Louisiana Highway Research

TYPICAL MOISTURE-DENSITY CURVES

PART II

LIME TREATED SOILS

Louisiana Department of Highways – Research & Development Section

TYPICAL MOISTURE-DENSITY CURVES

PART II

LIME TREATED SOILS

by

C. M. HIGGINS
Soils Research Engineer

Research Report No. 21

Research Project No. 61-11S

Conducted by
LOUISIANA DEPARTMENT OF HIGHWAYS
Research & Development Section
in Cooperation with
U. S. Department of Commerce
BUREAU OF PUBLIC ROADS

May 1966

SYNOPSIS

The objective of the study covered by this report was to determine whether the family of curves developed for untreated soils (Louisiana Department of Highways Research Report No. 16), could be used for determining the optimum moisture and maximum density of lime "treated" soils. This investigation was initiated because of the extensive use of lime with plastic clays and silty clays to reduce plasticity and increase friability.

The study revealed that the family of curves developed for untreated soils is suitable for use with lime treated soils. Approximately 93% of the curves for lime "treated" soils that were checked fit the family of curves with reasonable accuracy.

TYPICAL MOISTURE-DENSITY CURVES

PART II

LIME TREATED SOILS

INTRODUCTION

Lime is used extensively in Louisiana as a modifying and/or stabilizing agent for a variety of clay and silty clay materials which in their native form are not suitable for use as base or subbase materials.

The problem of obtaining the correct moisture-density curve for use in determining whether a satisfactory fill density has been obtained with lime treated soils is of major importance. When lime and soil are mixed a reaction occurs which causes a change in the moisture-density characteristics of the soil lime mixture with time. A major problem has been to use the correct laboratory delay in molding the moisture-density curves in order to duplicate as nearly as possible the field delay between mixing and compaction. This is especially true since various mixing processes are allowed and thus variable mixing times occur in the field. One solution to this problem has been to run field density curves on the soil lime mixture at the time of compaction. This solution has not been entirely satisfactory, however, since too much field time is consumed.

In an effort to eliminate this problem the Soil Research Unit of the Louisiana Department of Highways instigated a study to determine whether the family of typical moisture-density curves designed for untreated soil could be used for lime "treated" soil. The results of this investigation are included herein.

SCOPE

This phase of this research project was designed to determine whether the family of typical moisture-density curves developed for raw soils could be used for lime "treated" soil. It consists of laboratory and field checks of lime "treated" soil data for its applicability to the existing raw family of curves.

METHOD OF PROCEDURE AND RESULTS OBTAINED

Compaction curves and work sheets from completed construction projects using lime "treatment" were obtained from Department files. Using this data the Moisture-Density curves were checked for accuracy and replotted when necessary.

After thus assuring the accuracy of the information to be used, the moisture-density curves were checked against the family of curves developed for raw soils (Figure 1). This checking was accomplished in the same manner as for raw soils. A point was picked near the optimum moisture of the laboratory or field curve and plotted on the family of curves. The maximum dry densities and optimum moistures obtained by the two methods were then compared. A total of 476 curves were checked in this manner.

The following is a summary of the accuracy check information.

% of curves with	±2 lbs. density	and ±1% optimum moisture	=	67% (319)
	±2 lbs. density	±2% optimum moisture	=	90% (429)
	±3 lbs. density	±2% optimum moisture	=	93% (442)

The figures in parentheses represent the actual number of curves in each category.

In summary, of the 476 curves checked 93 percent fit the developed family of curves for raw soils and seven percent do not.

DISCUSSION OF RESULTS

As was the case for raw soils, any curve within two percent optimum moisture and three pounds dry weight density of the optimum moisture and maximum density of the appropriate curve from the family of curves is a "hit"; that is, it may be considered to be identical to the curve from the family without appreciable error. The percentage of lime "treated" soil curves which fit the family of curves is approximately the same as that for raw soils. For raw soils the percentage of "hits" is 95 and for the lime "treated" soils the percentage is 93.

A check of several of the projects indicates, in general, that if a raw soil fits the family of curves then the same soil after treatment with lime will also fit. The optimum moisture and maximum density of the soil will change after application of the lime, of course, but will tend to move parallel to the peaks of the family of curves rather than to deviate from them.

