Please note: This is NOT the official training manual being used in the KDOT/KSU-Salina Certified Inspection and Testing Training (CIT^2) Program. This manual covers the same tests as the course manual and can be used as a reference guide for those tests. For more information about the training manual used in the CIT^2 Program, please contact Lora Kowach at (785)291-3836 or at lora@ksdot.org .

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Final Report

Soils Sampling and Testing Training Guide for Field and Laboratory Technicians on Roadway Construction

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December 1999

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16 Abstract

This manual has been developed as a training guide for field and laboratory technicians responsible for sampling and testing of soils used in roadway construction. It was completed in conjunction with K-TRAN Project KSU-96-10, entitled “Pilot Study to Determine Personnel Certification and Training.”

The development and implementation of Quality Control/Quality Assurance (QC/QA) specifications by the Kansas Department of Transportation has been a driving force behind the development of a soils training and certification program. Soils training and certification will increase the knowledge of laboratory, production, and field inspectors. Both the owner agency and the contractor will benefit with an increased number of qualified personnel to perform acceptance and quality control functions. In addition, it is anticipated that this program and its standardized set of core tests will help to achieve certification reciprocity throughout the region. This manual is a guide for training personnel to perform the core soils tests they should understand in order to be certified.

The manual is based on ASTM and AASHTO test methods and procedures. During the 4th Annual FHWA Region 5 & 7 Training and Certification Workshop, a core content of ASTM and AASHTO tests for soil technician training was defined by the Soils Training Development Team. This training manual implements this core content for certification of laboratory soil field inspectors.

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PREFACE

This research project was funded by the Kansas Department of Transportation K-TRAN research program and the Mid-America Transportation Center (MATC). The Kansas Transportation Research and New-Developments (K-TRAN) Research Program is an ongoing, cooperative and comprehensive research program addressing transportation needs of the State of Kansas utilizing academic and research resources from the Kansas Department of Transportation, Kansas State University and the University of Kansas. The projects included in the research program are jointly developed by transportation professionals in KDOT and the universities.

NOTICE

DISCLAIMER

SOILS SAMPLING AND TESTING TRAINING GUIDE FOR FIELD AND LABORATORY TECHNICIANS ON ROADWAY CONSTRUCTION

Mid-America Transportation Center Project:

"Pilot Study to Determine Personnel Certification and Training"

With Matching Funds from
Kansas Department of Transportation
K-TRAN Project, KSU-96-10

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Training Manual for Soil Technicians

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PREFACE

This manual is a product of K-TRAN Project KSU 96-10, entitled Pilot Study to Determine Personnel Certification and Training. It was developed as a training guide for field and laboratory technicians responsible for sampling and testing of soils used in roadway construction. During the 4th annual FHWA Region 5 & 7 Training and Certification Workshop, a core content was defined by the Soils Training Development Team. This manual was developed in conjunction with this core content for Soil Field and Laboratory Inspectors. It is anticipated that the issue of reciprocity will be eliminated by implementing a standardized set of core tests throughout the region.

The development and implementation of Quality Assurance/Quality Control specifications by the Kansas Department of Transportation have been a driving force behind the development of a soils training and a certification program. Soils training and certification will increase knowledge of laboratory, production, and field inspectors. Both the owner agency and industry will benefit with an increased number of qualified personnel to perform acceptance and quality control functions.

This manual has been developed to follow ASTM/AASHTO test methods and procedures. Appendix 1 at the end of the manual contains ASTM/AASHTO test methods. The New England Transportation Technician Certification Program (NETTCP) soils manual was used as a model. The authors of this manual would like to express their gratitude to NETTCP.

CHAPTER I

Common Tests for Field and Laboratory Technicians

REDUCING FIELD SAMPLES OF AGGREGATE TO TEST SIZE

AASHTO T 248

1.0 Purpose

Aggregates and other field materials must be reduced to appropriate sizes for testing. With other factors being equal, larger samples will be more representative of the total supply. The methods that follow describe the reduction of a large field sample to a convenient size for conducting tests that will describe the material and measure its quality. These methods provide for reducing the large sample into a smaller one that is representative of the field sample and thus of the total supply.

Failure to follow the procedures in these methods correctly could provide a non-representative sample of the supply. The methods that follow should be used to minimize variations during handling.

2.0 Method Selection

Table 1 gives the appropriate splitting method for materials in various conditions.

Method A **Use the Mechanical (Riffle) Splitter for the following:**
Field samples of fine aggregates drier than Saturated Surface Dry (SSD)
Coarse aggregates drier than SSD
Mixtures of coarse and fine aggregates drier than SSD
Method B **Use Quartering for the following:**
Field samples of fine aggregates having free moisture on the particles surfaces (at SSD or wetter)
Coarse aggregates with free moisture on surface
Mixtures of coarse and fine aggregates with free moisture on surface
Method C **Use Miniature Stockpile Sampling for the following:**
Fine aggregates with free moisture on particle surface
Method C not permitted for coarse aggregates or mixtures of coarse and fine aggregates

Table 1: Splitting methods for various material conditions.

Saturated Surface Dry (SSD): State in which the aggregate is neither absorbing water nor giving off water. The aggregate does not contain free water on the surface.

3.0 Method A - Mechanical Splitter

Mechanical splitters (Figure 1) come in a variety of sizes. The splitter should have an even number of equal-width chutes. The chutes discharge alternatively to each side of the splitter. The sample size and type will dictate which splitter to use.

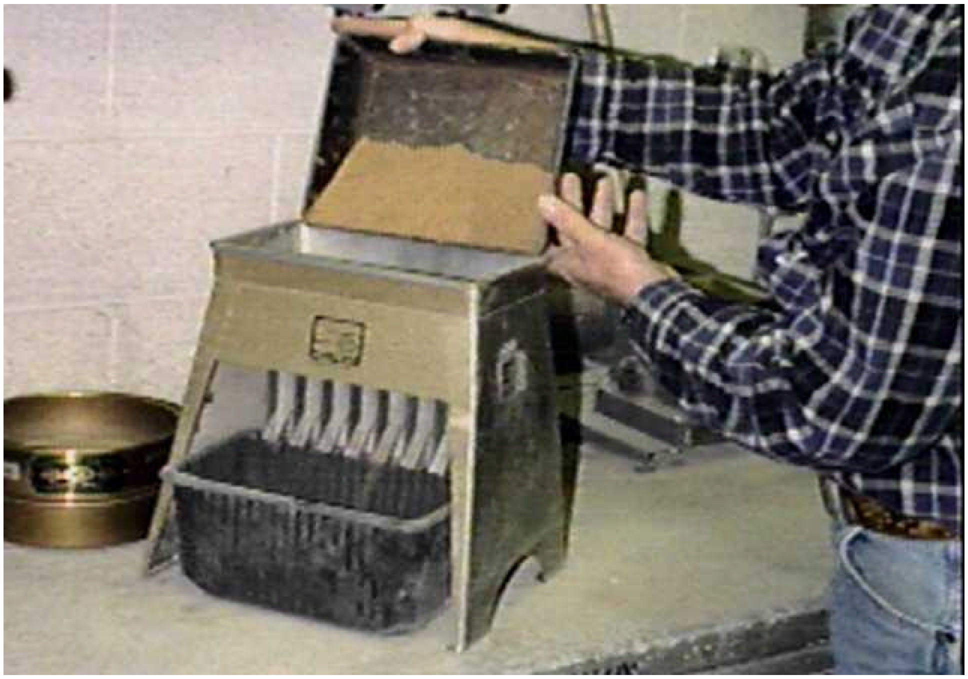


Figure 1: Mechanical Splitter

3.1 Mechanical Splitter requirements for coarse aggregates:

There must be at least eight chutes for coarse aggregates. Sample chutes for coarse aggregate must be at least 50% greater in width than the largest particle size in the sample. There must be receptacles which can contain the two halves of the sample being split and minimize loss of sample material.

3.2 Mechanical Splitter requirements for fine aggregates:

There must be at least 12 chutes for fine aggregates. Sample chutes for fine aggregates must be from 12.5 mm to 20 mm wide. There must be receptacles which can contain the two halves of the sample being split and minimize loss of sample material.

Figure 2: Equal amounts of sample should flow through each chute

3.3 Procedure

(1) Place the field sample into the hopper or pan and distribute from edge to edge. This will allow equal amounts of the sample to flow through each chute (Figure 2). The rate of sample introduction should be such that the material will flow freely through the chutes into the receptacles.

(2) Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the specified size.

4.0 Method B - Quartering

The quartering method should be used when splitters are not available. This method will require the following equipment:

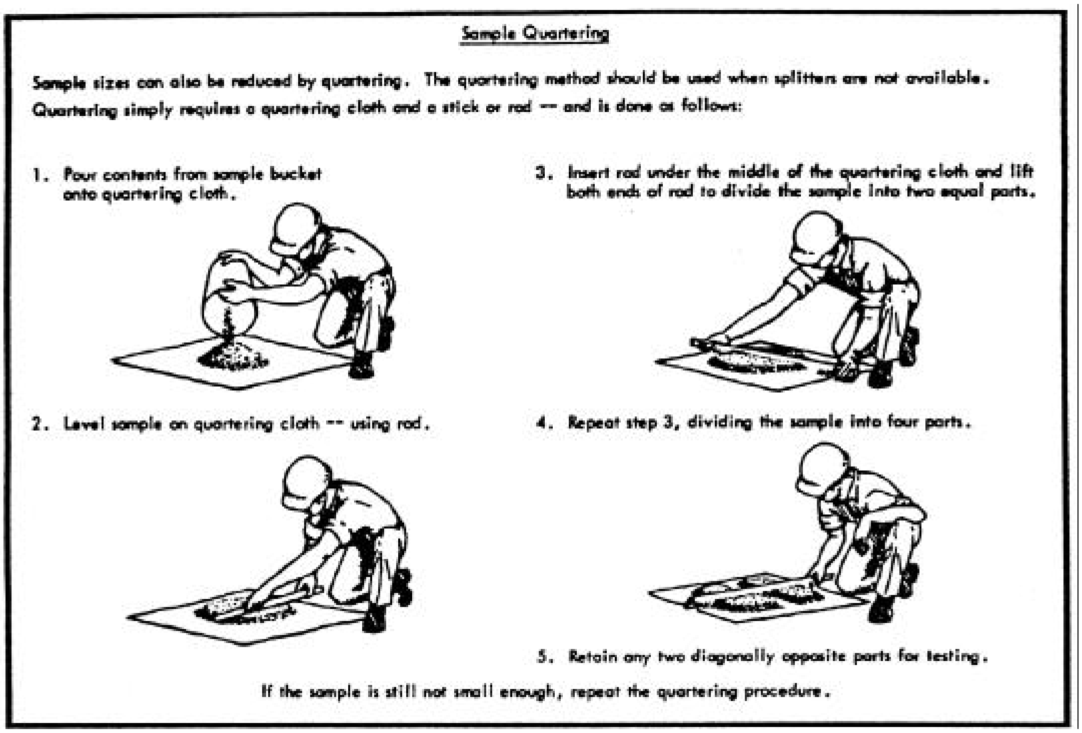
(1) Straight-edged scoop, shovel, or a trowel

(2) Broom or brush

(3) Canvas blanket approximately 2 m by 2.5 m in size

4.1 Procedure

(1) Place sample in a quartering box or pan. Mix the sample thoroughly (turn pile over itself at least three times).



Sample Quartering

Sample sizes can also be reduced by quartering. The quartering method should be used when splitters are not available. Quartering simply requires a quartering cloth and a stick or rod -- and is done as follows:

1. Pour contents from sample bucket onto quartering cloth.
2. Level sample on quartering cloth -- using rod.
3. Insert rod under the middle of the quartering cloth and lift both ends of rod to divide the sample into two equal parts.
4. Repeat step 3, dividing the sample into four parts.
5. Retain any two diagonally opposite parts for testing.

If the sample is still not small enough, repeat the quartering procedure.

Figure 3: Quartering Method; reproduced from Asphalt Institute MS-22, p. 105

(2) Shovel the material into a layered conical pile by placing each shovel full on top of the previous. A pile with a diameter four to eight times its thickness should be created.

(3) Flatten the pile to a uniform thickness.

(4) Divide and separate the sample into four equal quarters.

(5) Remove two diagonally opposite quarters of the pile. Retain the remaining two quarters.

(6) Mix the remaining sample thoroughly and repeat the process until desired sample size is achieved.

5.0 Method C - Miniature Stockpile Sampling

This method requires the use of straight-edged scoop, shovel, or trowel to mix the aggregate. To sample the aggregate, either a small sampling thief, small scoop, or spoon should be used.

