



Illinois Department of Transportation

Memorandum

To: ALL GEOTECHNICAL MANUAL USERS 05.3
From: Ralph E. Anderson *Ralph E. Anderson*
Subject: Revised Appendix II of the Geotechnical Manual
Date: October 26, 2005

This memorandum has been issued to inform you that Appendix II "IBR/IBV Tests and Laboratory Evaluation/Design Procedures" in the current Geotechnical Manual has been revised. The attached version shall replace and supersede the 1999 version. Laboratory testing and mix design procedures have been revised to better reflect the geotechnical field practices. The revision includes the following changes:

1. The new title is "Tests and Laboratory Evaluation/Design Procedures".
2. It introduces the various soil testing services available at the Central Soils Laboratory of the Bureau of Materials and Physical Research.
3. The 1999 Attachment II-B "Lime Stabilized/Lime Modified Soil Mixtures - Laboratory Evaluation/Design Procedures" has been separated into two attachments: A new Attachment II-B "Soil Modification with Various Materials - Laboratory Evaluation/Design Procedures" which includes other soil modifiers besides lime, and new Attachment II-F "Lime Stabilized Soil Mixtures - Laboratory Evaluation/Design Procedures".

The table of contents, in which Attachments II-A through II-E are listed under Appendix II, will be revised to reflect the above changes.

If you have questions or need further assistance, please contact Bill Kramer at (217) 782-7773 or Riyadh Wahab at (217) 782-2704, of our Central Geotechnical Unit.

WMK/RMW/jp691
cc: Regional Engineers
Eric Harm

Attachments

APPENDIX II

TESTS AND LABORATORY EVALUATION/DESIGN PROCEDURES

1 - INTRODUCTION

This appendix contains the following attachments:

- Attachment II-A: Method of Determining the IBR and the IBV of Soils,
Treated Soils and Aggregates
- Attachment II-B: Soil Modification with Various Materials
Laboratory Evaluation/Design Procedure
- Attachment II-C: Soil-Cement Mixture
Laboratory Evaluation/Design Procedures
- Attachment II-D: Cement-Aggregate Mixture
Laboratory Evaluation/ Design Procedures
- Attachment II-E: Pozzolanic-Stabilized Mixture
Laboratory Evaluation/Design Procedure
- Attachment II-F: Lime Stabilized Soil Mixtures
Laboratory Evaluation/Design Procedure

The above lab procedures can be performed at the BMPR's Central Soils Lab. It should be noted that as of March 1, 2005, the geotechnical engineers at the BMPR were combined with those at the BBS to form a new Central Geotechnical Unit (CGU) within the BBS. The Central Soils Lab and the Soils Instrumentation Lab remained within the BMPR, under the Engineer of Concrete and Soils. However, the CGU will continue to provide "Technical Supervisory" responsibilities over the Soils Lab. Technical supervision includes engineering/analysis of the test results and providing response and recommendations regarding applicability of soil data for use in design. Acceptance tests, with pass or fail results, can be accessed through IDOT's MISTIC system and will not be reported by the BBS.

In addition to the above mentioned lab procedures, BMPR provides various soil testing services as outlined below. Request for soil testing should be directed to the CGU's Chief, with a copy to BMPR's Engineer of Concrete and Soils.

(a) Services Provided by BMPR Soils Laboratory

(i) Tests performed in Soils Laboratory:

AASHTO T 87 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
AASHTO T 88 Particle Size Analysis of Soils
AASHTO T 89 Determining the Liquid Limit of Soils
AASHTO T 90 Determining the Plastic Limit and Plasticity Index of Soils
AASHTO T 99 Moisture-Density Relations of Soils (standard effort)
AASHTO T 100 Specific Gravity of Soils
AASHTO T 134 Moisture-Density Relations of Soil-Cement Mixtures
AASHTO T 135 Wetting-and-Drying Test of Compacted Soil-Cement Mixtures
AASHTO T 136 Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures
AASHTO T 146 Wet Preparation of Disturbed Soil Samples for Test
AASHTO T 180 Moisture-Density Relations of Soils (modified effort)
AASHTO T 208 Unconfined Compressive Strength of Cohesive Soil
AASHTO T 215 Permeability of Granular Soils (constant head)
AASHTO T 216 One-Dimensional Consolidation Properties of Soils
AASHTO T 265 Laboratory Determination of Moisture Content of Soils
AASHTO T 288 Determining Minimum Laboratory Soil Resistivity
AASHTO T 296 Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression
AASHTO T 297 Consolidated, Undrained Triaxial Compression Test on Cohesive Soils
Illinois Bearing Ratio (IBR)
Immediate Bearing Value (IBV)
Erosion Function Apparatus (Pier Scour Testing)
Unconfined Compressive Strength of Rock Cores

(ii) Tests Coordinated by Soils Laboratory, but performed in Analytical Laboratory:

▪ Top Soils:

AASHTO T 194 Determination of Organic Matter in Soils by Wet Combustion
AASHTO T 267 Determination of Organic Content in Soils by Loss on Ignition
ASTM D 2976 pH of Peat Materials

- Lime & Lime By-products:

ASTM C 25 Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

ASTM C 114 Chemical Analysis of Hydraulic Cement (Magnesium Oxide)

- MSE Wall Materials:

AASHTO T 267 Determination of Organic Content in Soils by Loss on Ignition

AASHTO T 289 Determining pH of Soil for Use in Corrosion Testing

AASHTO T 290 Determining Water-Soluble Sulfate Ion Content in Soil

AASHTO T 291 Determining Water-Soluble Chloride Ion Content in Soil

- Fly Ash with an R Factor greater than 3.0 and used in concrete:

AASHTO T 290 Determining Water-Soluble Sulfate Ion Content in Soil

Illinois Modified ASTM D 516-82 Test Method for Sulfate Ion in Water under Fly Ash and under Drilled Shafts.

- Drilled Shafts:

AASHTO T 290 Determining Water-Soluble Sulfate Ion Content in Soil

Illinois Modified ASTM D 516-82 Test Method for Sulfate Ion in Water under Fly Ash and under Drilled Shafts.