Laboratory checks should be made to insure that the lime treated material will fit the family of curves. It can probably be safely assumed that if the lime treated soil fits the family of curves in the Laboratory it will also fit in the field even though the time delay after mixing is different. A copy of a proposed test method for use with raw and lime "treated" soils is included in the appendix.

CONCLUSIONS

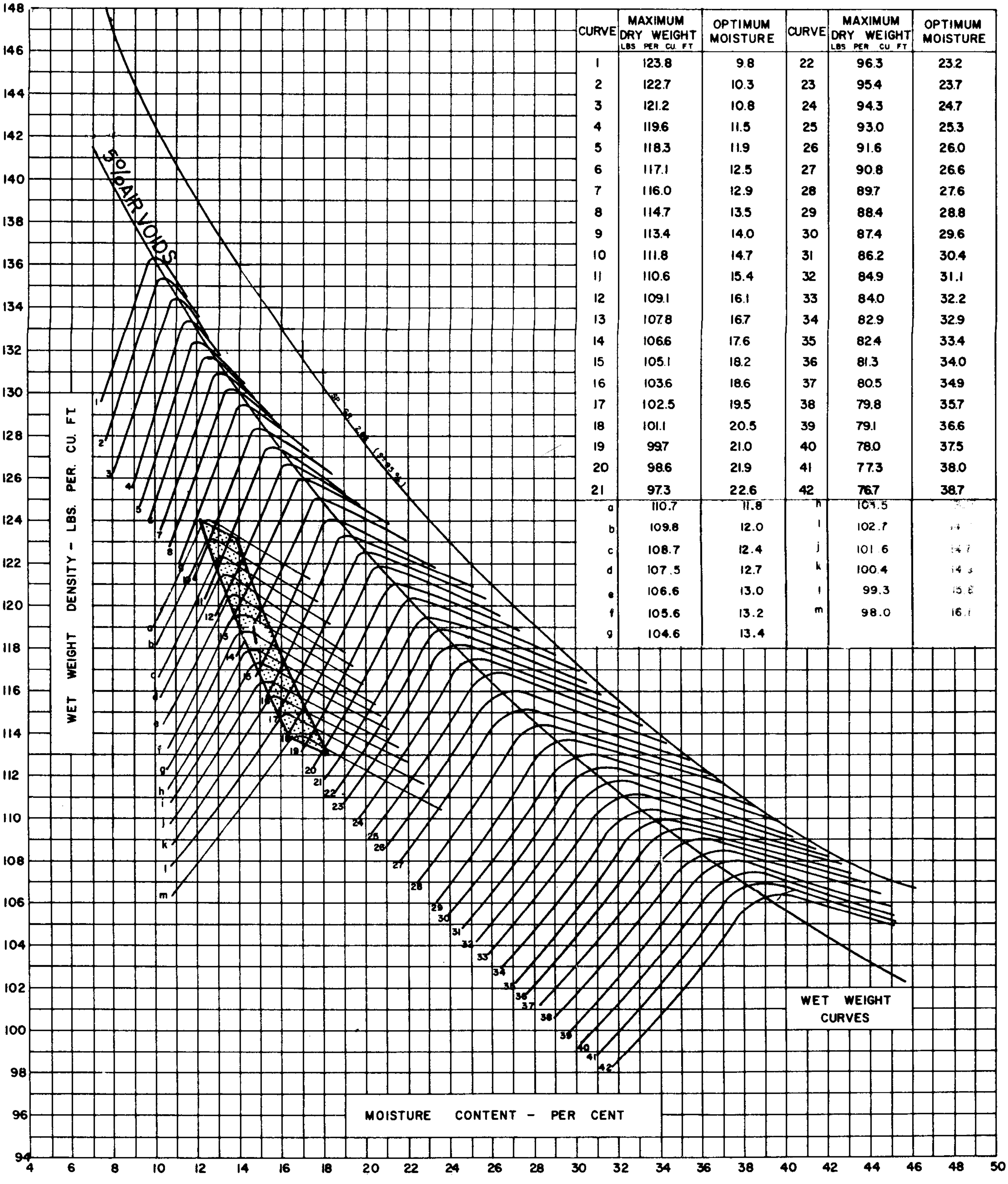
1. The family of curves developed for untreated soils is also suitable for use with lime "treated" soils.

