Designation: D 6276 – 99a

Standard Test Method for Using pH to Estimate the Soil-Lime Proportion Requirement for Soil Stabilization[1]

This standard is issued under the fixed designation D 6276; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides a means for estimating the soil-lime proportion requirement for stabilization of a soil. This test method is performed on soil passing the −425-µm (No. 40) sieve. The optimum soil-lime proportion for soil stabilization is determined by tests of specific characteristics of stabilized soil such as unconfined compressive strength or plasticity index.

1.2 Some highly alkaline by-products (lime kiln dust, cement kiln dust, and so forth) have been successfully used to stabilize soil. This test method is not intended for these materials and any such product would need to be tested for specific characteristics as indicated in 1.1.

1.3 This test method is used to determine the lowest percentage of lime that results in a soil-lime pH of 12.4.

1.4 Lime is not an effective stabilizing agent for all soils. Some soil components such as sulfates, phosphates, organics, and so forth can adversely affect soil-lime reactions and may produce erroneous results using this test method.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 51 Terminology Relating to Lime and Limestone (as used by the industry)[2]

C 977 Specification for Quicklime and Hydrated Lime for Soil Stabilization[2]

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[3]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 1193 Specification for Reagent Water[4]

D 1293 Test Methods for pH of Water[4]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[3]

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[3]

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Testing Soil, Rock, and Related Construction Materials[3]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[5]

E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens[5]

3. Terminology

3.1 *Definitions*:

3.2 Refer to Terminology C 51 for definitions of terms relating to lime.

3.3 Refer to Terminology D 653 for terms relating to soil.

3.4 *Definitions of Terms Specific to This Standard:*

3.4.1 *buffer solution*—a solution of specific pH value used to calibrate the pH meter.

3.4.2 *free lime*—lime in a soil-lime mixture that has not dissociated into calcium and hydroxyl ions.

3.4.3 *hydrated lime*—lime that is predominately calcium hydroxide ($Ca(OH)_2$) or a mixture of calcium hydroxide and magnesium oxide (MgO) or magnesium hydroxide ($Mg(OH)_2$).

3.4.4 *lime*—a general term which, for the purpose of this test method, includes hydrated lime and quicklime.

3.4.5 *lime content*—the ratio expressed as a percentage of the mass of lime to the dry mass of soil.

3.4.6 *lime stabilization*—addition of lime to a soil in sufficient quantities to promote long-term pozzolanic reactions that result in strength gain and permanent improvement in stability. Textural improvement alone, such as reduced plasticity, is often referred to as "modification." Modification can be effected by lime addition rates less than those required for stabilization and may not be permanent.

3.4.7 *pH*—the negative logarithm of the effective hydrogen-ion concentration or hydrogen-ion activity, in gram equivalents per litre. The pH values range from 0 to 14; where pH 7

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization and Admixtures.

Current edition approved June 10, 1999. Published September 1999. Originally published as D 6276 – 98. Last previous edition D 6276 – 99.

[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vol 11.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

represents neutrality, pH values less than 7 indicate increasing acidity, and pH values greater than 7 indicate increasing alkalinity.

3.4.8 *quicklime*—lime that is predominately calcium oxide (CaO) or calcium oxide in association with magnesium oxide (MgO).

3.4.9 *stabilization*—a process to improve the engineering properties of soils at a site.

4. Summary of Test Method

4.1 A series of specimens is prepared containing a range of percentages of lime content in soil. Measurements of pH are made on slurries of the specimens to determine the minimum lime content of the soil-lime mixture to obtain a pH of at least 12.4.

4.2 The pH of at least 12.4 achieved in this test method results from free lime remaining in the soil-lime mixture. Normally, the pH of the specific lime being used for soil stabilization should be determined and used as the indicator pH.

5. Significance and Use

5.1 The soil-lime pH test is performed as a test to indicate the soil-lime proportion needed to maintain the elevated pH necessary for sustaining the reactions required to stabilize a soil. The test derives from Eades and Grim.[6]

5.2 Performance tests are normally conducted in a laboratory to verify the results of this test method.

5.3 This test method will not provide reliable information relative to the potential reactivity of a particular soil, nor will it provide information on the magnitude of increased strength to be realized upon treatment of this soil with the indicated percentage of lime.

5.4 This test method can be used to estimate the percentage of lime as hydrated lime or quicklime needed to stabilize soil.

5.5 Agricultural lime (crushed limestone) will not stabilize soil.

NOTE 1—Notwithstanding the statements on precision and bias contained in this test method: The precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not itself ensure reliable testing. Reliable testing depends on several factors; Practice D 3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Balance or Scale*:

6.1.1 A balance or scale for determining the mass of soil and lime having a minimum capacity of 600 g and meeting the requirements of Specification D 4753 for a balance or scale of 0.01 g readability.

