Method of Test for

DETERMINATION OF THE PERCENTAGE OF LIME FOR TREATMENT OF SOILS OR SOIL-AGGREGATE MIXTURES

DOTD Designation: TR 416

I. Scope

A. This method of test is designed to determine the minimum percentage of hydrated or quicklime to be added to a soil or soil-aggregate mixture.

B. Reference Documents

1. DOTD TR 403 - Determination of Moisture Content
2. DOTD TR 407 - Mechanical Analysis of Soils
3. DOTD TR 411 - Dry Preparation of Disturbed Samples for Test
4. DOTD TR 418 - Moisture -Density Relationships
5. DOTD TR 423 - Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
6. DOTD TR 428 - Determining Atterberg Limits of Soils

Note 1: *Some soils may not react satisfactorily with lime. For such soils, lime treatment may not be effective.*

II. Apparatus

A. Mold

1. A cylindrical metal mold, having a capacity of 1/30 cu ft., with an internal diameter of 4.000±0.016 in. and a height of 4.584 ±0.005 in., and with a detachable collar approximately 2.5 in. in height, which can be fastened firmly to a base plate.
2. Molds shall be replaced if any diameter is more than 4.024 in. or the height is less than 4.550 in. at any point.

Note 2: *Different makes of compactive devices may use mold base plates of different designs. The mold base plate must be compatible with the make of compactive device used.*

B. Compactive device

1. Automatic Rammer: a metal 5.50 ± 0.05 lb. rammer, with a striking face that is a 3.1416 sq. in. sector face for use with a 4 in. Inside diameter mold and arranged to control the height of drop to 12.00±0.06 in.
2. Manual Rammer: A metal 5.50±0.05 lb. rammer with a circular striking face with a diameter of 2.00±0.01 in. and arranged to control the height of drop to 12.00 ± 0.06 in.

C. Scale - sensitive to 0.01 lb. or .1 g

D. Sieve - 1/2 in. sieve conforming to the requirements of the Standard Specification for Wire Cloth Sieves for Testing Purposes (AASHTO Designation: M 92).

E. Tools

1. Mixing pans with appropriate covers.
2. Drying pan.
3. Spoons.
4. Trowel or Spatula.

F. Graduated Cylinders - incremented in ml.

G. Wax paper - if applicable.

H. Hydrated lime**.**

Note 3: *Hydrated lime shall meet DOTD specifications. A unit weight of 35 lb. /cu ft. shall be used.*

I. Plastic bags.
J. Personal Protective Equipment -
   1. Respirator.
   2. Gloves.
   3. Apron.
   4. Goggles.
K. Extrusion apparatus - mechanical device for removing the compacted soil from the mold consisting of a closed cylindrical sleeve slightly less than 4.0 in. in diameter or a piston of the same diameter, actuated mechanically, hydraulically or pneumatically.
L. Moist-curing room - with 95% minimum relative humidity.
M. Engineer's Curve - Dietzgen 2152-21 or equivalent.
N. Lime Treatment Worksheet - DOTD Form No. 03·22·4192. (Figure 1)
O. Additive Conversion Chart. (Figure 2)
P. Soils/Soil-Aggregate Form - DOTD Form No. 03·22-0723. (Figure 3)

III. Health Precautions

A. Care must be taken not to allow lime to contact skin or to inhale its reaction fumes. Proper equipment and precautions are to be used whenever hot materials or equipment must be handled.

IV. Sample

A. Obtain approximately 10 lb. of soil or 30 lb. of soil-aggregate mixture sealed in plastic bags, which have been placed in friction top cans and maintained in field condition.

Note 4: *If the maximum dry weight density end Atterberg Limits of this materiel have not been determined in accordance with DOTD TR 418 end DOTD TR 428, additional materiel will be required.*

V. Procedure

A. Determine the Atterberg Limits of the material in accordance with DOTD TR 428. Record the Liquid Limit, Plastic Limit, and Plasticity Index as LL, PL, and PI, respectively on the worksheet. Identify the specification requirements for Liquid Limit (If applicable) and Plasticity Index and record on the worksheet.
B. Determine the maximum dry weight density and the optimum moisture content in accordance with the applicable method of DOTD TR 418 and record on the worksheet.