5.1 Procedure

(1) Place the damp fine aggregate sample in a splitting tray and mix it thoroughly. Adequate mixing should consist of turning the entire pile over at least three times.

(2) Shovel the sample into a conical pile. Each shovel full should be placed on top of the previous one, layering the pile.

(3) Representative samples should be taken from at least five locations in the pile using a large spoon or scoop.

Sample Test

True or False

1. Mechanical splitters are especially appropriate for fine aggregates in SSD condition.
2. For coarse aggregates, mechanical splitters should be set so that the openings are about 50% larger than the largest particles.
3. When using a mechanical splitter, the "chosen" half of the split sample should always be on the same side from which the last half was chosen.
4. The requirements for mechanical splitters stipulate that, for fine aggregates, there must be at least eight chutes with an equal width, which must be at least 50% greater than the largest particle size in the sample.
5. It is necessary to reduce field samples to test size because it minimizes the chance of variability in test results.
6. The miniature stockpile method is best for splitting samples of coarse aggregates.
7. When mixing a miniature stockpile, the sample should be turned over three or more times, and then shoveled into a conical pile.
8. The cone-and-quarter method is appropriate for splitting wet coarse aggregate samples.
9. The quartering method is not appropriate for splitting samples at SSD or wetter.
10. Test samples should always be placed in containers and labeled and tagged for easy identification.

11. The chute opening on riffle splitters for fine aggregates is required to be at least 20 mm wide.
12. When using the quartering method, after layering the pile and reducing it to a uniform thickness and dividing it into four quarters, perpendicular quarters should be chosen for the sample.

LABORATORY DETERMINATION OF MOISTURE CONTENT OF SOILS

AASHTO T 265

1.0 Purpose

Moisture content is defined as the ratio of the weight of water to weight of soil solids and is generally expressed as a percentage. A material's moisture content determines its ability to be excavated, consolidated, moved, dried out, screened, or weighed. Moisture content values are useful in calculating a number of material properties, including density, plasticity, and permeability.

2.0 Apparatus

Source of Heat: a force-draft drying oven, capable of maintaining a temperature of 110° +/- 5°C (230° +/- 9°F) for non-organic soils.

Balance: general purpose, must meet the requirements of AASHTO M 231.

Containers: should be corrosion resistant and must not undergo changes in mass when subjected to repeated heating and cooling. Containers must have tight-fitting lids unless samples are weighed immediately upon removal from oven. A container without a lid may be used provided the moist or dried sample is weighed immediately after removal from the oven.

Stirrer : aid for water evaporation, mix sample during drying.

Desiccator : for soils where containers without tight-fitting lids are used.

3.0 Sample Size

Select a representative sample of soil in the amount specified by the test method. If no amount is indicated, a proper sample size should be selected from Table 1.

Maximum Particle Size, mm	Minimum Sample Size, grams
0.425 mm	**10 g**
4.75 mm	**100 g**
12.5 mm	**300 g**
25 mm	**500 g**
50 mm	**1000 g**

Table 1: Moisture content sample sizes

4.0 Procedure

(1) After the proper sample size is determined, obtain the sample and protect it from moisture loss during transport. Use an airtight container or plastic bag.

(2) Weigh a clean, dry container with its lid (W_c).

(3) Place the sample in the container and replace lid immediately. Weigh the container, including lid and sample (W_1).

(4) Remove the lid and place the container with sample in drying oven maintained at 110° +/- 5°C (230° +/- 9°F). Dry to a constant mass (Figure 1).

(5) Remove container from oven and immediately replace the lid. Allow sample to cool to room temperature.

6) Weigh the container including lid and dry sample (W_2).

Figure 1: Samples being dried in oven at 110° ± 5°C (230° ± 9°F)

If checking sample mass over successive periods to determine constant mass is found to be impractical, an overnight period of 15 or 16 hours is usually sufficient to dry to a constant mass. Samples can usually be dried to a constant mass in several hours.

Dry samples can absorb moisture from wet samples. Remove dried samples from oven before placing wet samples in oven.

5.0 Calculation

The calculation for moisture content (*w*) is as follows: divide the mass of moisture by the mass of oven-dry soil and multiply by 100. Calculate to the nearest tenth.

$$w \quad \frac{(W_1 \quad W_2)}{(W_2 \quad W_c)} \quad 100$$

where: w = moisture content (%)

W_1 = mass of container and moist soil (g)

W_2 = mass of container and oven-dried soil (g)

W_c = mass of container (g)

5.1 Example

Mass of Container, plus lid = 506.8 g

Mass of Container, plus lid and moist sample = 535.2 g

Mass of Container, plus lid and dried sample = 530.8 g

$$w \quad \frac{(535.2 \;\; 530.8)}{(530.8 \;\; 506.8)} \; X \; 100 \quad 18\%$$

Sample Test

True or False

1. The value of any soil's moisture content will always fall between 0 and 10%.
2. The minimum mass required for a soil sample with a maximum particle size of 25 mm is 500 grams.
3. It is advisable to remove dried samples from an oven prior to placing wet samples in the same oven.
4. Extra care should be taken when using a microwave to dry material to ensure that the particles are not cracking.
5. When transporting the sample to the testing facility, make sure it is in an airtight, sealed container to prevent the loss of moisture.
6. All soil samples for moisture content should be placed in the microwave.
7. Samples may be assumed to have dried to a constant mass when they have been in an oven for a length of time that has been previously demonstrated to achieve constant mass for samples of a similar nature with similar oven loading conditions.

Calculation

Mass of container = 510.0 g

Mass of container and moist sample = 538.4 g

Mass of container and dried sample = 533.8 g

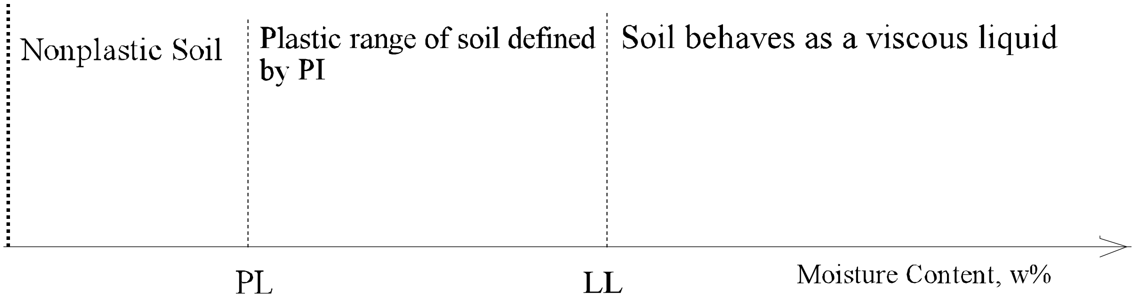
Determine the moisture content in the sample.

Determining the Liquid Limits of Soils

AASHTO T 89

1.0 Purpose

A soil's liquid limit is the moisture content at which the soil passes from a plastic to a liquid state. The liquid limit is useful in describing a soil's reaction with water. The liquid limit along with the plastic limit (AASHTO T 90) can be used to determine the Plasticity Index (PI), which is useful for soil classification and determining engineering properties of the soil.



2.0 Apparatus

Dish: A porcelain dish, preferably unglazed, or similar mixing dish about 115 mm in diameter.

Spatula: A spatula or pill knife having a blade of about 75 mm to 100 mm in length and about 20 mm in width.

Liquid Limit Device: See Figure 1. There are two types, manual or mechanically operated. Specifications for the manual and mechanically operated devices are identical except that the mechanical device is motorized. The mechanical devices must be shown to produce the same results as the manually operated device.

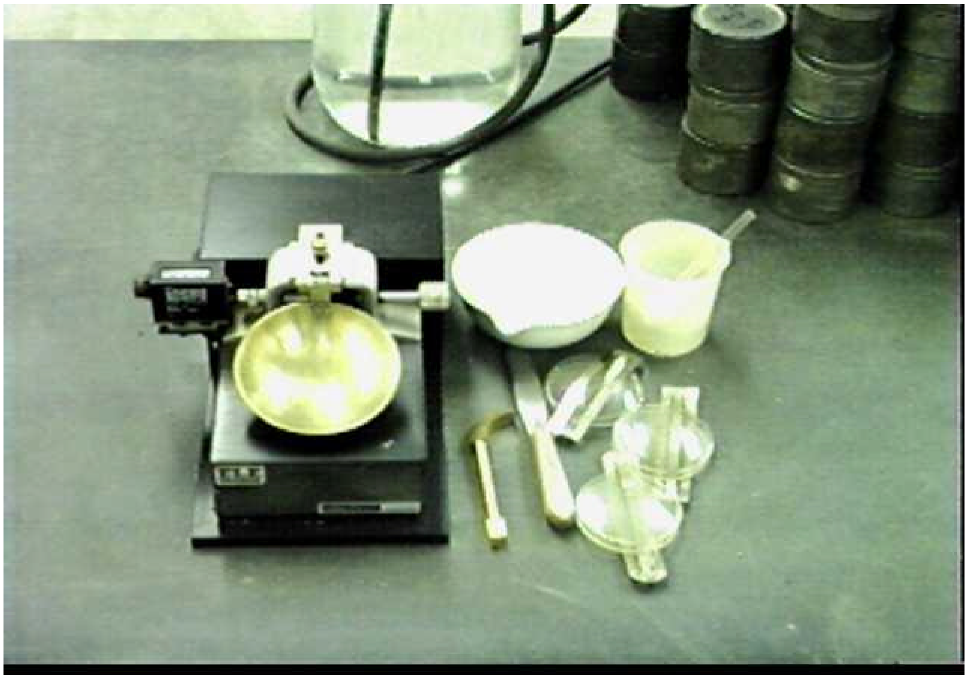


Figure 1: Liquid Limit Device and associated equipment

Manually Operated: Device consisting of a brass dish and carriage.

Mechanically Operated: Motorized device equipped to produce the rise and rate of shocks to a brass cup as required in this procedure.

<u>Grooving Tool</u>: A tool used to cut the soil pat in the liquid limit device. It is required to have the precise dimensions.

<u>Gage</u>: Can be attached to the grooving tool or separate. If separate, it may be a metal bar 10.0 +/- 0.2 mm thick and approximately 50 mm long. It must conform to the dimensions given.

Containers: Should be suitable for constant heating and cooling. The mass should not change and no disintegration should occur. Containers should also have close-fitting lids to prevent the loss of moisture prior to initial mass determination and to prevent absorption of moisture from the environment. One container is needed for each moisture content determination.

Balance: Must conform to AASHTO M 231. It must be class C with sensitivity to the nearest 0.01 g and a capacity of 1200 g.

Oven: A thermostatically controlled oven that is capable of maintaining a consistent temperature of 110 +/- 5°C (230 +/- 9°F).

3.0 Adjustment of Liquid Limit Device

The device should be inspected regularly to ensure that it is in good working order. An inspection should include an examination of the pin connecting the cup to make sure it is not worn sufficiently to allow side play, the screws connecting the cup and hanger arm should be checked to ensure they are tight, the points of contact on the cup and base should be checked for excessive wear, and the lip of the cup as well as the cup itself should be inspected to ensure the grooving tool has not worn away the surface. See Note 1 in AASHTO T 89 for direction as to the evaluation of worn liquid limit devices.

The height of the drop of the cup on the base should be checked and adjusted (Figure 2), if necessary, each time the test is run. The highest rise of the cup should be 10.0 +/- 0.2 mm from the point of contact on the base. The gauge should be used to check the drop height.

Figure 2: Checking height of liquid limit cup drop with height gauge.

See AASHTO T 89 (Note 2 and Figure 2) for method to check the actual drop height of the cup.

