

SB201 Strength Specialist

TABLE OF CONTENTS

1. Rights and Responsibilities
2. Website
3. Tex-100-E Surveying and Sampling Soils for Highways
4. Tex-101-E Preparing Soil and Flexible Base Materials for Testing (Part 2)
5. Tex-113-E Determination of Moisture-Density Relationships of Soils and Base Materials
6. Tex-114-E Laboratory Compaction Characteristics and Moisture-Density Relationship of Subgrade and Embankment Soils
7. Tex-120-E Soil-Cement Testing
8. Tex-121-E Soil-Lime Testing
9. Tex-142-E Laboratory Classification of Soils for Engineering Purposes
10. Tex-400-A Sampling Stone, Gravel, Sand and Mineral Aggregates
11. Tex-600-J Sampling and Testing Lime (Part 1)
12. Item 247 Flexible Base

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HMAT CERTIFIED SPECIALIST & APPLICANTS FOR CERTIFICATION: RIGHTS AND RESPONSIBILITIES

This agreement (the "Agreement") affirms that, _____, the below Applicant for Certification or the current Certified Specialist (collectively, the "Specialist") seeks to meet or has successfully met the requirements for certification by the Texas Asphalt Pavement Association ("TXAPA"), a/k/a the Hot Mix Asphalt Center (HMAC) as a certified technician. In that connection, the Specialist agrees as follows:

RIGHTS AND RESPONSIBILITIES - HMAC certification includes the exclusive right to perform certified sampling, testing and reporting on Texas Department of Transportation (TxDOT) projects involving Hot Mix Asphalt (HMA) and Soils & Base (SB) in accordance with TxDOT specifications and test procedures (as may be amended by TxDOT from time to time) for the level of certification issued. Specialists are required to perform and report test results with the accuracy and precision required of a certificated HMA or SB Specialist. It is important that the Specialist fully understands the significance of performing these duties in accordance with the certification level received by the Specialist.

Each Specialist is responsible for performing their own independent sampling, testing and reporting in accordance with TxDOT specifications, test procedures and standard operating procedures. These duties must be performed in a diligent and professional manner to produce TxDOT projects of the highest possible quality.

CONTACT INFORMATION - It is the Specialist's responsibility to provide the HMAC with current contact information by logging into www.txhmac.org. Communications from the HMAC will primarily be sent electronically to the most recent contact information provided by the Specialist.

ANNUAL PROFICIENCY - Once certified, Specialists are required to complete annual proficiency testing and the reporting of results to the HMAC. The testing and reporting must be timely and independently performed by the Specialist and, where applicable, in conformance with the requirements of the Specialist's certifications. TxDOT will ship the annual proficiency samples to the Specialist's address of record. (If this address is not current, the Specialist may not timely receive a proficiency sample and his/her certification may be danger of lapsing.)

Failure to submit proficiency test results or to respond to low rating(s) by the appointed deadlines may result in a change of certification status from active to inactive. Specialists whose certifications are inactivated because their annual proficiency testing/reporting is not current or whose certifications have been revoked or inactivated are prohibited from performing the duties associated with all certifications held by that Specialist.

RECERTIFICATION - Certification(s) are valid for three (3) years from the date originally issued, after which the Specialist must be recertified by again passing the requirements for certification. Specialists may seek recertification up to one year prior to the expiration of their certificate(s).

Failure to timely obtain recertification will cause all dependent certifications held by a Specialist to be inactivated. It is the Specialist's responsibility to maintain an active certification(s). (The HMAC will not provide reminders of pending expiration dates.)

ALLEGATIONS OF MISCONDUCT - Allegations of misconduct should be submitted to the HMAC, P.O. Box 149, Buda, TX 78610 and must include the name, address and signature of the individual asserting the allegations as well as a brief description of the allegations.

If the allegations are properly submitted and appear to have merit, the HMAC Steering Committee (the "Committee") the individual asserting misfeasance and the person so accused will be asked to meet in person (but at separate dates/times) with members of the Committee. At the conclusion of the meeting(s), the Committee will issue its determination.

Misconduct generally consists of (i) neglect, (ii) abuse and/or (iii) breach of trust which are generally defined as:

1. Neglect: unintentional deviation(s) from specifications or testing procedures;
2. Abuse: careless or deliberate deviation from specifications or testing procedures; and
3. Breach of Trust: violation of the trust placed in Certified Specialists including, but not limited to, acts such as:
 - a. Falsification of or deliberate omission from material records or information; or
 - b. Awareness of improprieties in sampling, testing and/or production by others and the failure to timely report those improprieties to the appropriate project supervision.

The Committee may issue written reprimands (private or public) and/or revoke or inactivate a certification (if the Specialist has made a false representation or misstatement to the Committee or to the public or has engaged in misconduct) or take such other actions as the Committee, in its sole discretion, determines to be appropriate with respect to the Specialist's certification(s).

Specialists who do not achieve recertification or whose certification is revoked or inactivated by the Committee may appeal to a separate appeals committee comprised of industry members (the "Appeal Committee"). The exhaustion of this right of appeal to the Appeal Committee is a prerequisite to the exclusive remedy of administrative review by final and binding arbitration in Hays County, Texas, as administered by the American Arbitration Association by a single-member panel. Any and all other claims related in any way to this Agreement are exclusively subject to final and binding arbitration in Hays County, Texas as administered by the American Arbitration Association by a single-member panel.

In consideration for the HMAC certification/recertification process, Specialist hereby waives any and all claims of whatsoever kind or character related, directly or indirectly, to this Agreement, against the TXAPA, HMAC (including, but not limited to, the Committee and the Appeal Committee and their members), that s/he may have (including claims for attorney's fees) and further agrees to save, indemnify and hold TXAPA, the HMAC (including, but not limited to, the Committee and the Appeal Committee and their members) harmless from any claim, action or cause of action arising as a result of, or relating to this Agreement including, but not limited to, Specialist's certification, or any refusal, reprimand, revocation and/or suspension of certification or recertification of Specialist.

ACKNOWLEDGED & AGREED:

SPECIALIST:

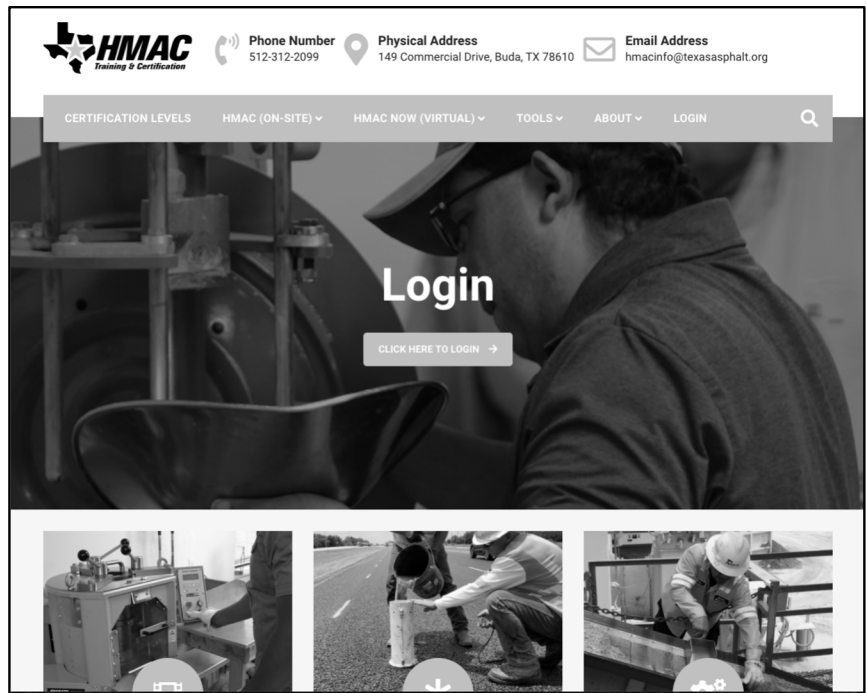
SIGNATURE

DATE

PRINTED NAME



**IT IS YOUR
RESPONSIBILITY
TO KEEP YOUR
INFORMATION
UP TO DATE**



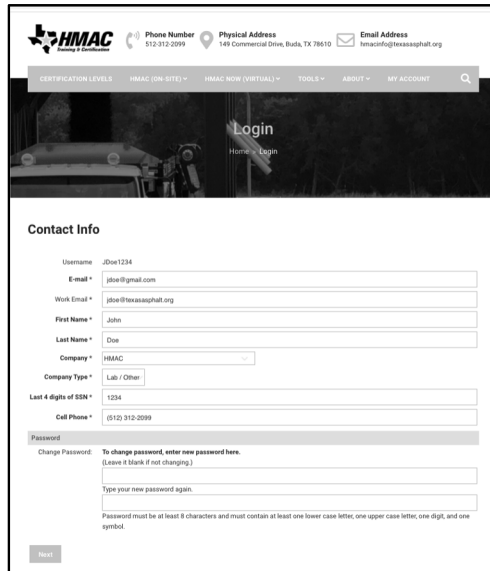
FIRST TIME LOGIN

- Username: Capitalize the **FIRST LETTER OF YOUR FIRST AND LAST NAME** then spell out the rest of your last name in lower case, followed by the last 4 digits of your SSN.
- Password: The same but add a "+" at the end.

Example: John Doe
Username: **JDoe1234**
Password: **JDoe1234+**

UPDATE INFORMATION

- Verify that all information is correct.



HMAC Phone Number 512-312-2099 Physical Address 149 Commercial Drive, Buda, TX 78610 Email Address hmactinfo@texasasphalt.org

CERTIFICATION LEVELS HMAC (ON-SITE) HMAC NOW (VIRTUAL) TOOLS ABOUT MY ACCOUNT

Login
Home > Login

Contact Info

Username jbow1234
 E-mail * jbow@gmail.com
 Work Email * jbow@texasasphalt.org
 First Name * John
 Last Name * Doe
 Company * HMAC
 Company Type * Lab / Other
 Last 4 digits of SSN * 1234
 Cell Phone * (512) 312-2099

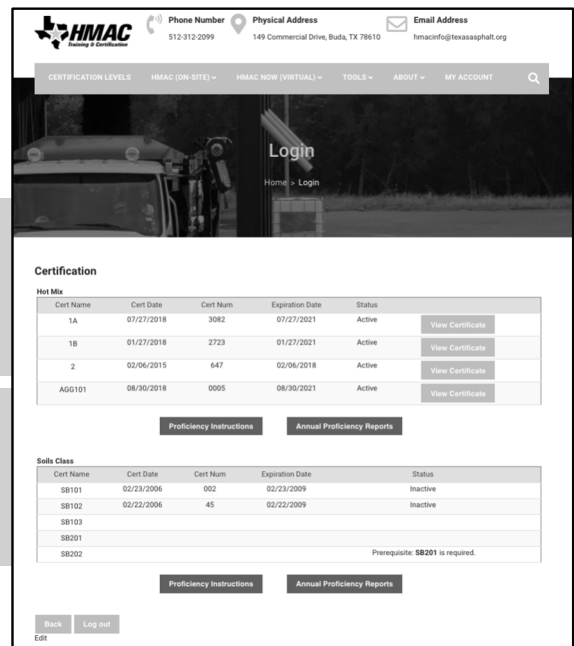
Password
 Change Password: To change password, enter new password here.
 (Leave it blank if not changing.)
 Type your new password again.
 Password must be at least 8 characters and must contain at least one lower case letter, one upper case letter, one digit, and one symbol.

Next

UPDATE INFORMATION

VIEW/PRINT
CERTIFICATIONS

PROFICIENCY



HMAC Phone Number 512-312-2099 Physical Address 149 Commercial Drive, Buda, TX 78610 Email Address hmactinfo@texasasphalt.org

CERTIFICATION LEVELS HMAC (ON-SITE) HMAC NOW (VIRTUAL) TOOLS ABOUT MY ACCOUNT

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Certification

Cert Name	Cert Date	Cert Num	Expiration Date	Status	
1A	07/27/2018	3082	07/27/2021	Active	View Certificate
1B	01/27/2018	2723	01/27/2021	Active	View Certificate
2	02/06/2015	647	02/06/2018	Active	View Certificate
AGG101	08/30/2018	0005	08/30/2021	Active	View Certificate

[Proficiency Instructions](#) [Annual Proficiency Reports](#)

Soda Class

Cert Name	Cert Date	Cert Num	Expiration Date	Status
SB101	02/23/2006	002	02/23/2009	Inactive
SB102	02/23/2006	45	02/23/2009	Inactive
SB103				
SB201				
SB202				

Prerequisite: SB201 is required.

[Proficiency Instructions](#) [Annual Proficiency Reports](#)

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Test Procedure for

SURVEYING AND SAMPLING SOILS FOR HIGHWAYS



TxDOT Designation: Tex-100-E

Effective Date: August 1999

1. SCOPE

- 1.1 This method provides definitions of some basic terms and describes the procedures for surveying and sampling soils for highways. It describes the information required from the survey and the sampling methods required, and it discusses the apparatus necessary to carry out the sampling process.
 - 1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.
-

2. DEFINITIONS

- 2.1 *Aggregate*—Aggregate is granular material of mineral composition such as sand, gravel, shell, slag, crushed stone or lightweight. Aggregate may be used with a cementing medium to form mortars or concrete, or alone in base courses or as a surface treatment.
 - 2.2 *Bank Gravel*— Bank Gravel is found in natural deposits, usually intermixed with fine material, such as sand or clay, or combinations thereof; the terms “gravelly clay,” “gravelly sand,” “clayey gravel,” or “sandy gravel” indicate the varying proportions of the materials in the mixture.
 - 2.3 *Blast Furnace Slag*—Blast furnace slag is a non-metallic by-product, developed in a blast furnace simultaneously with iron in a molten condition, essentially consisting of silicates and alumina-silicates of calcium and other bases.
 - 2.4 *Bottom Ash*—Bottom Ash is the heavy residue from the combustion of ground or powdered coal or lignite.
 - 2.5 *Clay*—Clay is a fine grained soil that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry.
 - 2.6 *Clay Size*—Clay size refers to any material finer than 0.002 mm (2 μ m), though not necessarily exhibiting clay characteristics.
-

- 2.7 *Coarse Aggregate*—Coarse aggregate is the portion of aggregate retained on the 2.00 mm (No. 10) sieve for Bituminous Concrete or retained on the 4.75 mm (No. 4) sieve for Portland Cement Concrete.
- 2.8 *Concrete*—Concrete is a composite material consisting of a binding medium within which are embedded particles or fragments of aggregate; in hydraulic cement concrete, the binder is formed from a mixture of hydraulic cement and water.
- 2.9 *Conglomerate*—Conglomerate is the coarse grained, clastic, sedimentary accumulation of particles, composed of rounded to sub-angular fragments larger than 2 mm (0.08 in.) in diameter, set in a fine-grained matrix of sand or silt and commonly cemented by calcium carbonate, iron oxide, silica or hardened clay.
- 2.10 *Crushed Face*—Crushed face is a fractured surface produced by the mechanical crushing of an aggregate. Crushed aggregate faces are identified by fresh fractures and lack of evidence of weathering.
- 2.11 *Crushed Gravel*—Crushed gravel is the product resulting from the mechanical crushing of gravel, with substantially all fragments having at least one face resulting from a fracture.
- 2.12 *Crushed Stone*—Crushed stone is the product excavated from an in-situ deposit of rock, crushed and processed for construction purposes with substantially all faces resulting from the crushing operation.
- 2.13 *Detrital (Weathered)*—Detrital material consists of particles that have been formed through the disintegration of other particles by erosion or weathering.
- 2.14 *Fine Aggregate*—Fine aggregate is the portion of the aggregate passing the 2.00 mm (No. 10) sieve for Bituminous Concrete or passing the 4.75 mm (No. 4) sieve for Portland Cement Concrete.
- 2.15 *Fly Ash*—Fly ash is the finely divided residue from the combustion of ground or powdered coal or lignite that is transported from the firebox through the boiler by flue gases.
- 2.16 *Granite*—Granite is an igneous rock consisting of quartz and alkali feldspars.
- 2.17 *Gravel*—Gravel consists of unconsolidated or loose detrital sediment (aggregate resulting from natural disintegration and abrasion of rock) with particle sizes passing the 76.2 mm (3 in.) sieve and retained on the 2.00 mm (No. 10) sieve.
- 2.18 *Lightweight Aggregate*—Lightweight aggregate consists of expanded shale, clay, or slate, and is produced by the rotary kiln method.
- 2.19 *Limestone Rock Asphalt*—Limestone rock asphalt is limestone impregnated with naturally occurring asphalt.
- 2.20 *Lithification*—Lithification is the process of hardening, induration, and compaction of sediments, leading to the formation of solid materials.

- 2.21 *Mineral Filler*—Mineral filler is a fine aggregate or manufactured material used to supply particle sizes where the mix design is deficient in gradation.
- 2.22 *Quarry*—A quarry is an open surface excavation of minerals or construction materials.
- 2.23 *Riprap*—Riprap is quarried stone especially selected, graded, and placed to prevent erosion and thereby preserve the shape of a surface, slope, or underlying structure.
- 2.24 *Rock*—Rock is a mass of solid, naturally occurring material from an in-situ deposit, excluding conglomerates. The formation may or may not be laminated.
- 2.25 *Sand*—Sand consists of fine aggregate particles that are retained on the 75 µm (No. 200) sieve, either as natural sand resulting from natural disintegration and abrasion of rock, or as manufactured sand, which is produced by the crushing of rock, gravel, slag, etc.
- 2.26 *Sandstone*—Sandstone is sedimentary rock consisting predominantly of weathered sand-sized particles naturally cemented together.
- 2.27 *Silt*—Silt is soil passing the 75 µm (No. 200) sieve that is non-plastic or very slightly plastic and that exhibits little or no strength when air dry.
- 2.28 *Silt Size*—Silt size is any material passing the 75 µm (No. 200) sieve that is coarser than 0.002 mm (2 µm), though not necessarily exhibiting silt characteristics.
- 2.29 *Slag*—Slag is a non-metallic by-product of the smelting or refining of metals and consists of calcium and alumina-silicates.
- 2.30 *Soil*—Soil is a superficial, unconsolidated deposit of disintegrated and decomposed rock material produced by surface weathering.
- 2.31 *Source*—A source is a geographical location of naturally occurring material that can be mined or quarried from the original in-situ deposit. In the case of manufactured or by-product material, it is the location of the plant at which the material is produced.
- 2.32 *Stone*—Stone consists of crushed, angular particles of rock.
- 2.33 *Traprock*—Traprock consists of various fine-grained, dense, dark colored igneous rocks, typically basalt or diabase; also called “trap.”
- 2.34 *Virgin Material*—Virgin material is material not previously used in construction.

Note 1—The Specification Committee has approved the above definitions.

3. APPARATUS

- 3.1 Many factors, such as the nature of the terrain, the kind of material, the depth of material below the surface, the equipment available, and the use to be made of the survey information, will affect the type and amount of equipment to be used in sampling.

- 3.2 Small hand tools are satisfactory for sample collection where the materials are at a shallow depth and can be easily dug. However, if the materials are very hard, power equipment may be more economical. The only feasible method of sampling strata located at a considerable depth below the surface is the use of a power drill machine with a core or auger attachment.
- 3.3 The following equipment should suffice for ordinary conditions:
- *Sample bags and moisture cans* for disturbed samples
 - *Materials*, to maintain moisture content, and *boxes* for packing undisturbed cores
 - *Power drill rig*, with core and/or auger attachments
 - *Metallic tape*, 30 m (100 ft.) long
 - *Post hole digger, shovel, prospector's pick, other hand tools*
 - *Jackhammer and air compressor*
 - *Sample splitter or quartering cloth*
 - *Engineer's level and level rod*
 - *Stakes*
 - *Gasoline burner and pan*
 - *Ruler*, 2 m (6 ft.)
 - *Soil auger.*
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4. SOIL SURVEY

- 4.1 The soil survey is an important part of the engineering survey for the design, location and construction of a highway. The investigation should furnish the following information:
- The extent and location of each type of soil or rock in the subsurface
 - The condition of subsoils (moisture and density) upon which embankments will be constructed
 - The design of ditches and backslopes in cut sections to prevent slides
 - The location and selection of suitable material for fills, sub-grade treatment and backfill adjacent to structures
 - The location of local material for base and aggregate
 - The need for stabilization of sub-grade, sub-base and base materials
 - The supporting values of soils as foundation materials.
-

5. SAMPLING

- 5.1 A representative sample of disturbed soil consists of a combination of the various particles in exactly the same proportion as they exist in the natural ground, roadway, or pit.
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- 5.1.1 The proper method of obtaining a sample will depend on the place, the quantity of material, the proposed treatment, and tests to be performed in the laboratory.
- 5.1.2 Unless different types of materials are to be uniformly mixed in certain proportions, samples should contain only materials of like color and texture, and should not be composite of materials apparently different in character.
- 5.2 It is impossible to obtain a sample from the earth that is entirely undisturbed, because the removal of the surrounding soil releases the pressure from the specimen, which causes a certain amount of disturbance.
- 5.3 The intent of sampling, however, is to obtain a core of soil from the earth with as little disturbance as possible to the natural density, moisture content, and structural arrangement of the particles.
- 5.3.1 Such a soil core is satisfactory for all practical purposes and can be classified as an undisturbed sample of soil.

Test Procedure for

PREPARING SOIL AND FLEXIBLE BASE MATERIALS FOR TESTING



TxDOT Designation: Tex-101-E

Effective Date: January 2010

1. SCOPE

- 1.1 This method describes three procedures for preparing of soil and flexible base samples for soil constants and particle size analysis, compaction and triaxial, and sieve analysis of road-mixed material.
 - 1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.
-

2. DEFINITIONS

- 2.1 *Soil Binder*—Soil binder is any material passing the 425 μm (No. 40) sieve.
 - 2.2 *Percent Soil Binder*—Percent soil binder is equal to 100 times the ratio of the oven-dry mass of the soil binder to the oven-dry mass of the total.
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3. APPARATUS

- 3.1 *Set of standard U.S. sieves*, meeting the requirements of Tex-907-K.
 - 3.2 *Scale*, with a minimum capacity of 36 kg (80 lb.), with a minimum accuracy and readability of 5 g or 0.1% of the test load, whichever is greater.
 - 3.3 *Drying oven*, maintained at 60°C (140°F).
 - 3.4 *Crusher* (optional), which can be adjusted to produce material passing a 2.00 mm (No. 10) sieve.
 - 3.5 *Mechanical pulverizer* (optional).
 - 3.6 *Wedgewood mortar and pestle*.
 - 3.7 *Scoop*.
 - 3.8 *Small siphon tube* (optional).
-

3.9 *Sample containers, metal pans, cardboard cartons.*

3.10 *Filter paper, non-fibrous.*

3.11 *Sample splitter, quartering machine, or quartering cloth.*

3.12 *Mechanical mixer (stirring device).*

3.13 *Dispenser cup.*

3.14 *Plaster of Paris molds (optional).*

Note 1—Dry the plaster of Paris molds at a temperature not to exceed 60°C (140°F) after forming, and wash and dry after each use.

4. **MATERIALS**

4.1 *Tap water.*

5. **SAMPLE IDENTIFICATION**

5.1 Give each sample an identification number on a suitable card. This card should remain with the sample throughout the processing and testing.

PART I—PREPARING SAMPLES FOR SOIL CONSTANTS AND PARTICLE SIZE ANALYSIS

6. **SCOPE**

6.1 If only soil constants are desired, use either “Dry Preparation (Method A)” or “Wet Preparation (Method B).” However if particle size analysis or percent soil binder is also desired, use Method A. Furthermore, use Method A when preparing a referee test.

7. **PREPARING SAMPLES**

7.1 *Dry Preparation (Method A)*—to be used for analysis of soil constants, particle size, or percent soil binder, or when preparing a referee test

7.1.1 Select a representative sample according to the appropriate test method (Tex-100-E or Tex-400-A) large enough to yield at least 300 g of soil binder.

7.1.2 Dry the sample in a 60°C (140°F) oven.

7.1.3 Examine the sample by visual inspection or slake small portions in water to determine if the material has any particles larger than 425 µm (No. 40).

- 7.1.4 If the amount of aggregate larger than 425 μm (No. 40) is easily distinguishable, remove these particles by hand and proceed to Section 7.1.27.
- 7.1.5 For materials containing a considerable amount of aggregate, separate the fine loose binder from the coarse particles by sieving over a 425 μm (No. 40) sieve.
- 7.1.6 Set the soil binder passing the sieve aside to recombine with the additional binder obtained from Sections 7.1.8 through 7.1.24.
- 7.1.7 If desired, slake the total material.
- 7.1.8 Place the material to be slaked into a pan.
- 7.1.9 Cover the material completely with water and soak for a minimum of 12 hours, unless Tex-102-E determines a shorter time.
- 7.1.10 Place the empty 425 μm (No. 40) sieve into a clean pan and pour the liquid from the wet sample through it.
- 7.1.11 Transfer the wet sample to the sieve in increments not exceeding 450 g.
- 7.1.12 Pour water over the sieve until the water level is about 12.5 mm (0.5 in.) above the sample on the sieve.
- 7.1.13 Alternately agitate the sieve up and down and stir the sample by hand.
- 7.1.14 If the material retained on the sieve contains lumps that have not disintegrated, crumple any that can be broken down between thumb and fingers and wash through the sieve.
- 7.1.15 After all the soil binder appears to have passed through the sieve, hold the sieve above the pan and wash the retained aggregates clean by pouring a small amount of water over it and letting the water drain into the pan.
- 7.1.16 Transfer the retained aggregate from the sieve to a clean pan.
- 7.1.17 Repeat the procedure in Sections 7.1.10 through 7.1.16 until all of the soaked sample has been washed.
- 7.1.18 Dry the retained aggregate portion of the sample in a 60°C (140°F) oven.
- 7.1.19 Re-screen over the 425 μm (No. 40) sieve and add the binder passing the sieve to the soil binder obtained in Section 7.1.6.
- 7.1.20 Weigh the mass of the aggregate and retain for use in Tex-110-E, Part I.
- 7.1.21 Place the pan containing the soil binder and wash water aside, where it will not be disturbed, until all the soil has settled to the bottom of the pan and the water above the soil is clear.
- 7.1.22 Decant the water off the soil.

- 7.1.23 Dry the remaining soil in a 60°C (140°F) oven.
- 7.1.24 In cases where the materials fail to settle overnight, evaporate the water by placing the sample in a 60°C (140°F) oven until it is dry, or siphon the water on to a plaster of Paris mold lined with filter paper.
- 7.1.25 When the water has disappeared, place the filter paper with adhering soil in a pan and dry in the oven.
- 7.1.26 Sweep the dry soil from the filter paper with a stiff brush into the pan of fines.
- 7.1.27 Break down the dried soil binder with a mortar and pestle or use a suitable mechanical pulverizer with an opening set from 635 to 889 μm (0.025 to 0.035 in.)
- 7.1.28 If a pulverizer is used, any material still aggregated in lumps larger than 425 μm (No. 40) should be broken down with a mortar and pestle.
- 7.1.29 Combine all of the soil binder obtained and weigh the mass to the nearest 5 g.
- 7.1.30 Mix thoroughly to produce a uniform sample of all of the particles.
- 7.1.31 Add the masses obtained in Sections 7.1.20 and 7.1.29, and record the sum as the Total Dry Mass of the sample.
- 7.2 *Wet Preparation (Method B)*—to be used for the analysis of soil constants only
 - 7.2.1 Select a representative sample according to Tex-100-E or Tex-400-A.
 - 7.2.2 Make the sample large enough to yield at least 300 g of soil binder.
 - 7.2.3 Place the sample in a clean pan.
 - 7.2.4 Cover the sample completely with clear water.
 - 7.2.5 Soak soils with moderate to high Plasticity Indices (PI) for a minimum of 12 hours, unless Tex-102-E determines a shorter time.
 - 7.2.6 Soak flexible base and low PI materials for a minimum of two hours.
 - 7.2.7 Sieve the wet sample into a clean pan in increments of approximately 450 g over a 2.00 mm (No. 10) sieve to remove large aggregate particles.
 - 7.2.8 Wash the aggregate retained on the sieve with a small amount of water.
 - 7.2.9 Discard the portion of material retained on the sieve.
 - 7.2.10 For soils and base materials with low PI, go to Section 7.2.14.
 - 7.2.11 For soils with moderate to high PI, place the wet material passing the 2.00 mm (No. 10) sieve into the dispersion cup of a mechanical malt mixer.

- 7.2.12 Do not fill the cup more than half-full.
- 7.2.13 Mix the material for three to five minutes or until the soil binder is separated.
- 7.2.14 Pour the material through a 425 μm (No. 40) sieve into a plaster of Paris bowl lined with filter paper.
- 7.2.15 Vigorously agitate the sieve up and down over the bowl while occasionally stirring the sample by hand to allow as much material as possible to pass the 425 μm (No. 40) sieve.
- 7.2.16 If the material retained on the sieve contains lumps that have not disintegrated, return to the dispersion cup, and remix and wash through the sieve.
- 7.2.17 Sieve until at least 95% of the soil binder appears to have passed through the sieve.
- 7.2.18 Reduce the water content of the material in the plaster of Paris bowl to below the liquid limit.
- 7.2.19 When the sample can be divided into pie-like wedges, and each wedge can be easily removed, it can be used for testing of soil constants.
- 7.2.20 If the soil constants are not to be determined immediately, place the material into an airtight container to prevent moisture loss.

8. CALCULATION

- 8.1 Use the following to calculate the percent soil binder:

$$\text{Percent Soil Binder} = 100(W_I / W_T)$$

Where:

W_I = dry mass of soil binder

W_T = dry mass of total sample.

9. REPORT

- 9.1 Report the percent soil binder to the nearest whole percent.

PART II—PREPARING SAMPLES FOR COMPACTION AND TRIAXIAL TESTS

10. SCOPE

- 10.1 Use this part to prepare samples for the compaction and triaxial tests. This procedure applies to all materials, except stabilized material, in the roadway or stockpile condition.

11. PREPARING SAMPLES

11.1 Select approximately a 90 kg (200 lb.) representative sample according to Tex-100-E or Tex-400-A.

11.2 Check specifications for maximum aggregate size.

11.3 Spread sample on a clean floor to air dry or use a forced draft of warm air not to exceed 140°F (60°C) for soils and 230°F (110°C) for flexible base material.

11.4 Dry soils in accordance with Section 11.4.1 and flexible base in accordance with Section 11.4.2.

11.4.1 Reduce the water content of soil samples to slightly below the estimated optimum moisture content.

11.4.2 Dry flexible base materials to constant weight. Constant weight will be considered achieved when the weight loss is less than 0.1% of the sample weight in four hours of drying.