2. Greater accuracy in selecting the proper optimum moisture and maximum density will probably be obtained by this method since the curve may be selected, with little delay, in the field at the time of compaction.

3. Approximately 93 percent of the curves checked fit the family of curves.

4. A test procedure for use of the family of curves with raw and lime "treated" soils has been developed.

Figure 1



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a	110.7	11.8	h	104.5	[illegible]
b	109.8	12.0	i	102.7	[illegible]
c	108.7	12.4	j	101.6	14.7
d	107.5	12.7	k	100.4	[illegible]
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g	104.6	13.4			

TYPICAL MOISTURE - DENSITY CURVES

Method of Compaction LDH TR: 418 Maximum size aggregate - Minus #4 material only.

APPENDIX

METHOD OF DETERMINATION OF MOISTURE-DENSITY RELATIONSHIP USING FAMILY OF CURVES LDH TR 415-66

SCOPE

1. This method of test is intended to determine the relationship between the moisture content and resulting densities (oven-dry weight per cu. ft.) of soils and soil-lime mixtures utilizing the family of moisture-density curves (Fig. 7), when the soil is compacted as specified herein. It is intended to be used as an accurate short cut procedure for LDH Designation: TR 418 and TR 401, and is to be used with the minus No. 4 material of soils only.

APPARATUS

2. The apparatus shall consist of the following:

(a) Mold - A cylindrical metal mold having a capacity of 1/30 cu. ft. (0.0333 cu. ft.) with an internal diameter of 4.0 inches (± 0.005 in) and a height of 4.584 ± 0.005 inches, which has a detachable collar approximately 2 1/2 inches in height. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base plate. Molds shall be replaced if the diameter is more than 4.01 inches or the height is less than 4.50 inches on any side.

(b) Compactive Device - A metal rammer having a 2.00 ± 0.01 inch diameter circular face or a segment of a 2-inch radius circle with an equivalent area and weighing 5.50 ± 0.05 lb. The rammer shall be equipped with an arrangement to control the height of drop to 12.0 ± 0.1 inches.

(c) Straightedge - A steel straightedge

(d) Balances - A balance or scale of 25 lb. capacity sensitive to 0.01 lb. (or equivalent metric balance), and a 500 gram capacity balance sensitive to 0.1 gram.

(e) Drying Apparatus - A thermostatically controlled drying oven set so as not to exceed 230°F for drying moisture samples. A hot plate or an approved Speedy Moisture Device may be used for moisture determinations in the field.

(f) Sieve - A number 4 sieve conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (AASHO Designation: M 92).

(g) Mixing Tools - Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc. or a suitable mechanical device for mixing thoroughly the sample of soil with water.

(h) Graduated Cylinder (250 cc) - For measuring water to be added to sample. (For Central Laboratory and Dist. Labs.)

SAMPLE

3. (a) A representative sample of soil or soil and lime mixture weighing approximately 6 lbs. (or 2724 grams) shall be taken for each one-point Proctor.

PROCEDURE

4. (a) The 6 lb. sample shall be thoroughly mixed with sufficient water to bring the sample to slightly less than its optimum moisture content.

A compacted specimen shall then be formed by compacting the thoroughly mixed sample in the mold (with collar attached) in three equal layers to give a total compacted depth of about 5 inches; each layer being compacted by 25 blows of the rammer dropping free from a height of 12 inches or 12 inches above the approximate elevation of each finally compacted layer when a stationary mounted type of rammer is used. During compaction the mold shall rest on a uniform, rigid foundation. The blows shall be uniformly distributed over the surface of the layer being compacted. After the specimen has been compacted, the collar shall be removed from the mold and the compacted specimen carefully trimmed even with the top of the cylinder by means of a straightedge.

(b) The mold containing the compacted soil specimen shall be weighed. This weight minus the weight of the mold shall then be multiplied by 30 and the result recorded as the wet weight per cubic foot of compacted material.

(c) The base plate shall be detached and the specimen removed from the mold. A representative sample shall be taken from a location near the center of the specimen.

(d) For moisture content determination in the field a 200 gram sample shall be secured as described in "c", weighed immediately and dried to a constant weight by use of a hot plate.