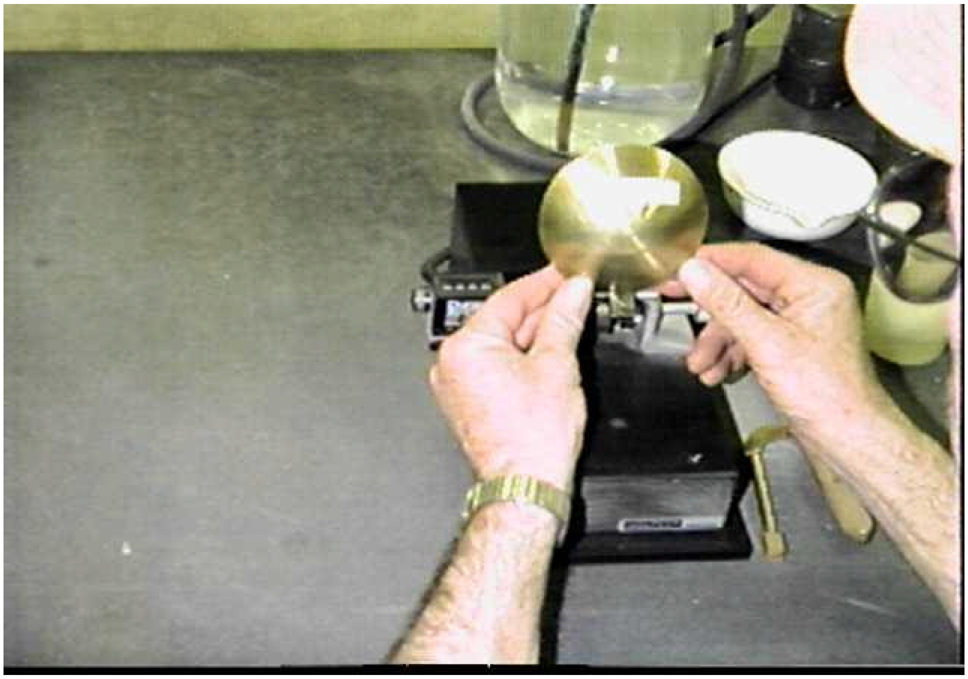


Figure 3: Place a piece of tape which bisects wear spot on bottom of liquid limit cup. This will provide the height gauge with a measuring point.

4.0 Sample Preparation

This procedure allows either a dry preparation (AASHTO T 87) or a wet preparation (AASHTO T 146). If determining the soil's liquid limit for structural purposes, use AASHTO T 146. All samples shall be taken from the portion passing the 0.425 mm sieve.

The choice of method depends on the condition of the sample and the time allotted to complete the test. AASHTO T87 requires one drying period, while AASHTO T146 requires two 12-hour drying periods before actually testing for the liquid limit.

The size of the sample depends on whether Method A or B is being used. Method A requires more material because it is a multipoint method. Method A needs approximately 100 g and Method B approximately 50 g.

5.0 Method A (Multi-Point Method)

Method A is required when running comparison or referee testing on a particular sample. It is generally considered a better indication of liquid limit of the material than the single point method (Method B).

1. Place the prepared 100 g soil sample in the mixing dish and thoroughly mix with 15 to 20 mL of distilled water. Mix by repeatedly stirring, kneading, and chopping with a spatula. Further additions of water should be made in 1 to 3 mL increments (Figure 4).

Figure 4: Add small increments of water when sample nears liquid limit.

Note: Tap water can be used if comparisons indicate that no difference in liquid limit occurs when using both types of water.

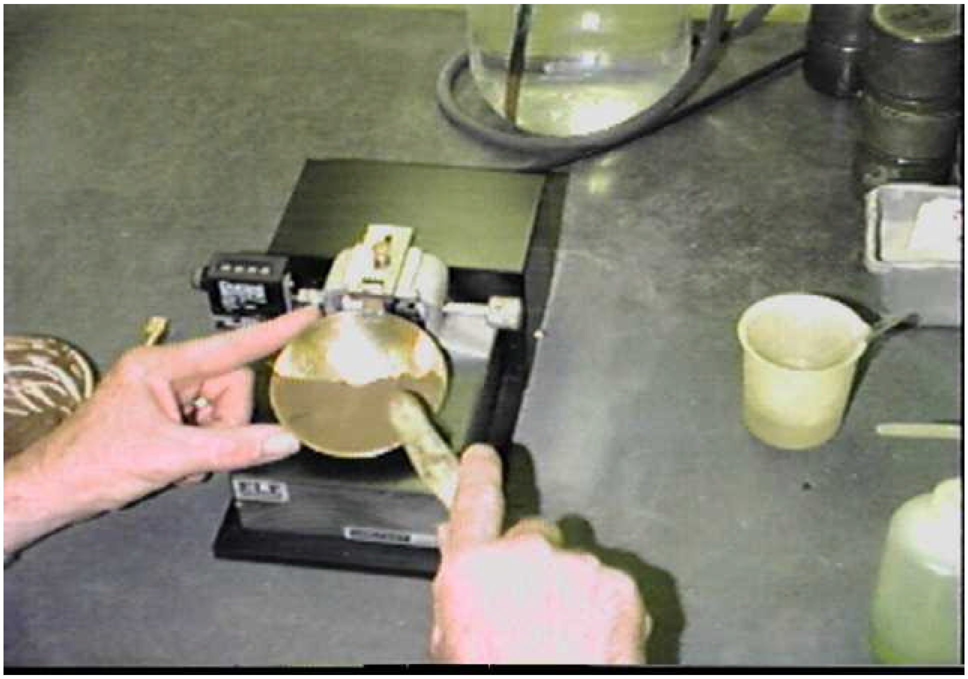


Figure 5: Squeezing and spreading sample into cup.

2. Add sufficient water to form a uniform mass of soil with a stiff consistency. Place enough material into the cup so that when it is squeezed and spread with the spatula the soil will rest in the cup above the spot where the cup rests on the base and will be a 10 mm thick at the point of maximum thickness (Figure 5).

   "As few strokes of the spatula as possible shall be used, care being taken to prevent the entrapment of air bubbles within the mass" (AASHTO T 89, 5.2).
3. Divide the soil in the cup with the grooving tool by making a smooth firm stroke perpendicular to the edge of the soil in the center of the cup (Figure 6). Cut the soil without allowing the soil pat to tear or slide within the cup itself. AASHTO T 89 allows up to 6 strokes of the grooving tool to make the cut. Only the last stroke is allowed to contact the cup surface. Wipe the grooving tool clean between cuts.

Figure 6: Dividing soil with AASHTO grooving tool.

When cutting the soil with the AASHTO grooving tool, the depth of the tool should be level with the depth of the soil. Other grooving tools that are available cut the soil pat to the proper 10 mm depth. However, if the AASHTO specification is to be followed, the initial depth prior to cutting is required to be 10 mm. Some experience will be necessary to gauge the relative volume of soil to place initially within the cup.

4. Once the groove has been cut, drop the cup by turning the crank at a rate of approximately two revolutions per second until the two halves of the soil pat come together along a distance of about 13 mm. Record the number of shocks required to close the groove. The base unit should not be held during this operation.

   AASHTO T 89 (Note 4) stipulates that for soils which tend to slide on the cup (as opposed to flowing), moisture should be added to the sample and the procedure should be repeated. If the soil continues to slide in the cup then it should be reported that the liquid limit of the material could not be determined.

5. Slice the soil pat with the spatula perpendicular and through the center of the previously cut groove (Figure 7). Obtain this cross-section of soil and place it into a container for moisture determination (Figure 8). The container should have a lid and should be tared to within 0.01 g. Determine the moisture content of the soil cross-section by drying in an oven regulated at 110 +/- 5°C (230 +/- 9°F) to a constant mass (Figure 9), determining the water loss, and expressing this as a percentage of the dry mass.

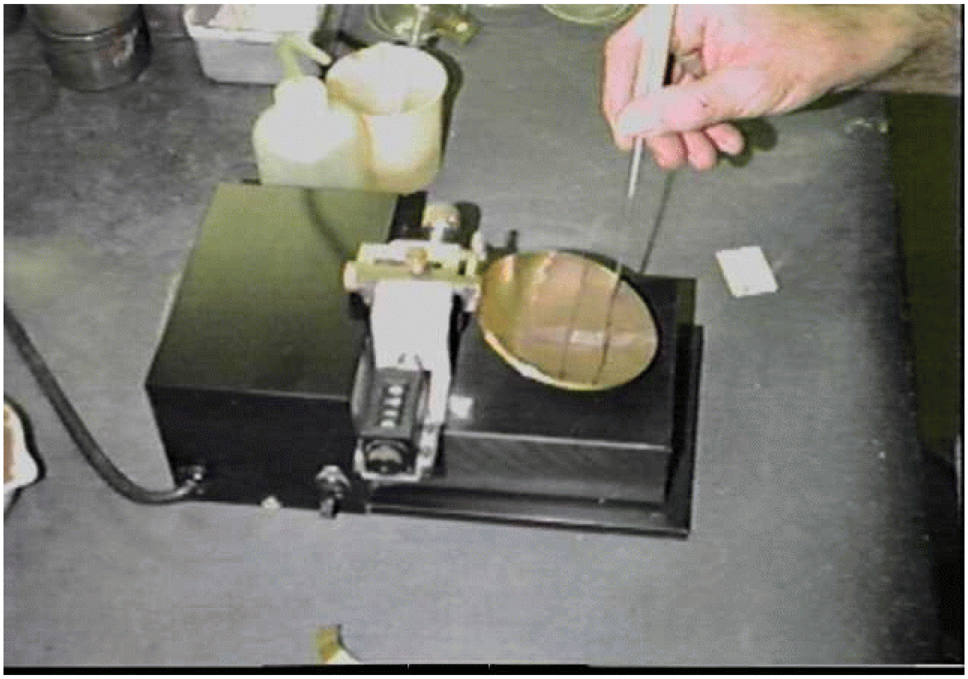


Figure 7: Slicing soil with spatula through previously-cut groove.

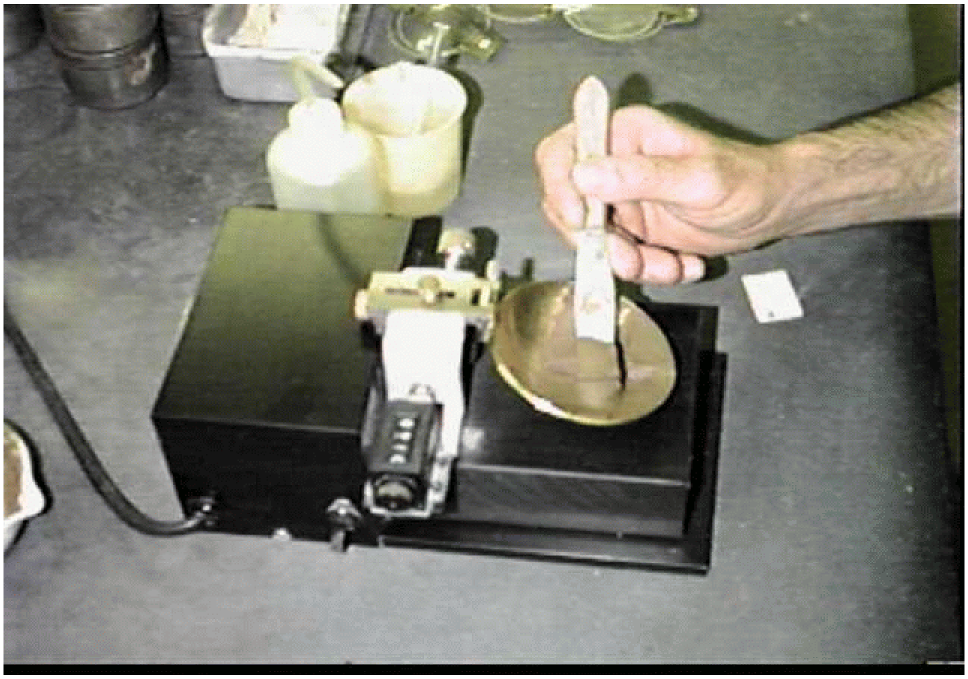


Figure 8: Obtain moisture sample with spatula.

6. Plac e the soil

rema ining in

the cup into the mixing dish and place additional water (1 to 3 mL) into the sample, or use previously prepared additional portions to which sufficient water has been added to result in a more fluid condition. "The object of this procedure is to obtain samples of such consistency that at least one determination will be made in each of the following ranges of shocks: 25-35, 20-30, 15-25, so the range in the three determinations is at least 10 shocks" (AASHTO T 89, 5.6).

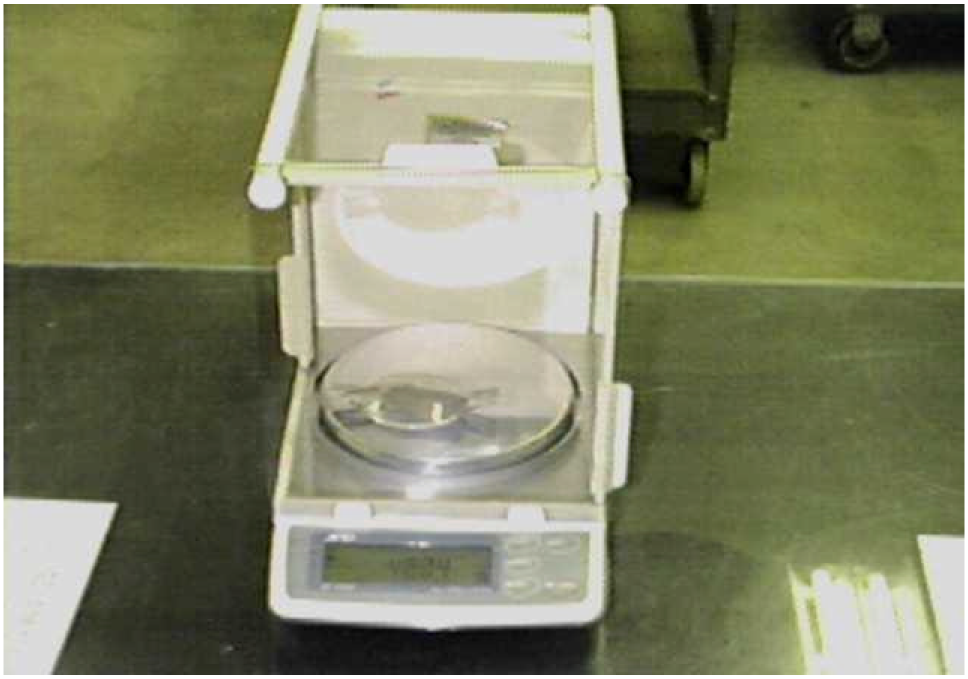


Figure 9: Weigh samples on balance with sensitivity to nearest 0.01g.