(iii) Repair Services coordinated by Soils Laboratory:

- Rimac Repair and calibration

(b) Services Provided by BMPR Nuclear Laboratory

(i) Calibration Services:

- AASHTO T 287 Asphalt Cement Content of Asphalt Concrete Mixtures by the Nuclear Method
- AASHTO T 310 In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

(ii) Repair Services:

- Asphalt Content Gauge
- Nuclear Gauge

- Slope Inclinometer
- Earth Resistivity

(c) **Equipment Available for Loan:**

- Slope Inclinometer Equipment (SINCO Company – 1973)
- AASHTO T 254 Installing, Monitoring, and Processing Data of the Traveling Type Slope Inclinometer
- ASTM D 6230 Monitoring Ground Movement using Probe-Type Inclinometers
- Earth Resistivity Equipment (Bison Instruments Incorporated – 1970)
- ASTM D 6431 Using the Direct Current Resistivity Method for Subsurface Investigation

ATTACHMENT II-A - METHOD OF DETERMINING THE IBR AND THE IBV OF SOILS, TREATED SOILS AND AGGREGATES

A. IBR Test

1. Scope

- (a) This test method is for determining the Illinois bearing ratio (IBR) of treated or untreated base, subbase, and subgrade materials; prepared at the OMC and SDD, and soaked in water for four days. The IBR, thus obtained, will primarily be used for pavement design. The IBR is the same as the CBR, determined according to AASHTO T 193, except for the slight modifications described herein for the IBR test. Since the IBR is assumed to have the same numerical value as the CBR for design purposes, AASHTO T 193 may be used in lieu of the IBR test.
- (b) This test method is also for determining the extent to which materials will expand or swell during a four-day soaking period.

2. Equipment

Equipment shall meet the requirements of AASHTO T 193, except that subsection 4.8 shall be replaced by the following:

Loading Device - A compression type equipment capable of applying a uniformly increasing load, up to 267 kN (60,000 lb.), at a constant rate of 1.27 mm (0.05 in.) per minute (see Note 1). This loading device is to be used for compacting the entire material within the mold in one layer and is to be used for the penetration test.

Note 1. Some soils may require greater than 267 kN (60,000 lb.) load to fully compact the sample.

3. Sample

Sample preparation shall be according to AASHTO T 193 and T 224, if applicable, with the following modification:

- (a) Duplicate test specimens are required (see Note 2).

Note 2. Two test specimens are necessary to determine whether an individual specimen is being unduly influenced by the arrangement of the coarser particles or by unequal moisture distribution.

4. Procedure

The procedure shall be according to AASHTO T 193, except that Section 7.1.4 shall be replaced by the following:

- (a) Determine the mass of dry soil or material and the amount of water required to make a compacted sample at the OMC and SDD, previously determined according

to AASHTO T 99 (Method C). Thoroughly mix the soil and water until a homogeneous mixture is obtained.

- (b) Place the moist soil or material into the mold, tamping lightly, if necessary, (a piece of wax paper on the solid base plate will prevent the material from adhering to the metal plate). Place a solid steel plate [25.4 (1 in.) minimum thickness and 151 mm (5.95 in.) diameter] into the compaction mold using the loading device. The sample shall then be compacted (pressed) in one layer. During the final 12.7 mm (1/2 in.) of compaction, the head of the loading device shall be operated at the rate of 1.27 mm (0.05 in.) per minute. The load shall be held for 1 minute and then released slowly.
- (c) The height of the compacted specimen shall be measured and recorded, and the assembly and specimen shall be weighed. The mass of specimen shall be recorded as the compacted mass of specimen.

5. Soaking

Prior to the penetration test, the sample shall be soaked according to AASHTO T 193.

6. Penetration Test

Penetration test shall be according to AASHTO T 193.

7. Calculations

The IBR shall be calculated according to AASHTO T 193, except that the IBR at 5 mm (0.2 in.) penetration shall be reported.

8. Report

Report requirements shall be according to AASHTO T 193, except that the compactive effort need not be reported and that the following data shall also be recorded and reported for each of the samples tested:

- (a) OMC (%), as determined according to AASHTO T 99, Method C.
- (b) SDD [kg/m^3 (pcf)], as determined according to AASHTO T 99, Method C.
- (c) The IBR (%) to the nearest tenth on values below 10, and to the nearest whole number for values above 10.

B. IBV Testing

1. Scope

This test method is for determining the immediate bearing value (IBV) of treated or untreated subgrade materials prepared at a range of moisture contents. For untreated soil, the test is conducted immediately after compacting the material, according to AASHTO T 99, without soaking in water. For modified soils, the test is conducted 24 hours after compaction to allow for curing, without soaking in water. The IBV, thus

obtained, will primarily be used for determining the subgrade stability under construction traffic, the need for subgrade treatment and the depth of treatment.

2. Equipment

Equipment shall meet the requirements of:

- (a) AASHTO T 99 (Method C or D, depending on the soil type as defined in 3. below).
- (b) Penetration piston and loading device meeting the requirements of AASHTO T 193.
- (c) Dynamic cone penetrometer (DCP) that conforms closely to that diagramed in Figure 2.9.

3. Sample

Type 1 Soils - Soils with > 10% clay (and < 90% silt* and/or sand*) - Samples shall be prepared according to AASHTO T 87 and T 99 [Method C or D, using 100 mm (4 in.) or 150 mm (6 in.) diameter mold].*

Type 2 Soils - Soils with < 10% clay (and > 90% silt* and/or sand*) - Samples shall be prepared according to AASHTO T 87 and T 99 [Method D, using 150 mm (6 in.) diameter mold].*

* Determined according to AASHTO T 88.

4. Procedure

- (a) Compaction - Samples shall be compacted according to AASHTO T 99 (Method C or D, depending on the soil type as defined in 3. above) at the OMC, or at a specified field moisture content. Modified soils shall be mellowed according to Attachment II-B prior to compaction.
- (b) Curing – After compaction, and prior to IBV testing, modified soil shall be cured according to Attachment II-B.
- (c) Penetration Test – *For Type 1 Soils only* – For untreated soils, penetration test shall be conducted according to AASHTO T 193 on each compacted sample of the moisture-density test, immediately after compaction without soaking in water. For modified soils, the test is conducted 24 hours after compaction to allow for curing, without soaking in water.
- (d) DCP Test – *For Type 2 Soils only* – For untreated soils, DCP test shall be conducted on each compacted sample of the moisture-density test, immediately after compaction without soaking in water. For modified soils, the test is conducted 24 hours after compaction to allow for curing, without soaking in water. The DCP test shall be conducted as follows:
 - i. Seat the DCP cone into the sample such that the zero point coincides with the top of sample. This will require an initial cone penetration of 25 to 50 mm (1 to 2 in.)

into the sample, depending on the manufacturer. It will also leave approximately 60 to 90 mm (2.5 to 3.5 in.) of total penetration into the sample, considering the mold height approximately 117 mm (4.6 in.). Seating the sample requires careful tapping into the sample with the hammer, depending on the soil strength.