11.5 Process soils in accordance with Section 11.5.1 and flexible base in accordance with Section 11.5.2.

11.5.1 Process moist clay and other soils (which form hard lumps when dried or contain aggregates) so that it will pass a 6.3 mm (1/4 in.) wire-mesh.

11.5.2 Separate flexible base by dry sieving into the following sizes:

- 1 3/4 in. (44.5 mm)
- 1 1/4 in. (31.7 mm)
- 7/8 in. (22.2 mm)
- 5/8 in. (16 mm)
- 3/8 in. (9.5 mm)
- No. 4 (4.75 mm)
- No. 40 (0.425 mm).

Note 2—Do not overload the screens. The material passing the No. 4 and retained on the No. 40 sieve may need to be shaken separately and in several small batches to avoid overloading the screen.

11.5.3 When material contains aggregate retained on the 44.5 mm (1-3/4 in.) sieve, add the material passing the 1-3/4 in. (44.5 mm) sieve and retained on the 1-1/4 in. (31.7 mm) sieve for recombining individual specimens.

Note 3—Do not use particles larger than 1-3/4 in. (44.5 mm) in the compacted specimens.

11.6 When aggregate between 1- 3/4 in. (44.5 mm) and 1-1/4 in. (31.7 mm) is needed, crush particles larger than 1-3/4 in. (44.5 mm) or obtain additional material from the project.

Note 4—Do not crush the material if it is an uncrushed gravel.

- 11.7 Mix each size to make moisture as uniform as possible.
- 11.8 Weigh each size of material to the nearest 0.1 lb (5 g).
- 11.9 Calculate the cumulative percentages retained on each sieve size as shown under Section 12.
- 11.10 These values are to be used in recombining the sample for compaction specimens.

12. CALCULATION

- 12.1 Calculate the cumulative percentages retained on each sieve.

$$\text{Percent Retained} = 100(\text{Mass Retained} / \text{Total Mass of Sample})$$

PART III—SIEVE ANALYSIS OF ROAD-MIX STABILIZED MATERIAL

13. SCOPE

- 13.1 This procedure applies to chemically stabilized materials sampled from the roadway during construction. These materials may be tested in the roadway condition for adequate pulverization, using sieves required by the governing Department Standard Specifications.

14. PROCEDURE

- 14.1 Select a representative sample from the roadway according to Tex-100-E.
- 14.2 Reduce the sample, using a sample splitter or other approved method, to a minimum of 4.5 kg (10 lb.)
- 14.3 Remove all non-slakable aggregates retained on the specified sieves.
- 14.4 Weigh the sample to the nearest 5 g and record as the Total Mass under Section 15.
- 14.5 Use the specified sieves to separate the sample into different size fractions.
- 14.6 Use either a sieve shaker or the hand method in the sieving operation.
- 14.7 Sieve the sample with a lateral and vertical motion of the sieves, accompanied by a jarring action to keep the material moving over the surface of the sieve.
- 14.8 Continue the sieving operation until no more than one percent of the test sample, by mass, passes through any sieve after one minute of continuous shaking.

- 14.9 Weigh the material passing each of the required sieves and record its mass to the nearest 5 g.
-

15. CALCULATION

- 15.1 Use the following to determine percent material passing each sieve.

$$\text{Percent Passing} = 100(\text{Mass Passing a Sieve} / \text{Total Mass of Sample})$$

16. REPORT

- 16.1 Report test results to the nearest whole percent.
-

17. ARCHIVED VERSIONS

- 17.1 Archived versions are available.



Tex-101-E Part II, Preparing Samples for Compaction and Triaxial

Sieve Size	Individual Weight Retained	Individual % Retained	Cumulative % Retained
1 $\frac{3}{4}$ "			
1 $\frac{1}{4}$ "			
$\frac{7}{8}$ "			
$\frac{5}{8}$ "			
$\frac{3}{8}$ "			
#4			
#40			
- #40			
Total			

Test Procedure for

LABORATORY COMPACTION CHARACTERISTICS AND MOISTURE-DENSITY RELATIONSHIP OF BASE MATERIALS



TxDOT Designation: Tex-113-E

Effective Date: June 2011

1 SCOPE

- 1.1 This method determines the relationship between water content and the dry unit mass (density) of base materials. Base materials are compacted in a 6-in. diameter × 8-in. tall mold with a 10-lb. rammer. The test is performed on prepared materials passing the 1-3/4 in. (45 mm) sieve. Follow Tex-114-E to determine moisture-density relationships of untreated subgrade and embankment soils.
- 1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard..
- 1.3 Instructional videos are available using the following links.
- [Definitions](#)
 - [Apparatus](#)
 - [Procedure](#)
-

2 DEFINITIONS

- 2.1 *Maximum Dry Density (D_A)*—Maximum dry density is the maximum value obtained from the compaction curve using the specified compactive effort.
- 2.2 *Optimum Water Content (W_{OPT})*—Optimum water content is the water content at which the soil can be compacted to the maximum dry density.
- 2.3 *Compactive Effort (C.E.)*—Compactive effort is the total energy, expressed as foot-pounds per cubic inch (kilo-Newton-meters per cubic meter), used to compact the specimen.
- 2.3.1 Calculate compactive effort as follows:

$$C.E. = \frac{Ht.of\ Drop(m\ or\ ft) \bullet Wt.of\ Hammer(k\ or\ lb) \bullet \#Drops \bullet \#Layers}{Volume\ of\ Mold(m^3\ or\ in.^3)}$$

2.3.2 This procedure requires 15 ft-lb per drop (13.26 ft-lb /in.³).

Note 1—In the metric system, the units for weight and mass are not the same. In order to convert the mass of the hammer to the metric "weight," you must multiply the mass by the force of gravity, g , which in the metric system is 9.8 m/sec^2 . The resulting unit is a Newton. Divide that number by 1,000 to get kilo-Newtons (kN).

3 APPARATUS

- 3.1 *Automatic tamper (compaction) device*, with base plate to hold 6-in. (152.4 mm) inside diameter (I.D.) molds, equipped with a $10 \pm 0.02 \text{ lb.}$ ($4.54 \pm 0.01 \text{ kg}$) rammer and adjustable height of fall.
- 3.1.1 Striking face of the rammer should conform to a $43 \pm 2^\circ$ segment of a $2.9 \pm 0.1 \text{ in.}$ ($74 \pm 2.5 \text{ mm}$) radius circle.
- 3.1.2 Bolt the base plate of the tamper to a rigid foundation, such as a concrete block, with a mass of not less than 200 lb. (91 kg). Use an alternate foundation support, such as a rigid stand or table, only if the D_A produced is within 2% of that produced by an automatic tamper bolted to a concrete floor.
- 3.2 *Rigid metal compaction mold*, with a 6 in., $+1/16$, or $-1/64 \text{ in.}$ (152.4 mm, $+1.59$ or -0.40 mm) I.D. and $8.5 \pm 1/16 \text{ in.}$ ($215.9 \pm 1.6 \text{ mm}$) height, with removable collar.
- 3.3 *Metal stand*, with a set of standard spacer blocks 1, 4, 6, and 11 in. (25.4, 101.6, 152.4, and 279.4 mm) accurate to 0.025 mm (0.001 in.), and a micrometer dial assembly with 2 in. (50 mm) travel for determining height of specimens.
- 3.4 *Balance*, Class G2 in accordance with Tex-901-K, with a minimum capacity of 35 lb. (16 kg).
- 3.5 *Extra base plate*, secured on a rigid, level stand to hold the mold.
- 3.6 *Hydraulic press*, to extrude compacted specimens from mold.
- 3.7 *Drying oven*, maintained at $230 \pm 9^\circ\text{F}$ ($110 \pm 5^\circ\text{C}$).
- 3.8 *Metal pans with lids*, wide and shallow for mixing and drying materials.
- 3.9 *Non-absorptive bowls with lids*.
- 3.10 *Set of standard U.S. sieves*, meeting the requirements of Tex-907-K, in the following sizes:
- 1-3/4 in. (44.5 mm)
 - 1-1/4 in. (31.7 mm)
 - 7/8 in. (22.2 mm)
 - 5/8 in. (16 mm)
 - 3/8 in. (9.5 mm)

- No. 4 (4.75 mm)
 - No. 40 (0.425 mm).
- 3.11 *Sprinkling jar and wash bottle.*
- 3.12 *Clean, circular, porous stones, slightly less than 6 in. (152.4 mm) in diameter and 2 in. (51 mm) high.*
- 3.13 *Non-porous paper discs, 6-in. (150 mm) diameter, Gilson MSA-121 or equivalent.*
- 3.14 *Supply of small tools, including a level, putty knife, spatula, horsehair bristle brush, plastic mallet, open-ended wrenches (7/16 in. and 9/16 in.), crescent wrenches (12 in. and 16 in.), Allen wrenches (1/8 in., 3/16 in., and 9/64 in.), and feeler gauges.*
- 3.15 *Soil Compactor Analyzer (SCA) approved by TxDOT, with sensor rod assembly, control box, computer, and compaction device analysis system software capable of turning the automatic tamper off once the required compactive energy has been delivered to the layer being compacted.*
- 3.15.1 *Sensor rod assembly consists of sensing rod, magnetostrictive linear displacement transducer, frame (powder coated), circular magnet, magnet mount, cable, and miscellaneous mounting hardware.*
- 3.15.2 *Control box consists of enclosure, power supply, data acquisition card, miscellaneous electronics, and emergency stop.*
- 3.15.3 *Computer with system software, TxDOT SCA V8.1.10, maintained by the Construction Division, Materials and Pavements Section.*
- 3.15.4 [SCA Reference Guide.](#)
- 3.16 *Slide finishing hammer, meeting the dimensions in Figure 1. The drop weight will be 10 ± 0.02 lb. (4.55 ± 0.01 kg), and drop height will be 18 in. along a vertical, fixed shaft. The finishing tool will have a smooth, flat surface. Weight of entire slide finishing hammer will be 23.4 ± 0.1 lb.*

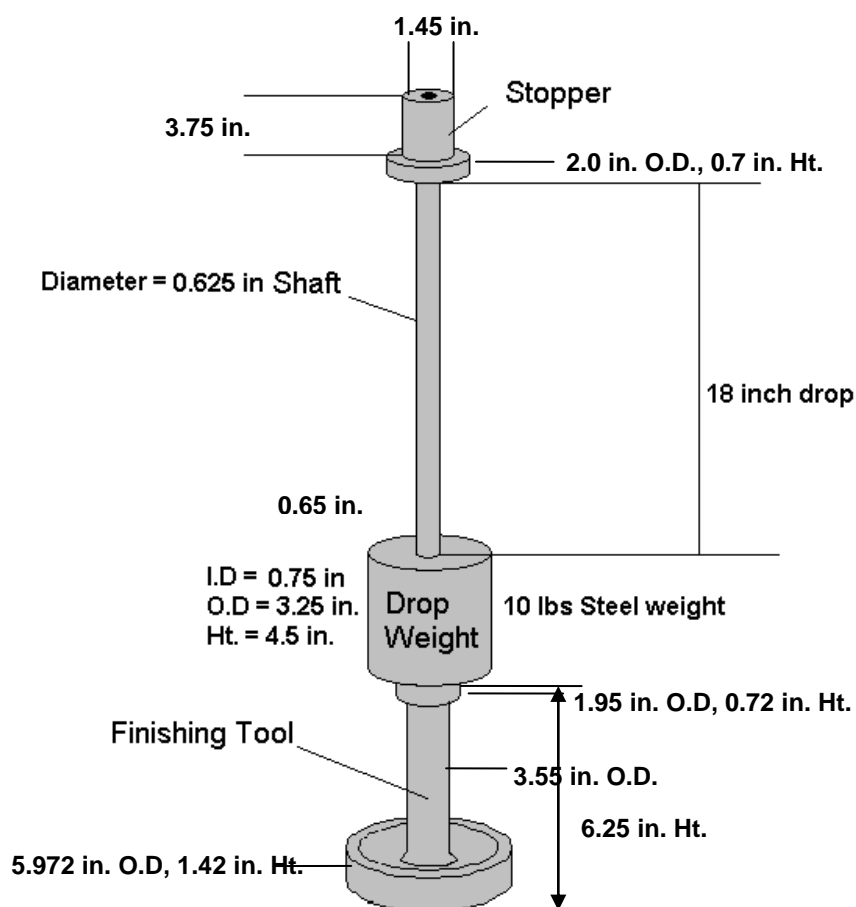


Figure 1—Slide Finishing Hammer

4 CALIBRATING EQUIPMENT

- 4.1 Calibrate and maintain all equipment required by this procedure in accordance with Tex-198-E.
- 4.2 Perform the following additional activities to properly maintain the automatic tamper:
 - 4.2.1 Wipe the guide rods and disc with a wet rag after each use.
 - 4.2.2 Wipe the guide rods and disc with alcohol weekly to ensure that no oil or residue begins to build up on them.
 - 4.2.3 Lubricate the guide disc prior to compaction with a graphite pencil. The rods will become lubricated by picking up a bit of the graphite from the edge of the disc during compaction.

- 4.2.4 Check the guide bushing located on top of the compactor weekly. There should be very little play between the shaft and the guide bushing. The acceptable clearance between the shaft and the guide bushing is 0.007–0.013 in. Replace the guide bushing if the clearance is outside these limits.
- 4.2.5 Check the guide rod brackets weekly. There should be very little to no play between the rods and the brackets. If the play is excessive, replace the brackets.
- 4.2.6 Check the spacing between the guide disc and rods weekly by pushing the shaft/disc towards two of the guide rods and measuring for a total clearance of 0.016 in. with feeler gauges. If the total clearance exceeds 0.016 in., adjust the spacing until it meets the tolerance.
-

5 MATERIAL SAMPLING AND PREPARATION

- 5.1 Obtain a representative sample in accordance with Tex-400-A.
- 5.2 Check specifications for maximum aggregate size.
- 5.3 Spread sample on a clean floor to air dry or use a forced draft of warm air not to exceed 230°F (110°C) and dry to constant weight. Constant weight will be considered achieved when the weight loss is less than 0.1% of the sample weight in four hours of drying.
- 5.4 Separate flexible base by dry sieving into the following sizes.
- 1-3/4 in. (44.5 mm)
 - 1-1/4 in. (31.7 mm)
 - 7/8 in. (22.2 mm)
 - 5/8 in. (16 mm)
 - 3/8 in. (9.5 mm)
 - No. 4 (4.75 mm)
 - No. 40 (0.425 mm)
- Note 2**—Do not overload the screens. The material passing the No. 4 and retained on the No. 40 sieve may need to be shaken separately and in several small batches to avoid overloading the screen.
- 5.5 When material contains aggregate retained on the 1-3/4 in. (44.5 mm) sieve, add the material passing the 1-3/4 in. (44.5 mm) sieve and retained on the 1-1/4 in. (31.7 mm) sieve for recombining individual specimens.
- Note 3**—Do not use particles larger than 1-3/4 in. (44.5 mm) in the compacted specimens.
- 5.5.1 When aggregate between 1-3/4 in. (44.5 mm) and 1-1/4 in. (31.7 mm) is needed, crush particles larger than 1-3/4 in. (44.5 mm) or obtain additional material from the project.
- Note 4**—Do not crush the material if it is an uncrushed gravel.
-

5.6 Weigh each size of material to the nearest 0.1 lb. (5 g).

5.7 Calculate the cumulative percentages retained on each sieve:

$$\text{Percent Retained} = 100(\text{Mass Retained} / \text{Total Mass of Sample})$$

Note 5—These values are to be used in recombining the sample for compaction specimens.

6 PROCEDURE

6.1 Estimate the mass of air-dry material that will fill the mold when wetted and compacted.

6.2 Using this estimated mass and the percentages of the various sizes of particles obtained in the preparation of the sample, compute the cumulative masses for each size to be combined to mold a specimen.

$$\text{Cumulative Weight Retained} = \left(\frac{\text{Cumulative Percent Retained}}{100} \right) \times \text{Estimated Mass of Material}$$

EXAMPLE: Estimated Mass of Material = 18.250 lb.

Sieve Size (in.)	Cumulative Percent Retained (%)	Cumulative Weight Retained (lb.)
1-3/4	0.0	$\left(\frac{0.0}{100} \right) \times 18.25 = 0.000$
1-1/4	2.6	$\left(\frac{2.6}{100} \right) \times 18.25 = 0.475$
7/8	10.6	$\left(\frac{10.6}{100} \right) \times 18.25 = 1.935$
5/8	20.6	$\left(\frac{20.6}{100} \right) \times 18.25 = 3.760$
3/8	35.7	$\left(\frac{35.7}{100} \right) \times 18.25 = 6.515$
No. 4	52.8	$\left(\frac{52.8}{100} \right) \times 18.25 = 9.636$
No. 40	82.1	$\left(\frac{82.1}{100} \right) \times 18.25 = 14.983$
(-)No. 40	100.0	$\left(\frac{100.0}{100} \right) \times 18.25 = 18.250$

- 6.3 Weigh a trial sample as calculated in Section 6.2.
- 6.3.1 Estimate the percent moisture at optimum and calculate the weight of water to add based on the mass of the air-dried material.

$$\text{Weight of Water} = \left(\frac{\text{Estimated Moisture at Optimum}}{100} \right) \times \text{Estimated Mass of Material}$$

EXAMPLE:

Estimated Mass of Material = 18.250 lb., Estimated Moisture at Optimum = 5.2 %

$$\text{Weight of Water} = \left(\frac{5.2}{100} \right) \times 18.250 = 0.949 \text{ lb}$$

- 6.3.2 Weigh the water calculated in Section 6.3.1 in a tared sprinkling jar.
- 6.3.3 Mold the trial sample in accordance with Sections 6.7–6.32.
- 6.4 Using the height and mass of the trial sample, calculate the corrected mass of material required to mold samples with a height of 8 ± 0.250 in. (203.2 ± 6.4 mm):
- $$\text{Corrected mass} = (8.000 \text{ in.}) \times (\text{trial mass/trial height})$$
- 6.5 Weigh four samples for the moisture-density curve using the corrected mass of material calculated in Section 6.4 and the percentages of the various sizes of particles obtained in the preparation of the sample.
- 6.6 Determine the moisture content of each specimen.
- 6.6.1 Estimate the optimum moisture content and calculate the water content of the first specimen at 2 percentage points below this estimate.
- 6.6.2 Calculate the water content of the other three specimens, increasing each in increments of one percentage point.
- 6.6.3 Calculate the weight of water to add to each specimen based on the mass of the air-dried material.
- 6.6.4 Weigh each of these water contents in a tared sprinkling jar.
- 6.7 Place the total sample in the mixing pan, mix thoroughly, and wet with all of the mixing water by sprinkling water in increments onto the sample during mixing.
- 6.7.1 Mix thoroughly, breaking up soil lumps. Do not break any aggregate particles in the sample.
- 6.7.2 Turn the wet material over with the mixing trowel to allow the aggregate particles to absorb water.

- 6.8 After it is thoroughly mixed, scrape all material off the mixing trowel into the pan. Weigh the sample and pan, and record the weight.
- 6.9 Cover the mixture with a non-absorptive lid to prevent moisture evaporation and allow to stand for 18–24 hours.
Note 6—Allow the trial sample to stand for a minimum of 2 hours before compaction.
- 6.10 Prior to compaction, weigh the sample (without the lid), replace evaporated water, and thoroughly mix to ensure even distribution of water throughout the sample. Scrape material off mixing tools and into pan.
- 6.11 Cover and allow the samples to stand 1–2 hours before molding.
Note 7—For the trial sample, this step can be eliminated.
- 6.12 Weigh the compaction mold and record on [Form Tx113.4](#), “Moisture-Density Relations of Base Material and Sand or Subgrade and Embankment Soils.”
- 6.13 Place one non-porous paper disc in the bottom of the mold.
- 6.14 Separate the sample using a 7/8 in. (22.6 mm) sieve.
- 6.14.1 Distribute the material retained on the 7/8 in. (22.6 mm) sieve equally, based on size, shape, and number of particles, into four separate non-absorptive bowls.
- 6.14.2 Cover each bowl to prevent loss of moisture.
- 6.14.3 Using the horsehair bristle brush, brush the material stuck to the 7/8 in. (22.6 mm) sieve back into the pan containing the material passing the 7/8 in. (22.6 mm) sieve.
- 6.14.4 Divide the material passing the 7/8 in. sieve into four equal, homogeneous portions.
- 6.15 Estimate the mass needed for one 2-in. (51-mm) layer of compacted material (approximately one-quarter of the total material for the specimen). Weigh one of the portions of material retained on the 7/8 in. sieve with one of the portions of material passing the 7/8 in. sieve, adjusting the amount of material as needed to attain the estimated weight for one layer.
- 6.16 Construct the layer.
- 6.16.1 Cover the bottom of the mold with approximately 1/4 in. of material passing the 7/8 in. sieve and level with a spatula.
- 6.16.2 Hand place all of the aggregate particles retained on the 7/8 in. (22.6 mm) sieve that are contained in one of the non-absorptive containers, minimizing contact with the edges of the mold.
- 6.16.3 Place aggregates in their most stable position. Aggregates may be placed on top of each other in order to make them all fit, but they must also fill the entire diameter of the mold.

- 6.16.4 Use a scoop held slightly above the top of the mold to pour the remaining weighed portion of material passing the 7/8 in. (22.6 mm) sieve into the mold.
- 6.16.5 Use a spatula to move the material passing the 7/8 in. sieve around to fill voids between the aggregate particles retained on the 7/8 in. sieve. Do not rearrange the aggregate particles retained on the 7/8 in. sieve.
- 6.16.6 Completely cover the aggregate particles retained on the 7/8 in. sieve with material passing the 7/8 in. sieve.
- 6.16.7 Use a spatula to spade around the inside perimeter of the mold to allow some of the material passing the 7/8 in. sieve to fill cavities around the edge.
- 6.16.8 Level the surface with the spatula. Do not push this layer down by hand or other means than those described above.
- 6.17 Lower the hammer and allow it to rest on the surface of the uncompacted lift.
- 6.18 Prepare the SCA for data collection in accordance with the SCA Reference Guide. Use the option that allows the SCA to shut the automatic tamper off when the required compactive energy is attained.
- 6.19 Use the SCA to start the compactor. Compact the layer by dropping the 10-lb. (4.55-kg) rammer from a height of $18 \pm 1/2$ in. (457 ± 12.7 mm) until the SCA indicates the total energy delivered to the lift equals 750 ± 15.0 ft-lb. The number of blows needed to achieve 750 ft-lb must be a minimum of 50 and a maximum of 60. If the number of blows is outside this range, discard the sample and adjust the compactor so that the specified energy is attained within the allowable number of blows.
- Note 8**—The SCA will turn the compactor off when the correct energy has been delivered to the lift.
- 6.20 Remove material sticking to the ram face after completing compaction of each lift.
- 6.21 Use the sample mass and compacted thickness of the first layer (measured by the SCA) to adjust the mass of the subsequent lifts.
- 6.22 Weigh one of the portions of material retained on the 7/8 in. sieve with one of the portions of material passing the 7/8 in. sieve. Adjust the amount of material to attain the mass for one layer determined in Section 6.21.
- 6.23 Use a spatula to scarify the surface of the lift just compacted. Do not dislodge aggregates from the previously compacted lift.
- 6.24 Repeat Sections 6.16.2–6.23 for each of the remaining lifts. Use all material to mold the sample. The surface of the fourth lift should be as free as possible from large aggregates.
- Note 9**—Use a flexible collar to extend the height of the mold collar on the fourth lift to prevent loss of material, if needed.
- 6.25 After the fourth layer has been compacted, fasten the mold containing the material on top of the extra base plate.

- 6.25.1 Ensure that the mold sits level on the base plate.
- 6.25.2 Use a spatula or other suitable hand tool to dislodge material from the side of the mold that extends above the compacted surface. Press this material into the surface.
- 6.26 Use a small level to check the levelness of the specimen's surface.
- 6.26.1 If needed, level the surface by placing the slide hammer on top of the specimen's surface and tap the bottom edge of the slide hammer with the plastic mallet. Repeat until the top of the specimen is level.
- Note 10**—Do not trim the compacted material with a straight edge. The compacted material should not completely fill the mold after compaction.
- 6.26.2 After the surface is level, apply ten blows to the top of the specimen with the slide hammer.
- Note 11**—Ensure that the shaft of the slide hammer is maintained perpendicular to the specimen surface when dropping the 10 lb. weight.
- 6.26.3 Repeat Sections 6.26.1–6.26.2 a second time.
- 6.26.4 Use a small level to check the levelness of the specimen's surface and tap the edge of the slide hammer if needed to level the sample one final time.
- 6.27 Remove the mold from the base plate.
- 6.28 Weigh the specimen in the mold to the nearest 0.001 lb. (0.5 g) and measure the sample height with the micrometer dial assembly to the nearest 0.001 in. (0.03 mm). The height of the finished specimen should be 8 ± 0.250 in. (203.2 ± 6.4 mm).
- 6.29 Record data on Form Tx113,4.
- 6.30 Turn the specimen over and carefully center it over a porous stone. Place a non-porous paper disc between the stone and the specimen to prevent moisture from traveling from the specimen into the porous stone.
- 6.31 Place in the hydraulic press and extrude the specimen from the mold.
- 6.32 If unconfined compressive strengths are desired, proceed to Section 6.33; otherwise proceed to Section 6.34.
- 6.33 Immediately after extruding the specimen from the mold, enclose the specimen in a triaxial cell, with top and bottom porous stones in place, and allow it to remain undisturbed at room temperature until the entire set of test specimens has been molded.
- 6.33.1 After the entire test set has been molded, break the specimens at 0 psi lateral pressure in accordance with Tex-117-E, Section 5.19 when using an automated load frame or Section 5.20 when using a screw jack press.
- 6.33.2 Remove the triaxial cell from each specimen just before testing.

- 6.33.3 Place a drying pan under the sample to catch the material as it breaks.
- 6.33.4 Plot the test results in accordance with Section 8.2 to establish the effect of moisture content and density on strength characteristics of the material.
- 6.34 Record the weight of a flat drying pan. Remove the porous stones and place the specimen in the flat drying pan.
- 6.35 Break up the specimen and place the identification tag with the loose material in the tared drying pan.
- 6.36 Weigh the tared pan and wet sample to the nearest 0.001 lb. (0.5 g) and record on Form Tx113,4.
- 6.37 Place the drying pan with wet material in an oven at a temperature of 230°F (110°C) until a constant mass is reached.
- 6.38 Weigh the tared pan and oven-dried material to the nearest 0.001 lb. (0.5 g) and record on Form Tx113,4.
Note 12—Do not reuse material from compacted sample(s) for preparation of other compaction specimens.
- 6.39 Repeat Sections 6.6–6.38 for each sample.
-

7 CALCULATIONS

- 7.1 Use [Form Tx113,4](#) to calculate and record the following:
- 7.1.1 Calculate the wet density of the compacted specimens, lb./ft.³ (kg/m³):

$$D_{WET} = (W_T - W_M) / V_M$$

Where:

W_T = mass of the mold and the compacted sample, lb. (kg)

W_M = mass of the mold, lb. (kg)

V_M = volume of the mold, ft.³ (m³).

- 7.1.2 Calculate the percent water content:

$$WC = 100[(W_w - W_d) / W_d]$$

Where:

W_w = wet mass of the sample, lb. (kg)

W_d = oven dried mass of the molded sample, lb. (kg).

- 7.1.3 Calculate the dry density of the compacted specimens:

$$D_{DRY} = 100 \bullet D_{WET} / (100 + WC)$$

Where:

WC = water content of the compacted specimen, % (includes hygroscopic moisture).

- 7.1.4 Calculate the zero air voids density:

$$D_{ZAV} = (Specific\ Gravity \bullet 62.5) / \{1 + [Specific\ Gravity \bullet (\%WC / 100)]\}$$

Where the specific gravity is unknown, use a value of 2.65 as an average value.

- 7.2 Use the electronic worksheets contained in [Form Tx117](#), “Triaxial Compression Tests,” to record and calculate unconfined compressive strength results.

8 GRAPHS

- 8.1 Construct the M/D curve.

- 8.1.1 Plot the dry density versus the percent of molding moisture on Form Tx113,4 for each compacted specimen, as shown in Figure 2.

- 8.1.2 To obtain a well-defined compaction curve, provide at least two water content percentages on both sides of optimum.

- 8.1.3 The R-square value for the fit of the data to the curve must be greater than or equal to 0.9500. If it is not, mold additional samples to improve the fit of the data to the curve and to achieve a minimum R-square value of 0.9500.

- 8.1.4 Use the zero air void line as an aid in drawing the moisture-density curve. For materials containing more than 10% fines, the wet leg of the moisture-density curve generally parallels with the zero air void curve. Theoretically, the moisture-density curve cannot plot to the right of the zero air void curve. If it does, there is an error in specific gravity, in measurement, in calculation, in sample preparation, or in plotting.

- 8.2 If strength behavior is required, plot unconfined compressive strength versus the percent of molding moisture on Form Tx113,4 for each compacted specimen, as shown in Figure 3.