6.2 *Sieve*—A 425-µm (No. 40) sieve, conforming to the requirements of Specification E 11.

6.3 *Plastic Bottles*—Six 150-mL (or larger) plastic bottles with tight-fitting screw caps.

6.4 *A pH Meter*—A pH meter equipped with reference electrode and low-sodium error glass pH-sensitive electrodes (or combination electrode) and a meter capable of displaying 0.01 units pH at 0.2 pH accuracy over a range from 0 to 14.

6.5 *Drying Oven*—Oven conforming to requirements of Specification E 145.

6.6 *Miscellaneous Equipment*—An airtight, moisture-proof container for preserving the moisture content of the soil; mixing tools and scoops for use in preparing test specimens.

7. Reagents and Materials

7.1 *Water*—Reference to water shall be understood to mean Type II reagent water conforming to Specification D 1193. Store the water in a tightly capped container; boil and cool the water immediately before use.

NOTE 2—If the pH of the site water to be used is highly acidic (<6) or highly basic (>9) test results should be checked against a specimen made up with site water rather than Type II water.

7.2 *Buffer Solution*—Use a buffer solution having a pH of 12, either commercially available or prepared in accordance with Test Methods D 1293.

7.3 *Hydrated Lime*—Only fresh lime meeting the requirements of Specification C 977 may be used.

7.4 *Quicklime*—Only fresh lime meeting the requirements of Specification C 977 may be used.

8. Safety Hazards

8.1 Quicklime becomes hot when mixed with water. Use protective gloves when handling containers of soil-quicklime-water mixtures.

8.2 Hydrated lime and quicklime are strong caustics and may cause severe irritation of skin, eyes, and mucous membranes. Appropriate safety equipment such as heavy rubber gloves, protective eye wear, and a plastic apron should be worn when handling lime. Ensure that adequate ventilation (or a respirator) is provided.

9. Technical Hazards

9.1 Lime readily absorbs water and carbon dioxide from the air, therefore, store lime in tightly closed containers.

9.2 The soil-lime-water mixture is alkaline and will react with metal and glass; therefore, use plastic bottles and beakers.

10. Specimens

10.1 Prepare a representative sample of air-dried soil in accordance with Practice D 421. Soil may be oven-dried at a temperature $\leq$ 60°C.

10.2 Pass 350 g of material through the 425-µm (No. 40) sieve.

10.3 Thoroughly mix the material passing the 425-µm (No. 40) sieve.

10.4 Determine the water content, in accordance with Test Method D 2216, of a representative specimen of the material obtained in 10.3. Place the remaining material obtained in 10.3 in an airtight container to preserve the moisture content until the procedure described in Section 12 is performed.

[6] Eades, J.L., and Grim, R.E., A Quick Test to Determine Lime Requirements for Lime Stabilization,*Highway Research Record No. 3*, 1996, National Academy of Sciences, National Research Council, Highway Research Board, Washington, DC.

11. Calibration and Standardization

11.1 Calibrate the pH meter in accordance with the manufacturer's instructions using a pH 12 buffer solution at 25 ± 1°C. The calcium hydroxide reference buffer solution described in 11.1.2 of Test Methods D 1293 may also be used as a calibration standard.

12. Procedure

12.1 *Specimen Preparation*:

12.1.1 Using the air-dried sample in accordance with Section 10, obtain five specimens, each equivalent to 25.0 g of oven-dried soil. Splitting or other appropriate means should be used to obtain each of the five specimens.

12.1.2 Determine the mass of each air-dried soil specimen equivalent to 25.0 g of oven-dry soil as follows:

$$M_a = 25 \times (1.0 + W/100) \quad (1)$$

where:

M_a = mass of air-dried soil specimen, and
W = water content, %, of air-dried sample determined in 10.4.

12.1.3 Place each specimen into dry plastic bottles and cap tightly.

12.1.4 Obtain six representative specimens of lime meeting the requirements of Specification C 977. Five specimens are representative of 2, 3, 4, 5, and 6 % of the equivalent 25-g oven-dried soil mass. The sixth specimen of 2.0 g of lime represents a saturated lime solution. Place the 2.0 g of lime into a dry plastic bottle and cap tightly.

NOTE 3—The range of lime percentages for soil-lime mixtures may be adjusted to meet the requirements of Section 13.

NOTE 4—The appendix of Specification C 977 notes that if quicklime is used, rapidly crush to pass a 3.35-mm (No. 6) sieve.

12.1.5 Add one of the first five lime specimens to one of the soil specimens in plastic bottles, cap tightly, mark the percentage on the bottle, and mix thoroughly by shaking. Repeat this procedure for the remaining four lime and soil specimens.