- ii. Carefully lift the DCP hammer to the maximum height [575 mm (22.6 in.)] and let it drop freely onto the anvil.
- iii. After each hammer drop, measure and record the depth of penetration to the nearest 2.5 mm (0.1 in.).
- iv. Terminate the test when 50 to 65 mm (2 to 2.5 in.) of penetration has been achieved. Care must be taken to prevent driving the DCP cone into the base plate.

5. Calculations

Penetration Test - The IBV shall be calculated according to AASHTO T 193.

DCP Test - Determine the average penetration rate [PR, mm (in.)/blow] for the data derived in Section B.4.(d) above. Using the chart in Figure 6.2 of Chapter 6, Section 6.5, determine the equivalent IBV.

6. Report

The following information shall be provided in the report:

- (a) The dry density and the IBV at the OMC, or at a specified field moisture content.

ATTACHMENT II-B: SOIL MODIFICATION WITH VARIOUS MATERIALS
LABORATORY EVALUATION/DESIGN PROCEDURES

1. Scope

This method describes the preparation and testing of a modified soil composed of soil, water, and a modifier. The modifier could be Class C fly ash (fly ash), Type I Portland cement, slag-modified Portland cement (SM cement), by-product hydrated lime, by-product non-hydrated lime (lime kiln dust), or lime slurry. The purpose of this method is to evaluate the properties of the modifier-soil mixture and to recommend a design modifier content for construction.

2. Equipment

Equipment shall meet the requirements of AASHTO T 87, T 88, T 89, T 90, and T 99 tests, and the IBV Testing in Attachment II-A of this manual.

3. Samples

Samples of soil and the appropriate modifier shall be provided as follows: 200 pounds of soil and 25 pounds of dry modifier (or 2 gallons of lime slurry). The modifier shall be transported and stored in air-tight container.

4. Procedures

- (a) Dry Preparation of Soil – The soil, as received, shall be prepared according to AASHTO T 87.
- (b) Particle Size Analysis (optional) – Particle size analysis shall be performed on the untreated soil according to AASHTO T 88.
- (c) Plasticity Testing (optional) – Tests for the liquid limit and the plastic limit of the untreated soil shall be conducted according to AASHTO T 89 and T 90, respectively.
- (d) Moisture Density Relations – The Standard Dry Density and the Optimum Moisture Content (OMC) of the untreated soil shall be determined according to AASHTO T 99. The IBV shall be determined according to Attachment II–A, using either the penetration test or the DCP test depending on the soil type.
- (e) Soil–Modifier Mixtures
 - (1) Proportioning – The modifier shall be added to the untreated soil on a dry weight basis as follows:
 - i. Fly ash - Add increments of 5%, not to exceed 20%.
 - ii. Portland cement or SM cement - Add increments of 1%, between 2% and 5%.
 - iii. Lime mixtures - Add increments of 2%, up to 6%.

- (2) Mixing – At each modifier content, dry mix enough soil-modifier mixture for one AASHTO T 99 compaction point, until a homogeneous mixture is obtained. Gradually add the compaction water. Continue mixing for 2 minutes (Note 1). Place the resulting mixture in a sealed container to minimize moisture loss. Mellow the soil-modifier mixture for one hour, except for the by-product, hydrated lime which shall be mellowed for 24 hours before compaction. Prepare a new soil–modifier mixture at the next modifier content and repeat this mixing and mellowing procedure.

Note 1. The lime slurry shall be thoroughly agitated by shaking to ensure uniform suspension of the solids before mixing with the untreated soil.

- (f) Compaction - Compact the soil–modifier mixture, after the appropriate mellowing time, according to AASHTO T 99 [Method C or D, using 100 mm (4 in.) or 150 mm (6 in.) mold, depending on the soil type, as defined in Attachment II-A, Section B.3.].
- (g) Curing - Samples of soil treated at the rates determined in (e)(1) above, and compacted at various moisture contents, shall be moist cured inside the mold for 24 hours prior to conducting the IBV test.
- (h) IBV Testing – Conduct the IBV test, after curing, according to Attachment II-A, Section B.4. (Note 2).
- (i) Moisture Determination – After curing and the IBV testing, determine the moisture content of each sample according to AASHTO T 265. Obtain the standard dry density (SDD) and the optimum moisture content (OMC) for the untreated soil and for the treated soil, at each modifier content (Note 2).

Note 2. Repeat the compaction and the IBV testing procedures for each sample, at each modifier content, and each moisture content, until the moisture–density–IBV relationships are obtained for the series of modifier contents.

- (j) Evaluation of Test Results – Plot the dry density and the IBV versus moisture content for the untreated soil and the treated soil at each modifier increment.
- (k) Determination of the Design Modifier Content – The minimum modifier content shall be designated as the percent modifier which provides an IBV of 10 or more at 110% of the OMC. To offset construction loss or uneven distribution, increase the minimum fly ash content by 1%, the minimum Portland cement or SM Portland cement content by ½%, and the minimum lime content by ½ to 1%. This new value is called the design modifier content.

5. IBR Test (optional)

The IBR test may be conducted according to Attachment II-A, Section A, at the design modifier content and the OMC, or at a specified field moisture content, of the treated soil. The amount of swell after soaking in water for four days shall not exceed 4%.

6. Report

- (a) Route
(b) Section

- (c) County
- (d) Job number
- (e) Material identification and source
- (f) AASHTO M 145 classification and group index
- (g) IDH textural classification
- (h) The recommended design modifier content (%)
- (i) Laboratory OMC and SDD (AASHTO T 99) of the untreated soil and the treated soil at the design modifier content
- (j) Particle size analysis (AASHTO T 88)
- (k) Plasticity Index (AASHTO T 90)
- (l) Plots of dry density and IBV versus moisture content at each modifier content
- (m) Plot of percent modifier versus the IBV at OMC
- (n) Age of test specimens when tested
- (o) The IBR and the amount of swell (if the test is conducted)

**ATTACHMENT II-C: SOIL-CEMENT MIXTURE
LABORATORY EVALUATION / DESIGN PROCEDURES**

1. Scope

This method is to determine the proportions of soil, water, and either Type 1 or Type 1A Portland Cement which, when incorporated in a mixture with water, will provide durable support as a base course.

2. Equipment

Equipment necessary to perform Illinois Modified AASHTO T 27, and AASHTO T 87, T 88, T 89, T 90, T 134, T 135, T 136 and specification M 145.