Note 5: *If the Atterberg Limits, maximum dry weight density, and optimum moisture content have been previously determined for this materiel, those values may be used.*

C. Determine the moisture content of the sample in accordance with DOTD TR 403. Record as MC on the worksheet.
D. Weigh the remaining portion and record the wet weight of test sample as A on the worksheet.
E. Determine the dry weight of the test sample in accordance with Step VI. A. and record as B on the worksheet.
F. Determine the weight of the test sample at its Plastic Limit in accordance with Step VI.B. Record as C on the worksheet.
G. Adjust the weight of the test sample as described below and record as D on the worksheet.
   1. If the moisture content determined in Step C is equal to the PL ±2 %, proceed to Step I.
   2. If the moisture content determined in Step C is more than 2% above the PL, allow the sample to air dry at ambient room temperature or dry In an oven at no more than 140°F (60°C) until

the weight is within ± 2% of the weight determined in Step F. If the material dries to more than 2% below the weight determined in Step F, proceed with Step 3.

3. If the moisture content determined in Step C is greater than 2% below the Plastic Limit, add water and thoroughly mix until the weight is equal to the weight determined in Step F. Place the test sample in a plastic bag, seal, and place in the moist-curing room for a minimum of 30 minutes. After 30 minutes, remove material from bag.

H. Determine the moisture content of the test sample after the adjustments in Step G, in accordance with Step VI. C and record as E on the worksheet.

I. Break up soil clods with fingers until entire sample passes a 1/2 in. sieve. Use minimum pressure when breaking soil clods to prevent sealing the broken faces. Discard any aggregate.

J. Obtain at least 5 test specimens weighing approximately 500 g each. Record the wet weight of each test specimen on the worksheet as F. Place each test specimen in a plastic bag, seal, and protect from moisture loss.

K. Calculate the weight of lime needed to add 1.0% lime by dry weight to the first test specimen in accordance with Step VI. D. Record the weight as G for the appropriate test specimen number on the worksheet. Add and thoroughly mix 1.0% lime into the first test specimen.

L. Place the test specimen mixed with lime into the mold in one layer. Compact it using 15 blows of the rammer.

M. Extrude the sample, place in a plastic bag, seal, and place in moist-curing room for a minimum curing period of 72 hours.

N. Repeat Steps K-M for the four additional test specimens, substituting 2.0%, 3.0%, 4.0%, and 5.0% lime by weight for the 1.0% in Step K.

O. At the end of the curing period, remove the compacted test specimens from the plastic bags. Crumble each test specimen into a drying pan. Dry and prepare the test specimens in accordance with DOTD TR 411.

P. Determine the Atterberg Limits for each test specimen in accordance with DOTD TR 428 and record the Liquid Limit, Plastic Limit, and Plasticity Index as LL_n, PL_n, and PI_n on the worksheet.

VI. Calculations

A. Calculate the dry weight of the test sample (B) in g using the following formula:

$$B = \frac{A}{100 + MC} \times 100$$

Where:

A = wet wt. of test sample, g
MC = moisture content of sample, %
100 = constant

Example:

A = 4316.8
MC = 11.0

$$B = \frac{4316.8}{100 + 11.0} \times 100 = \frac{4316.8}{111.0} \times 100$$

$$= 38.89009 \times 100$$
$$B = 3889.0$$

B. Calculate the weight of the test sample at its Plastic Limit (C) in g using the following formula:

$$C = B\left(\frac{100 + PL}{100}\right)$$

Where:
B = dry wt. of test sample, g
PL = Plastic Limit
100 = constant
Example:
B = 3889.0
PL = 25

$$C = 3889.0\left(\frac{100 + 25}{100}\right) = 3889.0\left(\frac{125}{100}\right)$$

$$= 3889.0(1.25)$$
$$C = 4861.2$$

C. Calculate the moisture content of the test sample (E) in % after the adjustment in Step V. G. using the following formula:

$$E = \frac{D - B}{B} \times 100$$

Where:
B = dry wt. of test sample, g
D = wt. of test sample after adjustment, g
100 = constant
Example:
B = 3889.0
D = 4772.2

$$E = \frac{4772.2 - 3889.0}{3889.0} \times 100 = \frac{883.2}{3889.0} \times 100$$

$$= 0.22710 \times 100$$
$$E = 22.7$$

D. Calculate the weight for each percentage of lime (by weight) to be added to a test specimen (G) in g using the following formula:

