13 Family of Curves and the One-Point Proctor Procedures

CHAPTER THIRTEEN:
FAMILY OF CURVES AND THE ONE-POINT PROCTOR PROCEDURES

Highway embankments are composed of soil and/or aggregates placed in layers and compacted to an acceptable density. The purpose of a highway embankment is to provide adequate support of the overlying roadway and applied traffic loads. Section **203.23** discusses the methods of density control for embankment construction using most types of soils and aggregates. Section **215.09** addresses the maximum dry density and optimum moisture of chemically modified soils. Embankment fill is required to be compacted to 95 % of the maximum dry density with a moisture content within -2 and +1 % of the optimum value. Subgrade compaction requires 100 % of the maximum dry density.

MAXIMUM DRY DENSITY

Maximum dry density refers to the soil or aggregate density as determined in accordance with **AASHTO T 99**. **AASHTO T 99** sets forth a method of determining the density of a sample placed in layers in a certain size mold and compacted with a specified weight dropped from a specified height. The process is repeated on the same sample at various moisture contents. The resultant points are plotted on a chart of moisture content versus density. The maximum dry density and optimum moisture are found at the peak of the curve formed by joining the points.

FAMILY OF CURVES

Repeating the compaction process for several different types of cohesive soils yields graphs (i.e. curves) of similar shape and geometry. These similar graphs plotted on one sheet are called the Family of Curves (see **AASHTO T 272**). A copy of the INDOT developed Family of Curves is kept on file in each District Testing Department. The Family of Curves may be used to estimate the maximum dry density and optimum moisture content of a cohesive soil sample in the field. **AASHTO T 99** is used to determine the values in a laboratory process.

Each layer of soil is required to be tested for density and moisture during embankment construction. In preparation for testing the soil, samples are taken from the job-site cut areas or from proposed "borrow areas". By carefully observing the soil layers or horizons in a cut, the Technician may obtain samples of each soil type and submit those samples to District Testing. The samples are processed in accordance with **AASHTO T 99** and the maximum dry density and optimum moisture content of each sample is reported to the project in the form of a lab report.

The testing process works well if the embankment is constructed from just one soil type in each lift of embankment. However, the normal process is not nearly as well defined. Each embankment layer being placed may contain different portions of two or more types of the soils as sampled. Which target density and moisture content that is most representative of that specific lift of embankment may be difficult to determine.

ONE-POINT PROCTOR

If the soil is cohesive in nature, the INDOT Family of Curves may be used. After the Technician has conducted a field test to determine the actual field density of an embankment layer, a representative sample of soil, approximately 7 pounds, is removed from the area around the test site. The maximum dry density and optimum moisture of the soil sample is determined using the one point proctor method, **AASHTO T 272** Method A. The process involved is similar to that required in **AASHTO T 99**. The moisture of the sample may be determined in accordance with **ITM 506**. The resulting wet density and actual field moisture content are plotted on the Family of Curves to determine which curve fits the point as plotted. The curve number is recorded and the data from the box in the upper right corner of the chart is used for maximum dry density and optimum moisture content.

The following example illustrates the use of the INDOT Family of Curves to select a maximum dry density and optimum moisture content for a density test. The process is the same for nuclear gauge tests.

EXAMPLE PROBLEM

The Technician obtains the following information:

1) A sand cone density test is completed in accordance with **AASHTO T 191** to determine the wet density of an embankment lift (or layer). A moisture test is required to calculate dry density. **ITM 506**, Field Determination of Moisture Content of Soils, is used. The sample is required

to be protected from drying until the initial wet weight of the sample is obtained. Form IT 625 is used for recording these values.

2) A sample of the soil is obtained from the area immediately surrounding the sand cone test site. The sample size is required to exceed 7 pounds. A minimum of 2.2 pounds is required for the moisture test in accordance with **ITM 506** and approximately 4 to 5 pounds would be necessary to produce the molded soil sample for the one-point proctor. This sample need not be protected from drying.

The sand cone test resulted in the following: Wet Density of in-place soil was 123.0 lb/ft^3 and the moisture was 17.0 percent. The result wascompared to the maximum dry density and optimum moisture content results from the one-point proctor test. The calculated dry density of the field sample is 105.1 lb/ft^3.
From the one-point proctor test, the following information was obtained.

A.	Weight of prepared sample in the mold	9.60 lb
B.	Weight of the one-point mold	5.40 lb
C.	Net weight of Soil (A-B)	4.20 lb
D.	C x 30 = Weight of one cubic foot	126.00 lb
E.	**ITM 506** moisture content	16.6 %

By plotting 126.0 lb/ft^3 on the vertical axis of the chart and 16.6 % on the horizontal axis, Curve 6 is selected (Figure 13-1). The box on the upper right hand side of the chart lists the maximum dry density of Curve 6 as 108.3 lb/ft^3 at an optimum moisture content of 16.8 %. These values then become the target dry density and moisture content for the soil mixture being tested.

As previously mentioned, Specifications require that the moisture tested be within -2 and +1 of the optimum moisture content and the embankment layer be compacted to at least 95 % of the maximum dry density.