3. Samples

Samples of cement and soil shall be provided as required in Section 205 of the Standard Specifications.

4. Procedure

- (a) The soil shall meet the requirements of the "Soil-Cement Base Course" section of the Standard Specifications.
- (b) The soil gradation shall be determined according to Illinois Modified AASHTO T 27 and AASHTO T 88.
- (c) The LL and the PL shall be determined according to AASHTO T 89 and T 90, respectively. Calculate the Plasticity Index (PI) by subtracting the PL from the LL.
- (d) Using the gradation data obtained from T 88, along with the PI and LL, use AASHTO M 145 to determine the AASHTO Soil Group Classification.
- (e) Use the Group Classification and Table II-C.1 (fourth column) to determine the estimated cement content to be used in the moisture-density test performed according to AASHTO T 134. "A" horizon soils may contain organic, or other material that may deter cement reaction, and may require much higher cement percentages. For most "A" horizon soils, the cement contents (given in Table II-C.1) should be increased by 4 percentage points if the soil is dark grey to grey and 6 percentage points if the soil is black. It is not necessary to increase the cement percentage for brown or red "A" horizon soils.
- (f) Compact 2 specimens at the estimated cement content used in 4 (e) according to AASHTO T 134. Also, compact 4 additional samples ...two samples at 2 percentage points lower than the estimated cement content and two samples at 2 percentage points higher than the estimated cement content. Compact the specimens to the maximum dry density determined in 4 (e) above.

Table II-C.1 Cement Requirements of AASHTO Soil Group Classification

AASHTO Soil Group Classification	Usual range in cement requirement		Estimated cement content and that used in moisture-density test	Cement contents for wet-dry and freeze-thaw tests
	% by volume	% by mass	% by mass	% by mass
A-1-a	5 - 7	3 - 5	5	3-4-5-7
A-1-b	7 - 9	5 - 8	6	4-6-8
A-2	7 - 10	5 - 9	7	5-7-9
A-3	8 - 12	7 - 11	9	7-9-11
A-4	8 - 12	7 - 12	10	8-10-12
A-5	8 - 12	8 - 13	10	8-10-12
A-6	10 - 14	9 - 15	12	10-12-14
A-7	10 - 14	10 - 16	13	11-13-15

(Reprinted courtesy of the Portland Cement Association)

- (g) Moist cure the compacted specimens for 7 days. Cap the samples and soak them in room temperature water for 4 hours. Perform the compressive strength according to AASHTO T 22. The 7-day compressive strength (with no correction for the length-to-diameter ratio) shall meet or exceed 3500 kPa (500 psi) or a specified design strength, whichever is greater. Samples with a cement content not meeting the strength requirement are not to be tested further.

In the event that the initial estimated cement content (the cement content at which the moisture-density relationship was developed) fails to meet the strength requirement, choose a higher cement content and re-run the moisture-density test (T 134). Compact specimens as in 4 (f). Perform compressive strength test as in 4 (g).

- (h) Choose the lowest cement content that meets the compressive strength requirement. Following procedures described in T 135 (Wet / Dry Testing), mold specimens at the lowest cement content. Mold additional samples at 2 and 4 percent higher cement content. Test all specimens according to T 135.
- (i) Mold specimens as described in T 136 (Freeze / Thaw Test) at the lowest cement content that meets strength requirement. Mold additional samples at 2 and 4 percent higher cement content. Test all specimens according to T 136.
- (j) Determine the maximum allowable soil-cement loss percentage according to AASHTO T 135 and T 136. The maximum allowable losses, as determined by either of the tests, shall be as follows:

<u>Soil Group Classification</u>	<u>Maximum Allowable Loss (%)</u>
A-1, A-2-4, A-2-5, A-3	14
A-2-6, A-2-7, A-4, A-5	10
A-6, A-7	7

- (k) The design cement content shall be the minimum required to meet the allowable soil-cement loss percentage and the compressive strength requirement specified in 4 (g) above.

5. Report

- (a) Route
- (b) Section
- (c) County
- (d) Job Number
- (e) Material Identification and Source
- (f) Maximum Dry Density and Optimum Moisture Content (AASHTO T 134)
- (g) % Cement by Mass
- (h) % Cement by Volume
- (i) Kg (lb.) of cement per m² (ft²) per 25 mm (1 in.) of compacted thickness
- (j) AASHTO Group Classification (AASHTO M 145)
- (k) Soil-Cement Loss % Wet-Dry (AASHTO T 135)
- (l) Soil-Cement Loss % Freeze-Thaw (AASHTO T 136)
- (m) Compressive Strength (AASHTO T 22), kPa (psi)
- (n) The LL and PL (AASHTO T 89 and T 90, respectively)
- (o) Fine and Coarse Aggregate Sieve Analysis (AASHTO T 27)
- (p) Hydrometer Analysis (AASHTO T 88)

**ATTACHMENT II-D: CEMENT-AGGREGATE MIXTURE
LABORATORY EVALUATION / DESIGN PROCEDURES**

1. Scope

This method is to determine the proportions of cement and aggregate which, when incorporated in a mixture with water, will provide a workable, durable subbase.

2. Apparatus

Equipment necessary to perform Illinois Modified AASHTO T 11 / T 27, AASHTO T 87, T 88, T 89, T 90, T 99 (Method C), T 134, T 135 and T 136.

3. Samples

Samples of cement and aggregate shall be provided as required in Article 312.15 of the Standard Specification.

4. Procedure

- (a) Prepare the aggregate according to AASHTO T 87 and determine the moisture content according to AASHTO T 265.
- (b) Determine the particle size gradation of the aggregate according to Illinois Modified AASHTO T 11/T 27 and AASHTO T 88.
- (c) Determine the moisture-density relationships of the cement-aggregate mixture at 5, 6.5 and 8% cement by dry mass of the aggregate, according to AASHTO T 134.
- (d) Freeze-Thaw and Wet-Dry losses shall be determined at 5, 6.5 and 8% cement, according to AASHTO T 135 and T 136. The loss in mass shall not be more than 10% after 12 freeze-thaw or wet-dry cycles.
- (e) The design cement content shall be the minimum required to meet the allowable loss specified in 4.(d) above.