7. Calculate the water content for each sample by dividing the mass of water contained within the sample by the mass of the oven dried soil and multiplying by 100. For this procedure record moisture content to the nearest whole percent.

8. Prepare a flow curve (Figure 10) on a semi-logarithmic graph with moisture contents on the x axis and the corresponding number of shocks which closed the soil pat halves at least 13 mm on the y axis (number of shocks as ordinates on the logarithmic scale). The flow curve should be the straightest possible line drawn through three or more plotted points.
9. Determine the liquid limit as the moisture content which corresponds to the flow curve passing the 25 shock ordinate of the log scale. The following example illustrates a flow curve where the number of shocks (recorded on the curve) are plotted against the moisture content (recorded on the x-axis). In this case, the liquid limit would be 24 (24.24, rounded to the nearest whole number).

6.0 Procedure (Method B, Single-Point Method)

1. Prepare roughly 50 g of the soil and mix with roughly 8 to 10 mL of water and follow the mixing procedure for Method A, step 1.

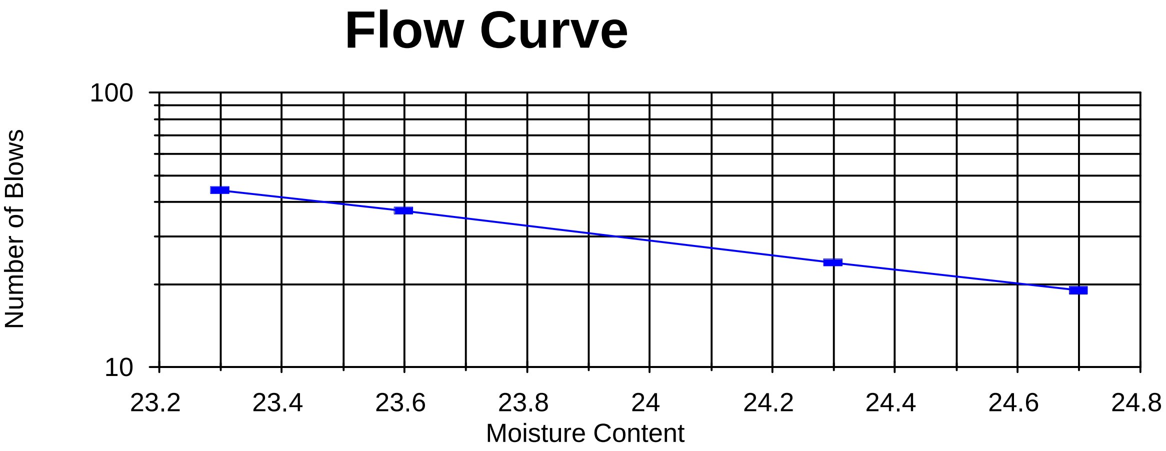


Figure 10: Flow Curve.

2. The procedure is identical to the Method A except that the soil pat should be prepared with water to produce a consistency which will close the two halves of the soil pat at least 13 mm within 22 to 28 shocks of the cup. AASHTO recommends running two liquid limit tests within the 22 to 28 shock range to ensure proper closure at the required number of shocks. "Groove closures between 15 and 40 blows may be accepted if variations of +/- 5% of the true liquid limit are tolerable" (AASHTO T 89, 10.3).
3. Determine the moisture content of the soil pat in accordance with AASHTO T 265.
4. The liquid limit for the single point method is derived from one of several means: the nomograph, the multi-curve, the slide rule with special blows scale, or by calculation. The standard three point method should be used as a referee test to settle all controversies (AASHTO T 89, 12.1).

   In most cases the determination of the liquid limit using the single point method is easiest using the Mean Slope Method, developed by the Army Corps of Engineers. The slope is reproduced on the following page from AASHTO T 89.

   For information on using the multi-curve or slide rule to determine liquid limit, please consult the appropriate section in AASHTO T 89.

7.0 Calculations

This example calculation demonstrates two trials using the single-point method (B). Liquid Limit is figured in the last column using the calculation found on the Nomograph in AASHTO T 89, Figure 4. Note that this calculation is based on the following equation:

$$LL \quad (Moisture\ \ Content)\ X\ (\frac{Blows}{25})^{0.121}$$

Tin #	Tin Mass (A), g	Tin w/ Wet Soil Mass (B), g	Wet Soils Mass (M_w) = (B-A)	Tin w/ Dry Soil Sample mass (C), g	Dry Soil Mass, (M_d) = (C-A)
1	14.176	23.178	9.002	6.064	2.938
2	14.433	25.453	11.020	21.867	7.434

Tin #	Loss, (L) = (M_w-M_d)	Moisture Content, (w) = (L/M_d) 100	Blows of LL Device, (N)	LL (equation)
1	2.938	48.4	24	48.2
2	3.586	48.2	23	47.7
	Avg			

Sample Test

True or False

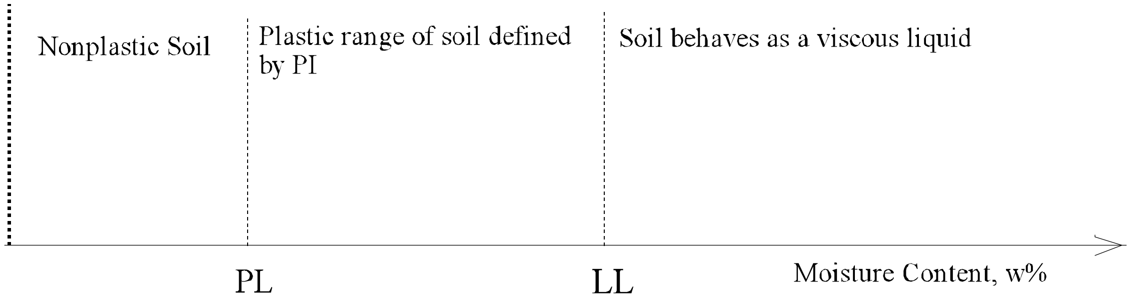
1. Liquid limit is used in conjunction with the moisture density relation to determine the plasticity index of soils.
2. The height of the drop of the LL cup should be checked and adjusted each time the test is run. The highest rise of the cup should be 10.0 +/- 0.2 mm.
3. The soil prepared for the liquid limit test should be passing the 4.75 mm sieve.
4. Mix the soil with water by alternately stirring, kneading, and chopping with a spatula.
5. If too much water is added to the sample then additional dry soil may be added to reduce overall moisture content.
6. Spread the prepared sample in the LL cup so that the soil is 10 mm thick at its thickest point.
7. When dividing the soil in the cup with the grooving tool, the division must be made in one cut or else the sample must be discarded.
8. Once the soil is cut, drop the cup by turning the crank at a rate of approximately two revolutions per minute.
9. The groove closure of the soil pat should be approximately 13 mm.
10. Soils should slide and not flow within the LL cup. If soils flow and do not slide, then the liquid limit may be indeterminable.

Determining the Plastic Limit and Plasticity Index of Soils

AASHTO T 90

1.0 Purpose

The plastic limit (PL), when used in conjunction with the liquid limit, is used internationally for soil identification and for strength correlations. The plastic limit is the lowest water content at which a soil remains plastic. When used with the liquid limit, the plastic limit will determine plasticity index. The plasticity index (PI) is the water content range within which a soil will be in a plastic state. The plasticity index is useful in soil classification and determining engineering properties of soils.



2.0 Apparatus

<u>*Dish*</u>: A porcelain evaporating dish or similar mixing dish should be used. It should be close to 115 mm in diameter and unglazed if possible.

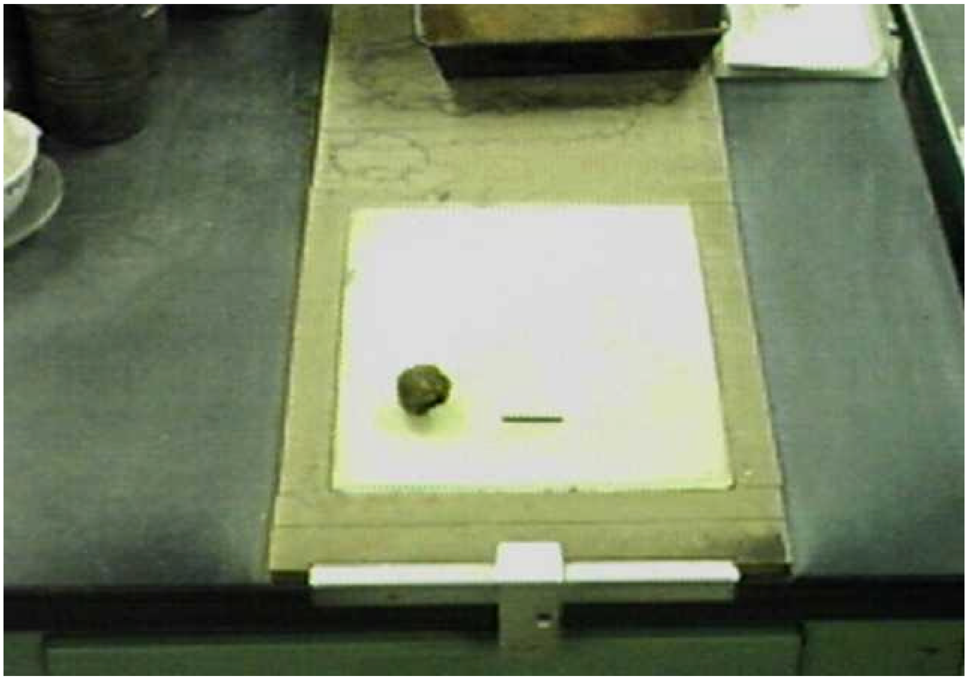


Figure 1: Sample on rolling surface.

Spatula: The spatula or pill knife should be approximately 75 mm in length and 20 mm in width. *Rolling Surface*: The sample should be rolled on a ground glass plate or a piece of smooth, unglazed paper (Figure 1).

Containers: Should be suitable for constant heating and cooling. The mass should not change and no disintegration should occur. Containers should also have close fitting lids to prevent the loss of moisture prior to initial mass determination and to prevent absorption of moisture from the environment. One container is needed for each moisture content determination.

Balance: Must conform to AASHTO M 231. It must be class C with sensitivity to the nearest 0.01 g and a capacity of 1200 g.

Oven: A thermostatically controlled oven that is capable of maintaining a consistent temperature of 110 +/- 5°C (230 +/- 9°F).

3.0 Sample Preparation

This test is usually run in conjunction with the liquid limit test. The sample for the plastic limit test should be obtained from the soil prepared for the liquid limit test. The sample can be obtained at any point in the mixing process where the soil is "plastic enough to be easily shaped into a ball without sticking to the fingers excessively when squeezed" (AASHTO T 90). Take a sample of approximately 8 g to run the plastic limit test.

If the sample will be used for the plastic limit test only, take a sample of about 20 g from the material passing the 0.425 mm sieve. Use either dry preparation (AASHTO T 87) or wet preparation (AASHTO T 146).

4.0 Test Procedure

(1) Place sample in mixing dish and thoroughly mix with distilled or demineralized water until the mass is plastic enough to be shaped into a ball. Take approximately 8 g of this sample to use in the plastic limit test.

(2) "Squeeze and form the test sample ... into an ellipsoidal-shape mass. Roll this mass between the fingers or palm and the ground-glass plate or a piece of paper lying on a smooth horizontal surface with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length (Figure 2). The rate of rolling, shall be between 80 and 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position again" (AASHTO T 90, 4.1).