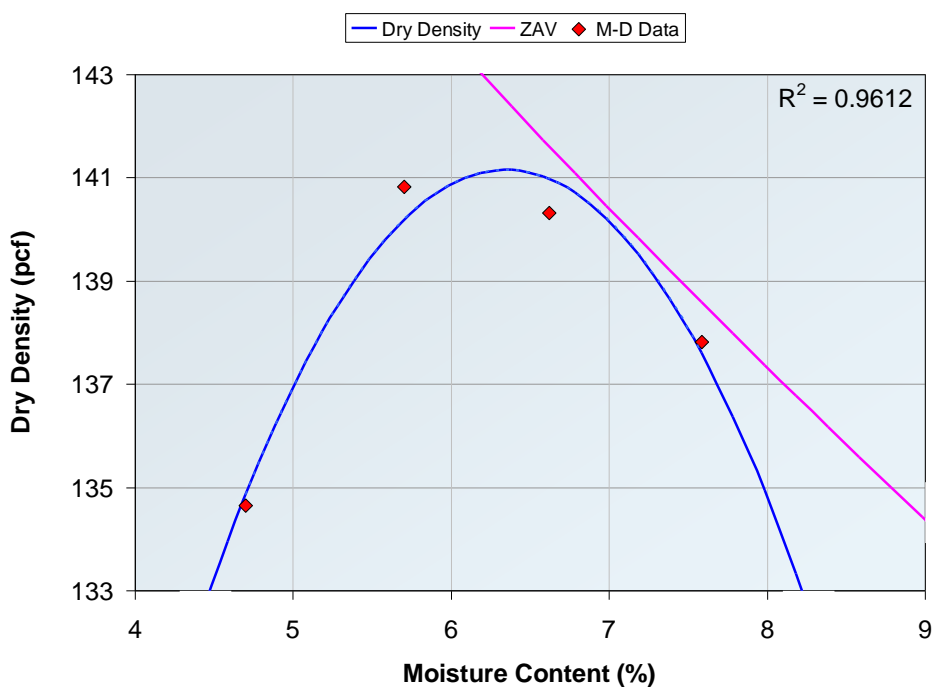


Figure 2—Example of Moisture-Density Curve

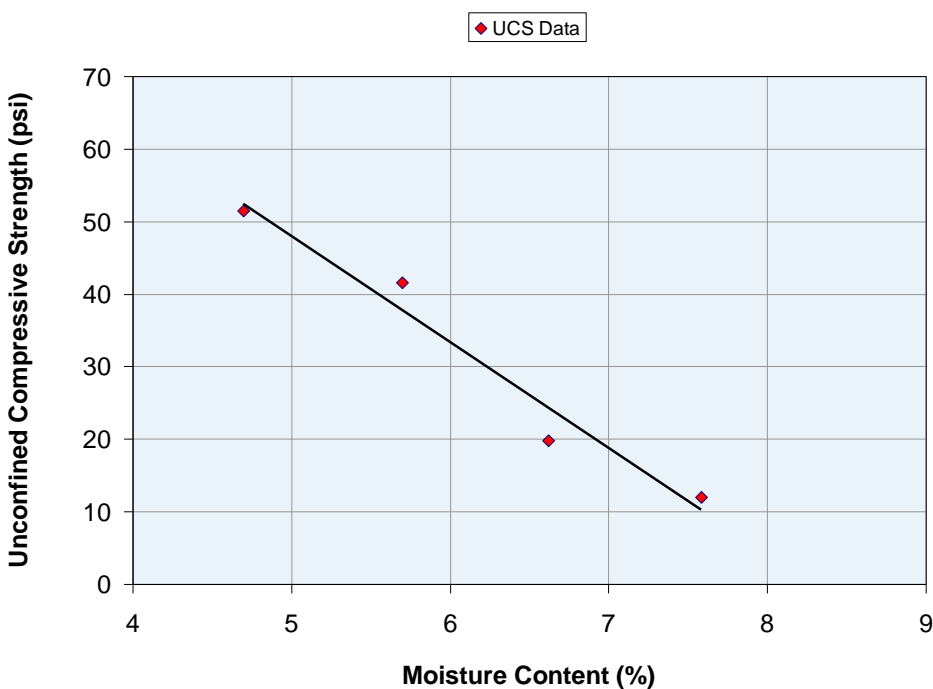


Figure 3—Example of Unconfined Compressive Strength versus Percent Molding Moisture

9 GENERAL NOTES

- 9.1 When determining the M/D curve for lime treated subgrade and base materials, determine the percent lime needed to achieve a pH of 12.4 in accordance with Tex-121-E, Part III.
- 9.2 For wetted stabilized materials taken from the roadway, see appropriate test method for preparation procedure for specification compliance, density, and/or strength:
- Cement Stabilization: Tex-120-E
 - Lime Stabilization: Tex-121-E
 - Lime-Fly Ash Stabilization: Tex-127-E
- 9.3 *Materials Difficult to Compact:*
- 9.3.1 Materials that are difficult to compact are an exception and require special attachments to the compaction apparatus.
- *Rammer*, 10 lb. \pm 0.02 (4.54 \pm 0.01 kg), with twin striking face.
 - *Neoprene pad*, 0.5 in. (12.7 mm) thick, Type A Shore durometer 65 ± 3 . The 6-in. (152.4-mm) diameter neoprene pad should just slide into the mold on top of the sand layer and will divert some of the impact to vibrations.
- 9.3.2 Compact the material in eight 1-in. (25.4-mm) layers using the neoprene pad and 100 ram blows of the 10-lb. (4.55-kg) rammer for each layer.
- 9.3.3 Use the rammer with a twin striking face when the material—wetted to slightly below optimum water content, mixed thoroughly, and molded in two 2-in. (51 mm) lifts—is sheared or torn by the ram in excess of 1 in. (25.4 mm) on the last blow.
-

10 REPORTING TEST RESULTS

- 10.1 Record test data on [Form Tx113,4](#) and [Form Tx117](#).
- 10.2 Record the following SCA data on Form Tx113,4 for each lift compacted for each molded specimen:
- total energy,
 - average drop height,
 - average energy per blow, and
 - number of blows per lift.
- 10.3 Report all test data recorded in Sections 6, 7, and 8.
- 10.4 Report maximum dry density (D_A) to the nearest 0.1 lb./ft.³ (kg/m³).
- 10.5 Report optimum moisture content (W_{OPT}) to the nearest 0.1%.
-

11 ARCHIVED VERSIONS

11.1 Archived versions are available.



Tex-113-E, Moisture-Density Worksheet

	Lbs. Additive 0.000					
A	Total % Water 0.0					
B	lbs. Material 0.000					
C	lbs. Water Added (A x B) / 100 0.000					
D	Wet Mass Specimen & Mold 0.000					
E	Tare Mass of Mold, Base & Collar 0.000					
F	Wet Mass of Specimen (D – E) 0.000					
G	Height of Specimen 0.000					
H	Volume of Mold Linear mm/in 0.0000					
I	Volume of Specimen (G x H) 0.0000					
J	Wet Density of Specimen (F / I) 0.0					
K	Wet Mass Pan & Specimen 0.000					
L	Dry Mass Pan & Specimen 0.000					
M	Tare Mass of Pan 0.000					
N	Dry Mass of Material (L – M) 0.000					
O	Mass of Water (K – L) 0.000					
P	% Water Content on Total (O / N)100 0.0					
	Dry Density (100 x J) / (100 + P) 0.0					
	Maximum Dry Density 0.0					
	Optimum Moisture % 0.0					

Test Procedure for

LABORATORY COMPACTION CHARACTERISTICS AND MOISTURE-DENSITY RELATIONSHIP OF SUBGRADE, EMBANKMENT SOILS, AND BACKFILL MATERIAL



TxDOT Designation: Tex-114-E

Effective Date: February 2011

1. SCOPE

- 1.1 Use this test method to determine the relationship between water content and the dry unit mass (density) of sub-grade and embankment materials.
 - 1.1.1 Part I is a subgrade or embankment sample, 4 in. (101.6 mm) in diameter and 6 in. (152.4 mm) high, is molded in four layers, using a 5.5 lb. (2.5 kg) hammer dropped 25 times per layer from a height of 12 in. (304.8 mm). This part is intended for plastic and fine-grain soils, such as silts and clays (ML, MH, CL, and CH classifications as determined by Tex-142-E.)
 - 1.1.2 Part II is a subgrade or embankment sample, 6 in. (152.4 mm) in diameter and 8 in. (203.2 mm) high, is molded in four layers using a 5.5 lb. (2.5 kg) hammer dropped 75 times per layer from a height of 12 in. (304.8 mm). This part is intended for plastic, and coarse-grain soils, such as sands and gravels with fines (GM, GC, SM, and SC classifications as determined by Tex-142-E.)
 - 1.1.3 Part III is a cohesionless backfill (sand/silt) sample, 4 in. (101.6 mm) in diameter and 6 in. (152.4 mm) in height, is molded in four layers, using a 10 lb. (4.54 kg) hammer dropped 61 times per layer from a height of 12 in. (304.8 mm). Perform the test in Part III on prepared materials passing the 1/4 in. (6.3 mm) sieve. This part is intended for clean, cohesionless sands used for MSE backfill (SW and SP classifications as determined by Tex-142-E.)
- 1.2 Follow Tex-113-E to determine moisture-density relationships of flexible base materials, coarse-grained materials containing particles larger than 7/8 in. (22.4 mm), and treated subgrade and embankment materials. Use of the Soil Compactor Analyzer (SCA) is required at this time for flexible base materials only.
- 1.3 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

2. DEFINITIONS

2.1 *Maximum Dry Density* (D_a)—Maximum dry density is the maximum value obtained by the compaction curve using the specified compactive effort.

2.2 *Optimum Water Content* (W_{opt})—Optimum water content is the water content at which the soil can be compacted to the D_a .

2.3 *Compactive Effort* (C.E.)—Compactive effort is the total energy, expressed as foot-pounds per cubic inch (kilo-Newton-meters per cubic meter) used to compact the specimen.

- C.E. is calculated as follows:

$$\frac{Ht. \text{ of Drop (ft or m)} \times Wt. \text{ of Hammer (kN or lb)} \times \# \text{ Drops} \times \# \text{ Layers}}{\text{Volume of Mold (m}^3 \text{ or in}^3 \text{)}}$$

- This procedure requires, for Part I and Part II, 7.30 ft.-lb./in.³ (604 kN-m/m³) and, for Part III, 32.36 ft.-lb./in.³ (2677 kN-m/m³), equivalent to ASTM D 1557.

3. APPARATUS

3.1 *Automatic tamper (compaction) device*, with:

- Base plate to hold 4 in. (101.6 mm) or 6 in. (152.4 mm) inside diameter (ID) forming molds
- 5.5 ± 0.02 lb. (2.5 ± 0.01 kg) sector-face rammer
- 10 ± 0.02 lb. (4.55 ± 0.01 kg) sector-face rammer
- Adjustable drop height
- Striking face of the rammer conforming to a 43 ± 2° segment of a 2.9 ± 0.1 in. (74 ± 2.5 mm) radius circle
- Rigid foundation, such as a concrete block, with a mass of not less than 200 lb. (91 kg) on which the base plate of the tamper is secured. (An alternate foundation support, such as a rigid stand or table, is allowed if the D_a produced is within 2% of that produced by an automatic tamper bolted to a concrete floor).

3.2 *Rigid metal compaction mold*, with 4 ± 1/64 in. (101.6 ± 0.4 mm) average ID and a height of 6 ± 0.0026 in. (152.4 ± 0.7 mm) with removable collar, and/or a 6 in., +1/16 or -1/64 in. (152.6 mm, +1.6 or -0.4 mm) average ID and a height of 8-1/2 ± 1/16 in. (215.9 ± 1.6 mm) with removable collar.

3.3 *Metal stand*, with a set of standard spacer blocks and a micrometer dial assembly, with 2 in. (50 mm) travel, for determining height of specimens. Spacer blocks 1, 4, 6, and 11 in. (25.4, 101.6, 152.4, and 279.4 mm) accurate to 0.001 in. (0.025 mm).

- 3.4 *Balance*, Class G2 in accordance with Tex-901-K, with a minimum capacity of 35 lb. (15 kg).
- 3.5 *Extra base plate*, secured on a rigid stand to hold the forming mold.
- 3.6 *Hydraulic press*, to extrude molded specimens.
- 3.7 *Drying oven*, maintained at $230 \pm 9^{\circ}\text{F}$ ($110 \pm 5^{\circ}\text{C}$).
- 3.8 *Metal pans*, wide and shallow for mixing and drying materials.
- 3.9 *Circular porous stones*, slightly less than 6 in. (152.4 mm) in diameter and 2 in. (51 mm) high.
- 3.10 *Supply of small tools*, including a 4–5 lb. (1.8–2.3 kg) rawhide hammer, level, finishing tool, and others.
- 3.11 *Standard U.S. sieves*, meeting the requirements of Tex-907-K, in the following sizes:
 - 1-3/4 in. (45 mm)
 - 7/8 in. (22.4 mm)
 - 3/8 in. (9.5 mm)
 - No. 4 (4.75 mm).

4. CALIBRATING EQUIPMENT

- 4.1 Calibrate equipment in accordance with Tex-198-E. In addition, calibrate equipment before initial use, after repair, or after any occurrence that might affect the test results.
- 4.2 Follow the steps outlined in Tex-113-E, Section 4.

PART I—MEASURING MOISTURE-DENSITY RELATIONSHIP OF SUBGRADE AND EMBANKMENT SOILS

5. SCOPE

- 5.1 Part I uses a 4-in. (102 mm) ID mold and applies only to soils with:
 - 100% passing the 3/8 in. (9.5 mm) sieve
 - $\geq 80\%$ passing the 1/4 in. (6.3 mm) sieve
 - ML, MH, CL, and CH soil classification as determined by Tex-142-E.

6. PREPARING SAMPLE

- 6.1 Prepare the material in accordance with Tex-101-E, Part II. Do not use materials that have been previously laboratory compacted.
-

7. PROCEDURE

- 7.1 Determine the percent hygroscopic moisture of a representative sample of prepared material in accordance with Tex-103-E.
- 7.2 Separate sample on 7/8 in. (22.4 mm), 3/8 in. (9.5 mm), and 1/4 in. (6.3 mm) sieves and determine particle size distribution.
- 7.3 Estimate the mass of air-dried material that will fill the mold when wetted and compacted.
- 7.4 Using this estimated mass, and the percentages of the various sizes of particles obtained in Section 7.2, compute the cumulative masses of each size to combine to make a specimen.
- 7.5 Using the masses calculated in Section 7.3, recombine at least four specimens of approximately 7.7 lb. (3.5 kg) each.
- 7.6 Estimate the optimum percent moisture required to attain maximum density.
Note 1—The plastic limit is a good indicator of optimum moisture content, typically within 2%, or 3–4% higher for $PI > 35$ material.
- 7.7 Start the M-D curve using a sample with a moisture content of 2% below the estimated optimum moisture content. For soils with a low to moderate plasticity index ($PI < 35$), adjust the moisture content of the remaining samples in approximately 2% increments to attain two samples above and two samples below the optimum moisture content. For soils with high plasticity index ($PI \geq 35$), the moisture content may be adjusted in 4% increments to attain two samples above and two samples below the optimum moisture.
Note 2—After compacting the first two or three specimens, construct the initial M-D curve to aid in evaluation of the shape of the curve. If necessary, adjust the water content of the other prepared samples by adding additional water or air-drying to obtain a well-defined compaction curve.
- 7.8 Calculate the mass of the water to be added based on the air-dry mass of the material.
- 7.9 Weigh out this amount of water into a tared sprinkling jar.
- 7.10 Sprinkle water onto the soil during mixing, in increments.
- 7.11 Thoroughly mix each specimen to ensure even distribution of water throughout specimen.
-

- 7.12 Cover the mixed sample and allow sample to stand and cure for at least 12 hr. before compacting. When the PI is less than 12, reduce the curing time to no less than 3 hr. Cure split or referee samples for the full 12 hr.
- 7.13 Assemble and secure the mold and collar to the base plate.
- 7.14 Thoroughly remix the cured sample.
- 7.15 Obtain approximately 1 lb. (453.6 g) of the sample and determine water content as described in Tex-103-E, Section 7.
- 7.16 Place loose soil into the mold and spread into a layer of uniform thickness.
- 7.17 Before compaction, use hand tools to tamp the soil lightly until it is not fluffy or loose.
- 7.18 Separate the material in the pan into four equal portions. Each portion must contain representative quantities of all sizes and adequate material to compact four 1.5-in. (38-mm) layers.
- 7.19 For each layer, dump the material into the mold. Spade and level the layer of material with a spatula to fill cavities around the edge and to ensure an even distribution of material in each layer before compacting. Do not push this layer down by hand or other means than that described above.
- 7.20 Compact each layer using 25 per lift with a drop height of 12 in. (304.88 mm).
- 7.21 Use the soil mass and compacted thickness of the first lift to adjust the mass and thickness of the subsequent lifts.
- 7.22 Upon completion of compacting each of the first three lifts, use a knife or other convenient tool to scarify the surface to a depth of 1/4 in. (6.3 mm). Dislodge uncompacted soils that extend above the compacted surface.
- 7.23 Upon completion of the fourth lift, the compacted specimen should extend above the top, but by no more than 1/4 in. (6.3 mm). Discard the compacted specimen if it does not extend above the top of the mold at any point.
- 7.24 After compaction of the last lift, remove the collar and use a straight edge or draw knife to carefully trim the compacted specimen even with the top of the mold.
- 7.25 Invert the mold and trim the bottom of the specimen even with the bottom of the mold.
- 7.26 Use trimmed soil from the specimen to fill holes on the trimmed surfaces. Trim again as needed to ensure a smooth, level surface.
- 7.27 Determine and record the mass of the specimen and mold as W_T to the nearest 0.001 lb. (0.5 g) under Tex-113-E, Section 9.
- 7.28 Record the data on [Form 113.4](#), "Moisture Density Relations of Base Material and Sand or Subgrade and Embankment Soils."

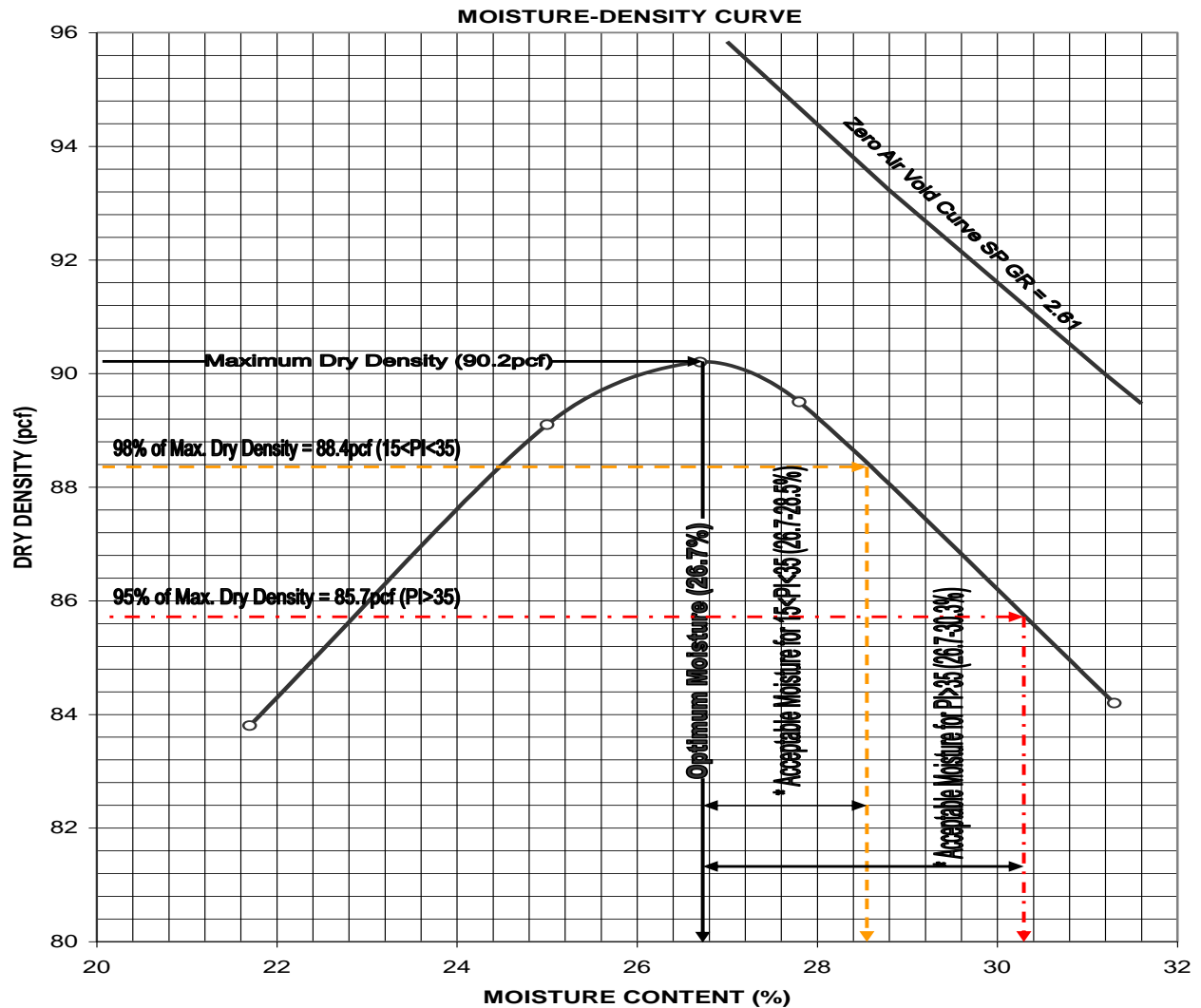
- 7.29 Use the hydraulic jack press to remove the specimen from the mold.
- 7.30 Place the compacted specimen and identification tag into a large pan and break into several pieces.
- 7.31 Obtain the mass of the drying pan and wet sample and record to 0.001 lb. (0.5 g).
- 7.32 Place the specimen in an oven at a temperature of $230 \pm 9^{\circ}\text{F}$ ($110 \pm 5^{\circ}\text{C}$) and dry to constant weight.
Note 3—Use a $140 \pm 9^{\circ}\text{F}$ ($60 \pm 5^{\circ}\text{C}$) oven for ML or MH soils (as determined by Tex-145-E).
- 7.33 Record the mass of the oven-dried material to the nearest 0.001 lb. (0.5 g) under Tex-113-E, Section 9.
- 7.34 Repeat Sections 7.8–7.33 for all samples.
-

8. CALCULATIONS

- 8.1 Use the equations in Tex-113-E, Section 9.
-

9. GRAPHS

- 9.1 Plot the molding moisture and dry density curve for D_a as shown in Figure 1.



PLOT OF SAMPLE MOISTURE-DENSITY CURVE
* Acceptance limits based on 2004 Item 132 Specifications

Figure 1—Plot of Sample Moisture-Density Curve

10. REPORTING TEST RESULTS

10.1 Report:

- D_a to the nearest 0.1 lbs/ft³ (1 kg/m³)
- W_{opt} to the nearest 0.1 %.

PART II—MEASURING MOISTURE-DENSITY RELATIONSHIP OF SUBGRADE AND EMBANKMENT SOILS

11. SCOPE

- 11.1 Part II uses a 6-in. (152.4-mm) diameter mold and applies only to soils with:
- 100% passing the 7/8-in. (22.4-mm) sieve
 - $\leq 20\%$ passing the 1/4-in. (6.3-mm) sieve
 - GM, GC, SM, or SC soil classifications as described by Tex-142-E
- 11.2 Use Tex-113-E for moisture-density curve determination of flexible base materials and coarse-grained materials containing particles larger than 7/8 in. (22.4 mm). Use of the Soil Compactor Analyzer (SCA) is required at this time for flexible base materials only.

12. PREPARING SAMPLE

- 12.1 Secure a representative sample of material and prepare approximately 132 lb. (60 kg) of moist soil as described in Tex-101-E, Part II for moisture-density test. Do not reuse soil that has been previously laboratory compacted.

13. PROCEDURE

- 13.1 Determine the percent hygroscopic moisture of a representative sample of prepared material in accordance with Tex-103-E.
- 13.2 Separate sample on 7/8 in. (22.4 mm), 3/8 in. (9.5 mm), and 1/4 in. (6.3 mm) sieves, and determine the particle size distribution.
- 13.3 Estimate the mass of air-dried material that will fill the mold when wetted and compacted.
- 13.4 Using this estimated mass and the percentages of the various sizes of particles obtained in Section 13.2, compute the cumulative masses of each size to combine to make a specimen.
- 13.5 Using the masses calculated in Section 13.3, recombine at least four specimens of approximately 22 lb. (10 kg) each.
- 13.6 Estimate the optimum percent moisture required to attain maximum density.
Note 4—The plastic limit is a good indicator of optimum moisture content, typically within 2%, or 3–4% higher for PI >35 material.
- 13.7 Start the M-D curve using a sample with a moisture content of 2% below the estimated optimum moisture content. For soils with a low to moderate plasticity index (PI < 35), adjust the moisture content of the remaining samples in approximately 2% increments to

attain two samples above and two samples below the optimum moisture content. For soils with high plasticity index ($PI \geq 35$), adjust the moisture content in 4% increments to attain two samples above and two samples below the optimum moisture.

Note 5—After compacting the first two or three specimens, the initial M-D curve can be constructed to aid in evaluation of the shape of the curve. If necessary, adjust the water content of the other prepared samples by adding additional water or air-drying to obtain a well-defined compaction curve.

- 13.8 Calculate the mass of the water to be added based on the air-dry mass of the material.
- 13.9 Weigh the required mass of water into a tared sprinkling jar.
- 13.10 Sprinkle water onto the soil during mixing, in increments.
- 13.11 Thoroughly mix each specimen to ensure an even distribution of water.
- 13.12 Cover the mixed sample and allow sample to stand and cure for at least 12 hr. before compacting. When the PI is less than 12, reduce the curing time to not less than 3 hr. Cure split or referee samples for the full 12 hr.
- 13.13 Assemble and secure the mold and collar to the base plate.
- 13.14 Thoroughly remix the cured sample.
- 13.15 Obtain approximately 1 lb. (453.6 kg) of the sample and determine water content as described in Tex-103-E, Section 7.
- 13.16 Place loose soil into the mold and spread into a layer of uniform thickness.
- 13.17 Use hand tools to tamp the soil lightly until it is not fluffy or loose.
- 13.18 Separate the material in the pan into four equal portions. Each portion must contain representative quantities of all sizes and adequate material to compact four 2-in. (50-mm) layers.
- 13.19 For each layer, dump the material into the mold. Spade and level the layer of material with a spatula to fill cavities around the edge and to ensure an even distribution of material in each layer before compacting. Do not push this layer down by hand or other means than that described above.
- 13.20 Compact each layer using 75 per lift with a drop height of 12 in. (304.88 mm).
- 13.21 Use the soil mass and compacted thickness of the first lift to adjust the mass and thickness of the subsequent lifts.
- 13.22 Upon completion of compacting each of the first three lifts, use a knife or other convenient tool to scarify the surface and dislodge the uncompacted soils that extend above the compacted surface.

- 13.23 Use the finishing tools outlined in Tex-113-E and four medium-firm blows of the 4–5 lb. (1.818–2.273 kg) rawhide hammer to level and finish the fourth lift.
- 13.24 Using the height-measuring stand, measure and record the specimen height to the nearest 0.001 in. (0.025 mm). The height of the finished specimen should be $8 \pm 1/4$ in. (2036.3 mm). Discard the specimen if it is too short or too tall.
- Note 6**—To adjust the molded height of specimen in Section 13.21, calculate as follows:
- Dry Weight of Specimen = (Dry Weight of Specimen \times 8") / Height of Specimen*
- 13.25 Determine and record the mass of the specimen and mold as W_T to the nearest 0.001 lb. (0.5 g), under Tex-113-E, Section 9.
- 13.26 Record the data on [Form 113.4](#).
- 13.27 Use the hydraulic jack press to remove the specimen from the mold.
- 13.28 Place the compacted specimen and identification tag into a large pan and break into several pieces.
- 13.29 Obtain the mass of the drying pan and wet sample and record to 0.001 lb. (0.5 g).
- 13.30 Place the specimen in an oven at a temperature of $230 \pm 9^\circ\text{F}$ ($110 \pm 5^\circ\text{C}$) and dry to constant weight.
- Note 7**—Use a $140 \pm 9^\circ\text{F}$ ($60 \pm 5^\circ\text{C}$) oven for ML or MH soils (as determined by Tex-142-E) or soils with measurable sulfates (as determined by Tex-145-E).
- 13.31 Record the mass of the oven-dried material to the nearest 0.001 lb. (0.5 g) under Tex-113-E, Section 9.
- 13.32 Repeat Sections 13.8–13.31 for all samples.

14. CALCULATIONS

- 14.1 Use the equations under Tex-113-E, Section 9.

15. GRAPHS

- 15.1 Plot the molding moisture vs. the dry density curve for D_a shown in Figure 1.

16. REPORTING TEST RESULTS

- 16.1 Report test results as described in Part I.

PART III—MEASURING MOISTURE-DENSITY RELATIONSHIP OF COHESIONLESS BACKFILL

17. SCOPE

17.1 Part III uses a 4-in. (102-mm) ID mold and applies only to cohesionless soils and backfills as described below:

- 100% passing the 1/4 in. (9.5-mm) sieve
- $\geq 50\%$ passing the No. 4 (4.75-mm) sieve
- $\leq 25\%$ passing the No. 200 (75-mm) sieve
- SW – SP classification.

18. PREPARING SAMPLES

18.1 Prepare the material in accordance with Tex-101-E, Part II.

19. PROCEDURE

19.1 Perform Part I, Sections 7.1–7.15, except for Section 7.12.

19.2 Mix the material thoroughly and separate into four equal portions. Each portion must contain representative quantities of all sizes and contain enough material to compact four 1.5-in. (38-mm) layers.

19.3 For each layer, dump the material into the mold. Spade and level the layer of material with a spatula to fill cavities around the edge and to ensure an even distribution of material in each layer before compacting. Do not push this layer down by hand or other means than that described above.

19.4 Compact each layer by applying 61 ram blows with a 10 lb. (4.55 kg.) rammer from a height of 12 in. (457.2 mm).

19.5 Stop the compactor as frequently as necessary to clean the ram face.

19.6 Use the soil mass and compacted thickness of the first layer to adjust the mass and thickness of the subsequent layers.

19.7 Each layer thickness should be approximately equal in height and mass. All material should be molded.

19.8 Upon completion of the fourth lift, the compacted specimen should extend above the top, but by no more than 1/4 in. (6.3 mm). Discard the compacted specimen if it does not extend above the top of the mold at any point.

- 19.9 Remove the collar and use a straight edge or draw knife to carefully trim the compacted specimen even with the top of the mold.
- 19.10 Use trimmed material from the specimen to fill holes on the trimmed surfaces. Trim again, as needed to ensure a smooth, level surface.
- 19.11 Determine and record the mass of the specimen and mold as W_T to the nearest 0.001 lb. (0.5 g) under Tex-113-E, Section 9.
- 19.12 Record the data on [Form 113.4](#).
- 19.13 Carefully center the specimen over a porous stone and place in the hydraulic press to extrude the specimen from the mold.
- 19.14 Place the compacted specimen and identification tag into a large pan and break into several pieces.
- 19.15 Obtain the mass of the drying pan and wet sample and record to 0.001 lb. (0.5 g).
- 19.16 Place the drying pan with wet material in an oven at a temperature of 230°F (110°C) and dry to constant weight.
- 19.17 Record the mass of the oven-dried material to the nearest 0.001 lb. (0.5 g) under Tex-113-E, Section 9.
- 19.18 Repeat Sections 19.2–19.17 for all samples.
- Note 8**—After compacting the first two or three specimens, the initial M-D curve can be constructed to aid in evaluation of the shape of the curve. If necessary, adjust the water content of the other prepared samples by adding additional water or air-drying to obtain a well-defined compaction curve.

20. CALCULATIONS

- 20.1 Use the equations under Tex-113-E, Section 9.

21. REPORTING TEST RESULTS

- 21.1 Report test results as described in Part I.