12.1.6 Add 100 mL of water to each of the soil-lime mixtures and to the bottle containing 2.0 g lime.

12.1.7 Cap the bottles and shake each of the soil-lime-water and lime-water mixtures for a minimum of 30 s or until the specimens are thoroughly mixed. Continue to shake the specimens for 30 s every 10 min for 1 h.

12.2 If necessary, heat or cool the specimen as needed to bring the temperature of the specimen to 25 ± 1°C.

12.3 Within 15 min of the end of the 1-h shaking period, determine the pH of each soil-lime-water and the lime-water mixture of 0.01 pH units. Maintain the temperature of the mixture at 25 ± 1°C when determining pH.

12.4 Record the pH value for each soil-lime-water mixture and for the lime-water mixture.

13. Soil-Lime Proportion and pH Relationship

13.1 The lowest percentage of lime in soil that gives a pH of 12.4 is the approximate lime percentage for stabilizing the soil. There may be some soils in which the pH is greater than 12.4. If this occurs, select the lowest percentage of lime where the higher pH value does not rise for at least two successive test samples at increasing lime percentages.

13.2 If the highest measured pH is 12.3 or less, then additional test samples using higher percentages of lime should be prepared and tested.

NOTE 5—There may be some soils where the pH of the soil-lime mixture will not go above 12.3. This phenomenon is thought to occur with soil (that is, clays) that are holding univalent ions such as sodium in exchange positions. As these ions are exchanged with calcium ions from lime, the pH electrode becomes sensitive to the sodium ions as well as the hydrogen ions.

13.3 If the highest measured pH is 12.3 and at least two successive specimens at increasing lime percentages yield values of 12.3, the lowest percentage of lime to give a pH of 12.3 is the approximate optimum lime percentage for stabilizing the soil.

13.4 If the highest measured pH is less than 12.3, the test is invalid due to equipment or material error or due to insufficient lime having been added. Check the pH electrode in the pH 12 buffer solution and the lime-water solution for possible equipment error or repeat the test using higher percentages of lime, or both.

14. Calculation

14.1 Convert percentage of lime as hydrated lime [$Ca(OH)_2$] to percentage of lime as quicklime (CaO) as follows:

$$L_Q = L_H \times 56/74 \quad (2)$$

where:

L_Q = percentage of quicklime, %,
L_H = percentage of hydrated lime, %,
56 = molecular weight CaO, and
74 = molecular weight $Ca(OH)_2$.

14.2 Convert percentage of lime as quicklime (CaO) to percentage of lime as hydrated lime [$Ca(OH)_2$] as follows:

$$L_H = L_Q \times 74/56 \quad (3)$$

where:

L_H = percentage of hydrated lime, %,
L_Q = percentage of quicklime, %,
74 = molecular weight $Ca(OH)_2$, and
56 = molecular weight CaO.

15. Report

15.1 Report the following information:

15.1.1 The estimated lime percentage required for stabilization to the nearest 1 % and the lime percentage and measured pH of each of the soil-lime-water mixtures tested.

15.1.2 The type of lime used to determine the estimated lime content for soil stabilization.

16. Precision and Bias

16.1 *Precision*—The precision of this test method is being determined by an interlaboratory test program on three types of soils.

16.2 *Bias*—The bias of this test method cannot be determined because no accepted reference material exists.

17. Keywords

17.1 lime content; lime proportion; pH; soil-lime; soil stabilization

SUMMARY OF CHANGES

In accordance with Committee D-18 policy, this section identifies the location of changes to this standard since the last edition that may impact the use of this standard.

(*1*) Paragraph 1.2 was added and the remainder of Section 1 was renumbered as needed.
(*2*) The phrase "and may produce erroneous results using this test method" was added to the end of 1.4.
(*3*) The language of the safety caveat in paragraph 1.5 (renumbered).
(*4*) Lime stabilization definition, 3.4.6, was changed from "addition of limt to a soil in sufficient quantities to decrease the plasticity index (PI) of the soil resulting in a soil that is less sticky, more tillable, more permeable, and with potentially greater bearing strength" to "addition of lime to a soil in sufficient quantities to promote long-term pozzolanic reactions that result in strength gain and permanent improvement in stability. Textural improvement alone, such as reduced plasticity, is often referred to as "modification." Modification can be effected by lime addition rates less than those required for stabilization and may not be permanent."
(*5*) In 5.4 change "indicate" to "estimate."
(*6*) Change the title of Section 14 from "Conversions" to "Calculation" to agree with standard headings.
(*7*) Add Summary of Changes.
(*8*) Miscellaneous editorial changes.