(e) An approved speedy moisture device may be used to determine the moisture content in the field.

(f) For moisture content determination in the Central or District Laboratories not less than a 100 gram sample shall be secured as in "c". This sample shall be weighed immediately and dried in an oven at 110° ± 5° C (230° ± 9° F) to a constant weight.

CALCULATIONS

5. The water content of the soil as compacted shall be calculated as follows:

$$W = \frac{(W_1 - W_2) \times 100}{W_2}$$

where:

W = Moisture content in percent based on weight of oven-dry soil.

W_1 = Weight of wet soil.

W_2 = Weight of oven-dry soil.

MOISTURE-DENSITY RELATIONSHIP AS DETERMINED FROM THE FAMILY OF TYPICAL MOISTURE-DENSITY CURVES

6. The calculations in section 4(b) and in section 5 shall be made to determine the wet density in lbs/cu. ft. and the corresponding water content. These determine a point which may now be plotted on the Family of Curves and extrapolated to arrive at a maximum wet weight and optimum moisture content. When this point falls between two family curves, a minor interpolation is necessary. The maximum dry density in lbs/cu. ft. and the corresponding per cent optimum moisture is then read from the chart or interpolated from the chart (Figure 7).

PRECAUTIONS

7. (a) Any point falling to the left of Area 1 applies to the supplemental (a-m) portion of the family. Any point falling in area one should be repeated using fresh material at a higher moisture content. If the density value for this point decreases the point previously run may be used to pick a curve from the (a-m) portion of the family. If the density value for the second point rises the proper

curve may be selected from the major (1-42) portion of the family using this point.

(b) The maximum wet density and optimum moisture point should be on the dry side of the curve at or near optimum as it is difficult to interpolate between curves for friable soils when on the wet side of the peak.

(c) When the moisture density values of a compacted material are plotted and found to be to the right of the 5.0% air voids curve, the test should be repeated using a lower moisture content. An exception to this rule must be made for those soils having high clay contents and relatively flat curves. These soils cannot readily be dried to optimum in the field due to the creation of a cloddy condition which will cause voids in the proctor. Proctors for these materials should be made as near to optimum as practicable. When the moisture density value of a compacted material is plotted and found to be to the right of the 95% saturation line the test should be repeated using a new sample.

In the event the result obtained on the "check" is found to be similar to the original, a complete curve shall be run on the material in question using LDH Designation: TR 418.

Example:

Suppose after running a one point density the results are: wet density = 118.0 lbs/cu. ft., moisture content = 18.0%. By plotting this point on the Family of Curves and extrapolating to the peak, it shows a point which is approximately 1/2 way between curves 17 and 18. From the chart the dry density for 17 = 102.5 at 19.5% moisture content and 18 = 101.1 at 20.5% moisture content. By interpolation:

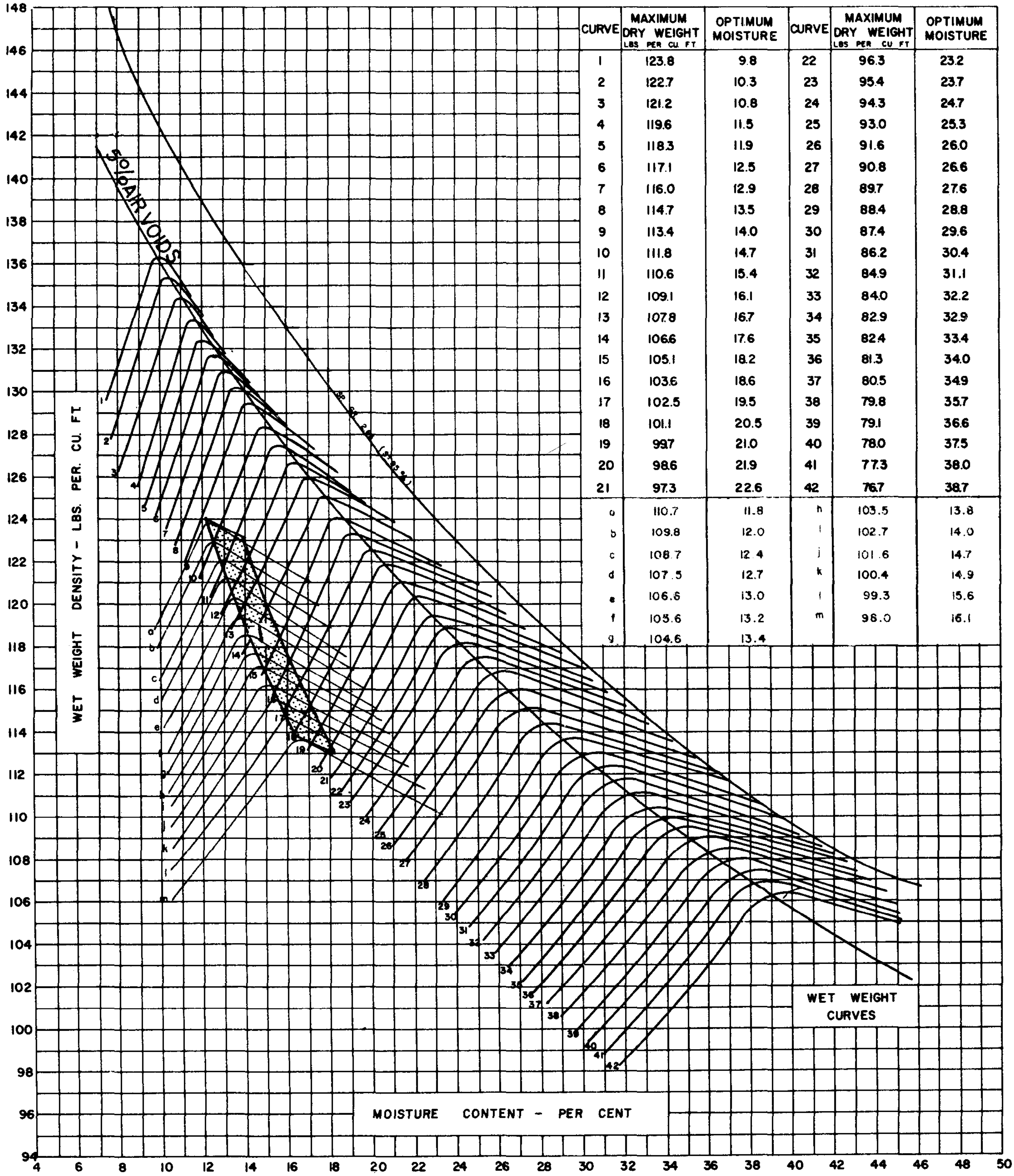
102.5 - 101.1 = 1.4 x .50 = 0.7 lbs/cu. ft. difference in density and;

20.5% - 19.5% = 1.0% x .50 = 0.5% difference in moisture content, thus;

102.5 - 0.7 = 101.8 or 101.1 + 0.7 = 101.8 lbs/cu. ft. and 20.5 - 0.5 = 20% or 19.5 + 0.5 = 20% moisture content, therefore;