5. Reports

- (a) Route
- (b) Section
- (c) County
- (d) Job Number
- (e) Material Identification and Source
- (f) Maximum Dry Density and Optimum Moisture Content (AASHTO T 134)
- (g) % Cement by Dry Mass of the Aggregate
- (h) Particle Size Gradation (Illinois Modified AASHTO T 27 / T 11 and AASHTO T 88)
- (i) Aggregate Classifications (AASHTO M 145)
- (j) % Loss Wet-Dry
- (k) % Loss Freeze-Thaw

ATTACHMENT II-E: POZZOLANIC-STABILIZED MIXTURE
LABORATORY EVALUATION/DESIGN PROCEDURE

1. Scope

This method is to determine those proportions of an activator (fly ash), pozzolan, and aggregate which, when incorporated in a mixture with water, will provide a durable subbase or base course. Activator refers to either lime or cement.

2. Equipment

Equipment necessary to perform Illinois Modified AASHTO T 27 / T 11, AASHTO T 87, T 88, T 89, T 90, T 180 (Method C), AASHTO T 255, and ASTM C 311.

3. Samples

Samples of aggregate, activator and pozzolan shall be provided as required in Article 312.21 of the Standard specifications.

4. General Approach

For a given set of component materials, the significant factors which may be varied are the ratio of an activator to pozzolan, and the ratio of the activator plus pozzolan to the aggregate. The activator to pozzolan ratio affects, primarily, the quality of the "matrix"; and the ratio of the activator plus pozzolan to aggregate, primarily, determines the quantity of matrix available to fill the voids of the aggregate, thus, assuring that the matrix-aggregate particle contact is maximized.

The concept of providing sufficient matrix to fill the voids in the aggregate is applicable, primarily, to aggregates containing sufficient amounts of coarse, + 4.75 mm (+ No. 4), aggregate, to create large void spaces. However, in the event that the aggregate contains a high fraction of fine material, - 4.75 mm (- No. 4), the concern should shift to not only providing sufficient matrix, but to the ability of the resultant mixture to compact and remain stable during construction. Thus, it may be necessary to reduce the amount of matrix in the mixture, or otherwise, reduce the overall fineness of the aggregate through blending.

5. Preliminary Testing (Optional)

Preliminary evaluations of activators and pozzolans may be performed to select the activator-pozzolan ratio which provides the greatest strength development. This may be accomplished according to Section 9 of ASTM C 593.

6. Preparation of Aggregate/Pozzolan

(a) Determine the particle size gradation for the aggregate and fly ash, according to Illinois Modified AASHTO T 27 / T 11. The aggregate and fly ash gradations shall meet the requirements of the Standard Specifications.

(b) Sieve and discard, if any, the aggregate retained on the 19 mm (3/4 in.) sieve.

- (c) Determine the moisture content according to AASHTO T 255, and absorption according to AASHTO T 84, of the aggregate fraction passing the 4.75 mm (No. 4). Determine the moisture content of the pozzolan according to ASTM C 311.

If the aggregate fraction between the 19 mm (3/4 in.) and the 4.75 mm (No. 4) sieve does not contain free surface moisture, that fraction shall be soaked 24 hours, and towel dried to obtain a saturated surface dry condition according to AASHTO T 85. Pozzolan which has agglomerated, due to drying, shall be crumbled with the fingers until the overall size is reduced to comply with the Standard Specifications.

7. Moisture-Density Relationship

Aggregates, pozzolan, and activator shall be proportioned on a dry mass basis. The moisture-density relationship, SDD and OMC of each trial mixture shall be determined, according to AASHTO T 180, Method C, except that three lifts shall be used instead of the five lift requirement. In determining the moisture-density relationship, dry materials shall be mixed in a counter current mechanical mixer (or its equivalent) for 1 minute, or until the mixture is uniform in color and texture; plus, an additional 3-minutes (after the water is added) in order to obtain the first point on the moisture-density curve. The original sample may be reused for subsequent trials. The batch shall be mixed for an additional minute, after the water has been added, for each subsequent trial.

8. Mix Design Procedure

- (a) Using Table II-E.1, determine the approximate initial proportions of activator and pozzolan for two trial mixtures. For example, using lime as the activator, and natural aggregate; trial 1 should contain 3.5% lime, and 10.5% pozzolan. The estimated amount of material needed to pass the 4.75 mm (No. 4) sieve, for a given maximum nominal aggregate particle size, is shown in Table II-E.2. The maximum nominal aggregate particle size is the largest sieve size which retains material. Blending aggregates may be necessary to obtain a sufficiently fine mixture, while keeping activator and pozzolan amounts at economical levels.
- (b) Determine the SDD and OMC of each trial mix, as previously outlined.
- (c) Compare the SDD of the two mixes. If the SDD increases between the first and second trial mix, either increase the percentage of activator and pozzolan, holding the ratio constant; or increase the percentage of one ingredient, while maintaining a constant percentage of the other. If the SDD decreases significantly, either decrease the percentage of activator and pozzolan, holding the ratio constant; or decrease the percentage of one ingredient, while maintaining a constant percentage of the other.
- (d) Repeat these procedures until the SDD remains constant; or decreases slightly, between two consecutive mixtures. The percentage of pozzolan and activator that produces the maximum SDD, between those two mixtures, should be used in further testing.

Table II-E.1 Suggested Percentages (dry weight basis) of Ingredients to be used in Pozzolanic Stabilized Mixture Design*

TRIAL #	ACTIVATOR		NATURAL AGGREGATE	BOILER SLAG AGGREGATE
	CEMENT	LIME	POZZOLAN	POZZOLAN
1	3	0	9	24
	0	3.5	10.5	26
2	4	0	12	28
	0	4.5	13.5	30

* These values may be adjusted to suit a particular situation.

**Table II-E.2
Estimation of - 4.75 mm (No. 4) Material Needed**

Maximum Nominal Aggregate Particle Size	Minimum % of Total Batch Passing 4.75 mm (No. 4) Sieve
	Activator + Pozzolan + Minus 4.75 mm (No. 4) Sieve Aggregate
25.4 mm (1")	45 %
19.0 mm (3/4")	50 %
12.7 mm (1/2")	60 %

9. Determining Compressive Strength

(a) Mixing and Molding Test Specimens

After the SDD and OMC are obtained as outlined in Section 7, a batch large enough to make six (6) cylinders, each 102 mm by 117 mm (4.0 in. x 4.6 in.), shall be mixed in the following manner: Mix the dry materials for 1 minute, or until the mixture is uniform in color and texture, in a counter current mechanical mixer or its equivalent. Add enough water to bring the mixture to OMC {corrected for the hygroscopic moisture of the minus 4.75 mm (No. 4) material}. Mix an additional 3 minutes. Mold the specimens immediately, according to AASHTO T 180, Method C, except that three lifts shall be used instead of the five lift requirement. Each lift shall be scarified to a depth of 6 mm (1/4 in.) before the next layer is compacted, in order to assure a good bond between the layers. Weigh a representative sample of the mixture, to determine the moisture content (use a container with a tight lid to prevent loss of moisture). Then carefully remove the specimen from the mold, by the use of a sample extruder such as a jack, a lever frame or other suitable device (see Attachment II-B).