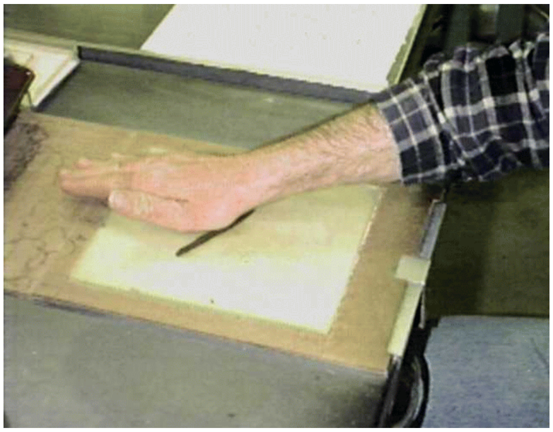


Figure 2: Rolling the plastic limit sample on the rolling surface.

(3)“When the diameter of the thread becomes 3.2 mm (Figure 3), break the thread into six or eight pieces (Figure 4). Squeeze the pieces, together between the thumbs and fingers of both hands into a uniform mass roughly ellipsoidal in shape and reroll. Continue this alternate rolling to a thread of 3.2 mm in diameter, gathering together, kneading and rerolling, until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The crumbling may occur when the thread has a diameter greater than 3.2 mm. This shall be considered a satisfactory end point, provided the soil has been previously rolled into a thread 3.2 mm in diameter. At no time shall the operator attempt to produce failure at exactly 3.2 mm diameter by allowing the thread to reach 3.2 mm, then reducing the rate of rolling or the hand pressure, or both, and continue the rolling without further deformation until the thread falls apart. It is permissible to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal shaped mass nearer to required 3.2 mm diameter”(AASHTO T 90, 4.2).

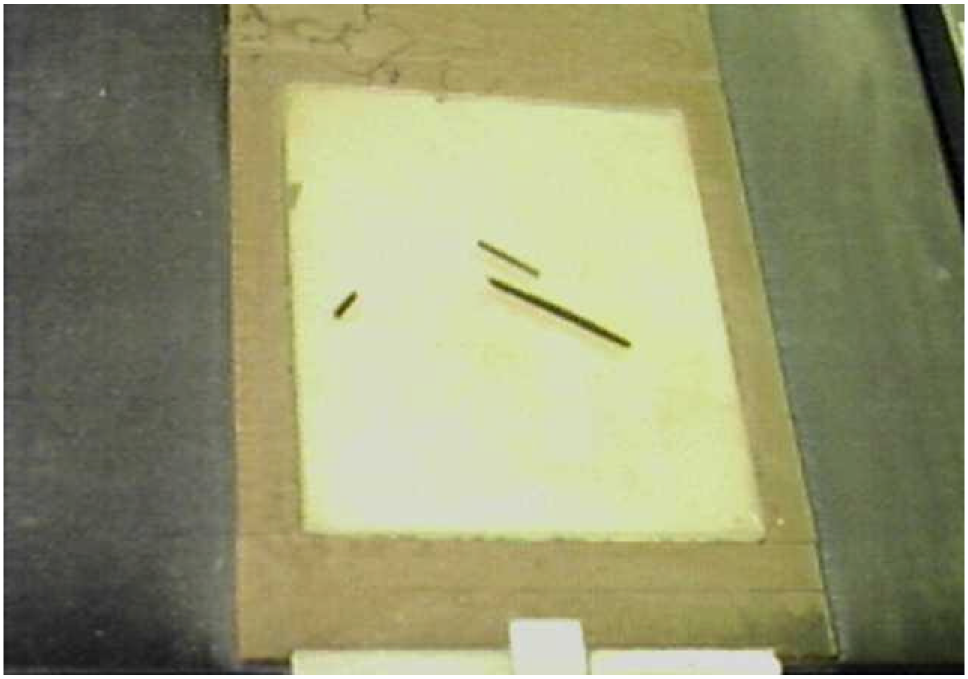


Figure 3: Roll into 3.2 mm diameter thread.

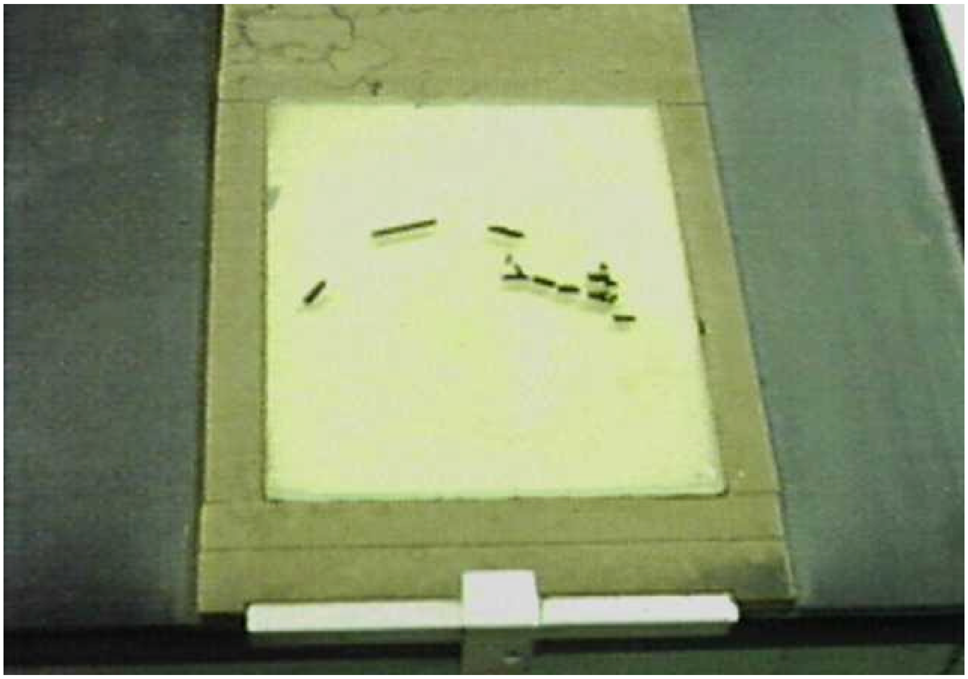


Figure 4: Break thread into 6 or 8 pieces

(4) Gather the portions of soil together and place in a suitable tared container; record the mass to the nearest 0.01 g. Dry the sample in accordance with AASHTO T 265 and record the dried sample mass to the nearest 0.01 g.

5.0 Calculations

5.1 Plastic Limit

The plastic limit (PL) is expressed as the water content in percentage of the mass of the oven-dry soil, as follows:

$$PL \quad \frac{Mass\ of\ Water}{Mass\ of\ Oven\ Dry\ Soil}\ X\ 100$$

The plastic limit should be reported to the nearest whole number.

5.2 Plasticity Index

The plasticity index (PI) is calculated as the difference between liquid limit (LL) and plastic limit as follow:

$$PI = LL - PL$$

When the liquid limit or plastic limit cannot be determined, record the plasticity index as NP (non-plastic). Also, if the plastic limit is greater than or equal to the liquid limit, record plasticity index as NP.

5.3 Example Calculation

Mass of tin, (M1)	Mass of tin w/wet soil, (M2)	Mass of tin w/ dry soil, (M3)	Wet soil mass, (M4)= (M2-M1)	Dry soil mass, (M5) = (M3-M1)	Mass of water, (M6) = (M4-M5)	PL = (M6/M5) 100
14.965 g	21.731 g	20.586g	6.766 g	5.621 g	1.145 g	20

Sample Test

True or False

1. The plastic limit is defined as the highest water content at which the material remains plastic.
2. The plastic limit is always at a higher water content than the liquid limit.
3. Distilled water should be used in preparing the sample for the liquid limit test if questions arise about the integrity of the tap water.
4. 8 grams of soil should be obtained to run the plastic limit test.
5. Samples should be rolled on a non-absorbent surface.
6. The soil should be rolled until it forms a thread approximately 3.2 mm in diameter.
7. The plasticity index is the sum of liquid limit and plastic limit.
8. If the liquid limit or plastic limit cannot be determined, report the plasticity index as zero.
9. The soil must crumble at 3.2 mm in order to be considered a satisfactory endpoint for the plastic limit.
10. It is permissible, for feebly plastic soils, to make the initial diameter of the ellipsoidal mass nearer to the required 3.2 mm when beginning the rolling process.

Calculation

Mass of Tin = 14.178 g

Mass of wet soil sample plus tin = 22.175 g

Mass of dry soil sample plus tin = 21.026 g

Calculate the plastic limit.

Mass of tin, (M1)	Mass of tin w/wet soil, (M2)	Mass of tin w/ dry soil, (M3)	Wet soil mass, (M4)= (M2-M1)	Dry soil mass, (M5)= (M3-M1)	Mass of water, (M6) = (M4-M5)	PL = (M6/M5) 100

Moisture-Density Relations Using a 2.5 kg Rammer and a 305 mm Drop

AASHTO T 99

1.0 Purpose

This procedure is also referred to as the standard proctor. It is used to determine the relation between moisture content and density of soils. The procedure ultimately determines the optimum moisture content (OMC) and maximum dry density (MDD).

The soil sample is prepared and compacted into a 100 mm or 150 mm diameter mold size using the 2.5 kg rammer and drop of 305 mm. The wet mass of the compacted sample is divided by the mold volume to yield the wet density. The dry density is determined by subsequent moisture content testing on the compacted mass of material. Density and moisture content are plotted over several moisture content values to determine optimum values (See Figure 1).

There are four alternative methods. The chosen method should be specified with regard to the material being tested. If no method is specified, Method A will govern.

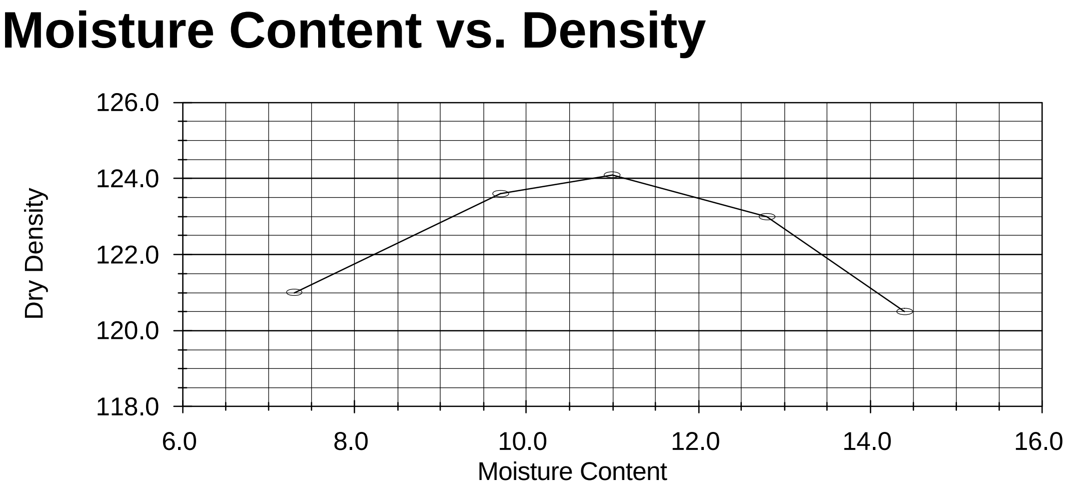


Figure 1: ***OMC occurs at approximately 13.0 and MDD is 124.1***

2.0 Apparatus for Standard Proctor

Rammer: See Figure 2.

- *Manually Operated Rammer*: See Figure 2. A manually operated metal rammer has a compacting head 50.8 mm (two in) in diameter and approximately 100 mm (4 in) in length, which is attached to the lower end of 9.5 mm (3/8 in) diameter rod approximately 550 mm (22 in) in length. Above the compacting head, a 50.8 mm (2 in) diameter steel weight with a hole drilled longitudinally through the center slides on the rod. The rod is provided with a stop so that when the weight is raised and released, it will fall a distance of 304.8 +/- 1.524 mm(12 +/- 1/16 in) to strike the head and impart compactive effort to the sample. The weight of the falling member is such as to overcome the inertia of the compacting head and impart a blow to the sample which is equivalent to that of 2.495 kg +/- 9 g (5.50 +/- 0.02 lb) rammer and having a free-fall of 304.8 +/- 1.524 mm(12 +/- 1/16 in).
- *Mechanical Compacting Rammer*: A mechanically operated rammer is equipped to control the height of the drop to 304.8 +/- 1.524 mm(12 +/- 1/16 in) above the elevation of the soil and has to distribute the blows over the soil surface. The rammer has a 50.8 mm (2 in) diameter, flat circular face and has a nominal weight of 2.495 kg +/- 9 g (5.50 +/- 0.02 lb). If a mechanical compacting ram is used then it must be calibrated to produce results repeatable with the manual methods using ASTM method D2168-90. The percentage difference of maximum dry unit mass values for a single set of data (the same sample ran through both manual and mechanical compaction procedures) may not exceed 2%, or the mechanical rammer apparatus may need to be adjusted. In addition to this density check, the deformation characteristics of both manual and mechanical compacting must be checked using a lead

mechanical compaction methods must not exceed 2%. Refer to ASTM D2168-90 for detailed procedures when calibrating mechanical rammers to manual rammers.