maximum dry density = 101.8 lbs/cu. ft.
optimum moisture = 20%

Figure 1



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RESEARCH PUBLICATIONS

1. Concrete Pavement Research. H. L. Lehmann and C. M. Watson, Part I (1956), Part II (1958).
2. Use of Self-Propelled Pneumatic-Tired Rollers in Bituminous Construction and Recommended Procedures. A Special Report, 1958.
3. Use of Expanded Clay Aggregate in Bituminous Construction. H. L. Lehmann and Verdi Adam, 1959.
4. Application of Marshall Method in Hot Mix Design. Verdi Adam, 1959.
5. Effect of Viscosity in Bituminous Construction. Verdi Adam, 1961.
6. Slab Breaking and Seating on Wet Subgrades with Pneumatic Roller. J. W. Lyon, Jr., January 1963.
7. *Lightweight Aggregate Abrasion Study*. Hollis B. Rushing, Research Project No. 61-7C, February 1963.
8. Texas Triaxial R-Value Correlation. Harry L. Roland, Jr., Research Project No. 61-1S, March 1963.
9. Asphaltic Concrete Pavement Survey. S. C. Shah, Research Project No. 61-1B, April 1963.
10. Compaction of Asphaltic Concrete Pavement with High Intensity Pneumatic Roller. Part I. Verdi Adam, S. C. Shah and P. J. Arena, Jr., Research Project No. 61-7B July 1963.
11. A Rapid Method of Soil Cement Design. Harry L. Roland, Jr., Ali S. Kemahlioglu, Research Project No. 61-8S, March 1964.
12. Correlation of the Manual Compaction Hammer with Mechanical Hammers for the Marshall Method of Design for Asphaltic Concrete. P. J. Arena, Jr., Research Project No. 63-1B, September 1964.
13. Nuclear Method for Determining Soil Moisture and Density. Harry L. Roland, Jr., Research Project No. 62-1S, November 1964.
14. Service Temperature Study for Asphaltic Concrete. P. J. Arena, Jr., Research Project No. 61-3B, October 1964.
15. Quality Control Analysis, Part I - Asphaltic Concrete. S. C. Shah, Research Project No. 63-1G, November 1964.
16. Typical Moisture - Density Curves. C. M. Higgins, Research Project No. 61-11S May 1965.
17. High - Pressure Lime Injection. C. M. Higgins, Research Project No. 63-7S, August 1965.
18. Durability of Lightweight Concrete - Phase III. Hollis B. Rushing, Research Project No. 61-8C, August 1965.
19. Compaction of Asphaltic Concrete Pavement with High Intensity Pneumatic Roller, Part II - Densification Due to Traffic. S. C. Shah, Research Project No. 61-7B, October 1965.
20. A Rapid Method of Soil Cement Design, Part II - Evaluation. C. M. Higgins, A. S. Kemahlioglu, and Verdi Adam, Research Project No. 61-8S, May 1966.
21. Typical Moisture - Density Curves, Part II, Lime Treated Soils, C. M. Higgins, Research Project No. 61-11S, May 1966.

Louisiana
DEPARTMENT OF HIGHWAYS
P. O. BOX 4245, CAPITOL STATION
BATON ROUGE, LA. 70804

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May 18, 1966

TYPICAL MOISTURE-DENSITY CURVES
PART II, LIME TREATED SOILS
RESEARCH PROJECT NO. 63-11S
LOUISIANA HPR 1(3)

Mr. F. E. Hawley
Division Engineer
Bureau of Public Roads
3444 Convention Street
Baton Rouge, Louisiana

Dear Mr. Hawley:

Enclosed are six copies of the final draft of the final report for the captioned project entitled TYPICAL MOISTURE-DENSITY CURVES, PART II, LIME TREATED SOILS.

This is being submitted for your review and approval prior to publication.

Yours very truly,

Verdi Adam
Research and Development Engineer

CMH:skw
cc: Mr. Grady Carlisle
Mr. C. J. Crouse, Sr. (2)
Soils Project Advisory Committee