(b) Curing of Test Specimens

Immediately after the specimens are removed from the mold, re-weigh the specimens and place them in a sealed container, to prevent any loss of moisture. The sealed container may be either a can with a friction lid, or double sealed plastic bags. Place three of the specimens, in the sealed containers, in a room or cabinet with forced air circulation maintained at 10° C ± 1° C (50° F ± 2° F), for a 7-day period. Place the

remaining three (3) specimens, in the sealed containers, in a room or cabinet with forced-air circulation maintained at 22° C ± 1° C (72° F ± 2° F), for a fourteen day period; re-weigh and allow to cool to room temperature. After the required period, remove the specimens from the containers, and cap the specimens for compressive strength testing. Soak the specimens in water for 4 hours, remove, allow to drain on a nonabsorbent surface, and test within 1 hour of the time of removal from the water.

(c) Vacuum Saturation (Optional)

If, specified or required, the Vacuum Saturated Compressive strength shall be determined according to Section 11 of ASTM C 593.

(d) Compression Testing

Specimens shall be tested according to AASHTO T 22, with no length-to-diameter ratio correction for computation of the compressive strength.

The average compressive strength of three specimens, tested at each curing condition, shall be designated as the test value for evaluation. The average vacuum saturation strength (if required) of the three specimens tested, shall be designated as the test value for evaluation. Coefficients of variation within groups, at each curing condition which exceed 10% for 10° C (50° F) and 10% for 22° C (72° F), shall be considered as cause for rejection of the samples; and a fresh batch shall be formulated, compacted, and tested. If the number of values are not large (say, less than 10), the corrected standard deviation shall be estimated by either of the following equations:

$$s_e = \frac{R}{d} \quad \text{or} \quad s_e = R \times m$$

Where: s_e = estimated standard deviation
 R = range of values; i.e. the difference between the greatest value and the smallest value
 d = factor (see Table II-E.3)
 m = factor (see Table II-E.3)

The coefficient of variation is computed by: dividing the corrected standard deviation by the average strength. For subbase or base courses, the cylinders cured at 22° C ± 1° C (72° F ± 2° F), for 14 days, should have a minimum average compressive strength of 4.1 MPa (600 psi), with no individual test below 3.4 MPa (500 psi).

To evaluate the effect of curing at low to moderate field temperatures, the average cured compressive strength (CS), obtained at both curing temperatures, shall be plotted versus the curing degree days (DD). The degree days are calculated as follows:

$$DD = [\text{Curing temperature (°C)} - 4.4^\circ \text{C}] \times \text{number of days, where the } 4.4^\circ \text{C (40° F) is base temperature representative of each average strength.}$$

Plots are to be arranged on 20 x 20/division graph-paper (at a convenient scale) with the DD plotted along the x-axis, and the CS along the y-axis. The “best fit” straight line

relationship shall be plotted to obtain the CS value at the degree days corresponding to 14-day curing. Plots shall be appropriately labeled as to: producer, month and year of analysis, and proportions of each component ingredient.

Table II-E.3 Factors For Estimating Standard Deviation

Number of Values, n	Factor, d	Factor, m
2	1.1284	0.8862
3	1.6926	0.5908
4	2.0588	0.4857
5	2.3259	0.4299
6	2.5344	0.3946
7	2.7044	0.3698
8	2.8472	0.3512
9	2.9700	0.3369
10	3.0775	0.3249

10. Plotting of Cured Compressive Strength (CS) vs. Degree Days (DD) Characteristic Curve

The DGE will analyze design test data, develop appropriate construction cut-off dates and predict the DD value, based on the anticipated temperatures during construction.

11. Report

Report of the mix design, compressive strength, and/or vacuum saturation strength tests shall include the following:

- (a) Identification of each material used in the preparation of the specimens
- (b) Aggregate gradation
- (c) Percentage, by dry mass, of each of the constituents
- (d) Actual, as compacted, percentage moisture content of mixture (AASHTO T 180)
- (e) Actual dry density of each specimen, to the nearest kg/m³ or lb./ft³ (AASHTO T 180)
- (f) Percentage compaction of each specimen
- (g) Cross-sectional area of each specimen, mm² or in.²
- (h) Compressive strength of each specimen, to the nearest 50 kPa or 5 psi and/or (AASHTO T 22, with no correction for length-to-diameter ratio)
- (i) Vacuum saturation strength (if required) of each specimen, to the nearest 50 kPa 5 psi (ASTM C 593)
- (j) Plot of cured compressive strength versus degree day curve

**ATTACHMENT II-F: LIME STABILIZED SOIL MIXTURES
LABORATORY EVALUATION/DESIGN PROCEDURES****1. Scope**

This method describes the preparation and testing of lime-soil mixtures for the purpose of recommending a design lime content for stabilization. This method can also be used for evaluating the properties of the lime-soil mixtures. In this method, the SDD and the OMC of the untreated soil and the soil-lime mixtures at different lime contents are to be determined. The lime content is designated as a percentage, by mass of the oven dry soil. The soil-lime mixtures are to be proportioned within the limits of 3 to 8% lime content. The unconfined compressive strength is to be determined at the OMC, or at a specified field moisture, for the untreated soil and for each mixture. The design lime content that meets the strength criteria, stipulated in this method for lime stabilized soil mixtures, is to be determined.

2. Equipment

- (a) Specimen Mold Assembly - Mold cylinders 51 mm (2 in.) in diameter by 102 mm (4 in.) in height, base plates, and extension collars shall conform to the details shown in Figure II-F.1.
- (b) Compaction Hammer - The compaction hammer (Figure II-F.2) shall have a flat, circular tamping face; and a 1.81 kg (4 lb) sliding mass, with a free fall of 305 mm (12 in.).
- (c) Sample Extruder - A jack, lever frame, or other suitable device adapted for the purpose of extruding compacted specimen from the specimen mold (Figure II-F.3).
- (d) Balance or scale - Minimum 5 kg (10 lb) capacity, sensitive to 0.1 g.
- (e) Oven - Thermostatically controlled, capable of maintaining temperatures at $49^{\circ} \pm 2^{\circ} \text{ C}$ ($120^{\circ} \pm 4^{\circ} \text{ F}$), and at $110 \pm 5^{\circ} \text{ C}$ ($230^{\circ} \pm 9^{\circ} \text{ F}$).
- (f) Curing Containers - The curing containers shall be capable of maintaining a positive moisture seal, as the specimens are to cure at the molding moisture content.
- (g) Compression Device - The compression device may be of any type, which maintains a minimum capacity of 8.9 kN (2,000 lb). The load shall be applied continuously, and without shock. The moving head shall travel at a constant rate of 1.27 mm (0.05 in.) per minute.
- (h) Miscellaneous Equipment - Equipment necessary to accomplish AASHTO T 87, T 88, T 90, T 99: scarifier, trimming and carving tools, moisture content cans, and data sheets, as required.