$$G = \left(\frac{F}{100 + E}\right)n$$

Where:
F = wt. of test specimen, g
E = moisture content of test specimen, %
n = lime by dry weight, %
100 = constant
Example:
F = 514.7
E = 22.7
n = 3.0

$$G = \left(\frac{514.7}{100 + 22.7}\right)3.0 = \left(\frac{514.7}{122.7}\right)3.0$$

$$= (4.1948)3.0 = 12.584$$

$$G = 12.6$$

E. Beginning with the lowest percent lime by weight (n), plot the point on the worksheet which represents the Intersection of a horizontal line projected from the percent lime by weight and a vertical line projected from the Liquid Limit (LL_n). Continue for each percent lime by weight until all points for Liquid Limit have been plotted. Repeat the process for each percent lime by weight, substituting the Plasticity Index (PI_n) for Liquid Limit.
F. Form a smooth line, using the engineer's curve, by connecting the plotted points to form two curves, Percent Lime by Weight vs. Liquid Limit, and Percent Lime by Weight vs. Plasticity Index. (Refer to the Lime Treatment Worksheet.)
G. Determine the recommended percent's lime by weight for the Liquid Limit and Plasticity Index, by identifying the minimum percent lime for each property which will produce a material which meets specification requirements. Record this data on the worksheet.
H. Determine the percent lime by volume from the Additive Conversion Chart in accordance with the following steps. When two different percentages of lime have been determined in Step G, use the higher of the two. Record the percent lime by volume on the worksheet and the Soils/Soil-Aggregate Form.

Note 6: *The additive conversion formula In DOTD TR 418, Method 8, with a lime unit weight of 35 lb. /cu ft. may be used In lieu of the Additive Conversion Chart.*

1. Enter the chart on the left scale. Reading vertically, place a point at the appropriate maximum dry weight density of the soil or soil-aggregate.
2. Re-enter the chart on the center scale. Reading vertically, place a point at the selected percent by weight of lime.
3. Draw a straight line across the chart connecting the two points plotted in Steps 1 and 2 and extend the line until it intersects the right scale.
4. Read the percent by volume directly from the intersection of the extended line and the right scale.
5. Record on the worksheet and on the Soils/Soil-Aggregate Form.

VII. Report

Report the minimum percent lime by volume, which will produce a material meeting specification requirements on the Soils/Soil-Aggregate Form. Round any partial percent to the next higher whole percentage.

VIII. Normal Test Reporting Time

Normal test reporting time is 7 days.

DOTD 03-22-4192

Louisiana Department of Transportation and Development
MATERIALS AND TESTING SECTION

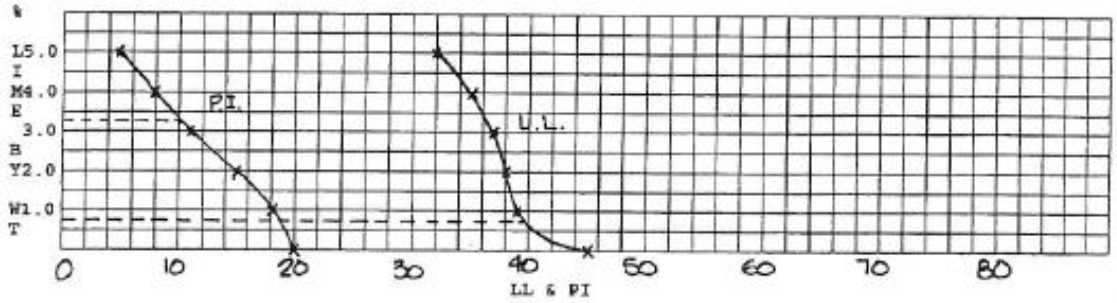
DETERMINATION OF THE PERCENTAGE OF LIME TREATMENT OF SOILS OR SOIL-AGGREGATE MIXTURES (DOTD TR 416)

PROJECT NO.: 999-99-9999 DATE: 1-4-93 LAB. NO.: 22-999999
TYPE SOIL: Heavy Clay SAMPLE NO.: C-1 SPEC., LL: 40 PI: 10
TESTED BY: JBW CHECKED BY: NDH