22. FAMILY OF CURVES

- 22.1 The materials used for subgrade and embankment construction are variable in color, texture, and moisture-density relationship.
- 22.2 To adequately control the compaction and field densities of these materials, it is necessary to have several compaction curves prepared and plotted on the same graph to

assist the inspector to make a sound judgment as to which curve is representative of the material being tested for field density.

- 22.3 The family of compaction curves shown in Figure 2 illustrates that, as the material's plasticity and fineness increase, the D_a will decrease with a corresponding increase in W_{opt} . The wet leg of the compaction curve is generally parallel with the 0% air void line.
- 22.4 To properly correlate the soil properties to a compaction curve, the soil properties presented in Table 1 should be provided along with the family of compaction curves.

Table 1—Soil Properties, Family of Curves, & One-Point Control

Curve No.	Max. Dry Density kg/m ³ (pcf)	Optimum Water Content %	Liquid Limit %	PI	Wet Gradation, % Retained			Material Description
					22.4 mm (7/8 in.)	9.5 mm (3/8 in.)	4.75 mm (No.4)	
1	93.6 (1499.5)	22.0	61	43	0	0	0	dark brown clay
2	96.6 (1547.5)	20.4	48	30	0	0	1.4	brown clay
3	100.3 (1606.8)	18.8	44	27	0	0	2.5	brown clay
4	104.6 (1675.7)	17.4	38	21	0	0	4.3	lt. brown clay

23. ONE-POINT CONTROL

- 23.1 In the event the material being tested for field density does not match the description and properties of any of the materials from the family of compaction curves, the one-point control method may be used to derive an adjusted D_a and W_{opt} by:
- air drying the field sample to a water content near the plastic limit of the material
 - molding one compaction specimen
 - using the one-point moisture-density data to construct a compaction curve which mimics the shape of the family of curves
- 23.2 The wet leg of the compaction curve is well defined by the 0% air void line; therefore, it is essential to air-dry the field sample to a water content near the plastic limit of the material and provide better definition of the dry side of the curve. Figure 2 shows an example of the one-point control method.

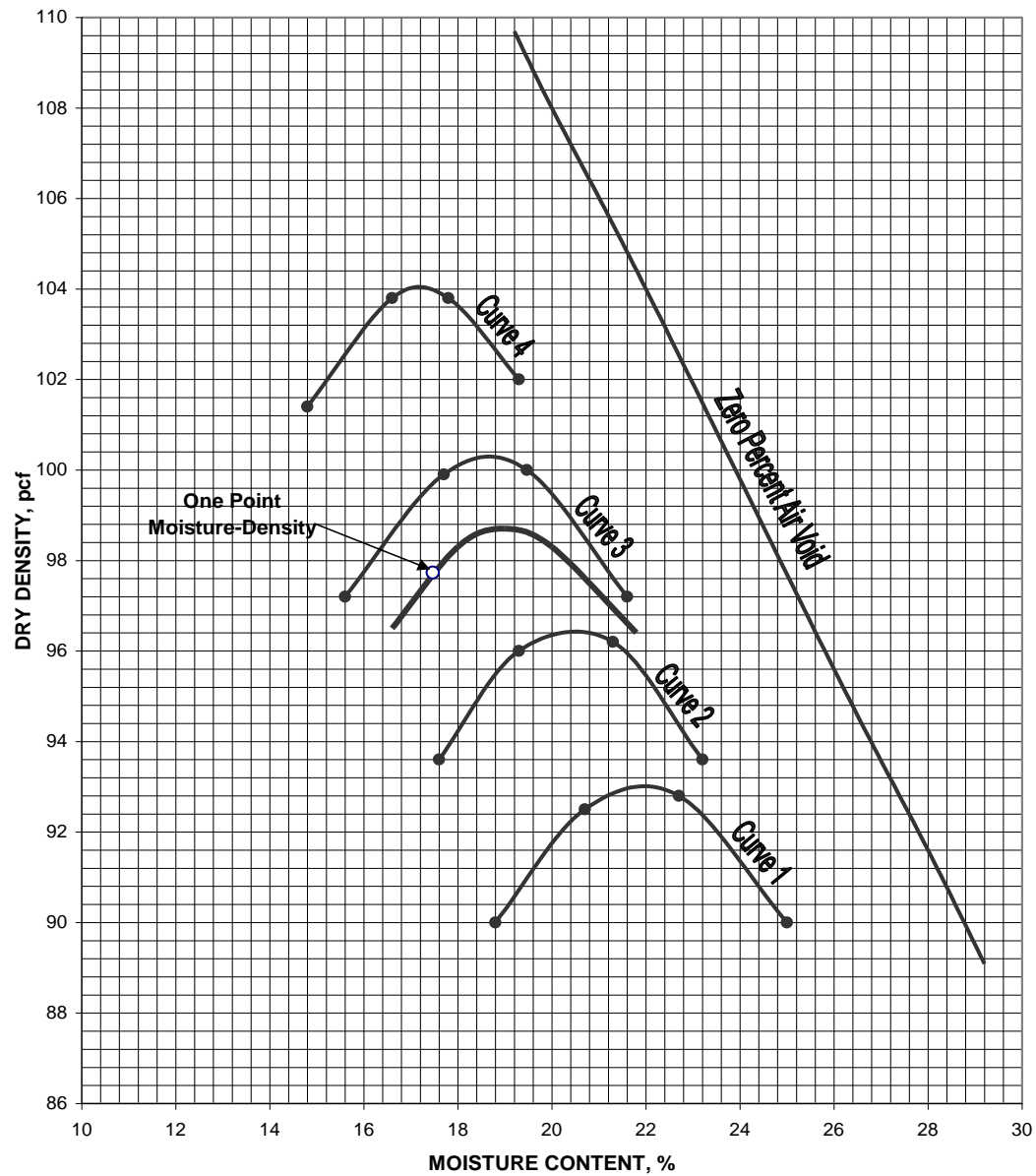


Figure 2—Family of Curves and One-Point Control (Example)

24. ARCHIVED VERSIONS

24.1 Archived versions are available.



Tex-114-E, Moisture-Density Worksheet

	lbs. Hygroscopic Moisture						
A	Total % Water						
B	lbs. Material						
C	lbs. Water Added $(A \times B) / 100$						
D	Wet Mass Specimen & Mold						
E	Tare Mass of Mold						
F	Wet Mass of Specimen $(D - E)$						
G	Height of Specimen						
H	Volume of Mold Linear mm/in						
I	Volume of Specimen $(G \times H)$						
J	Wet Density of Specimen (F / I)						
K	Wet Mass Pan & Specimen						
L	Dry Mass Pan & Specimen						
M	Tare Mass of Pan						
N	Dry Mass of Material $(L - M)$						
O	Mass of Water $(K - L)$						
P	% Water Content on Total $(O/N)100$						
	Dry Density $(100 \times J) / (100 + P)$						
	Maximum Dry Density						
	Optimum Moisture %						

Test Procedure for**SOIL-CEMENT TESTING****TxDOT Designation: Tex-120-E****Effective Date: April 2013**



1. SCOPE

- 1.1 This method consists of two parts.
 - 1.1.1 Part I determines the unconfined compressive strength of compacted soil-cement specimens after seven days curing (10 lb. hammer, 18-inch drop, 50 blows/layer using 6 × 8 in. mold).
 - 1.1.2 Part II applies to cement treated materials sampled from the roadway during construction.
 - 1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.
-

2. APPARATUS

- 2.1 As outlined in test methods:
 - Tex-101-E
 - Tex-113-E
 - Tex-117-E.
 - 2.2 *Compression testing machine*, with capacity of 267 kN (60,000 lb.), meeting the requirements of ASTM D 1633.
 - 2.3 *Triaxial screw jack press* (Tex-117-E), used when anticipated strengths are not in excess of 2758 kPa (400 psi).
-

3. MATERIALS

- 3.1 *Hydraulic (portland) cement.*
- 3.2 *Tap water.*

4. PREPARING SAMPLE

- 4.1 Select approximately 90 kg (200 lb.) of material treat with cement in accordance with Tex-101-E, Part II.

PART I—COMPRESSIVE STRENGTH TEST METHODS (LABORATORY MIXED)

5. PROCEDURE

- 5.1 Determine the optimum moisture content and maximum density for a soil-cement mixture containing 6% cement in accordance with Tex-113-E. The amount of cement added is a percentage based on the dry mass of the soil.
- 5.2 Recombine the sizes prepared in accordance with Tex-101-E, Part II, to make three individual samples and add the optimum moisture content, from Tex-113-E, to each sample. Mix thoroughly.
- 5.2.1 Cover the mixture to prevent loss of moisture by evaporation. Allow the wetted samples to stand for at least 12 hours before compaction. When the plasticity index (PI) is less than 12, the standing time may be reduced to not less than three hours. Split or referee samples should stand the full term.
- 5.2.2 Prior to compaction, replace any evaporated water and thoroughly mix each specimen.
- 5.2.3 Add cement uniformly and mix thoroughly.
- 5.3 Compact the specimen in four layers using Tex-113-E compactive effort.
- 5.3.1 Alter the percent molding water slightly as the percent cement is increased or decreased. Do this in order to mold nearer optimum moisture without running a new M/D curve for each percentage of cement.
- Note 1**—A new M/D curve for each percentage of cement may be performed, if desired.
- 5.3.2 Use the following equation to vary the molding water:
- $$\% \text{ molding water} = \% \text{ optimum moisture from M/D curve} + 0.25 (\% \text{ cement increase})$$
- Where:
- $$\% \text{ cement increase} = \text{difference in cement content between curve and other cement contents.}$$
- 5.4 Using the moisture contents outlined above, mold three specimens for each cement content using 4, 8, and 10% cement to complete the full set.

- 5.4.1 After the top surface of each specimen has been leveled and the specimen measured, carefully center over porous stone and remove specimen from mold by means of small press.
- 5.4.2 Place a card on each specimen showing the laboratory identification number and the percent of cement.
Note 2—In calculating the actual dry density of laboratory mix soil-cement specimens, the dry mass of material is the total mass of oven dry soil in the specimen plus the mass of cement. The amount of moisture should be the mass of hygroscopic moisture in the soil plus the amount of water added based on the dry mass of the soil plus cement. Determine moisture and density of road-mixed and wetted materials and soil-cement cores from the oven dry masses.
- 5.5 Store test specimens the same day as molded, with top and bottom porous stones, in the damp room for seven days. Do not subject specimen to capillary wetting or a surcharge. Do not use a triaxial cell. Place a pan on top of the top porous stone to protect the specimen from dripping water.
- 5.6 Remove test specimens from the damp room and use a cloth to remove any free water on the surface of the specimens.
- 5.7 Test specimens in compression at 0 kPa (0 psi) lateral confinement in accordance with Tex-117-E, Section 5.19 when using an automated load frame, or Section 5.20 when using a screw jack press.
-

6. TEST REPORT

- 6.1 Report molding moisture to the nearest 0.1%.
- 6.2 Report dry density to the nearest 1 kg/m³ (0.1 pcf).
- 6.3 Report unconfined compressive strength to the nearest whole kPa (psi) for each cement content tested.
- 6.4 Report recommended cement content to the nearest 0.5%.
Note 3—Store cement in airtight container or use fresh supply.
Note 4—When comparing laboratory strengths with roadway strength, use the H/D correction factors in Tex-118-E, Table 1 on both laboratory and roadway specimens.
-

PART II—COMPACTION TESTING OF ROAD MIXED MATERIAL

7. PROCEDURE

- 7.1 Obtain samples for moisture/density curve just prior to the start of compaction operations on the roadway.

- 7.2 Screen cement stabilized materials taken from the roadway during construction over a 6.3 mm (1/4 in.) sieve at field moisture content, without drying.
- 7.2.1 Mix each of these two sizes, plus 6.3 mm (1/4 in.) and minus 6.3 mm (1/4 in.), for uniformity and weigh.
- 7.2.2 Cover each size fraction to maintain field moisture.
- 7.3 Recombine and mold one specimen at the field moisture condition and estimated mass to produce specimen compacted using Tex-113-E compactive effort. Molding should be accomplished using the same equipment and compactive effort as in Part I.
- 7.3.1 Adjust mass, if necessary, and weigh out not less than two additional specimens at the field moisture content for compaction. Molding moisture can be adjusted in each specimen by adding or removing moisture uniformly as needed.
- 7.3.2 Compact cement stabilized material in the laboratory in approximately the same timeframe as on the road. Compaction sample of cement-stabilized material from the road mix should not be prepared by oven drying.
- Note 5**—To determine moisture-density relationship of fine-grained materials with less than 20% retained on the 6.3 mm (1/4 in.) sieve and 100% passing the 9.5 mm (3/8 in.) sieve, the engineer may elect to use a mold with approximate dimensions of 101.6 mm (4.0 in.) in diameter by 152.4 mm (6.0 in.) in height. The number of blows must be calculated when changing mold size to maintain a compactive effort of 1100 kN-m/m³ (13.26 ft-lb/in.³)
- Note 6**—The contractor should be provided an initial optimum moisture based on preliminary laboratory tests.
- 7.4 Store test specimens the same day as molded, with top and bottom porous stones, in the damp room for seven days. Do not subject specimen to capillary wetting or a surcharge. Do not use a triaxial cell. Place a pan on top of the top porous stone to protect the specimen from dripping water.
- 7.5 Remove test specimens from the damp room and use a cloth to remove any free water on the surface of the specimens.
- 7.6 Test specimens in compression at 0 kPa (0 psi) lateral confinement in accordance with Tex-117-E, Section 5.19 when using an automated load frame, or Section 5.20 when using a screw jack press.

8. TEST REPORT

- 8.1 Report density to the nearest 1 k/m³ (0.1 pcf).
- 8.2 Report moisture content to the nearest 0.1 %.
- 8.3 Report unconfined compressive strength to the nearest whole kPa (psi).

9. ARCHIVED VERSIONS

9.1 Archived versions are available.

Test Procedure for**SOIL-LIME TESTING****TxDOT Designation: Tex-121-E****Effective Date: August 2002**



1. SCOPE

- 1.1 This method consists of three parts.
- 1.1.1 Part I determines the unconfined compressive strength as an index of the effectiveness of hydrated lime treatment in improving structural properties in flexible base and subgrade materials (10 lb. hammer, 18-inch drop, 50 blows/layer using 6 x 8 in. mold).
- 1.1.2 Part II applies to lime treated materials sampled from the roadway during construction.
- 1.1.3 Part III determines the minimum percent lime needed for a soil-lime mixture to attain a pH of 12.4. Cation exchange occurs at this pH, resulting in modification of the soil particle structure to achieve improved workability and decrease swell and plasticity.
- 1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.
-

2. APPARATUS

- 2.1 Apparatus outlined in Test Methods:
- Tex-101-E
 - Tex-113-E
 - Tex-117-E.
- 2.2 *Compression testing machine*, with capacity of 267 kN (60,000 lb.), meeting the requirements of ASTM D 1633.
- 2.3 *Triaxial screw jack press*, if anticipated strengths do not exceed 2758 kPa (400 psi.)
-

3. MATERIALS

- 3.1 *Hydrated lime.*
- 3.2 *Tap Water.*
-

4. PREPARING SAMPLE

- 4.1 Select approximately 91 kg (200 lb.) of material and prepare in accordance with Tex-101-E, Part II.

PART I—COMPRESSIVE STRENGTH TEST METHODS (LABORATORY MIXED)

5. PROCEDURE

- 5.1 Determine the optimum water content and maximum dry density for the soil-lime mixture using Tex-113-E.
- 5.2 Determine the amount of lime needed based on the dry mass of the soil.
Note 1—Store lime in an airtight container or use a fresh supply.
- 5.3 Recombine the sizes prepared according to Tex-101-E, Part II to make three individual samples and add the optimum moisture content. Mix thoroughly and cover the mixture to prevent loss of moisture by evaporation.
- 5.3.1 Allow the wetted samples to stand for at least 12 hours before compaction.
- 5.3.2 A standing time of at least 12 hours is required for materials with a PI greater than or equal to 12. When the PI is less than 12, the standing time may be reduced to not less than three hours. Split or referee samples should stand the full term.
- 5.3.3 Prior to compaction, replace any evaporated water and thoroughly mix each specimen.
- 5.3.4 Add the desired amount of lime uniformly to a specimen and mix thoroughly.
- 5.4 Following Tex-113-E, compact three specimens, 152.4 mm (6 in.) in diameter, and 203.2 mm (8 in.) in height, at the optimum moisture content found in Section 5.1. You may use a 101.6 mm (4 in.) diameter mold 152.4 mm (6 in.) high when the material meets the requirements of Note 2.
Note 2—To determine moisture-density relationship of fine-grained materials with less than 20 % retained on the 6.3 mm (1/4 in.) sieve and 100 % passing the 9.5 mm (3/8 in.) sieve, the engineer may elect to use a mold with approximate dimensions of 101.6 mm (4.0 in.) in diameter by 152.4 mm (6.0 in.) in height. Calculate the number of blows when changing mold size to maintain a compactive effort of 1100 kN-m/m³ (13.26 ft.-lb./in.³).
- 5.4.1 Lime-treated subgrade soil specimens should be compacted as nearly identical as possible and three specimens cured and tested for unconfined compression.
- 5.4.2 If the material to be improved by lime treatment is a flexible base material, the unconfined compression test is used to evaluate the strength. Compact three identical specimens for each percentage of hydrated lime, cure, and test for unconfined compression.

- 5.5 Cover specimens with top and bottom porous stones and place in triaxial cells immediately after extrusion from molds.
- 5.5.1 Store specimens at room temperature for seven days of moist curing at room temperature on the countertop.
- 5.6 After curing, remove cells and place the specimens in an air dryer oven at a temperature not to exceed 60°C (140°F) for about six hours or until 1/3 to 1/2 of the molding moisture has been removed. All lime-treated soils are dried as given above even though a considerable amount of cracking may occur. Allow the specimens to cool to room temperature before continuing the test.
- 5.7 Weigh, measure, and enclose the specimens in triaxial cells, and subject them to capillarity for ten days. Use a constant lateral pressure of 6.9 kPa (1 psi), and a surcharge pressure of 3.4 kPa (1/2 psi) for base to 6.9 kPa (1 psi) for subgrade depending upon the use of the material being tested. (A wet room is not required for this curing.)
- 5.8 Test the specimens for unconfined compression without a cell. A compression testing machine of adequate range and sensitivity may be used.
-

6. CALCULATIONS AND GRAPHS

- 6.1 Calculate, plot and interpret test data for the unconfined compression test. Lime stabilized clay soils are not recommended for top course of base, regardless of strength.
-

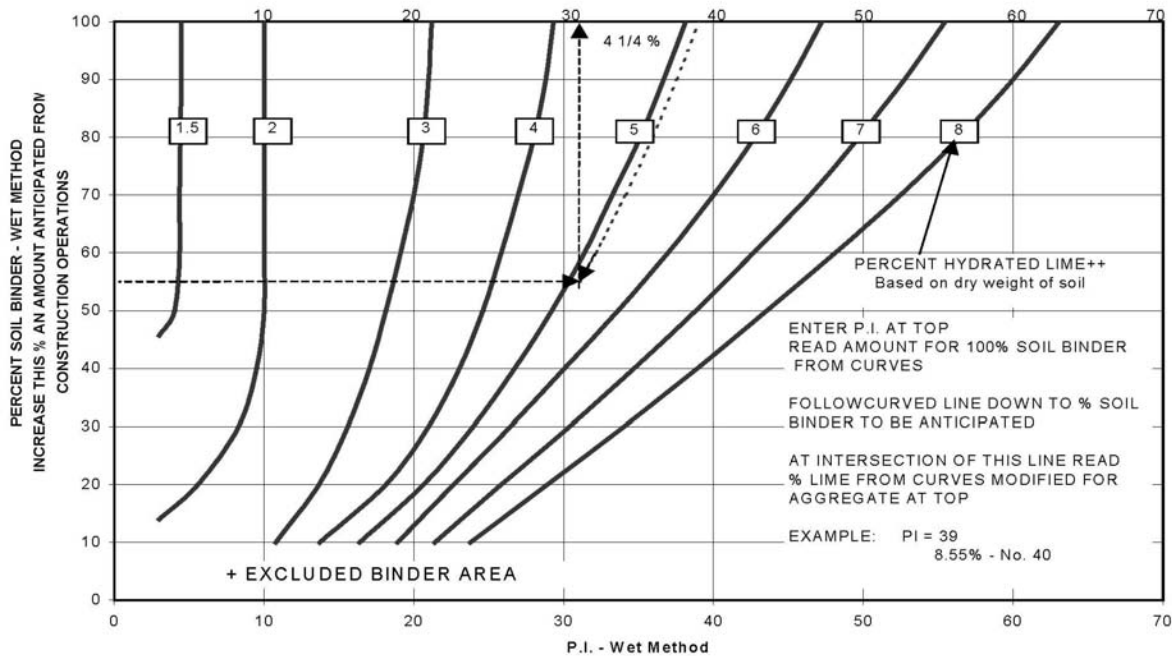
7. TEST REPORT

- 7.1 Strength value, reported to the nearest whole kPa (psi) for each lime content tested
- 7.2 Density, reported to the nearest 1 kg/m³ (0.1 pcf)
- 7.3 Optimum moisture content, reported to the nearest 0.1%
- 7.4 Recommended lime content, reported to the nearest 0.5%

Note 3—This test determines the quality of soils treated with lime to be used for subbase or base protected with a wearing surface. Flexible base materials and granular soils can usually be stabilized with about 3% lime. A larger amount of lime may be required to improve the strength of a very plastic clay subgrade. Unconfined compressive strength of 1035 kPa (150 psi) is satisfactory for final course of base construction and it is desirable that materials for such courses contain a minimum of 50 percent plus 425 µm (No. 40) before treatment.

The amounts of lime from Figure 1 are recommended amounts for stabilization of subgrade soils and base materials. These percentages of lime should be substantiated by these methods to insure adequate strengths. Unconfined compressive strengths of at least 345 kPa (50 psi) are suggested as adequate for subbase soils treated with lime. It is possible for short-term tests of soil-lime mixes, using smaller percentages of lime, to give

misleading results due to field variations in materials, mixing, lower densities, and so forth.



- + Exclude use of chart for materials with less than 10% minus 425um (No. 40) and cohesionless materials (PI less than 3).
- ++ Percent of relatively pure lime usually 90% or more of Ca and/or Mg hydroxides and 855 or more of which pass the 75um (No 200) sieve. Percentages shown are for stabilizing subgrades and base courses where lasting effects are desired. Satisfactory temporary results are sometimes obtained by the use of as little as 1/2 of above percentages. References to cementing strength is implied when such terms as "Lasting Effects" and "Temporary Results" are used.

Figure 1—Recommended Amounts of Lime for Stabilization of Subgrades and Bases

PART II—COMPACTION TESTING OF ROAD MIXED MATERIAL

8. PROCEDURE

- 8.1 Obtain samples for the moisture/density curve just prior to the start of compaction operations on the roadway.
- 8.1.1 If the material on the roadway is reworked and re-compacted for any reason, it will be necessary to obtain samples just prior to re-compaction of the reworked material for a new curve representing the reworked material.
- 8.2 Screen lime stabilized materials taken from the roadway during construction for density and/or strength testing over a 6.3 mm (1/4 in.) sieve at field moisture content, without drying.
- 8.2.1 Mix each size for uniformity and record the weight.

- 8.2.2 Cover each size material, plus 6.3 mm (1/4 in.) and minus 6.3 mm (1/4 in.) to maintain field moisture.
- 8.2.3 Recombine one representative specimen and mold at the field moisture condition.
- 8.2.4 Adjust mass, if necessary, and weigh out specimens for compaction and strength testing, if desired.
- 8.2.5 Molding moisture can be adjusted in each specimen by adding or removing moisture in the total specimen uniformly as needed.
- 8.2.6 Lime stabilized material should be sampled, prepared and molded during the same day compaction operations begin on the project.
- 8.2.7 Molding should be accomplished using the same equipment and compactive effort as in Part I.
- Note 4**—Compaction sample of lime-stabilized material from the road mix should not be prepared by oven drying.
- Note 5**—The contractor should be provided an initial optimum moisture based on preliminary tests.

9. TEST REPORT

- 9.1 Density, reported to the nearest 1 kg/m³ (0.1 pcf)
- 9.2 Optimum water content, reported to the nearest to 0.1%

PART III—DETERMINING STABILIZATION ABILITY OF LIME BY SOIL pH

10. APPARATUS

- 10.1 Same as for Tex-128-E.

11. MATERIALS

- 11.1 Same as for Tex-128-E.

12. PREPARING SAMPLE

- 12.1 Use the same sample preparation as described in Tex-128-E.

13. PROCEDURE

- 13.1 Heat sample and approximately 1400 mL (47.5 fl. oz.) of distilled water to 45–60°C (112–140°F) in separate containers.
- 13.2 Weigh to the nearest 0.01 g a series of 30 g samples of soil and place in separate containers.
- 13.3 Weigh to the nearest 0.01 a series of quantities of lime equivalent to 0, 2, 4, 6, 8, and 10% of the total dry soil sample.
- 13.4 Add one of the lime percentages to each of the soil samples, add 150 mL (5 fl. oz.) of distilled water to each combination, and stir vigorously.
- 13.5 Stir the samples every 15 minutes for 1 hour to disperse the soil and make sure all soluble material is in solution.
- 13.6 At the end of an hour, record the temperature of the mixture and adjust the pH meter to that temperature.
- 13.7 Standardize the meter (buffer solution of pH 7.0) according to the manufacturer's recommendations. (If the meter allows multiple standardizations, standardize the meter to buffer solutions of pH 7.0 and 10.0).
- 13.8 Clean electrode with distilled water.
Note 6—If there are scratches on the glass bulb of electrode, replace with new electrode.
- 13.9 Check the pH of each sample as described in Tex-128-E, Sections 5.7–5.9 and record.
- 13.10 Plot the pH of the samples versus the percent lime (pH on the y-axis, percent lime on the x-axis.) (See Figure 2.)
- 13.10.1 If the pH readings are 12.4 or higher, the lowest percentage of lime that gives a pH of 12.4 is the percent required to stabilize the soil.
- 13.10.2 If the pH readings do not go beyond pH of 12.3 and two percentages give this reading, the lowest percentage of lime to give a pH of 12.3 is the percent required to stabilize the soil.
- 13.10.3 If the highest pH reading is a pH of 12.3 and only the highest percentage of lime used gives a pH of 12.3, additional testing is required using higher percentages of lime.

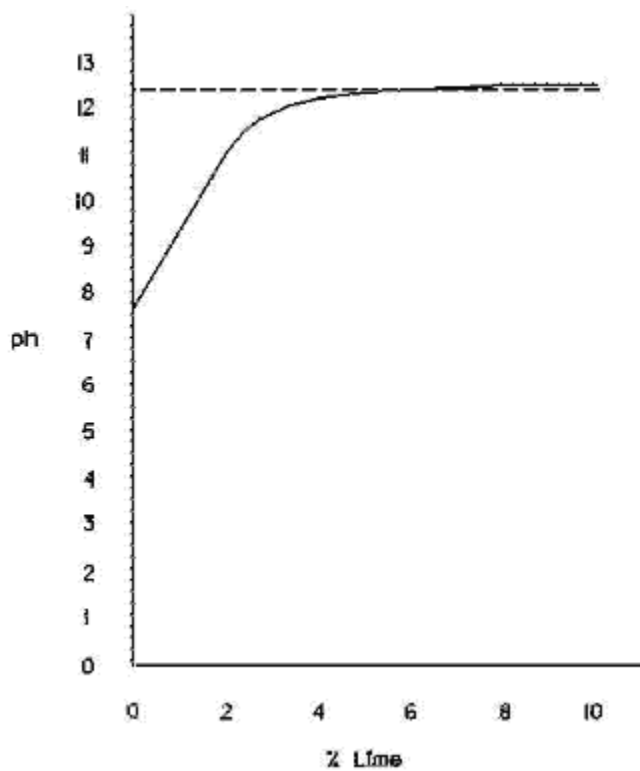


Figure 2—pH Versus Percent Lime

14. REPORT

14.1 Report the recommended percent lime to the nearest 0.1%.

15. ARCHIVED VERSIONS

15.1 Archived versions are available.

Test Procedure for

LABORATORY CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES



TxDOT Designation: Tex-142-E

Effective Date: August 1999

1. SCOPE

- 1.1 This method is a system for classifying disturbed and undisturbed soils based on laboratory determination of liquid limit, plasticity index, and particle-size characteristics.
 - 1.1.1 This method of soil classification is similar to the ASTM version of the Unified Soils Classification System (USCS). This classification system identifies three major soil groups: coarse-grained soils, fine-grained soils, and highly organic soils.
 - 1.1.2 Based on visual observations and prescribed laboratory tests, a soil is assigned a group symbol(s) and names and thereby classified.
 - 1.1.3 There are other parameters such as unconfined compressive strength, dry unit weight, and water content, which can be used in conjunction with this method to provide detailed description of undisturbed soil samplers.
 - 1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.
-

2. DEFINITIONS

- 2.1 *Plasticity Chart*—A plasticity chart is used to differentiate the plasticity and organic characteristics of the fine-grained soils based on liquid limit (LL) and plasticity index (PI) of the soils.
 - 2.2 *A-Line*—On the plasticity chart, A-line is a sloped line beginning at $PI = 4$ and $LL = 25.5$ with an equation of $PI = 0.73 (LL - 20)$.
 - 2.3 *Clay*—Clay is a fine grained soil that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry.
 - 2.4 *Silt*—Silt is soil passing the No. 200 (75 μm) sieve that is non-plastic or very slightly plastic and that exhibits little or no strength when air dry.
-

- 2.5 *Organic Clay*—Organic clay is a soil that would be classified as a clay except that its LL after oven drying (dry sample preparation) is less than 75% of its LL before oven drying (wet sample preparation).
- 2.6 *Organic Silt*—Organic silt is a soil that would be classified as a silt except that its LL after oven drying (dry sample preparation) is less than 75% of its LL before oven drying (wet sample preparation).
- 2.7 *Peat*—Peat is a soil composed of vegetable tissue in various stages of decomposition usually with a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.
- 2.8 *Gravel*—Gravel consists of unconsolidated or loose detrital sediment (aggregate resulting from natural disintegration and abrasion of rock) with particle sizes passing the 3 in. (76.2 mm) sieve and retained on the No. 10 (2.00 mm) sieve.
- 2.9 *Sand*—Sand consists of fine aggregate particles that are retained on the No. 200 (75 μ m) sieve, either as natural sand resulting from natural disintegration and abrasion of rock, or as manufactured sand, which is produced by the crushing of rock, gravel, slag, etc.
- 2.10 *Coefficient of Curvature, C_c* —Coefficient of Curvature is the ratio $(D_{30})^2 / (D_{10} \bullet D_{60})$, where D_{60} , D_{30} , and D_{10} are the particle diameters corresponding to 60, 30, and 10% finer on the cumulative particle-size distribution curve, respectively.
- 2.11 *Coefficient of Uniformity, C_u* —Coefficient of Uniformity is the ratio (D_{60}/D_{10}) , where D_{60} and D_{10} are the particle diameters corresponding to 60 and 10% finer on the cumulative particle-size distribution curve, respectively.
-

3. **PREPARING SOIL FOR CLASSIFICATION**

- 3.1 Before a sample can be classified according to this test method, determine the particle-size distribution of the minus 3 in. (75 mm) sieve and minus No. 4 (4.75 mm) sieve material and the soils constants (LL, PL & PI) of the minus No. 40 (425 μ m) sieve material.
- 3.2 Use the following test methods to determine these parameters:
- Tex-110-E
 - Tex-104-E
 - Tex-105-E
 - Tex-106-E.
- 3.2.1 Following are the criteria for assigning group symbols and group names using laboratory test results.
- 3.2.1.1 *Coarse-Grained Soil*—More than 50% by dry weight is retained on the No. 200 (75 μ m) sieve.