LOUISIANA HIGHWAY RESEARCH

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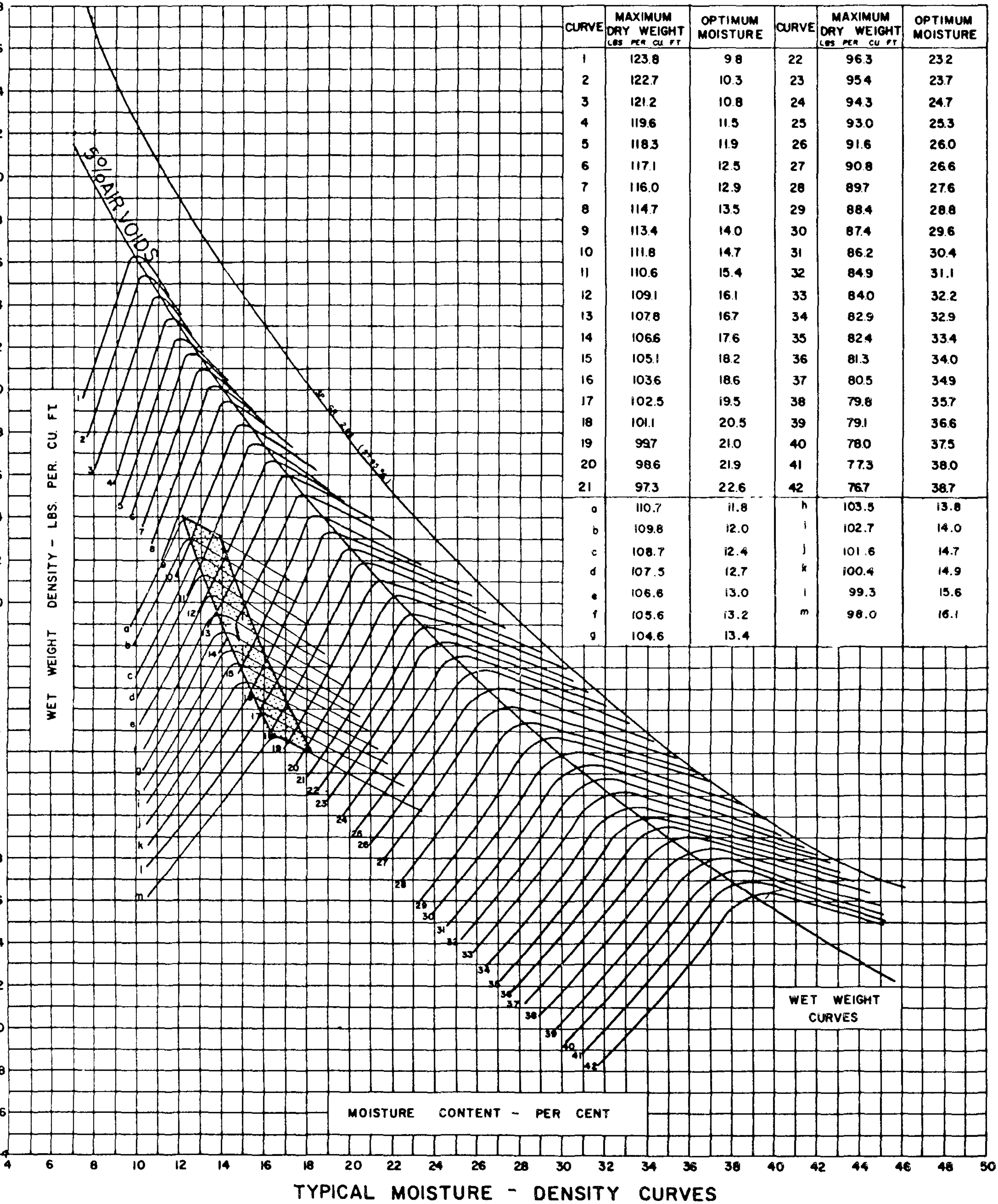

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2. The apparatus shall consist of the following:

(a) Mold - A cylindrical metal mold having a capacity of 1/30 cu. ft. (0.0333 cu. ft.) with an internal diameter of 4.0 inches (± 0.005 in) and a height of 4.584 ± 0.005 inches, which has a detachable collar approximately 2 1/2 inches in height. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base plate. Molds shall be replaced if the diameter is more than 4.01 inches or the height is less than 4.50 inches on any side.

(b) Compactive Device - A metal rammer having a 2.00 ± 0.01 inch diameter circular face or a segment of a 2-inch radius circle with an equivalent area and weighing 5.50 ± 0.05 lb. The rammer shall be equipped with an arrangement to control the height of drop to 12.0 ± 0.1 inches.

(c) Straightedge - A steel straightedge

(d) Balances - A balance or scale of 25 lb. capacity sensitive to 0.01 lb. (or equivalent metric balance), and a 500 gram capacity balance sensitive to 0.1 gram.

(e) Drying Apparatus - A thermostatically controlled drying oven set so as not to exceed 230°F for drying moisture samples. A hot plate or an approved Speedy Moisture Device may be used for moisture determinations in the field.

(f) Sieve - A number 4 sieve conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (AASHO Designation: M 92).

(g) Mixing Tools - Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc. or a suitable mechanical device for mixing thoroughly the sample of soil with water.

(h) Graduated Cylinder (250 cc) - For measuring water to be added to sample. (For Central Laboratory and Dist. Labs.)

SAMPLE

3. (a) A representative sample of soil or soil and lime mixture weighing approximately 6 lbs. (or 2724 grams) shall be taken for each one-point Proctor.

PROCEDURE

4. (a) The 6 lb. sample shall be thoroughly mixed with sufficient water to bring the sample to slightly less than its optimum moisture content.