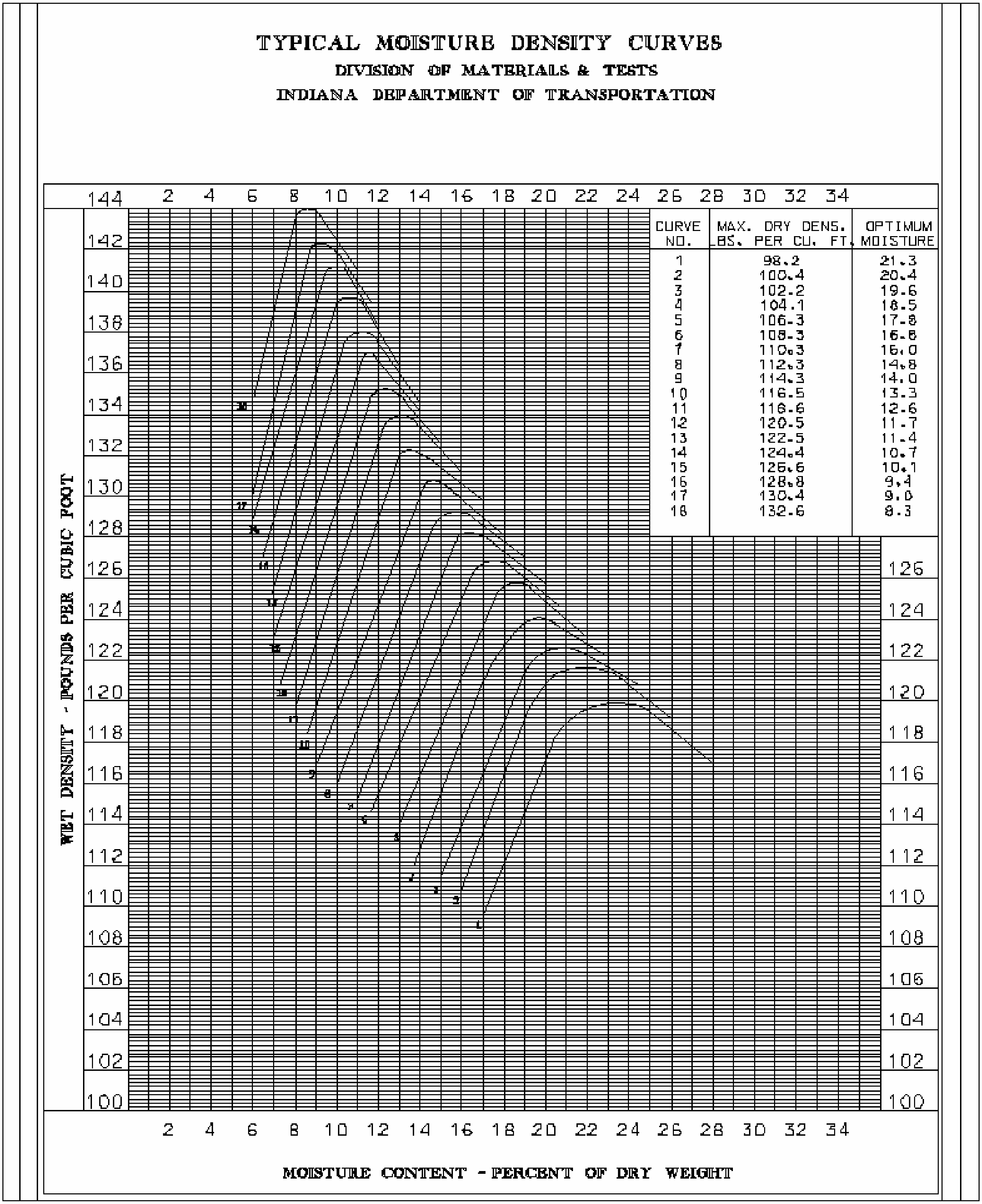
The site tested had a moisture content of 17 %. This is within Specification limits of -2 and +1 of optimum. The percent compaction is calculated by dividing field dry density by the target dry density and multiplying by 100 %.

$$(105.1 / 108.3) \times 100\% = 97.0\ \%\ \text{of target}$$

Specifications require 95 % of target up to the subgrade elevation. At the subgrade elevation, the Contractor is required to obtain 100 % of target. The above test would pass for embankment construction below subgrade elevation.

The points plotted on the Family of Curves do not always plot directly onto one curve. For example, if the one point proctor revealed a wet density of 131.0 lb/ft^3 and the moisture content results was 14.0 %, plotting this pair of points on the chart would locate a point between Curve 9 and Curve 10. For this situation, the average of the curve data may be obtained to select the maximum dry density and optimum moisture content. For these values, the dry density target would be 115.4 lb/ft^3 and the optimum moisture target would be 13.7 %, the average of the data from the two curves.

The moisture content used to plot on the Family of Curves is required to be between the optimum moisture and minus two percent of optimum moisture. If the plotted points fall outside of these limits, water may be added to the sample or the sample may be dried to allow the moisture to fall within the prescribed limits. The soil sample would then be recompacted in the one-point mold and a new wet density calculated and moisture obtained.



CURVE NO.	MAX. DRY DENS. LBS. PER CU. FT.	OPTIMUM MOISTURE
1	98.2	21.3
2	100.4	20.4
3	102.2	19.6
4	104.1	18.5
5	106.3	17.8
6	108.3	16.8
7	110.3	16.0
8	112.3	14.8
9	114.3	14.0
10	116.5	13.3
11	118.6	12.6
12	120.5	11.7
13	122.5	11.4
14	124.4	10.7
15	126.6	10.1
16	128.8	9.4
17	130.4	9.0
18	132.6	8.3

Figure 13-1. Typical Moisture Density Curves