Table 1—Gravels – More than 50% of Plus No. 200 (75 µm) Retained on the No. 4 (4.75 mm) Sieve

		Symbol	Group Name
Clean Gravel – less than 5% fines	$Cu \geq 4 \text{ \& } 1 \leq Cc \leq 3$	GW	Well-graded gravel
	$Cu < 4 \text{ \&/or } 1 > Cc > 3$	GP	Poorly graded gravel
Gravel with fines – 5 to 12% clay fines	$Cu \geq 4 \text{ \& } 1 \leq Cc \leq 3$	GW-GC	Well-graded gravel with clay
	$Cu < 4 \text{ \&/or } 1 > Cc > 3$	GP-GC	Poorly graded gravel with clay
Gravel with fines – 5 to 12% silt fines	$Cu \geq 4 \text{ \& } 1 \leq Cc \leq 3$	GW-GM	Well-graded gravel with silt
	$Cu < 4 \text{ \&/or } 1 > Cc > 3$	GP-GM	Poorly graded gravel with silt
Gravel with more than 12% fines	Fines classified as CL or CH	GC	Clayey Gravel
	Fines classified as ML or MH	GM	Silty Gravel

Note: If gravel contains $\geq 15\%$ sand, add “with sand” after group name. If fines are organic, add “with organic fines” after the group name.

Table 2—Sands – 50% or More of Plus No. 200 (75 µm) Passes the No. 4 (4.75mm) Sieve

		Symbol	Group Name
Clean Sands - less than 5% fines	$Cu \geq 6 \text{ \& } 1 \leq Cc \leq 3$	SW	Well-graded sand
	$Cu < 6 \text{ \&/or } 1 > Cc > 3$	SP	Poorly graded sand
Sand with 5 to 12% clay fines	$Cu \geq 6 \text{ \& } 1 \leq Cc \leq 3$	SW-SC	Well-graded sand with clay
	$Cu < 6 \text{ \&/or } 1 > Cc > 3$	SP-SC	Poorly graded sand with clay
Sand with 5 to 12% silt fines	$Cu \geq 6 \text{ \& } 1 \leq Cc \leq 3$	SW-SM	Well-graded sand with silt
	$Cu < 6 \text{ \&/or } 1 > Cc > 3$	SP-SM	Poorly graded sand with silt
Sand with more than 12% fines	Fines classified as CL or CH	SC	Clayey Sand
	Fines classified as ML or MH	SM	Silty Sand

Note: If sand contains $\geq 15\%$ gravel, add “with gravel” after group name. If fines are organic, add “with organic fines” after group name.

3.2.1.2 *Fine-Grained Soil*—50% or more passes the No. 200 (75 μ m) sieve.**Table 3—Silts and Clays – Liquid Limit Less than 50% & Have Less than 15% Material Retained on No. 200 (75 μ m) Sieve**

		Symbol	Group Name
Inorganic	PI > 7 & plots on or above "A" line	CL	Lean Clay
	PI < 4 or plots below "A" line	ML	Silt
	4 < PI < 7 & plots on or above "A" line	CL-ML	Silty Clay
Organic - defined by (LL-oven dried)/(LL-not dried) < 0.75	PI \geq 4 & plots on or above "A" line	OL	Organic Clay
	PI < 4 or plots below "A" line		Organic Silt

Note: If soil contains 15 to 29% plus No. 200 (75 μ m), add "with sand" or "with gravel" after group name, whichever is predominant. If soil contains 30% or more plus No. 200 (75 μ m), predominantly sand, add "sandy" before group name. If soil contains 30% or more plus No. 200 (75 μ m), predominantly gravel, add "gravelly" before group name.

Examples:

- (CL) lean clay w/sand; lean clay w/gravel; sandy lean clay; sandy lean clay w/gravel; gravelly lean clay; etc.
- (CL-ML) silty clay w/sand; silty clay w/gravel; sandy silty clay; sandy silty clay w/gravel; gravelly silty clay; etc.
- (ML) silt w/sand; silt w/gravel; sandy silt; sandy silt w/gravel; gravelly silt w/sand
- (OL) organic clay w/sand; organic clay w/gravel; sandy organic clay; sandy organic clay w/gravel; etc.
- (OL) organic silt w/sand; organic silt w/gravel; sandy organic silt; sandy organic silt w/gravel; etc.

Table 4—Silts and Clays – Liquid Limit of 50% or More & Have Less than 15% Material Retained on No. 200 (75 µm) Sieve

		Symbol	Group Name
Inorganic	PI plots on or above "A" line	CH	Fat Clay
	PI plots below "A" line	MH	Elastic Silt
Organic – defined by (LL-oven dried)/(LL-not dried)<0.75	PI plots on or above "A" line	OH	Organic Clay
	PI plots below "A" line	OH	Organic Silt

Note: If soil contains 15 to 29% plus No. 200 (75 µm), add "with sand" or "with gravel" after group name, whichever is predominant. If soil contains 30% or more plus No. 200 (75 µm), predominantly sand, add "sandy" before group name. If soil contains 30% or more plus No. 200 (75 µm), predominantly gravel, add "gravelly" before group name. (CH) fat clay w/sand; fat clay w/gravel; sandy fat clay; sandy fat clay w/gravel; gravelly fat clay; etc.

Examples:

- (MH) elastic silt w/sand; elastic silt w/gravel; sandy elastic silt; sandy elastic silt w/gravel; etc.
- (OH) organic clay w/sand; organic clay w/gravel; sandy organic clay; sandy organic clay w/gravel; etc.
- (OH) organic silt w/sand; organic silt w/gravel; sandy organic silt; sandy organic silt w/gravel; etc.

4. PROCEDURE

4.1 Determine the LL, PL, and PI of the soil in accordance with:

- Tex-104-E
- Tex-105-E
- Tex-106-E.

4.2 Determine the water content of the soil in accordance with Tex-103-E.

4.3 Determine the amount of material passing the No. 200 (75 µm) sieve in accordance with Tex-110-E for fine-grained soil, or Tex-401-A for coarse-grained soil.

4.4 Determine the particle size distribution of the materials retained on the No. 200 (75 µm) sieve in accordance with Tex-406-A decantation tests for concrete aggregates.

4.5 Use Figure 1, LL, PI, percent material passing the No. 200 (75 µm) sieve, and Cu and Cc, and classify the soil with group name and description with group symbol.

Note 1—Other than soil constants and particle size distribution, there are other engineering properties that can be measured in either the field or laboratory in conjunction with this classification system to provide a more complete description of the soil characteristics.

Note 2—In general, there is a close correlation among the soil classification and the engineering properties such as consistency, density, water content, and dry unit weight. When available, this information should be used in conjunction with soil classification to aid in the evaluation of the soil's significant properties for engineering use.

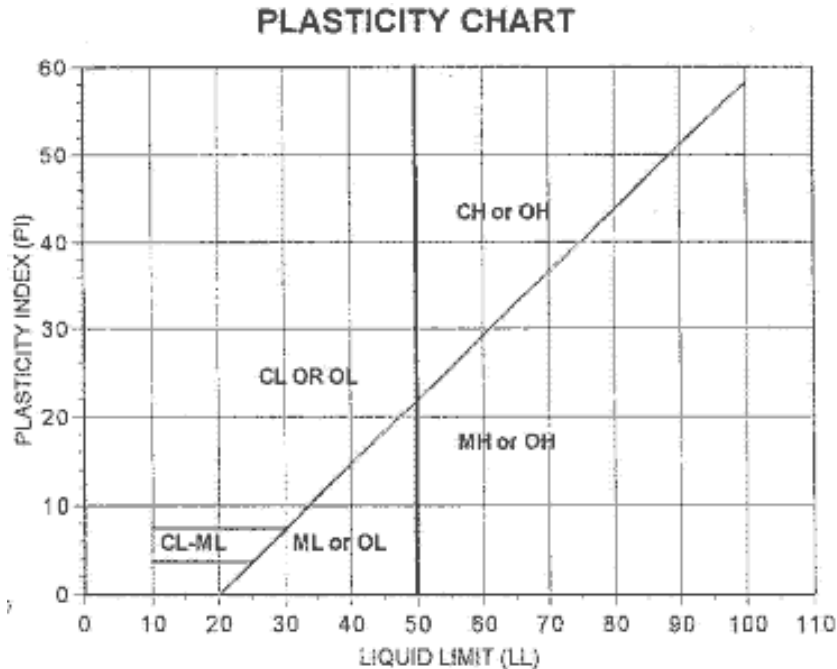


Figure 1—Plasticity Chart

5. CONSISTENCY

5.1 The consistency of a predominantly clay and/or silt is defined by its unconfined compressive (UC) strength when tested in the laboratory under the normal moisture condition in an undisturbed condition. Typically, one would find higher water content associated with lower unconfined compressive strength or softer material, and lower water content associated with a higher unconfined compressive strength or harder material.

5.2 Table 5 classifies soil by unconfined compressive strength.

Table 5—Soil Consistency

UC kg/cm ² (tsf)	Consistency
less than 0.25	Very Soft
0.25 to 0.5	Soft
0.5 to 1.0	Medium Stiff
1.0 to 2.0	Stiff
2.0 to 4.0	Very Stiff
greater than 4.0	Hard

6. DENSITY

6.1 Soil density as typically measured by the N-Value of in-situ Standard Penetration Test (SPT) or the Texas Cone Penetration Test (TCP) is an indication of the relative compactness and bearing capacity of a predominantly granular material such as sand, clayey sand, silty sand, and gravelly material. The water content of a granular material is mostly unimportant because the bearing strength is independent of water content, and the water content of a disturbed sample is not representative of the material.

6.2 Table 6 classifies soil by density.

Table 6—Soil Density

SPT N Value	TCP Blows/0.3 m (12 in.)	Density
less than 4	less than 8	Very Loose
4 to 10	8 to 20	Loose
10 to 30	20 to 60	Medium Dense
30 to 50	60 to 100	Dense
Greater than 50	greater than 100	Very Dense

7. DRY UNIT WEIGHT

7.1 Dry unit weight of the material usually increases with decreasing plasticity and/or increasing percentage of coarse-grained particles in the soils. One can usually find a higher than usual water content and lower dry unit weight in an organic material. The more plastic material such as clay has a greater propensity to hold water and therefore has a higher water content and lower dry unit weight.

7.2 Table 7 indicates the dry unit weight for soil types.

Table 7—Dry Unit Weight for Soil Types

Dry Unit Weight Kg/m3 (pcf)	Soil Type (Group Symbol)
0.77–1.03 (60–80)	Organic Clay (OH)
1.03–1.22 (80–95)	Clay (CH)
1.16–1.35 (90–105)	Clay (CL)
1.22–1.42 (95–110)	Sandy Clay (CL)
1.29–1.55 (100–120)	Clayey Sand (SC)

Test Procedure for

SAMPLING AGGREGATE, FLEXIBLE BASE, AND STONE RIPRAP

TxDOT Designation: Tex-400-A

Effective Date: April 2021

1. SCOPE

- 1.1 Use this test procedure for sampling completed stockpiles of coarse and fine aggregate used to produce concrete and retaining wall select backfill, stockpiles of flexible base, and stone riprap. This procedure may also be used to sample concrete aggregate during production when stored in bays or stockpiles that are not accessible in three directions.
- 1.2 Use this test procedure to sample completed coarse or fine aggregate stockpiles and materials using a front-end loader or shovel. The preference for sampling is to use a front-end loader. Only use a shovel where a front-end loader is not available.

2. SAMPLE SIZE

- 2.1 Use Table 1 to determine the minimum sample size to perform the required tests listed in the applicable specification.
- 2.2 Obtain samples that show the true nature and condition of the materials that they represent. Do not combine materials that apparently differ in property or character to make a composite sample. Differences may be indicated by color or texture.
- 2.3 Use a sample splitter or quartering cloth to reduce the field sample to laboratory test size.

Nominal Maximum Size of Aggregate ¹	Minimum Weight of Field Samples ² (lbs.)
No. 8	25
No. 4	25
3/8 in.	25
1/2 in.	35
3/4 in.	55
1 in.	110
1-1/2 in.	165
2 in.	220
2-1/2 in.	275
3 in.	330
Nominal Maximum Size of Flexible Base ¹	Minimum Weight of Field Samples ² (lbs.)
1-3/4 in.	400

1. The maximum aggregate size is the largest sieve size listed in the applicable specification upon which any material can be retained.
2. The minimum sample mass depends upon the maximum aggregate size as well as the number and type of tests required.

3. SAMPLING PROCEDURES

- 3.1 *This test procedure does not claim to address the safety concerns associated with its use. It is the responsibility of the user of this test procedure to establish the appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*
- 3.2 *Sampling procedure for aggregate from completed stockpiles using a front-end loader.*
- 3.2.1 *Use this procedure to sample completed stockpiles of coarse or fine aggregate using a front-end loader.*
- 3.2.2 *Determine the minimum number of samples required for approval based on TxDOT's Guide Schedule frequency for concrete or retaining wall select backfill.*
- 3.2.3 *Identify the sampling locations by dividing the stockpile in approximately equal sectors based on the number of samples determined from Section 3.2.2. Aggregate must be sampled from a minimum of two sectors or locations for acceptance.*
- 3.2.4 *Clean and level the ground at the sampling location to prevent contamination of the sampling pile.*
- 3.2.5 *Cut approximately at the ground level to the top edge of the stockpile until a clean face is exposed. This represents the full height of the stockpile.*
Note 1-*The exposed vertical face should be perpendicular to the top edge of the stockpile, but this may not be possible with stockpiles of dry, coarse aggregates.*
- 3.2.6 *Discard the material cut away while exposing the clean face.*
- 3.2.7 *Build a sample pad by cutting into the vertical face at the ground level to the full height of the stockpile to obtain material.*
- 3.2.8 *Lower the bucket as close as possible to the ground to avoid segregation and empty the entire contents of the bucket in one motion onto the ground.*
- 3.2.9 *Using the loader bucket, strike and level the sample pad at mid-height in the direction the bucket was emptied to create a flat surface for sampling. Back-drag the sampling pad only once.*
- 3.2.10 *Divide the sample pad into four quadrants of similar size.*
- 3.2.11 *Place clean sample bags or containers near the center of the sampling pad and obtain the sample across the flat area staying more than 1 ft. away from the edges.*
- 3.2.12 *Sample equal amounts of aggregate evenly across each quadrant. Fully insert the shovel as near as vertical as possible and then slowly roll the shovel back and lift slowly to avoid coarse aggregate rolling off the sides of the shovel.*
Note 2-*Spade-tip shovels are not recommended for sampling. Square-tip shovels work well preventing aggregate from rolling from the side.*
- 3.2.13 *Obtain additional shovelfuls from different quadrants of the sampling pad, and in areas avoiding previous shovel holes.*
- 3.2.14 *Place the aggregate into the clean sample bags or containers.*
- 3.2.15 *Seal and label the sample bags or containers.*

- 3.2.16 Repeat Section 3.2.4 to 3.2.15 for each additional location as determined from Section 3.2.3.
- 3.3 *Sampling procedure for aggregate from completed stockpiles using a shovel.*
- 3.3.1 Use this procedure to sample completed stockpiles of coarse or fine aggregate using a shovel where a front-end loader is not available. The preference for sampling is to use a front-end loader.
- 3.3.2 Determine the minimum number of samples required for approval based on TxDOT's Guide Schedule frequency for concrete or retaining wall select backfill.
- 3.3.3 Identify the sampling locations by dividing the stockpile in approximately equal sectors based on the number of samples determined from Section 3.3.2. Aggregate must be sampled from a minimum of two sectors or locations for acceptance.
- 3.3.4 Identify locations within each sector from the top third, at the mid-point, and bottom third of the stockpile. Sampling must be performed in no less than these three increments.
- 3.3.5 Dig a small trench into the stockpile at each location approximately 1 ft. deep and 3 ft. in diameter.
Note 3-A board may be shoved vertically into the stockpile just above the point of sampling to prevent segregation from coarser aggregate rolling down during sampling.
- 3.3.6 Do not use the aggregate removed from the trenched area as a part of the sample.
- 3.3.7 Shovel aggregate from the stockpile into clean sample bags or containers from the innermost part of the trench. Minimize larger sized aggregate falling back into the trench.
Note 4-When sampling sands, sampling tubes of at least 1-1/4 in. diameter may be used where experience has indicated representative samples cannot be obtained otherwise.
- 3.3.8 Seal and label the sample bags or containers.
- 3.3.9 Repeat Section 3.3.4 to 3.3.8 for each additional location as determined from Section 3.3.3.
- 3.4 *Sampling procedure for aggregate when sampling during concrete production at mixing plant/site.*
- 3.4.1 Use this procedure to sample coarse or fine aggregate at concrete mixing plants/sites during production from bays or stockpiles that are not accessible in three directions and for Optimized Aggregate Gradation (OAG) concrete. The preference for sampling is to use a front-end loader. Only use a shovel when a front-end loader is not available.
- 3.4.2 Identify the center of the open face of the aggregate bay.
- 3.4.3 Sample at this location using a front-end loader according to Section 3.2.
- 3.4.4 Sample at this location using a shovel when a front-end loader is not available according to Sections 3.3.
- 3.4.5 Sample at additional locations when the face of the open bay or face of the stockpile is significantly wide. Chose a minimum of two locations approximately equal offset from the center.
- 3.5 *Sampling Procedure for Flexible Base Stockpiles.*
- 3.5.1 Identify **four** locations around the perimeter of the stockpile that represent the approximate quarter-points of the stockpile.

Note 5— When the locations cannot be obtained from around the entire perimeter due to limited space, use four equally spaced locations.

- 3.5.2 Clean and level the ground at these four locations to prevent contamination of the sampling pile.
- 3.5.3 Sample each quarter-point of the stockpile using a front-end loader to cut into each quarter-point.
- 3.5.4 Cut at the ground level to the top edge of the stockpile until a clean vertical face is exposed that is perpendicular to the top edge of the stockpile. This represents the full height of the stockpile.
- 3.5.5 Discard this material cut away while exposing the clean face.
- 3.5.6 Build a sample pad by cutting into the vertical face at the ground level of the full height of the stockpile to obtain material.
- 3.5.7 Lower the bucket as close as possible to the ground to avoid segregation and empty the entire contents of the bucket in one motion onto the ground in one motion.
- 3.5.8 Using the loader bucket, strike and level the sample pad at mid-height in the direction the bucket was emptied to create a flat surface for sampling. Back-drag the sampling pad only once.
- 3.5.9 If material is visually segregated, discard the material and repeat Sections 3.5.6 to 3.5.8.
- 3.5.10 Place clean sample bags or containers near the center of the sampling pad and obtain the sample across the flat area staying more than 1 ft. away from the edges.
- 3.5.11 Divide the sample pad into four quadrants and sample equal amounts of aggregate evenly across each quadrant.
- 3.5.12 Using a square-tip shovel, fully insert the shovel as near as vertical as possible and then slowly roll the shovel back and lift slowly to avoid coarse aggregate rolling off the sides of the shovel.
Note 6—Spade-tip shovels are not allowed for sampling flexible base stockpiles.
- 3.5.13 Obtain additional shovelfuls from different quadrants of the sampling pad, and in areas avoiding previous shovel holes. Remove material from each quadrant to fill one sample bag or container. Minimize loose material falling from the sides of the hole and loss of material from the shovel into the hole or adjacent ground while filling sample bags or containers.
- 3.5.14 Place the aggregate into the clean sample bags or containers.
- 3.5.15 Repeat Sections 3.5.13 to 3.5.15 until a minimum of 100 lbs. of material is sampled from each sample pad.
- 3.5.16 Seal and label the sample bags or containers, and properly secure for transportation to avoid any loss of material.
- 3.5.17 Repeat Sections 3.5.4 to 3.5.16 at each of the stockpile quarter-points to provide a minimum of 400 lbs. of sampled flexible base material.
Note 7—The minimum amount of 400 lbs. of material is representative of the entire stockpile sampled. This minimum amount of material is required for a testing laboratory to perform all the required test procedures for stockpile approval.
- 3.6 Preparation of Sampled Flexible Base for Testing.

- 3.6.1 Allow the material to air dry or oven dry at a maximum temperature of 140°F for a minimum of 4 hours until the material is sufficiently dry for handling.
- 3.6.2 Quarter the material by emptying each container or sample bag onto a clean floor or a clean tarp. Optionally, use a mechanical quartering device or sample splitter to quarter the material in accordance with ASTM C702, Method A. Proceed to Section 3.6.6.
- 3.6.3 Thoroughly mix the material using a shovel. When using a tarp, the ends of the tarp may also be used to also mix the material.
- 3.6.4 Spread the material into the shape of a circle of uniform thickness and homogenous with no segregation.
- 3.6.5 Using a shovel or straightedge, visibly trace lines on top of the material to outline four evenly sized quarters.
- 3.6.6 Use a quarter of the sample and proceed to [Tex-101-E](#), Part I to prepare and test the material for gradation ([Tex-110-E](#)); and the liquid limit ([Tex-104-E](#)) and plastic limit ([Tex-105-E](#)) tests to determine the plasticity index ([Tex-106-E](#)).
- 3.6.7 Combine the remaining three quarters with any remaining material from Section 3.4.15 and proceed to [Tex-101-E](#), Part II to prepare the material for Moisture-Density curve ([Tex-113-E](#)), wet ball mill ([Tex-116-E](#)), and compressive strength ([Tex-117-E](#)) testing.
- 3.7 *Sampling Procedure for Stone Riprap.*
- 3.7.1 Obtain six to eight pieces of the stone riprap that is representative of the size of the riprap.
- 3.7.2 Crush or break down the entire sample to a maximum particle size of 6 in.
- 3.7.3 Select approximately 275 lbs. of the riprap and place into sample bags or containers.
- 3.7.4 Seal and label the sample.
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4. ARCHIVED VERSIONS

- 4.1 Archived versions are available.

Test Procedure for**SAMPLING AND TESTING LIME****TxDOT Designation: Tex-600-J****Effective Date: February 2006**

1. SCOPE

- 1.1 This method, divided into five parts, describes the sampling and testing of the following materials:
- hydrated lime,
 - quicklime,
 - commercial lime slurry, and
 - carbide lime slurry.
- 1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.
-

PART I—SAMPLING LIME PRODUCTS

2. SCOPE

- 2.1 This part covers the sampling of lime in powdered form as:
- bulk hydrated lime discharged from tank trucks,
 - bagged hydrated lime, as bagged hydrate from bag trucks being loaded, or from bagged shipments after delivery to warehouse or jobsite,
 - quicklime in crushed or pebble form, discharged from tank trucks,
 - commercial lime slurry, a mixture of hydrated lime solids in water, from a sampling port at the plant site or in the distributor truck, and
 - carbide lime slurry, a mixture of hydrated carbide lime solids in water, from a distributor truck.
-

3. APPARATUS

- 3.1 *Bulk Hydrated Lime:*
- 3.1.1 *Paint brush, 2 in. wide.*
-

- 3.1.2 *Bucket*, 1 gal., with double friction type lid and bail.
- 3.1.3 *Top hatch sampling device*, consisting of a 9-ft. length of 1.5-in. IPS PVC 1120 plastic pipe of SDR 1.10 MPa (26,160 psi), meeting ASTM D 2241:
 - 3.1.3.1 Fit the pipe at one end with a rubber stopper drilled with a 0.25-in. diameter hole.
 - 3.1.3.2 Cement the stopper in place using a standard adhesive epoxy.
 - 3.1.3.3 Spot-weld a hook to a 3 × 2-in. half-round plate of 12-gauge steel. Rivet and cement the plate with epoxy to the rubber stopper end of the pipe.
 - 3.1.3.4 The 3-in. long metal hook has a 0.5 × 0.75 in. doubled over section, with a 0.25-in. slot.
 - 3.1.3.5 The opening of the hook should face away from the rubber stopper.
 - 3.1.3.6 The hook will catch the bucket bail, so the sampler can lower the bucket and pipe to the ground. This allows the sampler to alight from the truck safely.
- 3.1.4 *Bottom sampling tube*, consisting of two concentric plastic pipes:
 - 3.1.4.1 The outer pipe is 126 in. long, 1.5 in. inside diameter, IPS PVC plastic pipe, fitted at one end with a tip made from a 7.5-in. length of solid aluminum round stock, 1-5/8 in. in diameter, tapered to a point along 6.5 in. of its length, inserted 1 in. into the tube, and fastened with two screws through the wall of the pipe into tapped holes on either side of the tip.
 - 3.1.4.1.1 Round the point of the tip to a 0.5-in. diameter point for safety.
 - 3.1.4.1.2 Use an adhesive epoxy to mold an epoxy tip in a metal, foil, or cardboard mold.
 - 3.1.4.2 The inner pipe is a 1.25-in. IPS PVC plastic pipe, measuring 10 ft. long.
 - 3.1.4.2.1 Slip this pipe inside the outer pipe. It will extend beyond the outer pipe at the upper end forming a handle to allow the sampler to rotate the inner tube within the outer tube.
 - 3.1.4.2.2 Cut a 1.25 in. wide × 12 in. long sampling port through both pipes 1.5 in. from the lower, plugged end.
 - 3.1.4.2.3 Create index marks on the outside of the outer and inner pipes at the upper end labeled “open” and “closed” to indicate the relative position of the opening in the inner pipe to that of the outer.
- 3.2 *Bagged Hydrated Lime:*
 - 3.2.1 *Paint brush*, 2 in. wide.
 - 3.2.2 *Bucket*, 1 gal., with double friction type lid and bail.
 - 3.2.3 *Bag sampling tube*, made from 0.75-in. diameter steel electrical conduit 3 ft. long. Taper the opening at one end with a 4-in. diagonal cut.

- 3.3 *Quicklime:*
 - 3.3.1 *Safety goggles.*
 - 3.3.2 *Respirator.*
 - 3.3.3 *Rubber gloves.*
 - 3.3.4 *Paint brush, 2 in. wide.*
 - 3.3.5 *Bucket, 1 gal., with double friction type lid and bail.*
 - 3.3.6 *Device designed to hold a sample bucket between the wheel path of a bulk transport discharging quicklime, without allowing the bucket to turn over, but permitting safe, easy removal of the container from the windrow with the sample intact. One suggested design:*
 - 3.3.6.1 From 0.75-in. plywood, cut into three squares: 18 in., 14 in., and 10 in.
 - 3.3.6.2 Cut holes to closely fit the 1-gal. sample bucket in the centers of the smaller two plywood squares.
 - 3.3.6.3 Center the 10-in. board on top of the 14-in. board, and fasten them together.
 - 3.3.6.4 Center these on top of the 18-in. board, and fasten together.
 - 3.3.6.5 To a corner of this unit, fasten an 8-ft. length of 1/8-in. diameter flexible, steel cable.
 - 3.3.6.6 To the other end of the cable, attach a 10-in. length of steel conduit or wooden dowel as a “T” handle used to slide the filled bucket from windrowed quicklime.
 - 3.3.7 *Plastic sample bag, 18 × 9.5 in.—General Warehouse No. 2005000.*
- 3.4 *Commercial Lime Slurry and Carbide Lime Slurry:*
 - 3.4.1 *Safety goggles.*
 - 3.4.2 *Polyethylene bottle, 1/2 gal., large mouth (3.5-in. diameter), with a screw cap—Nalgene Company No. 2234-0020.*
 - 3.4.3 *Plastic electrical tape, PVC 0.75 in. wide.*
 - 3.4.4 *Cloth rag or shop towel.*

4. SAMPLING PROCEDURES

4.1 *Hydrated Lime:*

4.1.1 *Bulk from Loaded Tank Trucks:*

WARNING: The Contractor pressurizes the trucks for unloading, and any attempts to open a pressurized top hatch could be fatal. Therefore, the Contractor should make the load available for sampling before pressurization with top hatches open. If the truck offered for sampling is pressurized, it is the Contractor's responsibility to bleed off the pressure and open the top hatches.

4.1.1.1 Randomly select a truck to sample. The preferred sampling method is rodding material from the truck through an open hatch before the truck is pressurized. Use the top hatch, sampling device or the bottom sampler.

4.1.1.2 The top hatch device samples the upper portion of the load through the top hatches of a bulk transport.

4.1.1.2.1 Insert the unit with the air hole in the rubber stopper open.

4.1.1.2.2 When withdrawing the tube, hold the hole shut with a thumb.

4.1.1.2.3 Place the sample in a 1-gal. bucket.

4.1.1.2.4 Collect at least a 1/2-gal. sample.

4.1.1.3 Use the bottom sampler to obtain bottom samples or to take samples at various levels within the truck.

4.1.1.3.1 Insert the device at the sampling level desired with its port closed.

4.1.1.3.2 Open the port, slide the tube back and forth, and then close the port.

4.1.1.3.3 Remove the tube.

4.1.1.3.4 To release the lime from the tube into the 1-gal. bucket, tap the device, and allow the lime to exit from the top end.

4.1.1.3.5 Collect at least a 1/2-gal. sample.

4.1.1.4 Use the paintbrush to clear the sample bucket rim of lime collected during sampling. This will ensure an effective seal and preserve the quality of the lime sample.

Note 1—Exposure to the atmosphere contaminates lime.

4.1.1.5 If unable to sample the material in the truck before unloading, then use another sampling method, provided the sample is representative and not contaminated by moisture, base, or other road material. These less desirable methods include:

- scoop samples obtained through open top hatches,
- as discharged from tank trucks,
- hose discharge, and
- dry application “catch-pan” method.

Note 2—Do not scoop samples from material applied on roadway due to likelihood of contamination.