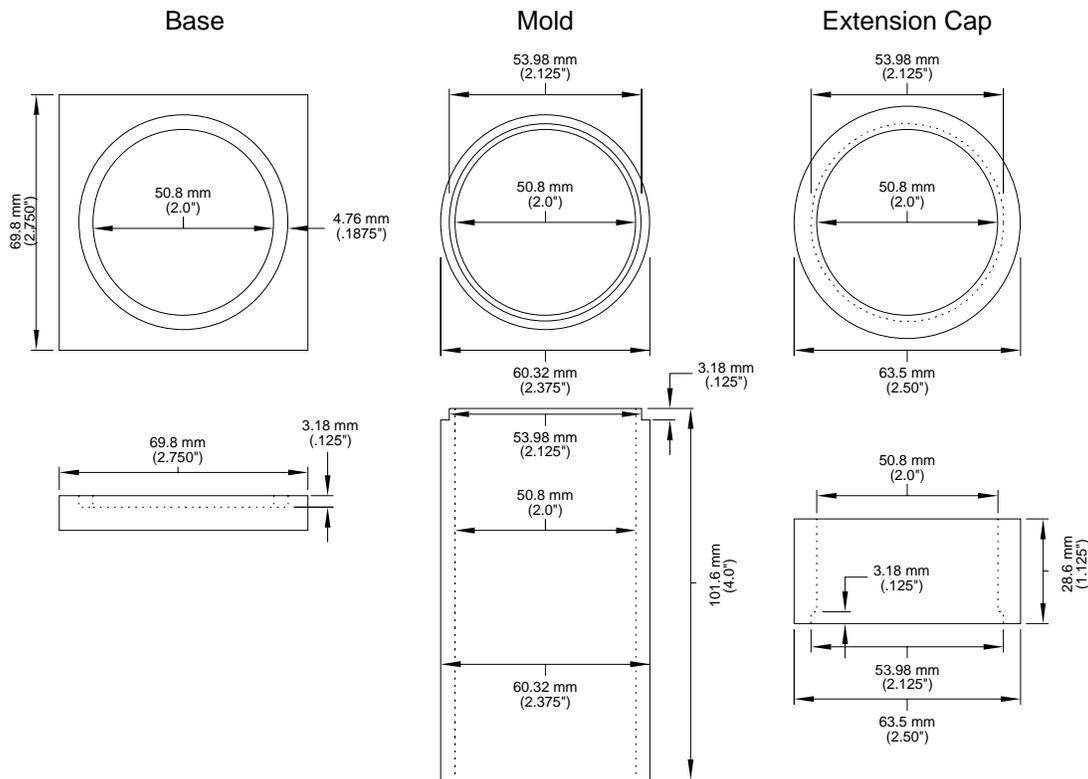


Figure II-F.1 Specimen Mold Assembly

3. Samples

Samples of soil and the appropriate lime content shall be provided as follows: 200 pounds of soil and 25 pounds of lime.

4. Procedure

- (a) Soil Preparation - The soil, as received, shall be prepared for test according to AASHTO T 87 and T 99.
- (b) Mechanical Analysis - The particle size analysis of the soil shall be determined according to AASHTO T 88.
- (c) PI of Soil - The PI of the soil shall be determined according to AASHTO T 90.
- (d) Moisture-Density Relationship - The moisture-density relationship of the soil-lime mixture shall be determined according to AASHTO T 99 (see Note 1). The soil and lime shall be dry mixed until a homogeneous mixture is obtained. The water shall be added, and the mixture thoroughly re-mixed. The moist mixture shall then be placed in a suitable container, formed into a lightly compacted mound, and then sealed to prevent moisture loss. The mixture shall be allowed to mellow for a period of one-hour before compaction.

Note 1. At each moisture content and each lime content, a separate, new sample of material shall be used, as described in Note 8 of AASHTO T 99.