Molds: Depending on the method, either a 102 mm or a 152 mm mold, solid wall metal cylinder, with dimensions and capacities as shown in AASHTO T 99, Figure 1. For either the 102 mm or 152 mm molds the height is 116.43+/- 0.13 mm (4.584 +/- .005 in). Molds that fail to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50%; and the volume of the mold, calibrated in accordance with Section 7 of AASHTO T 19, for Unit Mass of Aggregate, is used in the calculations.

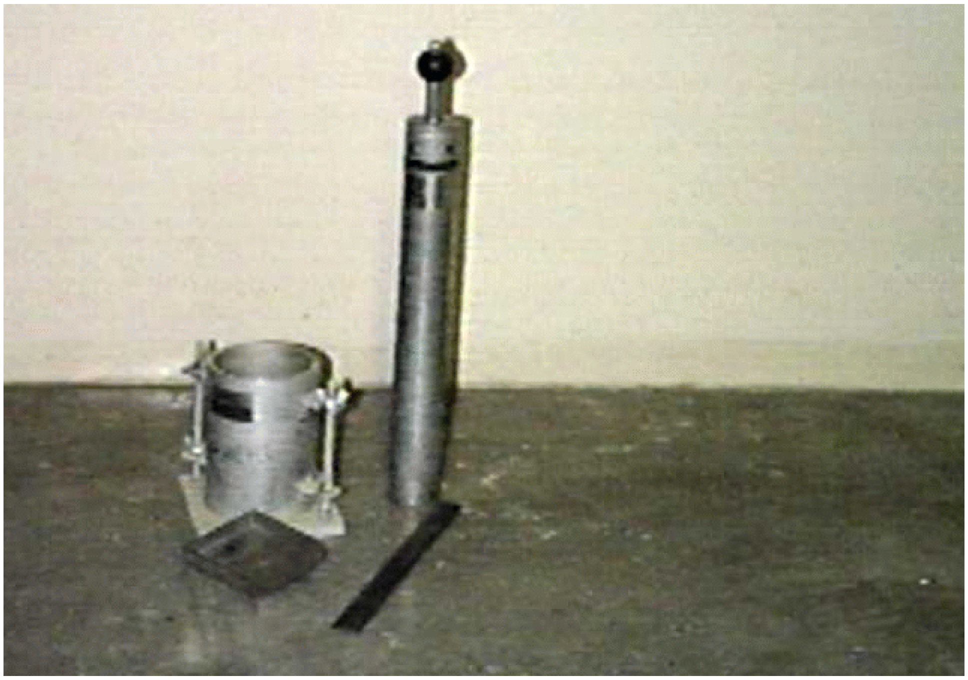


Figure 2: Apparatus for Standard Proctor.

Scales and balances: Must conform to requirements of AASHTO M 231, Class G20 and G2.

Drying Oven: Must be capable of maintaining a temperature of 110 +/- 5°C (230 +/- 9°F).

Straightedge: At least 50 mm length, made of hardened steel with one beveled edge. The straightedge is used to plane the surface of the soil even with the top of the mold. The straightedge may become beveled with use and should be checked periodically. The straightedge should not be so flexible as to cause a concave surface when trimming the soil from the top of the soil.

Sieves: 50 mm, 19.0 mm, and 4.75 mm sieves conforming to the requirements of AASHTO M 92.

Mixing Tools: Sample pans, spoons, scoops, trowels, used for mixing the sample with water.

Containers: Moisture resistant with close fitting lids to retain moisture content of prepared soil samples.

Miscellaneous: Graduated cylinders for adding water.

3.0 Test Methods

AASHTO T 99 stipulates four distinct test methods for these procedures: Method A, Method B, Method C, and Method D. The method to be used should be indicated in the applicable specification. If none is indicated, use Method A (AASHTO T 99, 1.2).

	Method A	Method B	Method C	Method D
Mold Size	101.60 mm	152.40 mm	101.60 mm	152.40 mm
Material Size	Passing 4.75 mm	Passing 4.75 mm	Passing 19.0 mm	Passing 19.0 mm
Blows per layer	25	56	25	56
Layers	3	3	3	3

Use caution when selecting the test method to be used. AASHTO test method designations are distinct from ASTM methods listed in D 698 and D 1557. ASTM contains three Methods (A, B, C) which correspond to different mold dimensions than their AASHTO counterparts.

AASHTO stipulates for each method that material must pass the designated sieve. Any material retained on the designated sieves is discarded, unless the oversize correction procedure is to be used.

4.0 Sample Preparation

1. If the sample is wet, dry it in an oven not exceeding 60°C (140°F) until it becomes friable under a trowel. Aggregations in a friable soil sample will break apart easily. Avoid breaking apart the natural particles when breaking up the soil aggregations.
2. Sieve the sample over the specified sieve for the Method being performed (A and B use a 4.75 mm sieve; C and D use the 19.0 mm sieve). Discard any material retained on the specified sieve.

   Rock Replacement: Note 7 in AASHTO T 99 states that “if it is advisable” to maintain the same percentage of coarse material in the lab sample as was found in the field, the material should be screened through a 50 mm and 19.0 mm sieves to ascertain the amount of material retained on the 19 mm sieve. Then an equal amount of material passing the 19 mm sieve but retained on the 4.75 mm sieve from the remaining portion of the sample should be recombined with the test sample prior to compaction. This procedure, when followed, necessitates a larger sample size than might ordinarily be obtained.

3. Thoroughly mix the remaining sample. Obtain at least enough material to prepare one "point" on the density curve. One "point" on the density curve would consist of enough material to fill the mold when compacted and provide enough extra material to ensure adequate material for increase in density as more water is added.

   In essence, this method uses the same soil sample for each "point" on the density curve. In some cases it may be necessary to prepare individual portions for each density "point" where soil or soil-aggregate mixtures are either too heavy-textured (silty or clayey materials), or where aggregates are prone to degradation from the repeated blows of the compaction rammer.

   In most cases enough material should be sampled from the field to permit four individual "points" of soils to be prepared at a range of moisture contents, beginning approximately 4% below the anticipated optimum moisture content, and then each subsequent "point" increased by 2% moisture. Optimum moisture content should be "bracketed" by the prepared samples in order to provide data for a more accurate moisture-density curve.

   "In instances where the soil material is fragile in character and will be reduced significantly in grain size by repeated compaction, a separate and new sample will be used in each compaction test" (AASHTO T 99, 4.4.1).

4. Prepare the sample(s) and mix with water to produce the desired moisture content. If the four "points" are prepared in advance make sure to store prepared material in moisture proof containers.

   Moisture is added to the soil or soil-aggregate material as a percentage of the sample's original mass. The following example illustrates this calculation:

° Given a sample of 6.09 kg, the sample needs to be prepared with approximately 2% additional moisture.

6.09 kg x 1.02% = 6.21 kg, i.e., enough water should be added
to the sample to produce a sample of 6.21 kg.

(6.21 - 6.09) = 0.12 kg of water added to bring up the moisture content by
approximately 2%

5.0 Procedure

1. Record the mass of the mold equivalent to tare weight of mold (without the extension collar) and record in kilograms to the nearest 5 grams.
2. Place a representative portion of the sample into the sample mold (102 mm diameter molds for Methods A and C, or a 152 mm diameter mold for Methods B and D) in order to fill it in three approximately equal layers (Figure 3) to give a total compacted depth of about 127 mm. Apply the required number of blows to the specimen layer (25 blows for Methods A and C, 56 blows for Methods B and D). Compact with the 2.495 kg rammer. Repeat this step for subsequent layers.

Figure 3: Adding a layer of soil.

The final specimen height after all layers have been compacted should be roughly 127 mm. When compacting the specimen using the manual rammer, uniformly distribute the blows over the entire surface area of the sample. At no time should the drop height vary from 305 mm. The technician should use care not to inadvertently lift the rammer and sleeve from the surface of the sample prior to compacting. The rammer and sleeve should also maintain a perpendicular orientation to the sample and mold during the compaction process (Figure 4). Clean the face of the hammer between lifts.

Figure 4: During compaction, technician should keep rammer perpendicular to the sample.

During the compaction process, the mold should rest “firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process” (AASHTO T 99, 4.2).

Figure 5: Sawing motion removes material above the top of the mold.

3. Remove the extension collar from the mold and trim the soil or soil-aggregate sample even with the top edge of the mold using a straightedge (Figure 5). Remove any particles that lodged between the mold and the base plate or bolt holders. If gaps exist in the plane of the material fill in with loose soil collected around baseplate (Figure 6).
4. Weigh the mold with sample in kilograms and record to the nearest 5 grams.
5. When using the 102 mm mold (Methods A and C), multiply the wet mass of the soil (mold mass with sample minus mold mass) by 1060, and record the wet density of the soil, W1, in kilograms per cubic meter.

Figure 6: Add soil to any noticeable gaps in soil surface after it has been planed.

When using the 152 mm mold (Methods B and D), multiply the wet mass of the (mold mass with sample minus mold mass) by 471, and record the wet density of the soil, W1, in kilograms per cubic meter.

6. Remove the compacted soil or soil-aggregate sample from the mold and slice vertically through the center of the specimen. Obtain a representative sample from one of the cut faces, determine the moist mass immediately and record and record and dry in accordance with AASHTO T 265 to determine moisture content.
7. Break up the remainder of the sample of the mold until it is judged by eye to completely pass a 4.75 mm sieve for Methods A and B. When using Methods C or D, break up the particle aggregates until those particles which are agglomerated will completely pass a 19.0 mm sieve and 90% of the fines in the sample will pass a 4.75 mm sieve. Add the broken up sample to the remainder of the sample being used for the test.

8. Add additional moisture to the sample so that the overall increase is approximately 2%. In no case should the increased water content be more than 4%. If separate density points were prepared prior to performing the procedure, then this step may be skipped. Continue compacting samples with moisture contents increasing by roughly 2% until there is a drop or no change in the calculated wet density, W1.

6.0 Calculations

1. Calculate the wet density (W_1) in kilograms per cubic meter

   Methods A and C: (mass of mold and soil - mass of mold) x 1060

   Methods B and D: (mass of mold and soil - mass of mold) x 471

2. Calculate the moisture content for each compacted sample by dividing the water content (loss between wet mass and dry mass for moisture sample) by the dry mass of the sample by multiplying by 100.

$$w = (\frac{M_1\ M_2}{M_2})\ X\ 100$$

w = moisture content of sample
M_1 = wet mass of soil
M_2 = dry mass of soil

3. Calculate the dry density (W) in kg/m^3 for each compacted sample in kilograms per cubic meter.

W=

$$(\frac{W_1}{w\ 100})\ x\ 100$$

4. Determine the moisture-density relationship by plotting density as the ordinates and the corresponding moisture contents as the abscissas.
5. Connect the points drawn on the moisture-density graph with a smooth curve. The moisture content corresponding to the peak of the curve will be termed the optimum moisture content.
6. The dry density at the optimum moisture content is the maximum dry density.

7.0 Example Calculation

Mass of Mold(kg) 4.29

Soils Test
Standard Compaction Test- AASHTO T 99

Point #	Mass of mold and soil (kg)	Mass of wet soil (kg)	Wet density in Kg/m^3 (W1)
1	6.30	2.01	2130.6
2	6.38	2.09	2215.4
3	6.40	2.11	2236.0
4	6.42	2.13	2257.8

Moisture Contents

Point #	Mass of container and wet soil (g)	Mass of container and dry soil (g)	Mass of container (g)	Moisture content *(w)*	Dry density (W) in kg/m^3; (W1/*w*+100)*100
1	370.9	356.4	115.2	6.0	2008.1
2	395.6	376.5	123.2	7.5	2060.8
3	384.9	362.9	115.4	8.9	2051.4
4	386.2	360.8	122.8	10.7	2035.6

Sample Test

True or False

1. The moisture-density relation determines the mass of soil in a known volume mold in order to calculate the density of the material.
2. Soil samples for the moisture density test are prepared so that each point is increased or decreased approximately 2% in moisture.
3. Separate soil samples must always be prepared for separate points on the moisture-density curve.
4. The mass of the empty mold with the collar should be recorded as the mold tare mass.
5. When running AASHTO T 99, fill the mold in approximately five equal layers.
6. Methods A and C require 25 blows of the rammer per lift.
7. Moisture samples should be obtained from the compacted specimen by slicing vertically through the center of the specimen and obtaining a representative portion from one of the cut faces.
8. Moisture content is expressed as a percentage of the wet mass of the soil.
9. During the compaction process, the mold should rest on a dense, uniform, rigid and stable foundation or base.
10. Maximum dry density is expressed as a density number with a corresponding moisture content.