4.1.1.6 Identify the truck on the sample ticket by seal number, name of producer, and date sampled. Never combine samples from separate trucks.

4.1.2 *Bagged from Bag Trucks:*

4.1.2.1 Sample at least six sacks to represent each truck delivery.

4.1.2.2 Sample at least four to six sacks from each inspected lot and combine the material to form a composite sample representing that lot.

4.1.2.3 Take samples from the separate lots that comprise the whole if the entire lot consigned for an individual truck is from several different warehouse lots.

4.1.2.4 Insert the bag sampling tube through the sack-loading spout and take sufficient diagonal roddings, to ensure a representative portion from each sack without significantly reducing the volume. Take care not to puncture the sack with the sampling tube. Place samples in a 1-gal. bucket.

4.1.2.5 Use the paintbrush to clear the sample bucket rim of lime collected during sampling. This will ensure an effective seal and preserve the quality of the lime sample.

Note 3—Exposure to the atmosphere contaminates lime.

4.1.3 *Bagged from Bagged Shipments:*

4.1.3.1 Use the bag sampling tube described in Section 3.1.5.3 to obtain a 1/2-gal. sample from at least six sacks of material.

4.1.3.2 Select sacks for sampling from various points in the load or shipment to collect a representative sample.

4.1.3.3 Insert the bag sampling tube through the sack-loading spout and take sufficient diagonal roddings to ensure a representative portion from each sack without materially reducing the poundage. Take care not to puncture the bottom or sides of the sack with the sampling tube. Place samples in a 1-gal. bucket.

4.1.3.4 Use the paintbrush to clear the sample bucket rim of lime collected during sampling. This will ensure an effective seal and preserve the quality of the lime sample.

Note 4—Exposure to the atmosphere contaminates lime.

4.2 *Quicklime:*

WARNING: Quicklime is extremely hazardous and capable of inflicting severe caustic burns to skin, lung damage, eye injury, and even blindness if handled improperly. Personnel handling, sampling, or testing quicklime should wear proper protective clothing, respirators, dust-proof goggles, and waterproof gloves.

4.2.1 *Discharged from Tank Trucks:*

4.2.1.1 Instruct the truck to pass over a collection device while unloading.

Caution: Quicklime generates fines in transit. Since air-blown quicklime fines are hazardous, quicklime is usually unloaded at the jobsite by gravity feed through ports at the bottom of each compartment on the truck. Most trucks are equipped with three or four such compartments, opened simultaneously to discharge the quicklime.

4.2.1.2 Collect samples from the midpoint of the unloading of the truck.

Note 5—Specifications limit the amount of fines in the sample and include sizing requirements. The sizing and gradation of the sample taken must be representative of the load. Quicklime fines tend to settle to the bottom of the compartments, and the initial discharge usually contains a higher percentage than the remainder of the load. The top of the load tends to contain the coarsest material. The center of the discharge run best represents the gradation of the entire load.

4.2.1.3 Pick up the collection device and carefully transfer the entire sample to a plastic sample bag. Close and seal the bag with tape or rubber band and place in a 1-gal. bucket for transport. Label the bucket as “caustic quicklime.”

4.2.1.4 Ship samples by motor freight only.

CAUTION: Do not ship by bus, parcel post, air, or rail. This is a hazardous material, which upon contact with water and combustibles can cause fires. For this and other safety-related reasons, the carriers listed have refused to accept the material for shipment.

4.2.2 *From Tank Trucks:*

4.2.2.1 Collect samples from the top of the trucks. Dig below the surface of the pebble quicklime at least 8 in. and scoop a sample with a 1-gal. bucket. A sample should be a minimum of 3/4 gal.

4.2.2.2 Carefully transfer the entire sample to a plastic sample bag. Close and seal the bag with tape or rubber band and place in a sample bucket for transport. Label the bucket as “caustic quicklime.”

4.2.2.3 Ship samples by motor freight only.

CAUTION: Do not ship by bus, parcel post, air, or rail. This is hazardous material, which, upon contact with water and combustibles, can cause fires. For this and other safety-related reasons, the carriers listed have refused to accept the material for shipment.

4.3 *Commercial Lime Slurry:*

4.3.1 *From the Truck:*

- 4.3.1.1 Draw the sample from the permanent sampling port located concentrically at the rear of the truck.

Note 6—The sampling port consists of a 0.5 in.-minimum, quick acting valve fitted to a 0.75-in. diameter pipe and outlet spout.

- 4.3.1.2 Open the sampling valve quickly and completely during sampling.

- 4.3.1.3 Half fill the plastic sample jug to permit agitation and testing.

- 4.3.1.4 Tightly seal the jug and tape the cap to avoid leakage during transport.

- 4.3.1.5 Take one sample to represent the truckload.

- 4.3.1.6 A Department representative must witness sampling.

Note 7—It is the sole responsibility of the truck driver to sample, cap, and seal the slurry sample upon direct request from a Department representative.

4.3.2 *From the Plant:*

- 4.3.2.1 Collect a sample from the sampling valve in the vertical riser from the slurry tank to the loading spout.

- 4.3.2.2 Half fill the plastic sample jug to permit agitation and testing.

- 4.3.2.3 Tightly seal the jug and tape the cap to avoid leakage during transport.

- 4.3.2.4 Take one sample to represent the truckload.

- 4.3.2.5 A Department representative must witness sampling.

4.4 *Carbide Lime Slurry:*

4.4.1 *From the Truck:*

- 4.4.1.1 Draw the sample from the permanent sampling port located concentrically at the rear of the truck.

Note 8—The sampling port consists of a 0.5-in. minimum, quick acting valve fitted to a 0.75-in. diameter pipe and outlet spout.

- 4.4.1.2 Open the sampling valve quickly and completely during sampling.

- 4.4.1.3 Half fill the plastic sample jug to permit agitation and testing.

- 4.4.1.4 Tightly seal the jug and tape the cap to avoid leakage during transport.

4.4.1.5 Take one sample to represent the truckload.

4.4.1.6 A Department representative must witness the sampling.

Note 9—It is the sole responsibility of the truck driver to sample, cap, and seal the slurry sample upon direct request from a Department representative.

PART II—TESTING HYDRATED LIME

5. SCOPE

5.1 This part discusses the method for testing high-calcium type hydrated lime. This method assumes the presence of the following constituents in the lime:

- calcium hydroxide,
- calcium oxide or water,
- calcium carbonate, and
- inert matter such as silica dioxide.

6. APPARATUS

6.1 *Electric muffle furnace*, at $2,000 \pm 20^\circ\text{F}$ ($1093 \pm 11^\circ\text{C}$).

6.2 *Platinum crucibles*, low-form, wide-bottom type, 30 cc capacity. Only substitute with ceramic crucibles if the crucibles are able to withstand temperatures of $2,000^\circ\text{F}$ (1093°C).

6.3 *Tongs*, for use with muffle furnace, 20-in. length.

6.4 *Hard-surfaced temperature resistant board*.

6.5 *Oven*, capable of maintaining a temperature of 212°F (100°C).

6.6 *Vacuum desiccator*.

6.7 *Silica-gel desiccant, indicating type*.

6.8 *Analytical balance*, Class A in accordance with Tex-901-K, for rapid weighing, with a minimum weighing capacity of 100 g.

6.9 *Top loading balance*, Class G1 in accordance with Tex-901-K, for rapid weighing, with a minimum weighing capacity of 2000 g.

6.10 *Weighing boats*.

6.11 *Spatula*.

6.12 *Balance brush*, camel's hair type.

- 6.13 *Tall form beakers*, 400 mL, borosilicate type glass.
- 6.14 *Beaker*, 200 mL.
- 6.15 *Buret*, class A, of the following types:
- 100-mL capacity, with a 50-mL bulb at the top and a 50-mL graduated tube
 - 50-mL capacity with 0.1-mL subdivisions.
- 6.16 *Flasks*, class A volumetric, with the following capacities:
- 250 mL
 - 1000 mL.
- 6.17 *Graduated cylinders*, with the following capacities:
- 100 mL
 - 200 mL
 - 1000 mL
 - 2000 mL.
- 6.18 *Stirrer*, magnetic type.
- 6.19 *Stopwatch*, to register up to 30 min.
- 6.20 *Plastic tubing*, 3/8-in. ID, 1/8-in. wall thickness of suitable length, fitted with a Bunsen “fan-type” burner attachment at the outlet end of the hose.
- 6.21 *Water pressure gauge*, 0–30 psi, 3-in. diameter face, with 0.375-in. IPS female thread fitting.
- 6.22 *Standard U.S. sieves*, meeting the requirements of Tex-907-K, in the following sizes:
- No. 6
 - No. 30.
- 6.23 *pH meter*, with an accuracy of ± 0.1 pH unit or better, with automatic temperature compensation and standard combination type electrode.
- 6.24 *pH meter reference electrode filling solution*, KCl, 4 M saturated with AgCl.
- 6.25 *Sample vial*, 1-3/4-in. diameter \times 3-in. high vial made of clear polystyrene with a tight fitting polyethylene cap.
- 6.26 *Plastic bottle*, 19 L, for storing 1.0 N sodium hydroxide.
- 6.27 *Glass bottle*, 19 L, for storing 1.0 N hydrochloric acid.

7. REAGENTS

7.1 Use the following reagents, which all must be American Chemical Society (ACS) reagent-grade:

- potassium hydrogen phthalate
- bromophenol blue
- ethyl alcohol
- hydrochloric acid (HCl), 36.5 to 38.0%
- phenolphthalein powder
- sodium tetraborate decahydrate
- sodium hydroxide (NaOH), 50% solution.

8. SOLUTIONS

8.1 *Sodium Hydroxide 1.0 N:*

8.1.1 *Preparation:*

8.1.1.1 Fill a 19-L plastic container 1/2–2/3 full with de-ionized water.

8.1.1.2 Add 967.6 mL of 50% sodium hydroxide solution.

Note 10—Add the sodium hydroxide solution to a sizable portion of water to dissipate the heat evolved and to avoid hazardous spattering.

8.1.1.3 Mix for 5–10 min.

8.1.1.4 Bring to 18.5 L mark on the container.

8.1.1.5 Stir for at least 6 hr., but preferably 12 hr.

8.1.1.6 Standardize with potassium hydrogen phthalate.

8.1.2 *Standardization of a 1.0 ± 0.0005 N sodium hydroxide solution:*

8.1.2.1 Transfer 50 mL of the sodium hydroxide solution into a 50-mL buret.

8.1.2.2 Weigh 7.5–8.5 g of potassium hydrogen phthalate onto a weighing boat. Record the weight to the nearest 0.0001 g.

8.1.2.3 Transfer the weighed material to a 400-mL tall-form beaker.

8.1.2.4 Add 185 mL of deionized water and mix with a magnetic stir bar. Stir the solution until all of the potassium hydrogen phthalate dissolves.

8.1.2.5 Add five drops of phenolphthalein indicator solution.

- 8.1.2.6 Titrate with the sodium hydroxide solution to a visual endpoint of light pink, which will persist for at least 60 sec.
- 8.1.2.7 Record the amount of sodium hydroxide used.
- 8.1.2.8 Calculate the normality. If the normality is not within the limits 1.000 ± 0.0005 N, add water or sodium hydroxide to adjust the normality.
- 8.1.2.9 If the sodium hydroxide solution is too:
- weak, follow “Example 1” below to calculate the amount of the 50% sodium hydroxide to add.
 - strong, follow “Example 2” below to calculate the amount of deionized water to add.
- 8.1.2.10 Measure and add the correct amount of sodium hydroxide or deionized water. Stir the solution for at least 4 hr.
- 8.1.2.11 Repeat the standardization procedure. Repeat adjustments, if necessary. After all adjustments are complete, standardize the resulting solution.
- 8.1.3 *Calculations:*
- 8.1.3.1 Calculate the normality of sodium hydroxide solution:
- $$\text{Normality of NaOH} = \frac{\text{Wt. of Potassium Hydrogen Phthalate in (g)}}{\text{mL of NaOH required} \times 0.204228}$$
- 8.1.3.2 Adjusting the sodium hydroxide solution to achieve a 1.0 N solution:
- 8.1.3.2.1 Example 1: If base is too weak, for example, if 18.5 L of 0.9907 N solution needs strengthening to 1.0000 N, calculate the amount of 50% sodium hydroxide to add:
- $18.500 \times 0.991 = 18.334$
 - $18.500 - 18.334 = 0.166$
 - $0.166 \times 52.3 = 8.68$ mL of 50% sodium hydroxide solution needed.
- 8.1.3.2.2 Example 2: If base is too strong, for example, if the 18.5 L of 1.021 N sodium hydroxide solution needs weakening to 1.0000 N, calculate the amount of deionized water to add:
- $18.500 \times 1.021 = 18.888$
 - $18.888 - 18.500 = 0.388$ L or 388 mL of deionized water needed.
- 8.2 *1.0 N Hydrochloric Acid Solution:*
- 8.2.1 *Preparation:*
- 8.2.1.1 Fill a 19-L glass container 1/2–2/3 full with deionized water.

- 8.2.1.2 Add 1625 mL of concentrated hydrochloric acid.
Note 11—It is important to add the acid to a sizable portion of water to dissipate the heat evolved and avoid hazardous spattering of hot acid, fuming, etc.
- 8.2.1.3 Add sufficient water to bring the total volume to 19 L.
- 8.2.1.4 Stir the solution at least 4 hr., but preferably 12 hr.
- 8.2.1.5 Standardize against the sodium hydroxide.
- 8.2.2 *Standardization of a 1.0 ± 0.0005 N hydrochloric acid solution:*
- 8.2.2.1 Transfer 40 mL of the hydrochloric acid solution into a 400-mL tall beaker using a pipette for accuracy.
- 8.2.2.2 Add 140 mL of deionized water.
- 8.2.2.3 Add five drops of phenolphthalein indicator.
- 8.2.2.4 Fill a 50-mL buret with 1.0 N sodium hydroxide solution. Titrate hydrochloric acid with the sodium hydroxide solution to a visual endpoint of light pink, which will persist for at least 60 sec. Record the amount of the sodium hydroxide solution used.
- 8.2.2.5 Calculate the normality. If the normality is not within the limits of 1.000 ± 0.0005 N, add hydrochloric acid or water to adjust the normality.
- 8.2.2.6 If the hydrochloric acid solution is too:
- weak, follow “Example 1” below to calculate the amount of the concentrated hydrochloric acid to add.
 - strong, follow “Example 2” below to calculate the amount of deionized water to add.
- 8.2.2.7 Measure and add the correct amount of hydrochloric acid or deionized water. Stir the solution for at least 2 hr.
- 8.2.2.8 Repeat the standardization procedure. Repeat adjustments, if necessary. After all adjustments are complete, standardize the resulting solution.
- 8.2.3 *Calculations:*
- 8.2.3.1 Calculate the normality of hydrochloric acid solution:

$$\text{Normality of HCL} = \frac{\text{mL of NaOH required} \times \text{N of NaOH used}}{\text{mL of HCL used}}$$

8.2.3.2 Adjusting the hydrochloric acid solution to achieve a 1.0 N solution:

8.2.3.2.1 Example 1: If acid solution is too weak, for example, if 19.7 L of 0.9908 N solution needs strengthening to 1.0000 N, calculate the amount of concentrated hydrochloric acid to add:

- $19.700 \times 0.991 = 19.523$
- $19.700 - 19.523 = 0.177$
- $0.177 \times 82.5 = 14.6$ mL of concentrated hydrochloric acid needed.

8.2.3.2.2 Example 2: If acid solution is too strong, for example, if 19.7 L of 1.024 N solution needs weakening to 1.0000 N, calculate how much deionized water to add:

- $19.700 \times 1.024 = 20.1732$
- $20.173 - 19.700 = 0.473$ L or 473 mL of deionized water needed.

8.3 4.0 pH Buffer (using Potassium Hydrogen Phthalate):

8.3.1 Weigh 10.21 ± 0.05 g of potassium hydrogen phthalate into a weighing boat.

8.3.2 Add 500 mL of deionized water to a 1000-mL volumetric flask.

8.3.3 Transfer the potassium hydrogen phthalate into the volumetric flask. Add a magnetic stir bar and stir the solution until all of the potassium hydrogen phthalate dissolves.

8.3.4 Dilute the solution to 1000 mL.

8.3.5 The pH of the potassium hydrogen phthalate solution at various temperatures is shown in Table 1.

Table 1—pH of 0.05 M Potassium Hydrogen Phthalate

Temperature °F (°C)	pH
59 (15)	3.999
68 (20)	4.002
77 (25)	4.008
86 (30)	4.015
95 (35)	4.024
104 (40)	4.035

8.4 *9.0 pH Buffer (using Sodium Tetraborate Decahydrate):*

8.4.1 Weigh 3.81 ± 0.01 g of sodium tetraborate decahydrate into a weighing boat.

8.4.2 Add 500 mL of deionized water to a 1000-mL volumetric flask.

8.4.3 Transfer the sodium tetraborate decahydrate into the volumetric flask. Add a magnetic stir bar and stir the solution until all of the sodium tetraborate decahydrate dissolves.

8.4.4 Dilute the solution to 1000 mL.

8.4.5 The pH of borax solution at various temperatures is shown in Table 2.

Table 2—pH of 0.01 M Borax Solution

Temperature °F (°C)	pH
59 (15)	9.276
68 (20)	9.225
77 (25)	9.180
86 (30)	9.139
95 (35)	9.102
104 (40)	9.068

8.5 *Phenolphthalein Indicator:*

8.5.1 Weigh 0.5 g of powdered phenolphthalein in a 200-mL beaker.

8.5.2 Add 50 mL of ethyl alcohol and a magnetic stir bar.

8.5.3 Stir until all the phenolphthalein dissolves.

8.5.4 Add 50 mL of deionized water and stir.

8.6 *Bromophenol Blue Indicator:*

8.6.1 Weigh 0.1 g of powdered bromophenol blue into a 250-mL volumetric flask.

8.6.2 Add 7.5 mL of 0.02 N sodium hydroxide solution. Add a magnetic stir bar and stir until all of the bromophenol blue dissolves.

8.6.3 Dilute the mixture with deionized water to 250 mL.

9. SAMPLE PREPARATION

- 9.1 Mix the sample well for 1–2 min.
- 9.2 Invert and shake the bucket at least three times.
- 9.3 Remove the bucket lid and scoop out enough material to fill a sample vial 1/2–3/4 full.
- 9.4 After sample withdrawal, close the bucket and sample vial to minimize atmospheric contamination.

Note 12—Moisture in the air tends to air slake calcium oxide, converting it to calcium hydroxide. Calcium hydroxide tends to react with carbon dioxide in the air to form calcium carbonate, which degrades the quality of the sample by reducing the active lime content.

10. TESTING PROCEDURES

- 10.1 *Titration to pH 8.3:*
- 10.1.1 Weigh out on an analytical balance 2.804 ± 0.0050 g of lime from the sample vial. Reseal the vial. Record the weight of the lime sample.
- 10.1.2 Add 150 mL of deionized water to a 400-mL tall-form beaker.
- 10.1.3 Transfer the weighed sample to the 400-mL tall-form beaker.
- Note 13**—To minimize loss of sample, transfer material slowly.
- 10.1.4 Add a stirring magnet and place the beaker on a magnetic stirrer. Stir the sample mixture.
- 10.1.5 Calibrate the pH meter using the 4.0 and 9.0 buffer solutions.
- 10.1.6 Fill a 100-mL buret with 1.0 N hydrochloric acid solution.
- 10.1.7 Titrate the sample with the first 50 mL of the 1.0 N hydrochloric acid solution to a pH of 9.0. Titrate as rapidly as the reaction rate of the sample will allow.
- Note 14**—The response or reaction time of the sample dictates the rate of addition. Lime samples will vary in response to additions of titrant. An excess of titrant causes localized pooling of titrant. Carbon dioxide gas evolves from the reaction of acid with calcium carbonate at a pH of less than 5.4. In the titration to pH 8.3, rapidly add the titrant, but slow enough to keep the pH greater than 6.0 at all times. With addition of titrant, the pH will drop and then, in most cases, recover or rise to a higher value as more solids dissolve and enter into the reaction.
- 10.1.8 Decrease the rate of titration to a rapid drop rate until reaching a pH of between 6.0 and 9.0 that persists for at least 30 sec.
- 10.1.9 Use smaller increments of titrant to maintain a pH slightly less than 8.3. As the pH increases, add more titrant until a pH of 8.3 or slightly less persists for 60 sec.

Note 15—The endpoint for the titration to pH 8.3 occurs when the addition of one 2-drop increment of titrant produces a pH of 8.3, or slightly less, for exactly 60 sec. after addition.

10.1.10 Record the volume of titrant required to reach this endpoint.

10.1.11 Add an excess of hydrochloric acid to the sample. Record the total volume of acid added.

Note 16—The sample mixture contains a “measured excess” of hydrochloric acid.

10.2 *Back-Titration to pH 4.4:*

10.2.1 Fill a 50-mL buret with 1.0 N sodium hydroxide solution.

10.2.2 Titrate the sample with 1.0 N sodium hydroxide solution to a pH of 4.4 or slightly greater when observed exactly 10 sec. after a 1-drop addition of titrant.

10.2.3 Record the sodium hydroxide volume at the first occurrence of the endpoint.

10.3 *Loss on Ignition:*

10.3.1 Weigh a crucible using an analytical balance, record the weight, and tare the balance.

10.3.2 Weigh out a 2.9–3.1-g sample in the crucible. Record the weight of the sample to the nearest 0.0001 g.

10.3.3 Place the crucible containing the sample in an electric muffle furnace set at $2,000 \pm 20^{\circ}\text{F}$ ($1093 \pm 11^{\circ}\text{C}$) for a minimum of 3 hr.

10.3.4 Use tongs to remove the crucible from the muffle furnace. Place the crucible on a hard-surfaced asbestos board. Allow the crucible to cool on the board for 10–30 sec.

10.3.5 Transfer the crucible to a vacuum desiccator for cooling. Allow 20 min. for cooling.

Note 17—If running several samples simultaneously, transfer all of the samples to the desiccator and replace the lid with the vacuum stopcock open. The heated air will expand through the opening for several seconds. Then close the stopcock.

10.3.6 After the sample has cooled, remove the sample from the desiccator. Weigh the sample on an analytical balance as rapidly as possible to minimize hydration of the residue. Record the weight to the nearest 0.0001 g.

10.4 *Dry Sieve Analysis:*

10.4.1 Use the remainder of the sample in the 1-gal. sample bucket for sieve analysis. Weigh the sample on a top loading balance to the nearest 0.1 g.

10.4.2 Shake the sample through a No. 6 sieve in 200-g increments.

Note 18—Perform this operation under a hood while wearing a dust/mist mask.

10.4.3 Weigh the amount retained on the No. 6 sieve to the nearest 0.1 g, and then recombine for the wet sieve analysis.

10.5 *Wet Sieve Analysis:*

10.5.1 Use the remainder of the sample in the 1-gal. sample bucket for wet sieve analysis. Individually weigh a No. 6 and a No. 30 sieve on a top loading balance. Record the weights to the nearest 0.1 g.

10.5.2 Weigh the sieve analysis sample to the nearest 0.1 g.

10.5.3 Water wash the sample through the nested No. 6 and No. 30 sieves. Ensure that none of the sample is lost over the sides of the sieve. Use a water pressure gauge to maintain 12 ± 0.3 psi water pressure.

Note 19—Apply the wash water in a fantail spray pattern from the 3/8-in. (9.5-mm) ID plastic tubing fitted with a Bunsen “fan-type” burner attachment at the outlet.

10.5.4 Continue to wash the sample for 30 min. or until the water coming through the sieve is clear, whichever occurs first.

10.5.5 Oven-dry the residue on each sieve for 1 hr. at $212 \pm 4^\circ\text{F}$ ($100 \pm 2^\circ\text{C}$).

10.5.6 Remove the sieves from the oven. Allow the sieves to cool to room temperature. Weigh each sieve to the nearest 0.1 g.

11. CALCULATIONS**11.1** *Wet and Dry Sieve Analysis:*

11.1.1 Calculate the percent of the hydrated lime retained on each sieve. Use this calculation for both wet and dry sieve analysis. Report values to the nearest 0.1%:

$$\% \text{ retained} = \frac{\text{residue retained}}{\text{sample wt.}} \times 100$$

Where:

% retained = weight percent of residue retained on the sieve

residue retained = weight in grams of residue retained on the sieve

sample wt. = weight in grams of the sample before being sieved.

11.2 *Total “Active” Lime Content:*

11.2.1 Limits for sample weight and titration solutions when using the following rapid calculation methods are as follows.

- Sample Wt. 2.804 ± 0.0050 g
- Acid $1.000 \text{ N} \pm 0.0005 \text{ N}$
- Base $1.000 \text{ N} \pm 0.0005 \text{ N}$.

- 11.2.2 Creating a hydrated lime sample worksheet:
- 11.2.3 Milliliters of hydrochloric acid to pH 8.3 is equivalent to the hydrate alkalinity. Record this value and the corresponding uncorrected Ca(OH)_2 from Table 3.
- 11.2.4 Total milliliters hydrochloric acid added, less the milliliters of sodium hydroxide required to obtain a pH of 4.4, is equal to the total alkalinity. Record this value and subtract hydrate alkalinity from total alkalinity to give carbonate alkalinity. From Table 4, obtain equivalent calcium carbonate and record this value.
- 11.2.5 Calculate the loss on ignition of the sample. Calculate the inert value by subtracting the sum of the loss on ignition and the total alkalinity from 100. Record the inert value (or an average or assumed inert value based on previous analysis of lime from a given source).
- 11.2.6 Total the uncorrected calcium hydroxide, calcium carbonate, and the inert value. If the total is less than 100%, the difference is free water. If the total is greater than 100%, quicklime is present. The following examples demonstrate each situation:

■ Example where calcium oxide is present:

$$\text{Uncorrected Ca(OH)}_2 = 94.8$$

$$\text{CaCO}_3 = 3.1$$

$$\text{Assumed inert} = 2.2$$

$$\overline{100.1}$$

$$\text{Subtotal } 100.1 - 100 = 0.1$$

$$\% \text{CaCO} = 0.1 \times 3.11 = 0.3$$

$$\text{Uncorrected Ca(OH)}_2 = 94.8$$

$$\text{Ca(OH)}_2 \text{ Correction Value} = -0.4$$

$$\overline{94.4}$$

Analysis shown as :

$$\text{Ca(OH)}_2 = 94.4$$

$$\text{CaCO}_3 = 3.1$$

$$\text{CaO} = 0.3$$

$$\text{Total} = \overline{100.0}$$

■ Example where water is present:

$$\begin{array}{rcl}
 \text{Uncorrected } Ca(OH)_2 & = & 93.0 \\
 CaCO_3 & = & 4.6 \\
 \text{Assumed Inert} & = & 1.0 \\
 \text{Total} & = & \overline{98.6} \\
 \% H_2O = 100 - 98.6 & = & 1.4
 \end{array}$$

Analysis is shown as:

$$\begin{array}{rcl}
 Ca(OH)_2 & = & 93.0 \\
 CaCO_3 & = & 4.6 \\
 \text{Assumed Inert} & = & 1.0 \\
 H_2O & = & 1.4 \\
 \text{Total} & = & \overline{100.0}
 \end{array}$$

11.2.7 If free water is present, the uncorrected hydrate alkalinity will be actual hydrate alkalinity as calcium hydroxide.

Table 3—Uncorrected Calcium Hydroxide Value

mL of Acid and Hydrated Alkalinity	% Ca(OH) ₂
68.0	89.8
69.0	91.2
70.0	92.5
71.0	93.8
72.0	95.1
73.0	96.4
74.0	97.8
75.0	99.1
Factor = 1.32126	

- 11.2.8 Calcium Carbonate Value as CaCO_3 —Whole milliliter difference between two endpoints:

Table 4—Calcium Carbonate Value

Carbonate Alkalinity	CaCO_3
0.0	0.0
1.0	1.8
2.0	3.6
3.0	5.4
4.0	7.1
Factor = 1.78479	

- 11.2.9 Correction for Calcium Hydroxide Value when CaO is Present:

Table 5—Correction for Calcium

Subtotal-100%	Correction Value
0.1	0.4
0.2	0.8
0.3	1.2
0.4	1.6
0.5	2.1
0.6	2.5
0.7	2.9
0.8	3.3
0.9	3.7
1.0	4.1
1.1	4.5
1.2	4.9

11.2.10 Amount of Subtotal Over 100%:

- When quicklime is present: $\% \text{CaO} = (\text{Subtotal} - 100\%) \times 3.11$
- When free water is present: $\% \text{free water} = 100\% - \text{Subtotal}$

Table 6—Proportional Parts

ml acid	% Ca(OH)_2
0.1	0.1
0.2	0.3
0.3	0.4
0.4	0.6
0.5	0.7
0.6	0.8
0.7	1.0
0.8	1.1
0.9	1.3
Factor = 1.32126	

11.2.11 Use Table 7 to obtain a corrected calcium hydroxide value by subtracting the calcium hydroxide correction value obtained from the uncorrected calcium hydroxide value.

Table 7—Proportional Parts

Fractional Carbonate Alkalinity	CaCO_3
0.1	0.2
0.2	0.4
0.3	0.5
0.4	0.7
0.5	0.9
0.6	1.1
0.7	1.3
0.8	1.4
0.9	1.6
Factor = 1.78479	

- 11.2.11.1 Use Table 7 if the subtotal (uncorrected calcium hydroxide value + calcium carbonate value + assumed inert value) is greater than 100%. This means that calcium oxide is present and not free water.
- 11.2.11.2 If the subtotal is less than 100%, then assume the uncorrected calcium hydroxide value is correct. Calcium hydroxide and free water are present.
-

12. OPTIONAL INDICATOR METHOD FOR THE TITRIMETRIC ANALYSIS

12.1 *Scope:*

- 12.1.1 Use this method in lieu of the prescribed pH meter method; however, for all referee tests, or in cases of dispute, the prescribed pH meter method is the official method.
- 12.1.2 In some cases, impurities such as aluminum compounds will prevent or hinder the appearance of the color change in the back-titration portion of this optional method. In these cases, use the prescribed pH meter method.