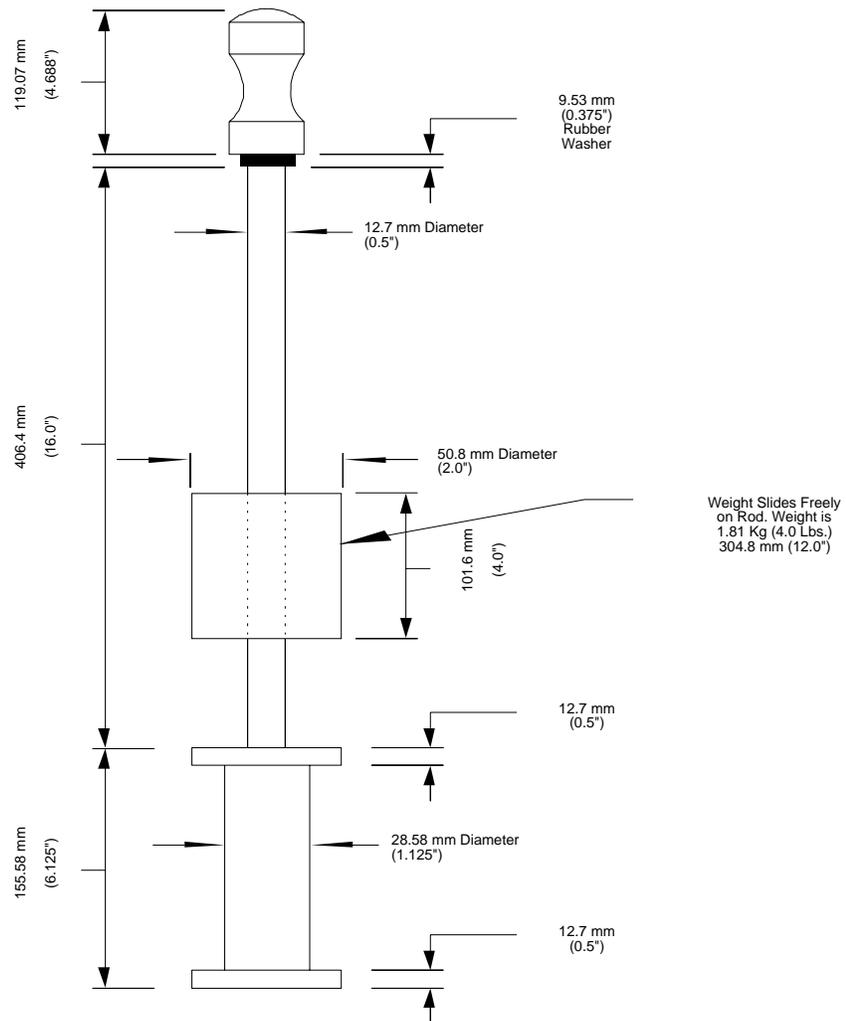


Figure II-F.2 Compaction Hammer

Since, for most soils, there is close agreement of moisture-density relationships for lime-soil mixtures with 3 to 8% lime, it is generally acceptable to determine the moisture-density relationship at 5% lime. Therefore, the moisture-density relations may not have to be established for the soil-lime mixtures at other lime contents. Instead, the resultant OMC is then adjusted up or down ½% water per 1% lime increase or decrease, respectively, for the other mixtures.

- (e) Preparation of Test Specimens - Four test specimens at each lime content to be considered, and four non-treated soil test specimens shall be molded at OMC and SDD, using the mixing procedure defined above. Each specimen shall be compacted dynamically, in the 51 mm X 102 mm (2 in. X 4 in.) mold, in three equal layers. The number of blows per layer, with the sliding hammer, shall be adjusted to obtain the SDD. It is important, that each of the first two lifts be scarified to promote bonding. The compacted sample is then trimmed, extracted, weighed, and mass recorded.

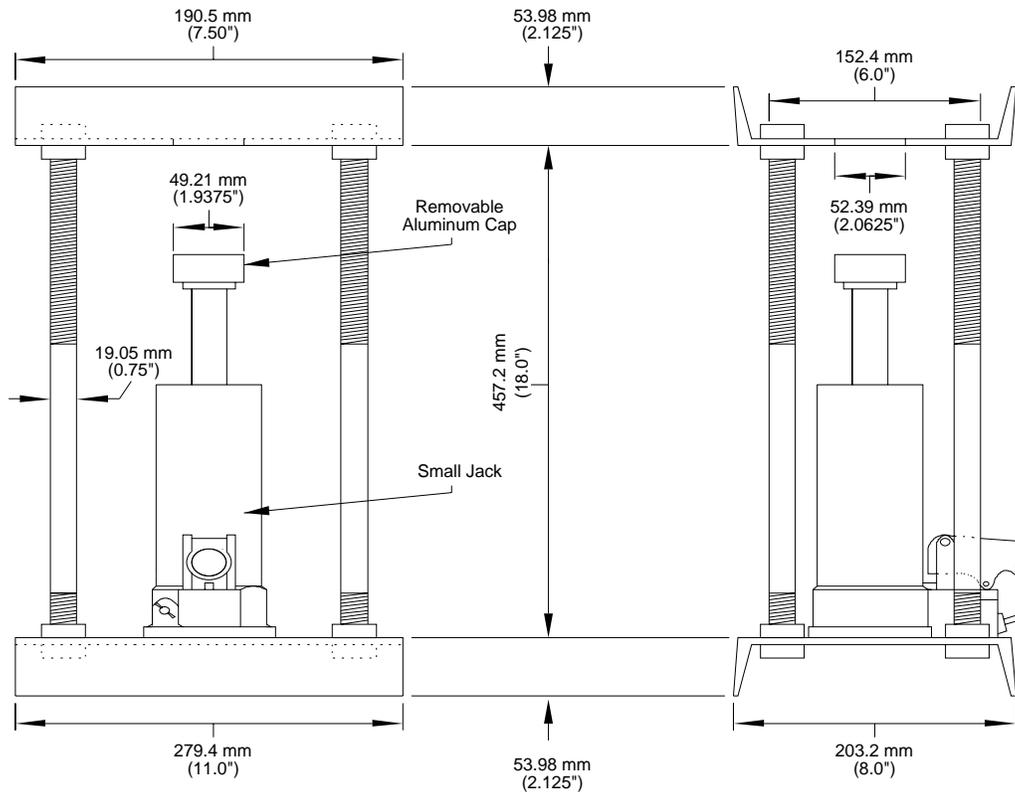


Figure II-F.3 Sample Extruder

- (f) Curing of Specimens - Cure the non-treated soil and lime-soil specimens at their molded moisture content, in sealed containers, in a temperature controlled oven. The specimens shall be cured at $49^{\circ} \pm 2^{\circ} \text{ C}$ ($120^{\circ} \pm 4^{\circ} \text{ F}$), for a period of 48 hours. The specimens shall then be removed from the curing containers and cooled to room temperature.
- (g) Compression Testing - Test each specimen to failure, at a constant rate of 1.27 mm (0.05 in.) per minute. The compressive strength shall be determined according to AASHTO T 208. Obtain a moisture sample from each failed specimen. The moisture sample is for evaluating the adequacy of the container seal during the curing period, and calculating the dry density of the specimens. The moisture content shall be determined according to AASHTO T 265.
- (h) Evaluation of Compression Test Results - Compare the average maximum compressive strength of the non-treated specimens, to those of the soil-lime specimens.
- (i) Design Recommendations - The minimum recommended lime content is the value which provides a compressive strength gain of 345 kPa (50 psi) over that of the untreated soil, and provides a minimum average compressive strength of 680 kPa (100psi) for the treated soil. The minimum lime content is increased by 1% to offset construction loss or uneven distribution. This new value is called the design lime content.

5. Report

- (a) Route
- (b) Section
- (c) County
- (d) Job No.
- (e) Material Identification and Source
- (f) AASHTO M 145 Classification and the Group Index
- (g) IDH Textural Classification
- (h) Laboratory OMC and SDD (AASHTO T 99, Method A) of the Soil-Lime Mixture
- (i) Gradation (AASHTO T 88)
- (j) The PI (AASHTO T 90)
- (k) Percent Lime for Test Specimens
- (l) Compressive Strength kPa (psi) for Test Specimens (AASHTO T 208)
- (m) Plot of Percent Lime Versus Compressive Strength
- (n) Recommended Lime Percentage
- (o) The IBR and the Amount of Swell (Optional)