A compacted specimen shall then be formed by compacting the thoroughly mixed sample in the mold (with collar attached) in three equal layers to give a total compacted depth of about 5 inches; each layer being compacted by 25 blows of the rammer dropping free from a height of 12 inches or 12 inches above the approximate elevation of each finally compacted layer when a stationary mounted type of rammer is used. During compaction the mold shall rest on a uniform, rigid foundation. The blows shall be uniformly distributed over the surface of the layer being compacted. After the specimen has been compacted, the collar shall be removed from the mold and the compacted specimen carefully trimmed even with the top of the cylinder by means of a straightedge.

(b) The mold containing the compacted soil specimen shall be weighed. This weight minus the weight of the mold shall then be multiplied by 30 and the result recorded as the wet weight per cubic foot of compacted material.

(c) The base plate shall be detached and the specimen removed from the mold. A representative sample shall be taken from a location near the center of the specimen.

(d) For moisture content determination in the field a 200 gram sample shall be secured as described in "c", weighed immediately and dried to a constant weight by use of a hot plate.

(e) An approved speedy moisture device may be used to determine the moisture content in the field.

(f) For moisture content determination in the Central or District Laboratories not less than a 100 gram sample shall be secured as in "c". This sample shall be weighed immediately and dried in an oven at 110° ± 5° C (230° ± 9° F) to a constant weight.

CALCULATIONS

5. The water content of the soil as compacted shall be calculated as follows:

$$W = \frac{(W_1 - W_2) \times 100}{W_2}$$

where:

W = Moisture content in percent based on weight of oven-dry soil.

W_1 = Weight of wet soil.

W_2 = Weight of oven-dry soil.

MOISTURE-DENSITY RELATIONSHIP AS DETERMINED FROM THE FAMILY OF TYPICAL MOISTURE-DENSITY CURVES

6. The calculations in section 4(b) and in section 5 shall be made to determine the wet density in lbs/cu. ft. and the corresponding water content. These determine a point which may now be plotted on the Family of Curves and extrapolated to arrive at a maximum wet weight and optimum moisture content. When this point falls between two family curves, a minor interpolation is necessary. The maximum dry density in lbs/cu. ft. and the corresponding per cent optimum moisture is then read from the chart or interpolated from the chart (Figure 7).

PRECAUTIONS

7. (a) Any point falling to the left of Area 1 applies to the supplemental (a-m) portion of the family. Any point falling in area one should be repeated using fresh material at a higher moisture content. If the density value for this point decreases the point previously run may be used to pick a curve from the (a-m) portion of the family. If the density value for the second point rises the proper

curve may be selected from the major (1-42) portion of the family using this point.

(b) The maximum wet density and optimum moisture point should be on the dry side of the curve at or near optimum as it is difficult to interpolate between curves for friable soils when on the wet side of the peak.

(c) When the moisture density values of a compacted material are plotted and found to be to the right of the 5.0% air voids curve, the test should be repeated using a lower moisture content. An exception to this rule must be made for those soils having high clay contents and relatively flat curves. These soils cannot readily be dried to optimum in the field due to the creation of a cloddy condition which will cause voids in the proctor. Proctors for these materials should be made as near to optimum as practicable. When the moisture density value of a compacted material is plotted and found to be to the right of the 95% saturation line the test should be repeated using a new sample.

In the event the result obtained on the "check" is found to be similar to the original, a complete curve shall be run on the material in question using LDH Designation: TR 418.

Example:

Suppose after running a one point density the results are: wet density = 118.0 lbs/cu. ft., moisture content = 18.0%. By plotting this point on the Family of Curves and extrapolating to the peak, it shows a point which is approximately 1/2 way between curves 17 and 18. From the chart the dry density for 17 = 102.5 at 19.5% moisture content and 18 = 101.1 at 20.5% moisture content. By interpolation:

102.5 - 101.1 = 1.4 x .50 = 0.7 lbs/cu. ft. difference in density and;

20.5% - 19.5% = 1.0% x .50 = 0.5% difference in moisture content, thus;

102.5 - 0.7 = 101.8 or 101.1 + 0.7 = 101.8 lbs/cu. ft. and 20.5 - 0.5 = 20% or 19.5 + 0.5 = 20% moisture content, therefore;

maximum dry density = 101.8 lbs/cu. ft.
optimum moisture = 20%