Sample Test

Calculation

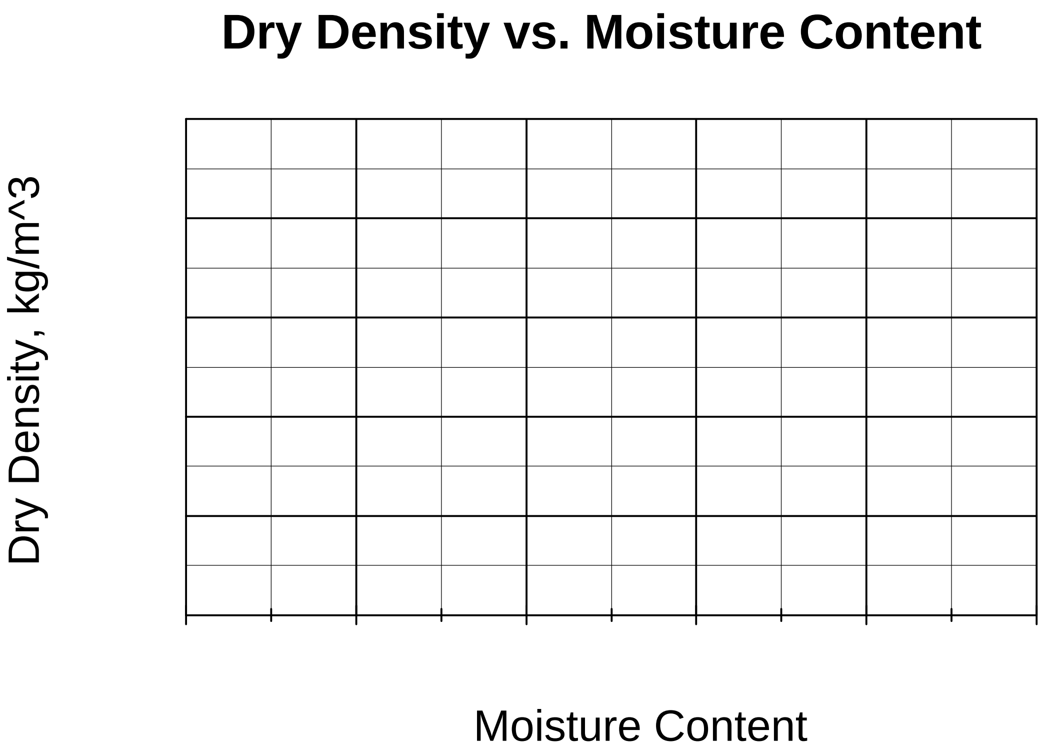
Mass of Mold (kg) 6.53

Soils Test
Standard Compaction Test- AASHTO T 99

Point #	Mass of mold and soil (kg)	Mass of wet soil (kg)	Wet density (W1)
1	11.11		
2	11.36		
3	11.39		
4	11.24		

Moisture Contents

Point #	Mass of container and wet soil (g)	Mass of container and dry soil (g)	Mass of container (g)	Moisture content *(w)*	Dry density (W) in kg/m^3; (W1/*w*+100) 100
1	361.9	347.8	115.2		
2	460.1	436.6	123.2		
3	505.1	471.9	115.4		
4	418.4	391.2	122.8		


Dry Density vs. Moisture Content
Dry Density, kg/m^3
Moisture Content

CHAPTER II

Soil Field Technician

STANDARD TEST METHOD FOR RANDOM SAMPLING

ASTM D3665

1.0 Scope

This method is used to eliminate any bias in materials sampling. Bias can be harmful even when it is unintentional. Technicians can easily fall into predictable sampling patterns that are biased.

The use of this method will eliminate the possibility for bias by implementing a set of numbers from a random number table. The numbers are then used to quantify sampling locations within the lot or sublot. This method describes how to determine sampling times and locations.

2.0 Sampling Definitions

A **lot** is the quantity of material evaluated by quality control procedures. The lot is a predetermined unit. Some examples of lots are a day's production, an interval of time, or a truckload of material. **Sublots** are portions which comprise the lot. The agency will specify how many sublots represent the lot. The random sampling procedures in this section determine when sublots should be obtained.

3.0 Straight Random Sampling vs. Stratified Random Sampling

The agency will specify whether to use straight or stratified random sampling. In straight random sampling, the entire lot is considered as a single unit and the determination of sample location is based on the entire lot size. Stratified random sampling divides the lot into a specified number of sublots and determines sample location within the specific sublots.

4.0 Sampling for Control vs. Acceptance

Quality Assurance is a concept that includes the functions of **process control, quality acceptance, and independent assurance (IA).** These are the necessary activities to verify, evaluate, and audit quality.

Quality control (QC) is also known as the process control function. QC testing is the responsibility of the material's producer. Sampling for QC is performed daily on the material during production. This provides data for instant evaluation should the material need to be controlled. Quality cannot be tested or inspected into the product, it must be present from step 1 of the project.

Quality acceptance (QA) testing is performed on produced material to determine conformance to specification requirements. QA samples may be obtained independently or on a comparison basis with QC testing. It is common for agencies to specify frequencies for QA samples at longer intervals than for QC samples.

Independent assurance (IA) is a management tool that requires a third party, without responsibility for QC or QA functions, to provide an independent assessment of the product. Independent assessments are performed to determine the reliability of process control and acceptance testing. The results of IA testing should not have a bearing on acceptance of the product.

5.0 Using the Random Number Table

1. Table 1, which is adapted from ASTM D 3665, contains three-digit numbers from 0.001 to 1.000.
2. Point to a number on the table without looking. The use of a pointed object may be advantageous. The number that is picked will establish the location of the sought-after number.
3. The first two digits of the three-digit number locate the line(row) number. The line number is the vertical column on the table's left side. For example, if you point to 0.156 in step 2, you will be looking for line 15.
4. Repeat step 2 and use the first digit to locate your column number. If you point to 0.469, then use column 4.
5. The location of the random number will be the intersection of your line and column numbers. Using line 15 and column 4, we will get a random number of 0.253.

Any page of the table can be used, but be sure to alternate pages between successive uses. The table must be entered separately for any and all numbers selected. If an unusable number is obtained, repeat the selection procedure. If this procedure is followed correctly, bias will be eliminated.

Table 1:
Random Number Table (Adapted from ASTM D 3665)

	0	1	2	3	4	5	6	7	8	9
1	0.534	0.323	0.402	0.460	0.391	0.920	0.610	0.793	0.924	0.595
2	0.887	0.518	0.905	0.269	0.109	0.546	0.340	0.276	0.975	0.583
3	0.843	0.722	0.639	0.638	0.028	0.740	0.625	0.724	0.995	0.178
4	0.735	0.147	0.463	0.748	0.721	0.369	0.202	0.020	0.299	0.088
5	0.582	0.118	0.665	0.849	0.160	0.164	0.613	0.246	0.227	0.528
6	0.040	0.687	0.313	0.200	0.916	0.387	0.862	0.655	0.739	0.022
7	0.718	0.590	0.494	0.836	0.013	0.769	0.853	0.056	0.109	0.946
8	0.934	0.094	0.049	0.447	0.543	0.155	0.408	0.439	0.723	0.642
9	0.879	0.971	0.985	0.973	0.461	0.144	0.654	0.627	0.735	0.954
10	0.516	0.146	0.912	0.354	0.155	0.488	0.068	0.219	0.307	0.005
11	0.756	0.174	0.525	0.586	0.650	0.070	0.703	0.341	0.740	0.772
12	0.734	0.234	0.921	0.787	0.507	0.573	0.680	0.141	0.681	0.525
13	0.700	0.635	0.750	0.104	0.190	0.760	0.570	0.464	0.798	0.473
14	0.454	0.067	0.700	0.952	0.909	0.645	0.050	0.198	0.466	0.889
15	0.465	0.514	0.947	0.210	0.253	0.882	0.396	0.808	0.164	0.396
16	0.919	0.605	0.422	0.835	0.552	0.689	0.475	0.574	0.678	0.006
17	0.020	0.504	0.877	0.852	0.307	0.220	0.288	0.711	0.534	0.626
18	0.177	0.873	0.978	0.285	0.607	0.095	0.212	0.917	0.553	0.502
19	0.284	0.997	0.787	0.792	0.453	0.950	0.192	0.849	0.645	0.689
20	0.356	0.340	0.666	0.841	0.713	0.593	0.537	0.662	0.604	0.158
21	0.670	0.481	0.254	0.663	0.112	0.923	0.819	0.631	0.382	0.603
22	0.498	0.628	0.930	0.991	0.650	0.680	0.840	0.035	0.139	0.714
23	0.685	0.627	0.107	0.376	0.957	0.697	0.619	0.315	0.173	0.684
24	0.278	0.582	0.535	0.951	0.004	0.658	0.067	0.798	0.142	0.774
25	0.111	0.156	0.709	0.932	0.004	0.731	0.234	0.290	0.886	0.016

	0	1	2	3	4	5	6	7	8	9
26	0.856	0.021	0.489	0.609	0.492	0.341	0.919	0.999	0.987	0.920
27	0.446	0.550	0.151	0.124	0.740	0.463	0.137	0.187	0.496	0.868
28	0.751	0.314	0.657	0.718	0.829	0.257	0.093	0.926	0.459	0.663
29	0.739	0.069	0.812	0.222	0.327	0.562	0.006	0.586	0.192	0.541
30	0.593	0.047	0.795	0.017	0.266	0.661	0.565	0.772	0.092	0.624
31	0.997	0.021	0.846	0.997	0.717	0.788	0.210	0.267	0.282	0.931
32	0.336	0.334	0.807	0.445	0.327	0.399	0.755	0.134	0.859	0.078
33	0.899	0.366	0.095	0.873	0.873	0.730	0.469	0.661	0.001	0.041
34	0.048	0.826	0.644	0.529	0.328	0.406	0.262	0.367	0.896	0.929
35	0.808	0.873	0.728	0.114	0.644	0.227	0.953	0.924	0.145	0.537
36	0.192	0.905	0.771	0.050	0.576	0.170	0.378	0.317	0.669	0.311
37	0.525	0.844	0.372	0.354	0.123	0.464	0.606	0.694	0.803	0.100
38	0.448	0.832	0.989	0.322	0.888	0.995	0.596	0.045	0.296	0.703
39	0.353	0.152	0.993	0.691	0.517	0.205	0.455	0.290	0.405	0.865
40	0.800	0.570	0.565	0.796	0.481	0.976	0.885	0.406	0.227	0.650
41	0.632	0.907	0.628	0.444	0.184	0.040	0.913	0.080	0.534	0.371
42	0.716	0.088	0.913	0.806	0.512	0.957	0.278	0.577	0.874	0.148
43	0.580	0.201	0.467	0.152	0.469	0.541	0.205	0.546	0.138	0.848
44	0.082	0.517	0.512	0.926	0.987	0.265	0.240	0.188	0.179	0.561
45	0.928	0.879	0.417	0.257	0.284	0.600	0.103	0.413	0.327	0.941
46	0.771	0.339	0.267	0.381	0.568	0.115	0.395	0.703	0.457	0.920
47	0.801	0.725	0.902	0.974	0.445	0.838	0.672	0.656	0.521	0.913
48	0.853	0.867	0.250	0.935	0.378	0.241	0.934	0.086	0.585	0.354
49	0.146	0.503	0.088	0.220	0.046	0.358	0.616	0.539	0.481	0.149
50	0.594	0.585	0.668	0.267	0.709	0.061	0.630	0.483	0.881	0.043