Liquid Limit (From DOTD TR 428)	LL		45
Plastic Limit (From DOTD TR 428)	PL		25
Plasticity Index (From DOTD TR 428)	PI		20
Max. Dry Weight Density (__ TR 418, __ TR 415-A), lb/ft³	****		97.3
Optimum Moisture Content, %	****		22.6
Moisture Content of Sample (From DOTD TR 403), %	MC		11.0
Wet Weight of Test Sample, lb or g	A		4316.8
Dry Weight of Test Sample, lb or g	B	[A/(100 + MC)] x 100	3889.0
Weight of Test Sample @ Plastic Limit, lb or g	C	B x [(100 + PL)/100]	4861.2
Weight of Test Sample After Adjustment, lb or g	D		4772.2
Moisture Content of Test Sample After Adjustment, %	E	[(D-B)/B] x 100	22.7

Test Specimen No.	***		1	2	3	4	5	6
Wet Weight of Test Specimen, g	F		509.1	515.2	514.7	508.0	511.6	
Lime By Dry Weight, %	n		1.0	2.0	3.0	4.0	5.0	
Weight of Lime Added to Test Specimen, g	G	$\frac{F}{100+E} \times n$	4.1	8.4	12.6	16.6	20.8	
Liquid Limit	LL_n		39	38	37	35	32	
Plastic Limit	PL_n		21	23	26	27	27	
Plasticity Index	PI_n		18	15	11	8	5	

GRAPH OF LL & PI vs. LIME BY WEIGHT



Recommended % Lime by Weight - LL: 1
Recommended % Lime by Weight - PI: 4
Recommended % Lime by Volume: 11