12.2 *Titration to Phenolphthalein Endpoint:*

- 12.2.1 Weigh out on an analytical balance 2.804 ± 0.0050 g of lime from the sample vial. Reseal the vial. Record the weight of the lime sample.
- 12.2.2 Add 150 mL of deionized water to a 400-mL tall-form beaker.
- 12.2.3 Transfer the sample to the beaker.
Note 20—To minimize loss of sample, transfer material slowly.
- 12.2.4 Add a stirring magnet and place the beaker on a magnetic stirrer. Stir the sample.
- 12.2.5 Add five drops of phenolphthalein indicator to the sample mixture.
- 12.2.6 Fill a 100-mL buret with 1.0 N hydrochloric acid.
- 12.2.7 Titrate to the point where the color of the solution changes temporarily from pink to clear.
- 12.2.8 Wait for the pink color to return.
- 12.2.9 Add titrant until the color change appears imminent.
- 12.2.10 Add acid in 4-drop increments until the pink coloration disappears for 35 sec.
- 12.2.11 Add acid in 2-drop increments until the endpoint occurs. Record the amount of hydrochloric acid used to reach the endpoint.
Note 21—The endpoint is the failure of the mixture to regain its pink coloration for 60 sec. after the last addition of the titrant. After reaching the endpoint, ignore the reappearance of pink color. The phenolphthalein endpoint is the equivalent to the pH 8.3 endpoint described in the official pH meter method of titration.

- 12.2.12 Add an excess of hydrochloric acid to the sample. Record the total volume of acid added.
Note 22—The sample mixture contains a “measured excess” of hydrochloric acid.
- 12.3 *Back Titration to the Bromophenol Blue Endpoint:*
- 12.3.1 Fill a 50-mL buret with 1.0 N sodium hydroxide.
- 12.3.2 Add 2.0 mL of bromophenol blue indicator to the sample mixture.
- 12.3.3 Titrate until the color of the mixture changes from yellow to blue with a slight tinge of purple and maintains the blue color for 10 sec., after a 1-drop addition of titrant.
- 12.3.4 Record the amount of sodium hydroxide used to reach the endpoint.
- 12.3.5 Use the same calculation method to determine active lime content as described under Section 10.

PART III—TESTING COMMERCIAL LIME SLURRY

13. SCOPE

- 13.1 This part discusses the method for testing high-calcium type commercial lime slurry and assumes that the principal constituents present in the lime are:
- calcium hydroxide,
 - water,
 - calcium carbonate, and
 - inert matter such as silica dioxide.

14. APPARATUS

- 14.1 *Equipment*, listed under Part II, Section 6.
- 14.2 *Eyedropper*, large bore polyethylene.
- 14.3 *Weight-per-gallon cup*, stainless steel, with tare weight.
- 14.4 *Polyethylene bottles*, 1 pt., with screw caps.
- 14.5 *Glass rod*.
- 14.6 *Beaker*, 1000 mL.

15. REAGENTS AND SOLUTIONS

- 15.1 Use chemical reagents and solutions listed for the testing of bulk hydrate or powdered lime in Part III, Sections 7 and 8.
-

16. SAMPLE PREPARATION**16.1** *Lime Slurry Sample Preparation:*

- 16.1.1 Set the slurry jug in a roller and agitate for 3–4 hr.
- 16.1.2 Use a glass rod to determine if the lime sample is in suspension. If any lime remains caked on the bottom or sides, place the slurry jug back on the roller and agitate.
- 16.1.3 When the slurry is well mixed, pour a representative sample into a 1-pt. polyethylene bottle with a screw top.
Note 23—Clean the threaded portion of the bottles and the inside threads of the cap. If slurry remains on these places, the seal will not be airtight, and the slurry will dehydrate.
- 16.2 *Determining Bulk Density:*
- 16.2.1 Weigh a clean and empty weight-per-gallon cup on a top loading balance. Tare the weight of the cup.
- 16.2.2 Shake the 1-pt. bottle of slurry vigorously for 1 min. Rapidly pour the slurry from the 1-pt. bottle into the weight-per-gallon cup. Fill the cup to just below the top rim.
- 16.2.3 Tap the bottom of the filled cup against a hard surface to remove air bubbles.
- 16.2.4 Place the lid on the cup, gently pressing it into place. Excess slurry will flow out the small center opening in the top.
Note 24—If slurry does not flow out of the opening, additional slurry is necessary. Agitate the sample before adding more slurry.
- 16.2.5 Carefully wipe off all of the excess slurry on the outside of the cup and lid.
- 16.2.6 Place the weight-per-gallon cup on a top loader balance. Weigh the cup and its contents to the nearest 0.1 g.
Note 25—Make sure that the tared weight remains displayed on the balance just before the weight of the filled cup is measured.
- 16.2.7 Divide the result by ten. Report this value as the bulk density of the slurry expressed in lb./gal.

16.2.8 *Calculations:*

16.2.8.1 Calculate bulk density:

$$BD = \frac{(\text{slurry wt.})}{10}$$

Where:

BD = bulk density, (lb./gal.)

slurry wt. = weight of the slurry in the weight-per-gallon cup, (g).

16.3 *Determination of Sample Size:*

16.3.1 Use Figures 1, 2, and 3 to determine the sample size for titrimetric analysis and loss on ignition. Find the bulk density of the slurry on one of the three graphs. Scan to the right to find the area between the minimum and maximum lines. Then, scan to the bottom of the graph to find the corresponding sample weight range. This quantity will contain the equivalent of 2.9–3.1 g of dry lime.

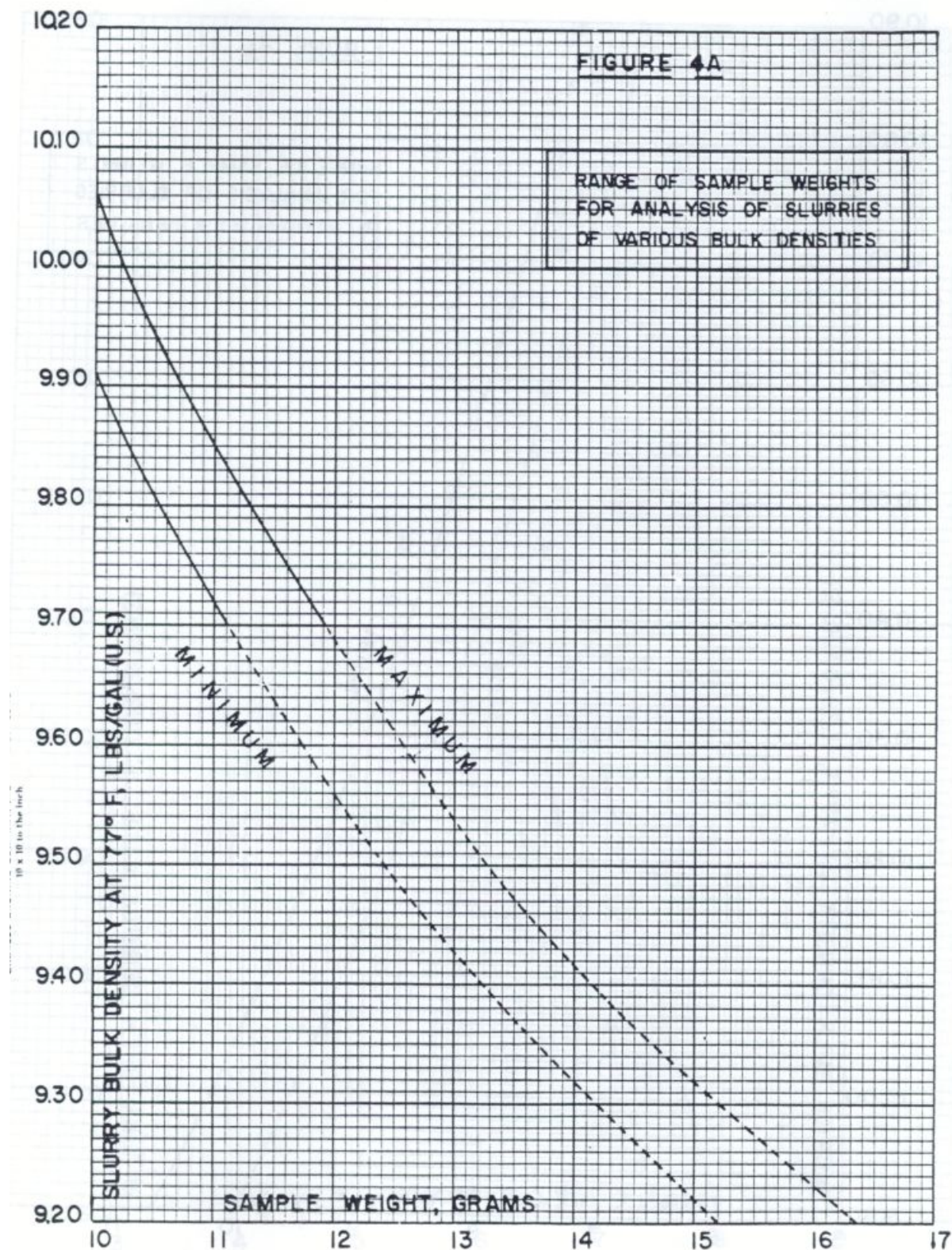


Figure 1—Range of Sample Weights for Analysis of Slurries—No. 1

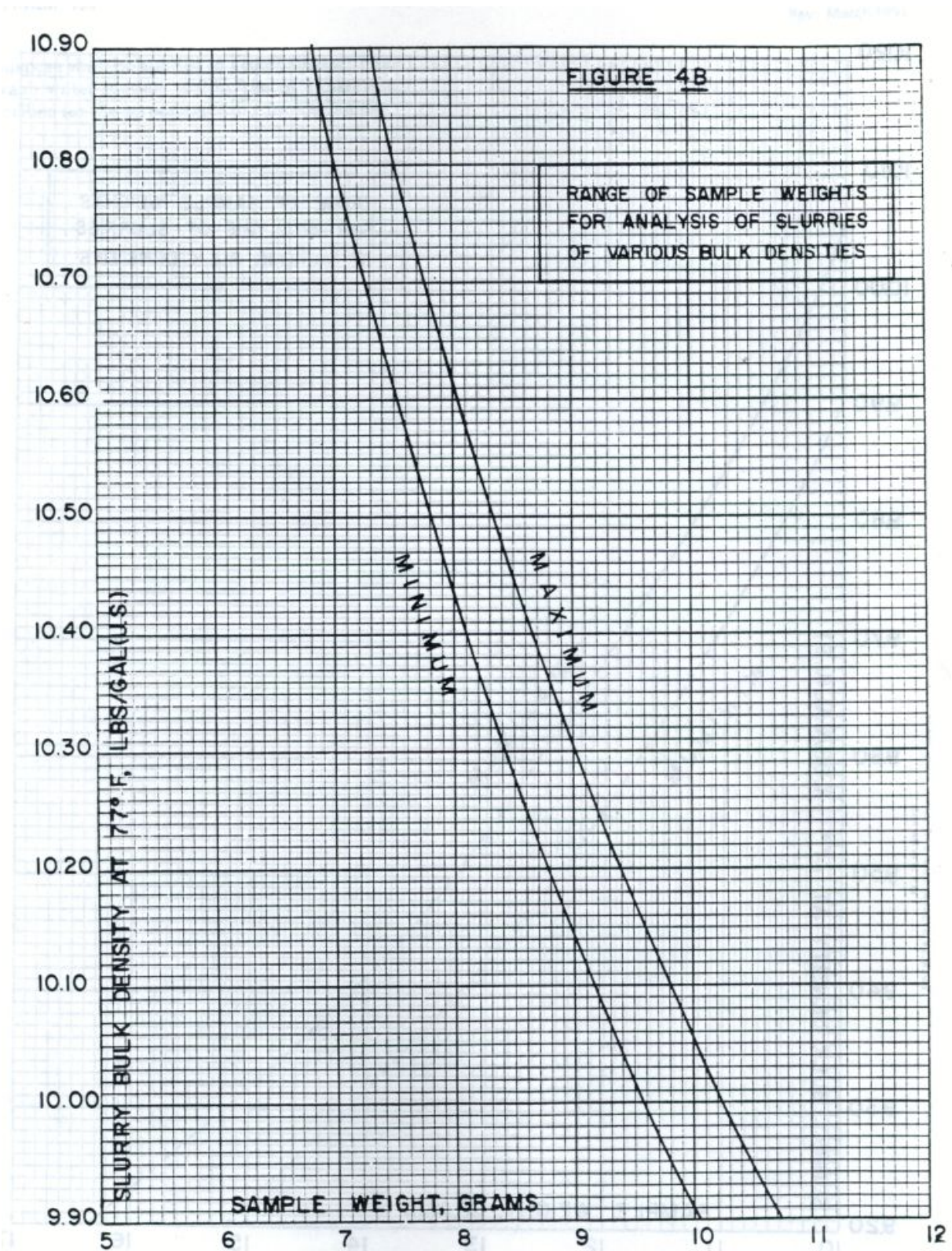


Figure 2—Range of Sample Weights for Analysis of Slurries—No. 2

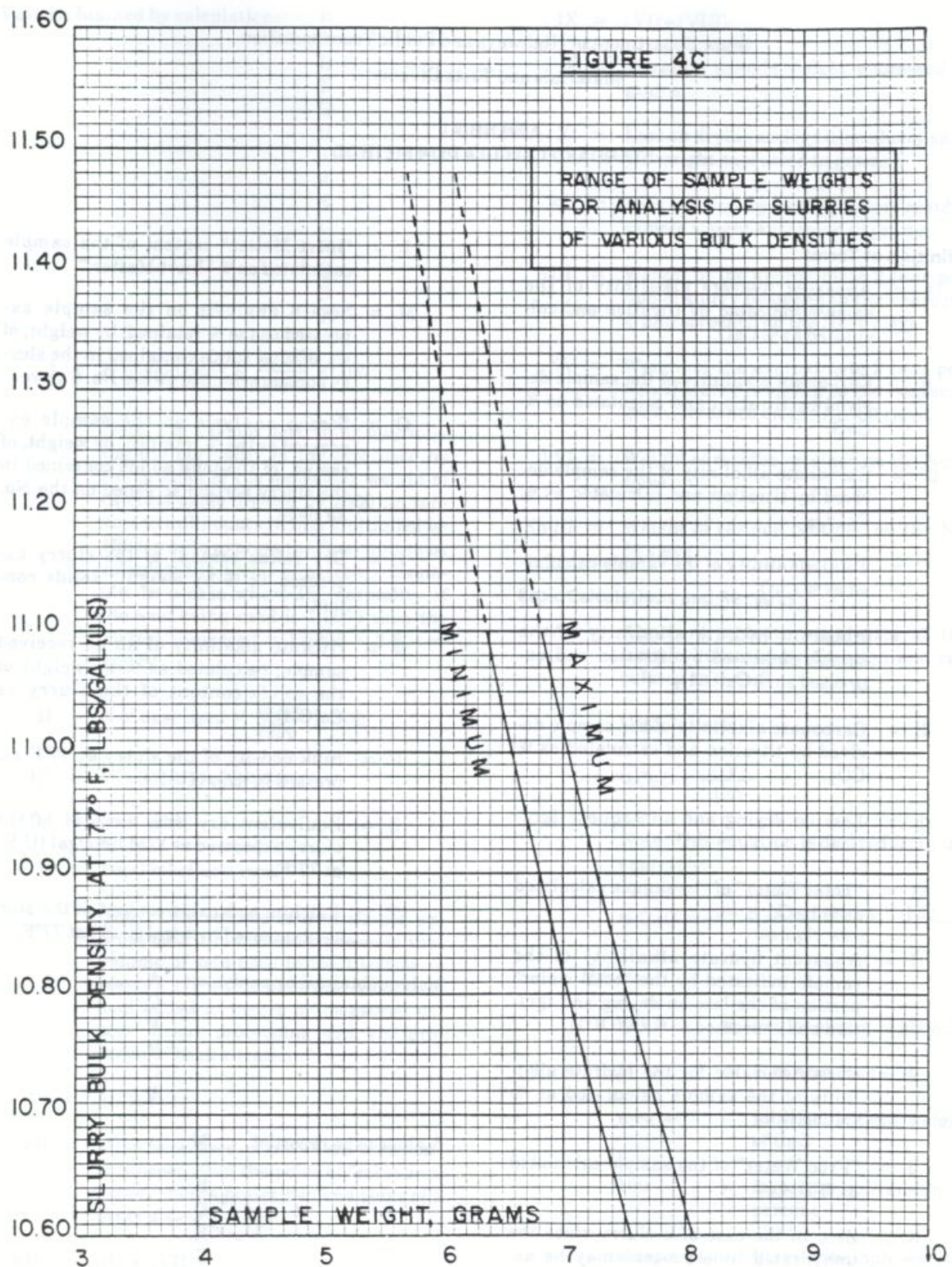


Figure 3—Range of Sample Weights for Analysis of Slurries—No. 3

17. TESTING PROCEDURES

17.1 *Titration to pH 8.3:*

17.1.1 Determine the sample size using the method indicated in Section 16.3.

17.1.2 Tare a 400-mL tall-form beaker on an analytical balance.

17.1.3 Agitate the 1-pt. bottle for 1 min. Pour the required weight of slurry sample, as determined above, into the 400-mL tall-form beaker. Record the weight of the sample to the nearest 0.0001 g.

17.1.4 Slowly add enough deionized water to bring the volume of mixture to 150 mL. Add a stirring magnet, place the beaker on a magnetic stirrer, and stir the sample.

17.1.5 Calibrate the pH meter using the 4.0 and 9.0 buffer solutions.

17.1.6 Fill the 100-mL buret with 1.0 N hydrochloric acid.

17.1.7 Insert the pH meter probe into the sample. Begin titrating the sample with 1.0 N hydrochloric acid. Add the hydrochloric acid at a rapid drop rate to obtain a pH indication of 9 or slightly less.

Note 26—A suitable rapid drop rate is approximately 12 mL/min.

17.1.8 After reaching a momentary pH of 9, decrease the rate of titration to approximately 2 mL/min. Continue at this rate until the pH is close to 8.5.

17.1.9 Once the pH is close to 8.5, add acid in 4-drop increments until maintaining a pH of 8.3 or less for approximately 35 sec.

17.1.10 Then add 2-drop increments until the endpoint of 8.3 or slightly less persists for 60 sec.

Note 27—The endpoint for the titration to pH 8.3 occurs when the addition of one 2-drop increment of titrant produces a pH of 8.3 or slightly less for exactly 60 sec.

17.1.11 Record the volume of titrant used to reach the endpoint.

17.1.12 Add excess hydrochloric acid to the sample. Record the total volume of acid added to the sample.

Note 28—The sample mixture contains a “measured excess” of hydrochloric acid.

17.2 *Back-Titration to pH 4.4:*

17.2.1 Fill a 50-mL buret with 1.0 N sodium hydroxide solution.

17.2.2 Titrate the sample with 1.0 N sodium hydroxide to the endpoint. The endpoint occurs when a pH of 4.4 or slightly greater occurs exactly 10 sec. after a 1-drop addition of titrant.

17.2.3 Record the volume of sodium hydroxide used to reach the endpoint.

17.3 *Loss on Ignition:*

- 17.3.1 Weigh a crucible using an analytical balance, record the weight, and tare the balance.
- 17.3.2 Determine the required slurry sample size from Section 16.3. Weigh that amount into the tared crucible. Record the weight of the sample to the nearest 0.0001 g.
- 17.3.3 Place the crucible with slurry into a $212 \pm 4^\circ\text{F}$ ($100 \pm 2^\circ\text{C}$) drying oven for 1 hr.
- 17.3.4 Remove sample from oven and place in a muffle furnace at $2,000 \pm 20^\circ\text{F}$ ($1093 \pm 11^\circ\text{C}$) for a minimum of 2 hr.
- 17.3.5 Use the long tongs to remove the crucible from the muffle furnace. Place the crucible on a hard-surfaced asbestos board. Allow the crucible to cool on the board for 10–30 sec.
- 17.3.6 Transfer the crucible to a vacuum desiccator for cooling. Allow 20 min. for cooling.
Note 29—If running several samples simultaneously, transfer the samples to the desiccator and replace the lid with the vacuum stopcock open. The heated air will expand through the opening for several seconds. Then close the stopcock.
- 17.3.7 After the sample has cooled, remove the sample from the desiccator. Weigh the crucible on an analytical balance as rapidly as possible to minimize hydration of residue. Record the weight to the nearest 0.0001 g.

17.4 *Sieve Analysis:*

- 17.4.1 Weigh a 1000-mL glass beaker on a top-loading balance, record the weight to the nearest 0.1 g, and tare the balance.
- 17.4.2 Pour 1 L of the well-mixed slurry into the beaker. Weigh the beaker with the slurry on the balance and record the weight to the nearest 0.1 g.
- 17.4.3 Weigh a No. 6 and a No. 30 sieve on a top loading balance. Record each weight to the nearest 0.1 g.
- 17.4.4 Wash the slurry through the No. 6 and No. 30 sieves simultaneously using regular tap water.
Note 30—Apply the wash water in a fantail spray pattern from the 3/8-in. ID plastic tubing fitted with a Bunsen “fan-type” burner attachment at the outlet. Monitor the water pressure with a water gauge at 12 ± 0.3 psi.
- 17.4.5 Continue washing the sample for 30 min. or until the water coming through the sieve is clear, whichever occurs first.
- 17.4.6 Oven-dry the residue on each sieve for 1 hr. at $212 \pm 4^\circ\text{F}$ ($100 \pm 2^\circ\text{C}$).
- 17.4.7 Remove the sieves from the oven and allow them to cool for 20 min. Weigh each sieve on a top loading balance. Record the weight to the nearest 0.1 g.

18. CALCULATIONS**18.1** *Percent Solids:*

18.1.1 Calculate all factors A through H and J. Then use the following equation to calculate percent solids:

$$\% \text{ Solids} = \frac{100 - J}{100}$$

Where:

J = free water of the sample, %.

18.1.2 Calculate A, apparent hydrate alkalinity of the sample, calculated as percent calcium oxide:

$$A = \frac{2.8054(\text{mL of HCl to 8.3})}{\text{sample wt.}}$$

Where:

mL of HCl to 8.3 = amount of hydrochloric acid used to reach 8.3 pH endpoint, mL
sample wt. = the weight of the sample used in the titration.

18.1.3 Calculate B, carbonate alkalinity of the sample derived by titration and calculated as percent calcium oxide:

$$B = C - A = (\text{total alkalinity}) - (\text{apparent hydrate alkalinity, CaO})$$

Where:

C = total alkalinity of the sample calculated as percent calcium oxide

A = apparent alkalinity of the sample indicated by titration calculated as percent calcium oxide.

18.1.4 Calculate C, total alkalinity of the sample calculated as percent calcium oxide:

$$C = \frac{2.8054 (\text{total ml of HCl} - \text{ml of NaOH to 4.4})}{\text{sample wt.}}$$

Where:

total mL of HCl = amount of hydrochloric acid used, including the “measured excess,”
mL

mL of NaOH to 4.4 = amount of sodium hydroxide used to reach 4.4 pH endpoint, mL
sample wt. = titration sample weight, g.

- 18.1.5 Calculate *D*, apparent hydrate alkalinity indicated by titration of the sample expressed as percent calcium hydroxide:

$$D = (1.32126) A = (1.32126)(\text{apparent hydrate alkalinity, CaO})$$

Where:

A = apparent hydrate alkalinity of the sample calculated as percent calcium oxide.

- 18.1.6 Calculate *E*, carbonate alkalinity of the sample calculated as percent carbon dioxide:

$$E = (0.78479) B = (0.78479)(\text{carbonate alkalinity, CaO})$$

Where:

B = carbonate alkalinity of the sample derived by titration and calculated as percent calcium oxide.

- 18.1.7 Calculate *F*, loss on ignition:

$$F = \frac{(\text{sample wt.} - \text{residue wt.}) 100}{\text{sample wt.}}$$

Where:

sample wt. = original weight of the loss on ignition sample, g

residue wt. = weight of the residue after the loss on ignition test, g.

- 18.1.8 Calculate *G*, total water of the sample, expressed in percent:

$$G = F - E = (\text{loss on ignition}) - (\text{carbonate alkalinity, CO}_2)$$

Where:

F = loss on ignition

E = carbonate alkalinity of the sample calculated as percent carbon dioxide.

- 18.1.9 Calculate *H*, apparent hydrate alkalinity of the sample indicated by the total water portion of the loss on ignition and expressed as percent calcium hydroxide:

$$H = (4.1128) G = (4.1128)(\text{total water})$$

Where:

G = total water of the sample, %.

- 18.1.10 Calculate J , free water of the sample, %:

$$J = 0.24314(H - D)$$

$$J = (0.24314)(\text{apparent hydrate alkalinity, total water} - \text{apparent hydrate alkalinity, titration})$$

Where:

H = apparent hydrate alkalinity indicated by the total water portion of the loss on ignition

D = apparent hydrate alkalinity indicated by titration of the sample expressed as percent calcium hydroxide.

- 18.2 Lime Slurry Alkalinity, % $\text{Ca}(\text{OH})_2$:

$$\% \text{Ca}(\text{OH})_2 = \frac{D}{\% \text{solids}} = \frac{(\text{apparent hydrate alkalinity, titration})}{\% \text{solids}}$$

Where:

D = apparent hydrate alkalinity of the sample indicated by titration and expressed as percent calcium hydroxide.

Note 31— D is the same value calculated for the percent solids determination.

- 18.3 Loss on Ignition:

$$\text{LOI} = \frac{(\text{sample wt.} - \text{residue wt.})100}{\text{sample wt.}}$$

Where:

sample wt. = original weight of the loss on ignition sample, g

residue wt. = weight of the residue after the loss on ignition test, g.

Note 32—This is the same calculation used for factor F in the percent solids determination.

- 18.4 Sieve Analysis:

$$\% \text{retained} = \frac{\text{residue retained}}{(\text{sample wt.})(\% \text{solids})} \times 100$$

Where:

% retained = weight of residue retained on the sieve, %

residue retained = weight of residue retained on the sieve, g

sample wt. = weight of the sample before being sieved, g

% solids = percent solids as calculated above.

PART IV—TESTING QUICKLIME

19. SCOPE

19.1 This part discusses the method for testing quicklime.

WARNING: Quicklime is extremely hazardous and capable of inflicting severe caustic burns to skin, lung damage, and eye injury. It can cause blindness if handled improperly. Personnel handling, sampling, testing, or working around quicklime should wear proper protective clothing, respirators, and dust-proof goggles to prevent injury.

20. APPARATUS

20.1 *Equipment*, listed under Part II, Section 6.

20.2 *Laboratory grinder*.

20.3 *Mechanical shaker*, with timer, to accommodate 8-in. diameter sieves.

20.4 *Mixer*, with 1-gal. capacity mixing bowl and type D wire whip attachment.

20.5 *Sample splitter*, (alternate slot type), *two catch pans of appropriate size*, and *one pour pan*.

20.6 *Erlenmeyer flasks*, 500 mL.

20.7 *Rubber stoppers*, No. 10 size.

20.8 *Ointment type cans*, 6 oz., with lids.

21. REAGENTS

21.1 Use chemical reagents listed for the testing of bulk hydrate or powdered lime in Part III, Section 7, of this method.

22. PREPARING SOLUTIONS

22.1 Use chemical solutions listed for the testing of bulk hydrate or powdered lime in Section 8 of this procedure with the following addition:

22.1.1 *Sugar Solution:*

22.1.1.1 Prepare a fresh sugar solution for each lime slurry sample.

22.1.1.2 In a 200-mL beaker, add 60 g of granulated cane sugar and 120 mL of deionized or distilled water. Add a stirring bar and place the beaker on a magnetic stirrer. Stir until all of the sugar dissolves.

22.1.1.3 Add one drop of phenolphthalein indicator.

22.1.1.4 Add 1.0 N sodium hydroxide, drop by drop, until observing a faint pink color.

23. SAMPLE PREPARATION

23.1 Divide the 1-gal. sample into two portions through the splitter.

23.2 Return and set aside one of the portions to the 1-gal. can.

23.3 Measure 300 g of the remaining portion.

23.4 Grind the 300-g portion for chemical analysis to pass a No. 30 sieve. Transfer the ground lime to a sample vial and close the lid tightly.

23.5 Measure 800 g from the remainder of this portion. Set aside this 800-g portion in a sealed container.

Note 33—Protect all portions from contamination. Crush samples that contain flint or other extremely hard material to pass through a 1/8-in. sieve in a jaw-type crusher before grinding.

24. TESTING PROCEDURES

24.1 *Titration to Phenolphthalein Endpoint:*

24.1.1 Boil 60 mL of deionized or distilled water. Add 10 mL of boiled water to a 500-mL Erlenmeyer flask.

24.1.2 Weigh 2.8 ± 0.3 g of the ground quicklime sample in a weighing boat. Record the exact amount of quicklime to the nearest 0.0001 g.

24.1.3 Transfer the lime sample to the Erlenmeyer flask.

24.1.4 Add 50 mL of boiled water to the Erlenmeyer flask.

24.1.5 Stopper the flask with a No. 10 rubber stopper and swirl for a few seconds.

24.1.6 Place the sample on a hot plate and boil for 2 min.

24.1.7 Remove the sample from the hot plate and allow it to cool to room temperature.

24.1.8 Add 150 mL of the sugar solution to the flask, stopper the flask, and let it stand for 15 min. Swirl the flask every 5 min.

24.1.9 Add five drops of phenolphthalein indicator solution and a stirring magnet to the sample. Stir the sample on a magnetic stir.

24.1.10 Fill a 100-mL buret with 1.0 N hydrochloric acid. Titrate the sample with the hydrochloric acid until the first instance the pink color disappears. This is the endpoint.

- 24.1.11 Record the volume of hydrochloric acid used to reach the endpoint. Use the calculations to determine the percent active CaO to the nearest 0.1%.
- 24.2 *Dry Sieve Analysis:*
- 24.2.1 Weigh the previously reserved 800-g portion on a top loading balance to the nearest 0.1 g.
- 24.2.2 Shake the 800-g portion through a nest of sieves into a catch pan in 200-g increments. The nest of sieves includes the 1 in., 3/4 in., No. 6, and No. 100.
Note 34—Perform this operation under a hood, while wearing a dust/mist mask.
- 24.2.3 Weigh the amount caught in each sieve to the nearest 0.1 g, and then recombine them for the wet sieve analysis.
- 24.3 *Wet Sieve Analysis:*
- 24.3.1 Add 2600 mL tap water to the mixer bowl, return to the mixer, and attach the wire whip.
- 24.3.2 Weigh 800 g of quicklime, in increments of 80 g, into ten tin containers.
- 24.3.3 Lower the wire whip, turn on the mixer, and add one of the increments. Lower the shield. Let stir for 3 min.
- 24.3.4 Continue adding the 80-g increments every 3 min. until 10 min. have lapsed. At 10 min., stop the mixer for 30 sec. and record the temperature of the slurry. After 30 sec., restart the mixer and mix the slurry for 2 min. to complete the 3 min. cycle of the last added increment.
- 24.3.5 Add the next increment. Continue the cycle of adding the 80-g increments every 3 min. and stopping every 10 min. for 30 sec. to read the temperature, until all the quicklime is mixed.
- 24.3.6 When finished, take the bowl out of the mixer and rinse the wire whip.
- 24.3.7 Weigh the No. 6 sieve on a top loading balance. Record the weight of the sieve to the nearest 0.1 g.
- 24.3.8 Using tap water, wash the reacted sample onto a No. 6 sieve. Ensure that none of the slurry sample is lost over the sides of the sieve. Use a water pressure gauge to maintain 14–18 psi water pressure.
Note 35—Apply the wash water in a fantail spray pattern from the 3/8 in. ID plastic tubing fitted with a Bunsen “fan-type” burner attachment at the outlet.
- 24.3.9 Continue to wash the sample for 30 min. or until the wash water is clear, whichever occurs first.
- 24.3.10 After washing, place the sieve in a drying oven at a temperature of $212 \pm 4^{\circ}\text{F}$ ($100 \pm 2^{\circ}\text{C}$) for 1 hr.

