Thus, maximum compaction at a specific compaction energy occurs at the maximum dry density. The maximum dry density of the soil we tested was found to be 123.25 lb/ft^3.

Relative compaction. Relative compaction is defined as:

$$R(\%) = \frac{\gamma_{d(field)}}{\gamma_{d(\max-lab)}} \times 100$$

Normally, a relative compaction of 90-95% will be specified for earth work. Thus, after performing our lab test, we can determine the moisture content and dry density that will produce the desired compaction of soil. We could either compact on the wet side of optimum or the dry side of optimum.

The values of the dry density and moisture contents at 90 and 95% relative compaction are located in table 4:

Table 4: The Dry Density and Moisture Contents at the Wet and Dry Sides of Optimum for 90% and 95% Relative Compaction.

Relative Compaction (%)	Dry Density (lb/ft^3)	Moisture Content (%)
95	117.08	8.0 or 13.75
90	110.93	6.75 or 15.5

If the soil is compacted on the wet side of optimum, it will have low permeability, low strength, and high ductility. But if the soil is compacted on the wet side of optimum, it will have the opposite properties. Table 4.2 in Das (1994) gives tentative requirements for relative compaction of all types of soils.

How Can the Soil be Classified?

Although the standard Proctor test was not used to classify the soil, we can compare its maximum dry unit weight with that of other soils. From Figure 4.5 in Das (1994), we can see the standard compaction curves for a sandy silt, a silty clay, a highly plastic clay, and a poorly graded sand. The approximate maximum dry unit weights for these soils are the following:

Table 5: Maximum Dry Densities for Various Types of Soils.

Type of Soil	Maximum Dry Density
Sandy Silt	119 lb/ft^3
Silty Clay	116 lb/ft^3
Highly Plastic Clay	111 lb/ft^3
Poorly Graded Sand	108 lb/ft^3
The Soil We Tested.	123.25 lb/ft^3

The compaction curve for the soil we tested comes closest to that of a sandy silt.

What Were the Sources of Error?

The following were possible sources of error:

1. In the standard Proctor compaction test, there was a high potential for error. Once a person becomes experienced in performing the Proctor test, that person can get reasonably accurate results. But with an amateur like myself, it is difficult to get an accurate result according to ASTM standards the first time.
2. The measured weights of the soil, the molds, and the containers may have been slightly different than what was read because of inaccuracy in the scale.
3. We may have applied too much force on the soil specimens, causing a compaction greater than the required compaction.

4. When we compacted the third soil sample (see table 2), we dumped the soil in with the other soil and neglected to obtain a reading of the weight of the evaporating dish and the dry soil. Thus, the moisture content of 11.76% was interpolated from the moisture contents of the other soil samples.
5. The compacted volume of soil in each compaction may have been less than 1/30 ft^3.

What Could be done to Reduce the Error?

To reduce the error, we could simply change the effects of the errors listed above. We could have reduced experimental error by:

1. Being more experienced and more careful in performing the test.
2. Insuring that an accurate scale is used to measure the mass of the soil specimen.
3. Insuring that the 5.5-lb. weight is dropped from the correct height for each soil compaction. Also, making sure that the weight is dropped only 25 times and in 3 equal layers.
4. Insuring that all required weights for each data point is obtained.
5. Carefully removing the top off the mold. Then leveling the soil off at the top so exactly 1/30 ft^3 of soil is left in the mold before weighing it.

V. Conclusion

From the standard Proctor compaction laboratory, I have learned the proper method for determination of the maximum dry density and the optimum moisture content for a soil. Also, I have learned the significance of the maximum dry density and the optimum moisture content in a soil.

This soil displayed a compaction curve similar to that of a sandy silt. (See table 5). The soil we tested had a lab maximum dry density of 123.25 lb/ft^3 and an optimum moisture content of 10.25%. If it was required to compact this soil to a relative compaction of 95%, it would have a maximum dry density of 117.08 lb/ft^3 at 95% relative compaction. The standard Proctor compaction test can be very efficient in representing actual field conditions during compaction.

VI. Appendix

References

Das, B. M. (1993). Principles of geotechnical engineering, PWS Publishing Company, Boston.

Das, B. M. (1992). Soil Mechanics Laboratory Manual, Engineering Press, Inc., San Jose, California.

Data and Calculations

**Raw data and calculations are located on the following pages.