Figure 1
Lime Treatment Worksheet

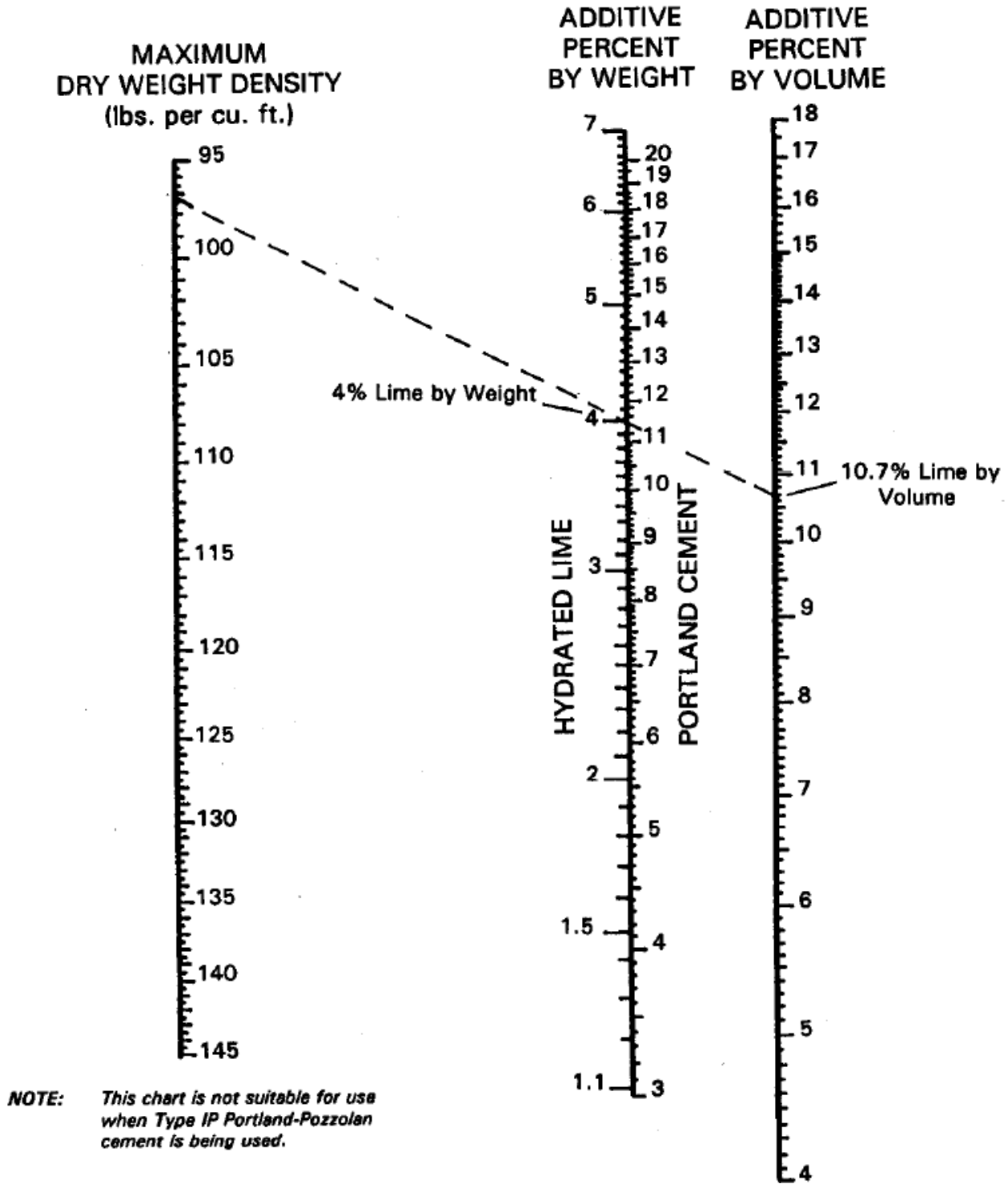
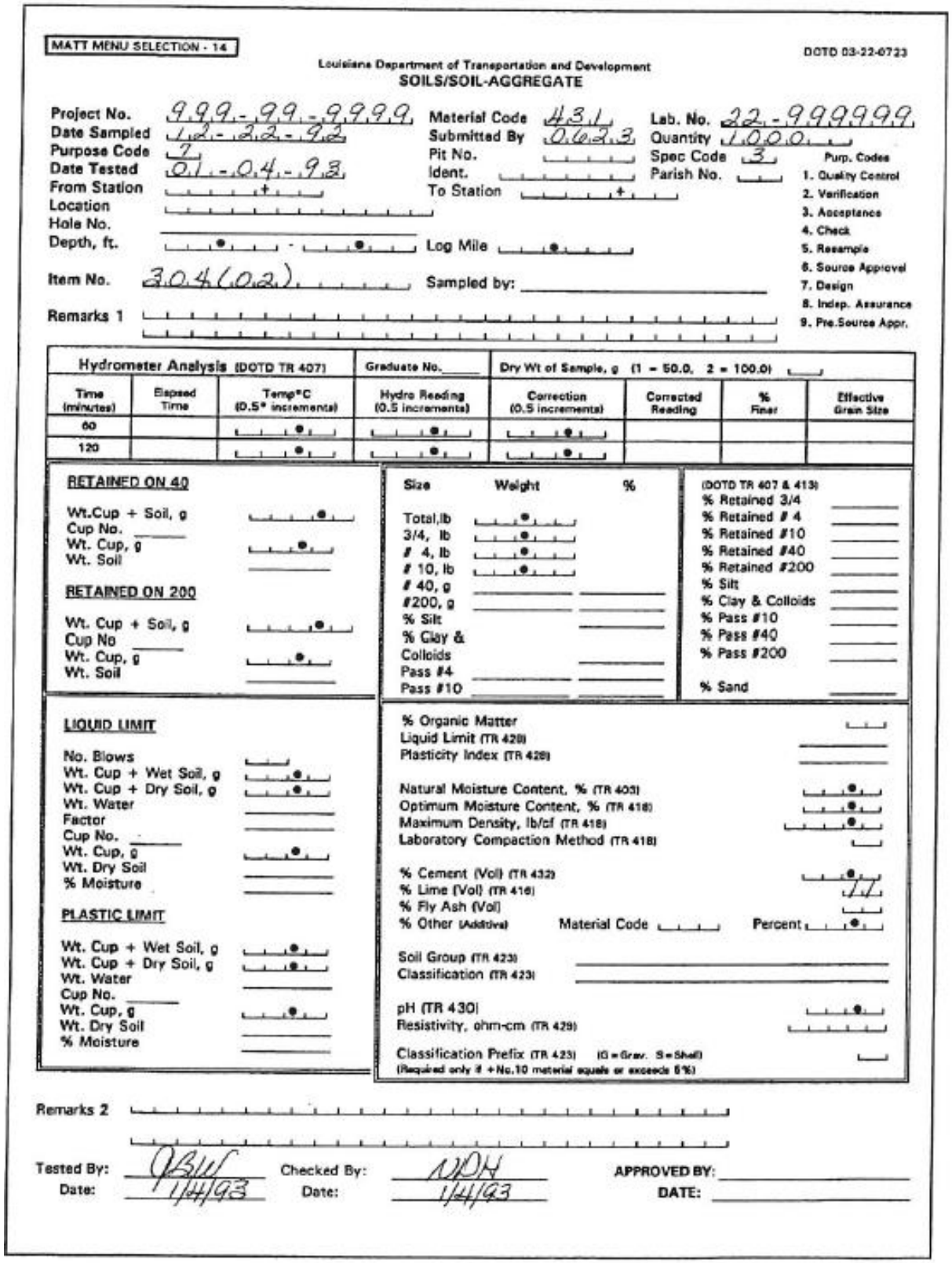