- 24.3.11 After drying, cool the sieve to room temperature and weigh it on a top loading balance to the nearest 0.1 g.

25. CALCULATIONS

- 25.1 Calculate Unhydrated Lime Content, % CaO:

$$\% \text{ CaO} = \frac{2.804 V N}{\text{sample wt.}}$$

Where:

V = volume of hydrochloric acid, mL

N = normality of hydrochloric acid

sample wt. = weight of quicklime used for titration, g.

- 25.2 Calculate the percent of the quicklime retained on each sieve. This calculation applies to both wet and dry sieve analysis. Report values to the nearest whole percent:

$$\% \text{ retained} = \frac{\text{residue retained}}{\text{quicklime sample wt.}} \times 100$$

Where:

% retained = weight percent of residue retained on the sieve

residue retained = weight of residue retained on the sieve, g

quicklime sample wt. = weight of the quicklime sample being sieved, g.

PART V—TESTING CARBIDE LIME SLURRY

26. SCOPE

- 26.1 This part discusses the method for testing high-calcium type carbide lime slurry and assumes that the principal constituents present in the lime are:

- calcium hydroxide,
- water,
- calcium carbonate, and
- inert matter such as silica dioxide.

27. APPARATUS

- 27.1 *Equipment*, listed under Part II, Section 6.
- 27.2 *Eyedropper*, large bore polyethylene.

- 27.3 *Weight-per-gallon cup, stainless steel, with tare weight.*
- 27.4 *Polyethylene bottles with screw caps, 1 pt.*
- 27.5 *Glass rod.*
- 27.6 *Beaker, 2000 mL.*
-

28. REAGENTS AND SOLUTIONS

- 28.1 Use chemical reagents and solutions listed for the testing of bulk hydrate or powdered lime in Part III, Sections 7 and 8, of this method.
-

29. SAMPLE PREPARATION

29.1 *Carbide Lime Slurry Sample Preparation:*

- 29.1.1 Set the slurry jug in a roller and agitate for 3–4 hr.
- 29.1.2 Use a glass rod to determine if the lime sample is in suspension. If any lime remains caked on the bottom or sides, place the slurry jug back on the roller and agitate.
- 29.1.3 When the slurry is well mixed, pour a representative sample in a 1-pt. polyethylene bottle with a screw top.
- Note 36**—Clean the threaded portion of the bottles and the inside threads of the cap. If slurry remains on these places, the seal will not be airtight and the slurry may dehydrate.

29.2 *Determining Bulk Density:*

- 29.2.1 Weigh a clean and empty weight-per-gallon cup on a top loading balance. Tare the weight of the cup.
- 29.2.2 Shake the 1-pt. bottle of slurry vigorously for 1 min. Rapidly pour the slurry from the 1-pt. bottle into the weight-per-gallon cup. Fill the cup to just below the top rim.
- 29.2.3 Tap the bottom of the filled cup against a hard surface to remove air bubbles.
- 29.2.4 Place the lid on the cup, gently pressing it into place. Excess slurry will flow out the small center opening in the top.
- Note 37**—If slurry does not flow out of the opening, use additional slurry. Agitate the sample before adding more slurry.
- 29.2.5 Carefully wipe off all of the excess slurry from the outside of the cup and lid.
- 29.2.6 Place the weight-per-gallon cup on a top loader balance. Weigh the cup and its contents to the nearest 0.1 g.
- Note 38**—Make sure the tared weight remains displayed on the balance just before measuring the weight of the filled cup.
-

29.2.7 Divide the result by 10. Report this value as the bulk density of the slurry.

29.3 *Calculations:*

29.3.1 Calculate bulk density:

$$BD = \frac{(\text{slurry wt.})}{10}$$

Where:

BD = bulk density, lb./gal.

slurry wt. = weight of the slurry in the weight-per-gallon cup, g.

29.4 *Determination of Sample Size:*

29.4.1 Refer to Part III, Section 16.3.

30. TESTING PROCEDURES

30.1 *Titration to pH 8.3:*

30.1.1 Determine the sample size using the method indicated in Section 29.4.

30.1.2 Tare a 400-mL tall-form beaker on an analytical balance.

30.1.3 Agitate the 1-pt. bottle for 1 min. Pour the required weight of slurry sample, as determined above, into the 400-mL tall-form beaker. Record the weight of the sample to the nearest 0.0001 g.

30.1.4 Slowly add enough deionized water to bring the volume of mixture to 150 mL. Add a stirring magnet, place the beaker on a magnetic stirrer, and stir the sample.

30.1.5 Calibrate the pH meter using the 4.0 and 9.0 buffer solutions.

30.1.6 Fill the 100-mL buret with 1.0 N hydrochloric acid.

30.1.7 Insert the pH meter probe into the sample. Begin titrating the sample with 1.0 N hydrochloric acid. Add the hydrochloric acid at a rapid drop rate to obtain a pH indication of 9 or slightly less.

Note 39—A suitable rapid drop rate is approximately 12 mL/min.

30.1.8 After reaching a momentary pH of 9, decrease the rate of titration to approximately 2 mL/min. Continue at this rate until the pH is close to 8.5.

30.1.9 Once the pH is close to 8.5, add acid in 4-drop increments until maintaining a pH of 8.3 or less for approximately 35 sec.

30.1.10 Then add 2-drop increments until the endpoint of 8.3 or slightly less persists for 60 sec.

Note 40—The endpoint for the titration to pH 8.3 occurs when the addition of one 2-drop increment of titrant produces a pH of 8.3 or slightly less, for exactly 60 sec.

30.1.11 Record the volume of titrant used to reach the endpoint.

30.1.12 Add excess hydrochloric acid to the sample. Record the total volume of acid added to the sample.

Note 41—The sample mixture contains a “measured excess” of hydrochloric acid.

30.2 *Back-Titration to pH 4.4:*

30.2.1 Fill a 50-mL buret with 1.0 N sodium hydroxide solution.

30.2.2 Titrate the sample mixture with 1.0 N sodium hydroxide to the endpoint. The endpoint occurs when a pH of 4.4 or slightly greater occurs exactly 10 sec. after a one-drop addition of titrant.

30.2.3 Record the volume of sodium hydroxide used to reach the endpoint.

30.3 *Loss on Ignition:*

30.3.1 Weigh a crucible using an analytical balance, record the weight, and tare the balance.

30.3.2 Determine the required slurry sample size from Section 28.4. Weigh the determined amount of slurry into the tared crucible. Record the weight of the sample to the nearest 0.0001 g.

30.3.3 Place the platinum crucible with slurry into a $212 \pm 4^{\circ}\text{F}$ ($100 \pm 2^{\circ}\text{C}$) drying oven for 1 hr.

30.3.4 Remove sample from oven and place in a muffle furnace at $2,000 \pm 20^{\circ}\text{F}$ ($1093 \pm 11^{\circ}\text{C}$) for a minimum 2 hr.

30.3.5 Use the long tongs to remove the crucible from the muffle furnace. Place the crucible on a hard-surfaced asbestos board. Allow the crucible to cool on the board for 10–30 sec.

30.3.6 Transfer the crucible to a vacuum desiccator for cooling. Allow 20 min. for cooling.

Note 42—If running several samples simultaneously, transfer the samples to the desiccator and replace the lid with the vacuum stopcock open. The heated air will expand through the opening for several seconds. Then close the stopcock.

30.3.7 After the sample has cooled, remove the sample from the desiccator. Weigh the crucible on an analytical balance as rapidly as possible to minimize hydration of residue. Record the weight to the nearest 0.0001 g.

30.4 *Sieve Analysis:*

30.4.1 Weigh a 2000-mL glass beaker on a top-loading balance, record the weight to the nearest 0.1 g, and tare the balance.

- 30.4.2 Pour 2 qt. of the well-mixed slurry from the 2-gal. polyethylene bottle into the beaker. Weigh the beaker with the slurry on the balance and record the weight to the nearest 0.1 g.
- 30.4.3 Weigh a No. 6 and a No. 30 sieve on a top loading balance. Record the weights to the nearest 0.1 g.
- 30.4.4 Wash the slurry through the nested No. 6 and No. 30 sieves using regular tap water.
Note 43—Apply the wash water in a fantail spray pattern from the 3/8-in. ID plastic tubing fitted with a Bunsen “fan-type” burner attachment at the outlet. Monitor the water pressure with a water gauge at 12 ± 0.3 psi.
- 30.4.5 Continue washing the sample for 30 min. or until the water coming through the sieve is clear, whichever occurs first.
- 30.4.6 Oven-dry the residue on each sieve for 1 hr. at $212 \pm 4^\circ\text{F}$ ($100 \pm 2^\circ\text{C}$).
- 30.4.7 Remove the sieves from the oven and allow them to cool for 20 min. Weigh each sieve on a top loading balance. Record the weight to the nearest 0.1 g.

31. CALCULATIONS

31.1 *Percent Solids:*

- 31.1.1 Calculate all factors A through H and J. Then use the following equation to calculate percent solids:

$$\% \text{ Solids} = \frac{100 - J}{100}$$

Where:

J = free water of the sample, %.

- 31.1.2 Calculate A, apparent hydrate alkalinity of the sample calculated as percent calcium oxide:

$$A = \frac{2.8054(\text{mL of HCl to 8.3})}{\text{sample wt.}}$$

Where:

mL of HCl to 8.3 = amount of hydrochloric acid used to reach 8.3 pH endpoint, mL

sample wt. = the weight of the sample used in the titration.

- 31.1.3 Calculate *B*, carbonate alkalinity of the sample derived by titration and calculated as percent calcium oxide:

$$B = C - A = (\text{total alkalinity}) - (\text{apparent hydrate alkalinity, CaO})$$

Where:

C = total alkalinity of the sample calculated as percent calcium oxide

A = apparent alkalinity of the sample indicated by titration calculated as percent calcium oxide.

- 31.1.4 Calculate *C*, total alkalinity of the sample calculated as percent calcium oxide:

$$C = \frac{2.8054(\text{total mL of HCl} - \text{mL of NaOH to 4.4})}{\text{sample wt.}}$$

Where:

total mL of HCl = amount of hydrochloric acid used, including “measured excess,” mL

mL of NaOH to 4.4 = amount of sodium hydroxide in milliliters used to reach 4.4 pH end point

sample wt. = titration sample weight, g.

- 31.1.5 Calculate *D*, apparent hydrate alkalinity indicated by titration of the sample expressed as percent calcium hydroxide:

$$D = (1.32126) A = (1.32126)(\text{apparent hydrate alkalinity, CaO})$$

Where:

A = apparent hydrate alkalinity of the sample calculated as percent calcium oxide.

- 31.1.6 Calculate *E*, carbonate alkalinity of the sample calculated as percent carbon dioxide:

$$E = (0.78479) B = (0.78479)(\text{carbonate alkalinity, CaO})$$

Where:

B = carbonate alkalinity of the sample derived by titration and calculated as percent calcium oxide.

- 31.1.7 Calculate F , loss on ignition:

$$F = \frac{(\text{sample wt.} - \text{residue wt.})100}{\text{sample wt.}}$$

Where:

sample wt. = original weight of the loss on ignition sample, g

residue wt. = weight of the residue after the loss on ignition test, g.

- 31.1.8 Calculate G , total water of the sample expressed in percent:

$$G = F - E = (\text{loss on ignition}) - (\text{carbonate alkalinity, } CO_2)$$

Where:

F = loss on ignition

E = carbonate alkalinity of the sample calculated as percent carbon dioxide.

- 31.1.9 Calculate H , apparent hydrate alkalinity of the sample indicated by the total water portion of the loss on ignition and expressed as percent calcium hydroxide:

$$H = (4.1128)G = (4.1128)(\text{total water})$$

Where:

G = total water of the sample, %.

- 31.1.10 Calculate J , free water of the sample, %:

$$J = 0.24314(H - D)$$

$$J = (0.24314)(\text{apparent hydrate alkalinity, total water} - \text{apparent hydrate alkalinity, titration})$$

Where:

H = apparent hydrate alkalinity indicated by the total water portion of the loss on ignition

D = apparent hydrate alkalinity indicated by titration of the sample expressed as percent calcium hydroxide.

31.2 Calculate carbide lime slurry alkalinity, % Ca(OH)₂:

$$\% \text{ Ca(OH)}_2 = \frac{D}{\% \text{ solids}} = \frac{(\text{apparent hydrate alkalinity, titration})}{\% \text{ solids}}$$

Where:

D = apparent hydrate alkalinity of the sample indicated by titration and expressed as percent calcium hydroxide.

Note 44—D is the same value calculated for the percent solids determination.

31.3 Calculate loss on ignition:

$$\text{LOI} = \frac{(\text{sample wt.} - \text{residue wt.}) 100}{\text{sample wt.}}$$

Where:

sample wt. = original weight of the loss on ignition sample, g

residue wt. = weight of the residue after the loss on ignition test, g.

Note 45—This is the same calculation used for factor F in the percent solids determination.

31.4 Calculate residue retained by sieve analysis, %:

$$\% \text{ retained} = \frac{\text{residue retained}}{(\text{sample wt.})(\% \text{ solids})} \times 100$$

Where:

% retained = weight percent of residue retained on the sieve

residue retained = weight of residue retained on the sieve, g

sample wt. = weight of the sample before being sieved, g

% solids = percent solids as calculated above.

32. ARCHIVED VERSIONS

32.1 Archived versions are available.

Item 247

Flexible Base



1. DESCRIPTION

Construct a foundation course composed of flexible base.

2. MATERIALS

Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications. Notify the Engineer of the proposed material sources and of changes to material sources. The Engineer may sample and test project materials at any time before compaction throughout the duration of the project to assure specification compliance. Use Tex-100-E material definitions.

- 2.1. **Aggregate.** Furnish aggregate of the type and grade shown on the plans and meeting the requirements of Table 1. Each source must meet Table 1 requirements for liquid limit, plasticity index, and wet ball mill for the grade specified. Do not use additives, such as but not limited to lime, cement, or fly ash to modify aggregates to meet the requirements of Table 1 unless shown on the plans.

Table 1
Material Requirements

Property	Test Method	Grade 1-2	Grade 3	Grade 4 ²	Grade 5
Sampling	Tex-400-A				
Master gradation sieve size (cumulative % retained)	Tex-110-E			As shown on the plans	
2-1/2"		0	0		0
1-3/4"		0-10	0-10		0-5
7/8"		10-35	-		10-35
3/8"		30-65	-		35-65
#4		45-75	45-75		45-75
#40		65-90	50-85		70-90
Liquid Limit, % Max	Tex-104-E	40	40	As shown on the plans	35
Plasticity Index, Max ¹	Tex-106-E	10	12	As shown on the plans	10
Plasticity index, Min ¹		As shown on the plans	As shown on the plans	As shown on the plans	As shown on the plans
Wet ball mill, % Max	Tex-116-E	40	-	As shown on the plans	40
Wet ball mill, % Max increase passing the #40 sieve		20	-	As shown on the plans	20
Min compressive strength, psi	Tex-117-E			As shown on the plans	
lateral pressure 0 psi		35	-		-
lateral pressure 3 psi		-	-		90
lateral pressure 15 psi		175	-		175

- Determine plastic index in accordance with Tex-107-E (linear shrinkage) when liquid limit is unattainable as defined in Tex-104-E.
- Grade 4 may be further designated as Grade 4A, Grade 4B, etc.

- 2.1.1. **Material Tolerances.** The Engineer may accept material if no more than 1 of the 5 most recent gradation tests has an individual sieve outside the specified limits of the gradation.

When target grading is required by the plans, no single failing test may exceed the master grading by more than 5 percentage points on sieves No. 4 and larger or 3 percentage points on sieves smaller than No. 4.

The Engineer may accept material if no more than 1 of the 5 most recent plasticity index tests is outside the specified limit. No single failing test may exceed the allowable limit by more than 2 points.

- 2.1.2. **Material Types.** Do not use fillers or binders unless approved. Furnish the type specified on the plans in accordance with the following:
- 2.1.2.1. **Type A.** Crushed stone produced and graded from oversize quarried aggregate that originates from a single, naturally occurring source. Do not use gravel or multiple sources.
- 2.1.2.2. **Type B.** Crushed or uncrushed gravel. Blending of 2 or more sources is allowed.
- 2.1.2.3. **Type C.** Crushed gravel with a minimum of 60% of the particles retained on a No. 4 sieve with 2 or more crushed faces as determined by Tex-460-A, Part I. Blending of 2 or more sources is allowed.
- 2.1.2.4. **Type D.** Type A material or crushed concrete. Crushed concrete containing gravel will be considered Type D material. Crushed concrete must meet the requirements in Section 247.2.1.3.2., "Recycled Material (Including Crushed Concrete) Requirements," and be managed in a way to provide for uniform quality. The Engineer may require separate dedicated stockpiles in order to verify compliance.
- 2.1.2.5. **Type E.** Caliche, iron ore or as otherwise shown on the plans.
- 2.1.3. **Recycled Material.** Reclaimed asphalt pavement (RAP) and other recycled materials may be used when shown on the plans. Request approval to blend 2 or more sources of recycled materials.
- 2.1.3.1. **Limits on Percentage.** Do not exceed 20% RAP by weight, when RAP is allowed, unless otherwise shown on the plans. The percentage limitations for other recycled materials will be as shown on the plans.
- 2.1.3.2. **Recycled Material (Including Crushed Concrete) Requirements.**
- 2.1.3.2.1. **Contractor-Furnished Recycled Materials.** Provide recycled materials, other than RAP, that have a maximum sulfate content of 3,000 ppm when tested in accordance with Tex-145-E. When the Contractor furnishes the recycled materials, including crushed concrete, the final product will be subject to the requirements of Table 1 for the grade specified. Certify compliance with DMS-11000, "Evaluating and Using Nonhazardous Recyclable Materials Guidelines," for Contractor furnished recycled materials. In addition, recycled materials must be free from reinforcing steel and other objectionable material and have at most 1.5% deleterious material when tested in accordance with Tex-413-A. For RAP, do not exceed a maximum percent loss from decantation of 5.0% when tested in accordance with Tex-406-A. Test RAP without removing the asphalt.
- 2.1.3.2.2. **Department-Furnished Required Recycled Materials.** When the Department furnishes and requires the use of recycled materials, unless otherwise shown on the plans:
- Department-required recycled material will not be subject to the requirements in Table 1,
 - Contractor-furnished materials are subject to the requirements in Table 1 and this Item,
 - the final product, blended, will be subject to the requirements in Table 1, and
 - for final product, unblended (100% Department-furnished required recycled material), the liquid limit, plasticity index, wet ball mill, and compressive strength is waived.
- Crush Department-furnished RAP so that 100% passes the 2 in. sieve. The Contractor is responsible for uniformly blending to meet the percentage required.
- 2.1.3.2.3. **Department-Furnished and Allowed Recycled Materials.** When the Department furnishes and allows the use of recycled materials or allows the Contractor to furnish recycled materials, the final blended product is subject to the requirements of Table 1 and the plans.

- 2.1.3.3. **Recycled Material Sources.** Department-owned recycled material is available to the Contractor only when shown on the plans. Return unused Department-owned recycled materials to the Department stockpile location designated by the Engineer unless otherwise shown on the plans.

The use of Contractor-owned recycled materials is allowed when shown on the plans. Contractor-owned surplus recycled materials remain the property of the Contractor. Remove Contractor-owned recycled materials from the project and dispose of them in accordance with federal, state, and local regulations before project acceptance. Do not intermingle Contractor-owned recycled material with Department-owned recycled material unless approved.

- 2.2. **Water.** Furnish water free of industrial wastes and other objectionable matter.
- 2.3. **Material Sources.** Expose the vertical faces of all strata of material proposed for use when non-commercial sources are used. Secure and process the material by successive vertical cuts extending through all exposed strata, when directed.

3. EQUIPMENT

Provide machinery, tools, and equipment necessary for proper execution of the work.

- 3.1. Provide rollers in accordance with Item 210, "Rolling." Provide proof rollers in accordance with Item 216, "Proof Rolling," when required.
- 3.2. When ride quality measurement is required, provide a high speed or lightweight inertial profiler certified at the Texas A&M Transportation Institute. Provide equipment certification documentation. Display a current decal on the equipment indicating the certification expiration date.

4. CONSTRUCTION

Construct each layer uniformly, free of loose or segregated areas, and with the required density and moisture content. Provide a smooth surface that conforms to the typical sections, lines, and grades shown on the plans or as directed.

Stockpile base material temporarily at an approved location before delivery to the roadway. Build stockpiles in layers no greater than 2 ft. thick. Stockpiles must have a total height between 10 and 16 ft. unless otherwise approved. After construction and acceptance of the stockpile, loading from the stockpile for delivery is allowed. Load by making successive vertical cuts through the entire depth of the stockpile.

Do not add or remove material from temporary stockpiles that require sampling and testing before delivery unless otherwise approved. Charges for additional sampling and testing required as a result of adding or removing material will be deducted from the Contractor's estimates.

Haul approved flexible base in clean trucks. Deliver the required quantity to each 100-ft. station or designated stockpile site as shown on the plans. Prepare stockpile sites as directed. When delivery is to the 100-ft. station, manipulate in accordance with the applicable Items.

- 4.1. **Preparation of Subgrade or Existing Base.** Remove or scarify existing asphalt concrete pavement in accordance with Item 105, "Removing Treated and Untreated Base and Asphalt Pavement," when shown on the plans or as directed. Shape the subgrade or existing base to conform to the typical sections shown on the plans or as directed.

When new base is required to be mixed with existing base, deliver, place, and spread the new flexible base in the required amount per station. Manipulate and thoroughly mix the new base with existing material to provide a uniform mixture to the specified depth before shaping.

Proof roll the roadbed in accordance with Item 216, "Proof Rolling," before pulverizing or scarifying when shown on the plans or directed. Correct soft spots as directed.

- 4.2. **Placing.** Spread and shape flexible base into a uniform layer with an approved spreader the same day as delivered unless otherwise approved. Construct layers to the thickness shown on the plans. Maintain the shape of the course. Control dust by sprinkling, as directed. Correct or replace segregated areas as directed, at no additional expense to the Department.

Place successive base courses and finish courses using the same construction methods required for the first course.

- 4.3. **Compaction.** Compact using density control unless otherwise shown on the plans. Multiple lifts are permitted when shown on the plans or approved. Bring each layer to the moisture content directed. When necessary, sprinkle the material in accordance with Item 204, "Sprinkling."

Begin rolling longitudinally at the sides and proceed towards the center, overlapping on successive trips by at least 1/2 the width of the roller unit. Begin rolling at the low side and progress toward the high side on superelevated curves. Offset alternate trips of the roller. Operate rollers at a speed between 2 and 6 mph as directed.

Rework, recompact, and refinish material that fails to meet or that loses required moisture, density, stability, or finish requirements before the next course is placed or the project is accepted. Continue work until specification requirements are met. Perform the work at no additional expense to the Department.

Before final acceptance, the Engineer will select the locations of tests and measure the flexible base depth in accordance with Tex-140-E. Correct areas deficient by more than 1/2 in. in thickness by scarifying, adding material as required, reshaping, recompact, and refinishing at the Contractor's expense.

- 4.3.1. **Ordinary Compaction.** Roll with approved compaction equipment as directed. Correct irregularities, depressions, and weak spots immediately by scarifying the areas affected, adding or removing approved material as required, reshaping, and recompact.

- 4.3.2. **Density Control.** Compact to at least 100% of the maximum dry density determined by Tex-113-E, unless otherwise shown on the plans. Maintain moisture during compaction within ± 2 percentage points of the optimum moisture content as determined by Tex-113-E. Measure the moisture content of the material in accordance with Tex-115-E or Tex-103-E during compaction daily and report the results the same day to the Engineer, unless otherwise shown on the plans or directed. Do not achieve density by drying the material after compaction.

The Engineer will determine roadway density and moisture content of completed sections in accordance with Tex-115-E. The Engineer may accept the section if no more than 1 of the 5 most recent density tests is below the specified density and the failing test is no more than 3 pcf below the specified density.

- 4.4. **Finishing.** After completing compaction, clip, skin, or tight-blade the surface with a maintainer or subgrade trimmer to a depth of approximately 1/4 in. Remove loosened material and dispose of it at an approved location. Seal the clipped surface immediately by rolling with a pneumatic tire roller until a smooth surface is attained. Add small increments of water as needed during rolling. Shape and maintain the course and surface in conformity with the typical sections, lines, and grades as shown on the plans or as directed.

Correct grade deviations greater than 1/4 in. in 16 feet measured longitudinally or greater than 1/4 in. over the entire width of the cross-section in areas where surfacing is to be placed. Correct by loosening and adding, or removing material. Reshape and re-compact in accordance with Section 247.4.3., "Compaction."

- 4.5. **Curing.** Cure the finished section until the moisture content is at least 2 percentage points below optimum or as directed before applying the next successive course or prime coat.

- 4.6. **Ride Quality.** This section applies to the final travel lanes that receive a 1 or 2 course surface treatment for the final surface, unless otherwise shown on the plans. Measure ride quality of the base course after placement of the prime coat and before placement of the surface treatment, unless otherwise approved. Use a certified profiler operator from the Department's MPL. When requested, furnish the Engineer documentation for the person certified to operate the profiler.

Provide all profile measurements to the Engineer in electronic data files within 3 days after placement of the prime coat using the format specified in Tex-1001-S. The Engineer will use Department software to evaluate longitudinal profiles to determine areas requiring corrective action. Correct 0.1-mi.sections having an average international roughness index (IRI) value greater than 100.0 in. per mile to an IRI value of 100.0 in. per mile or less for each wheel path, unless otherwise shown on the plans.

Re-profile and correct sections that fail to maintain ride quality until placement of the next course, as directed. Correct re-profiled sections until specification requirements are met, as approved. Perform this work at no additional expense to the Department.

5. MEASUREMENT

Flexible base will be measured as follows:

- **Flexible Base (Complete In Place).** The ton, square yard, or any cubic yard method.
- **Flexible Base (Roadway Delivery).** The ton or any cubic yard method.
- **Flexible Base (Stockpile Delivery).** The ton, cubic yard in vehicle, or cubic yard in stockpile.

Measurement by the cubic yard in final position and square yard is a plans quantity measurement. The quantity to be paid for is the quantity shown in the proposal unless modified by Article 9.2., "Plans Quantity Measurement." Additional measurements or calculations will be made if adjustments of quantities are required.

Measurement is further defined for payment as follows.

- 5.1. **Cubic Yard in Vehicle.** By the cubic yard in vehicles of uniform capacity at the point of delivery.
- 5.2. **Cubic Yard in Stockpile.** By the cubic yard in the final stockpile position by the method of average end areas.
- 5.3. **Cubic Yard in Final Position.** By the cubic yard in the completed and accepted final position. The volume of base course is computed in place by the method of average end areas between the original subgrade or existing base surfaces and the lines, grades, and slopes of the accepted base course as shown on the plans.
- 5.4. **Square Yard.** By the square yard of surface area in the completed and accepted final position. The surface area of the base course is based on the width of flexible base as shown on the plans.
- 5.5. **Ton.** By the ton of dry weight in vehicles as delivered. The dry weight is determined by deducting the weight of the moisture in the material at the time of weighing from the gross weight of the material. The Engineer will determine the moisture content in the material in accordance with Tex-103-E from samples taken at the time of weighing.

When material is measured in trucks, the weight of the material will be determined on certified scales, or the Contractor must provide a set of standard platform truck scales at a location approved by the Engineer. Scales must conform to the requirements of Item 520, "Weighing and Measuring Equipment."

6. PAYMENT

The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for the types of work shown below. No additional payment

will be made for thickness or width exceeding that shown on the typical section or provided on the plans for cubic yard in the final position or square yard measurement.

Sprinkling and rolling, except proof rolling, will not be paid for directly but will be subsidiary to this Item unless otherwise shown on the plans. When proof rolling is shown on the plans or directed, it will be paid for in accordance with Item 216, "Proof Rolling."

Where subgrade is constructed under this Contract, correction of soft spots in the subgrade will be at the Contractor's expense. Where subgrade is not constructed under this Contract, correction of soft spots in the subgrade will be paid in accordance with pertinent Items or Article 4.4., "Changes in the Work."

- 6.1. **Flexible Base (Complete In Place).** Payment will be made for the type and grade specified. For cubic yard measurement, "In Vehicle," "In Stockpile," or "In Final Position" will be specified. For square yard measurement, a depth will be specified. This price is full compensation for furnishing materials, temporary stockpiling, assistance provided in stockpile sampling and operations to level stockpiles for measurement, loading, hauling, delivery of materials, spreading, blading, mixing, shaping, placing, compacting, reworking, finishing, correcting locations where thickness is deficient, curing, furnishing scales and labor for weighing and measuring, and equipment, labor, tools, and incidentals.
- 6.2. **Flexible Base (Roadway Delivery).** Payment will be made for the type and grade specified. For cubic yard measurement, "In Vehicle," "In Stockpile," or "In Final Position" will be specified. The unit price bid will not include processing at the roadway. This price is full compensation for furnishing materials, temporary stockpiling, assistance provided in stockpile sampling and operations to level stockpiles for measurement, loading, hauling, delivery of materials, furnishing scales and labor for weighing and measuring, and equipment, labor, tools, and incidentals.
- 6.3. **Flexible Base (Stockpile Delivery).** Payment will be made for the type and grade specified. For cubic yard measurement, "In Vehicle" or "In Stockpile" will be specified. The unit price bid will not include processing at the roadway. This price is full compensation for furnishing and disposing of materials, preparing the stockpile area, temporary or permanent stockpiling, assistance provided in stockpile sampling and operations to level stockpiles for measurement, loading, hauling, delivery of materials to the stockpile, furnishing scales and labor for weighing and measuring, and equipment, labor, tools, and incidentals.