Figure 2
Additive Conversion Chart
Relation in percent by weight of oven-dry soil, soil aggregate, or aggregate to design percent by volume



MATT MENU SELECTION - 14

DOTD 03-22-0723

Louisiana Department of Transportation and Development

SOILS/SOIL-AGGREGATE

Project No. 999-99-9999 | Material Code 431 | Lab. No. 22-999999
Date Sampled 12-22-92 | Submitted By 062 3 | Quantity 1000
Purpose Code 2 | Pit No. | Spec Code 3
Date Tested 01-04-93 | Ident. | Parish No.
From Station + | To Station +
Location
Hole No.
Depth, ft. - | Log Mile
Item No. 304(02) | Sampled by:
Remarks 1

Purp. Codes
1. Quality Control
2. Verification
3. Acceptance
4. Check
5. Resample
6. Source Approval
7. Design
8. Indep. Assurance
9. Pre.Source Appr.

Hydrometer Analysis (DOTD TR 407) | Graduate No. | Dry Wt of Sample, g (1 = 50.0, 2 = 100.0)

Time (minutes)	Elapsed Time	Temp°C (0.5° increments)	Hydro Reading (0.5 increments)	Correction (0.5 increments)	Corrected Reading	% Finer	Effective Grain Size
60							
120							

RETAINED ON 40

Wt.Cup + Soil, g
Cup No.
Wt. Cup, g
Wt. Soil

RETAINED ON 200

Wt. Cup + Soil, g
Cup No
Wt. Cup, g
Wt. Soil

Size	Weight	%
Total,lb		
3/4, lb		
# 4, lb		
# 10, lb		
# 40, g		
#200, g		
% Silt		
% Clay & Colloids		
Pass #4		
Pass #10		

(DOTD TR 407 & 413)
% Retained 3/4
% Retained # 4
% Retained #10
% Retained #40
% Retained #200
% Silt
% Clay & Colloids
% Pass #10
% Pass #40
% Pass #200

% Sand

LIQUID LIMIT

No. Blows
Wt. Cup + Wet Soil, g
Wt. Cup + Dry Soil, g
Wt. Water
Factor
Cup No.
Wt. Cup, g
Wt. Dry Soil
% Moisture

PLASTIC LIMIT

Wt. Cup + Wet Soil, g
Wt. Cup + Dry Soil, g
Wt. Water
Cup No.
Wt. Cup, g
Wt. Dry Soil
% Moisture

% Organic Matter
Liquid Limit (TR 428)
Plasticity Index (TR 428)

Natural Moisture Content, % (TR 403)
Optimum Moisture Content, % (TR 418)
Maximum Density, lb/cf (TR 418)
Laboratory Compaction Method (TR 418)

% Cement (Vol) (TR 432)
% Lime (Vol) (TR 416) 11
% Fly Ash (Vol)
% Other (Additive) Material Code Percent

Soil Group (TR 423)
Classification (TR 423)

pH (TR 430)
Resistivity, ohm-cm (TR 429)

Classification Prefix (TR 423) (G = Grav. S = Shell)
(Required only if +No.10 material equals or exceeds 5%)

Remarks 2

Tested By: JBW | Checked By: NDH | APPROVED BY:
Date: 1/4/93 | Date: 1/4/93 | DATE:

Figure 3
Soils/Soil-Aggregate Form