	0	1	2	3	4	5	6	7	8	9
51	0.500	0.857	0.222	0.308	0.325	0.216	0.057	0.635	0.265	0.384
52	0.209	0.188	0.776	0.478	0.247	0.836	0.038	0.277	0.140	0.109
53	0.991	0.886	0.753	0.375	0.855	0.290	0.281	0.781	0.895	0.831
54	0.300	0.982	0.275	0.097	0.942	0.406	0.810	0.190	0.020	0.874
55	0.023	0.352	0.343	0.772	0.053	0.781	0.265	0.454	0.118	0.504
56	0.988	0.470	0.154	0.504	0.911	0.520	0.582	0.125	0.367	0.921
57	0.407	0.869	0.615	0.392	0.361	0.857	0.846	0.004	0.425	0.466
58	0.571	0.585	0.159	0.637	0.122	0.521	0.732	0.249	0.465	0.335
59	0.709	0.156	0.414	0.975	0.425	0.433	0.366	0.883	0.736	0.084
60	0.560	0.806	0.766	0.555	0.303	0.439	0.193	0.707	0.649	0.533
61	0.049	0.017	0.990	0.784	0.796	0.832	0.056	0.179	0.079	0.479
62	0.153	0.700	0.390	0.283	0.360	0.602	0.103	0.061	0.089	0.924
63	0.664	0.139	0.356	0.892	0.417	0.554	0.596	0.376	0.842	0.291
64	0.465	0.553	0.170	0.987	0.182	0.009	0.767	0.131	0.615	0.824
65	0.330	0.306	0.794	0.814	0.421	0.421	0.450	0.875	0.137	0.750
66	0.843	0.818	0.866	0.358	0.069	0.497	0.848	0.003	0.602	0.787
67	0.065	0.926	0.565	0.256	0.149	0.849	0.907	0.577	0.863	0.940
68	0.152	0.229	0.924	0.341	0.080	0.847	0.274	0.999	0.824	0.921
69	0.708	0.593	0.775	0.055	0.226	0.540	0.989	0.915	0.838	0.334
70	0.103	0.190	0.269	0.676	0.672	0.101	0.383	0.453	0.733	0.575
71	0.147	0.452	0.051	0.217	0.042	0.250	0.043	0.812	0.133	0.530
72	0.509	0.934	0.166	0.267	0.684	0.876	0.657	0.890	0.585	0.048
73	0.466	0.454	0.845	0.287	0.793	0.701	0.178	0.707	0.299	0.831
74	0.804	0.464	0.866	0.294	0.413	0.774	0.427	0.508	0.372	0.350
75	0.884	0.099	0.329	0.791	0.869	0.650	0.346	0.983	0.884	0.972

	0	1	2	3	4	5	6	7	8	9
76	0.824	0.536	0.440	0.783	0.647	0.410	0.605	0.376	0.399	0.034
77	0.530	0.675	0.006	0.614	0.125	0.790	0.300	0.943	0.516	0.109
78	0.113	0.421	0.903	0.030	0.007	0.269	0.024	0.083	0.647	0.003
79	0.169	0.051	0.109	0.337	0.821	0.209	0.093	0.716	0.666	0.079
80	0.350	0.404	0.467	0.774	0.859	0.503	0.775	0.124	0.896	0.504
81	0.660	0.504	0.110	0.802	0.100	0.773	0.426	0.103	0.963	0.438
82	0.317	0.890	0.711	0.320	0.685	0.127	0.208	0.233	0.756	0.623
83	0.016	0.176	0.047	0.012	0.450	0.610	0.311	0.100	0.932	0.235
84	0.843	0.922	0.121	0.209	0.687	0.280	0.341	0.791	0.654	0.694
85	0.001	0.861	0.961	0.042	0.063	0.175	0.357	0.455	0.324	0.249
86	0.192	0.674	0.193	0.660	0.661	0.739	0.383	0.902	0.116	0.820
87	0.432	0.637	0.450	0.269	0.437	0.458	0.930	0.669	0.257	0.510
88	0.771	0.754	0.910	0.508	0.432	0.342	0.983	0.388	0.352	0.712
89	0.227	0.409	0.986	0.111	0.804	0.207	0.472	0.853	0.773	0.229
90	0.351	0.673	0.534	0.144	0.925	0.249	0.952	0.453	0.612	0.722
91	0.192	0.970	0.103	0.614	0.022	0.783	0.690	0.082	0.857	0.455
92	0.267	0.531	0.129	0.888	0.469	0.760	0.103	0.306	0.345	0.188
93	0.507	0.477	0.057	0.536	0.318	0.802	0.650	0.296	0.486	0.649
94	0.654	0.901	0.532	0.898	0.445	0.696	0.280	0.098	0.643	0.044
95	0.104	0.166	0.508	0.585	0.723	0.876	0.616	0.999	0.827	0.123
96	0.599	0.656	0.968	0.964	0.068	0.292	0.438	0.206	0.169	0.326
97	0.503	0.592	0.440	0.813	0.350	0.101	0.024	0.545	0.164	0.594
98	0.144	0.105	0.480	0.223	0.590	0.852	0.509	0.094	0.468	0.026
99	0.363	0.445	0.127	0.160	0.146	0.062	0.461	0.720	0.548	0.344
100	0.673	0.737	0.935	0.049	0.901	1.001	0.687	0.285	0.997	0.872

6.0 Straight Random Sampling Procedures Using Random Numbers

6.1 Sampling from a Belt or Flowing Stream of Material:

Determine an amount of production time to be considered a lot and the number of samples (n). Pick n random numbers to determine the times (t) to take the samples.

Example: the lot size is a 10-hour day (600 minutes) and three samples are needed. The random numbers 0.324, 0.612, 0.032 are chosen to represent the sublots. Drop the decimal point from the random numbers and the sampling times are 32 minutes and 324 minutes. The third number (.612) is dropped because it exceeds the lot time. A new number should be picked. AASHTO allows the actual time to be rounded off to the nearest five (5) minutes.

6.2 Sampling from a Windrow of Material:

Determine the length (L) of one windrow that represents a lot of material. Also, determine how many samples (n) will be needed. Select n random numbers from the table. Multiply these numbers by L to obtain sample locations.

6.3 Sampling from a Loaded Truck:

Determine how many trucks consist of a lot and how many samples (n) will be taken. Pick (n) numbers from the random number table to determine which trucks to sample from. Multiply these numbers by the number of trucks in the lot. Determine the quadrant in each truck to be sampled by choosing n random numbers and multiplying by four (4). Figure 1 shows the quadrant locations of the truck.

Example: A lot consists of 15 trucks and three samples will be taken from each lot.

(1) Pick three random numbers. In this case, we have chosen the following numbers: 0.251, 0.424, 0.865

(2) Trucks numbered 4 (.251*15), 6 (.424*15), and 13 (.865*15) will be sampled.

(3) Determine the quadrant locations. The following three numbers were chosen: 0.110, 0.380, 0.064

(4) Multiply the numbers by 4. From Truck 4, take a sample in quadrant 4 (.110*4=.44). From Truck 6, take a sample in quadrant 1 (.380*4=1.52). From Truck 13, take the sample in quadrant 2 (.064*4=.256).

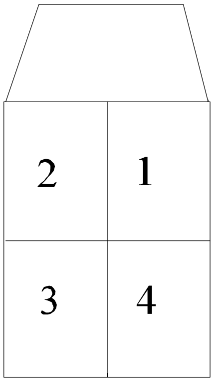


Figure 1.
Quadrant Locations

6.4 Sampling In-Place Paving Material:

Determine the length (L) of the lot, width (w) of the pavement, and the number of samples needed for each lot. Following the procedure for picking random numbers, pick L random numbers corresponding to length of pavement. Then, pick w random numbers for width determination. Sampling locations are then determined by multiplying the random numbers by the actual length (L) and width (w) of the lot.

Example: The lot is defined as 3.2 km and the pavement is 3.6 m wide. Two samples are needed from each lot. There are 3219 m in the lot.

(1) Enter the random number table and pick two numbers which will be multiplied by 3219.

(2) In this instance, 0.376 and 0.529 are chosen from the table. The two samples will be taken 1210 m and 1702 m from the beginning of the pavement.

(3) Select two more numbers to determine locations from the edge of the pavement. These numbers will be multiplied by 3.6.

(4) In this instance, 0.512 and 0.708 were selected. The two samples will be taken 1.8 m and 2 m from the edge of pavement.

(5) The first sample will be taken 1210 m from the beginning and 1.8m from the designated (right or left) edge of pavement. The second sample will be at 1702 m and 2 m.

6.5 Sampling from a Stockpile

AASHTO does not recommend the sampling of stockpiles. Stockpiles are prone to segregation and samples may not be representative of the material. Some agencies do use this procedure for determining sample locations in stockpiles.

Sample Test

<u>*True or False*</u>

1. A technician picks a number from the random number table to determine row number. The number was 0.792, which corresponds to row number 79.
2. AASHTO and ASTM do not recommend sampling from stockpiles.
3. When sampling loaded trucks, determine which trucks to sample by picking n random numbers from the table and multiplying these n numbers by the total number of trucks in the lot.
4. When sampling loaded trucks, additional random numbers need to be drawn for each sample in order to determine the quadrant of the truck to be sampled.
5. Straight random sampling procedures are identical to stratified random sampling procedures.
6. A technician picks a random number to determine column number. The number was 0.249, which corresponds to column number 9
7. Random numbers drawn are final; no matter what the situation they must be used or the random method will be jeopardized.
8. When sampling from a flowing stream of material, determine the total lot size by metric tons (t) and determine the number of samples needed. Random numbers represent the tonnage directly.
9. Stratified random sampling procedures mean that the sublot is divided into four sublots, which may or may not be equal.

Density of Soil In-Place by the Sand Cone Method

AASHTO T 191

1.0 Scope

The Sand-Cone Method determines the in-place density of soils. Density is important for determining a soil's level of compaction. Overall compaction is measured in relation to the laboratory moisture density test, which measures the maximum density of soil. In-place density is expressed as a percentage of the maximum laboratory dry density.

2.0 Apparatus

Density Apparatus: "shall consist of a 4 L jar and a detachable appliance consisting of a cylindrical valve with an orifice 12.7 mm in diameter and having a small funnel continuing to a standard G mason jar top on one end and a large funnel on the other end. The valve shall have stops to prevent rotating the valve past the completely open or completely closed positions" (AASHTO T 191, 2.1).

Sand: Use a clean, not-cementatious sand with few or no particles passing the 0.075 mm sieve, and none retained on the 2.00 mm sieve. AASHTO T 191 requires the bulk density of the sand to be measured several times to ensure that the sand does not have a variation in bulk density greater than 1 percent.

Balance: Conforming to AASHTO M 231, Class G20 (over 5 kg through 20 kg principle sample mass, sensitivity of 5 g or 0.1%); and conforming to AASHTO M 231, Class G2 (2 kg or less, sensitivity of 0.1 g or 0.1%).

Drying Equipment: A hot plate or sterno stove in the field suitable for drying moisture content samples.

Miscellaneous Equipment: Digging tools for test hole (small pick, chisels, spoons, scoops, etc.), suitable container for drying moisture sample (small pan), bucket or canvas bags to retain density sample, cache of density sand, thermometer for water temperature determination, brush for fines.

3.0 Equipment Preparation

Determining the bulk density of the sand (W_1) to be used in the test

1. Place the empty apparatus upright on a firm, level surface, close the valve, and fill the funnel with sand to determine the mass of the sandcone apparatus without sand in grams.
2. Open the valve and, keeping the funnel at least half full of sand, fill the apparatus. Close the valve sharply and empty excess sand.
3. Weigh the apparatus with the sand and determine the net mass of sand by subtracting the mass of the apparatus.
4. Calculate the bulk density of the sand as follows:

$$\mathbf{W_1 =} \quad \frac{W_2}{V_1}$$

W_1 = bulk density of the sand in grams per cubic centimeter

W_2 = grams of sand required to fill the apparatus

V_1 = volume of the apparatus in cubic centimeters

Remember to avoid any vibration of the sand during the mass/volume calculation. Vibration could cause the bulk density of the sand to be higher than normal.

Check the bulk density of the sand regularly. Slight changes in moisture or degradation of the sand during the storage and transport may affect the sand density determination. It is also acceptable to determine the bulk density of the sand using other volumetric containers, provided that the bulk density as determined by these other methods is shown to be equal to the bulk density of the sand as determined by the sand cone.

Determining the mass of the sand required to fill the cone

1. Put sand into the apparatus and close the valve.
2. Invert the apparatus on a clean, level surface so that the cone is facing down. If a base plate is used normally during testing then it must be used during the calibration process as well.
3. Open the valve and allow the sand to flow until its stops. Close the valve sharply and weigh the apparatus with the remaining sand in the jar. Determine the loss of sand and record it as the weight of sand required to fill the cone.
4. Replace the sand used for this determination and close the valve. The sand cone is now ready and calibrated for use.

When testing soils that will not permit a uniform and level testing area, AASHTO T 191 Note 7 recommends measuring the mass of sand required to fill the cone and the unbounded testing surface in lieu of measuring just the sand required to fill the cone. This is a special situation and is used to compensate for sand loss to uneven surfaces.

4.0 Procedure

1. Make sure the jar is filled with enough sand to fill the hole volume and the cone. Weigh the apparatus with sand prior to use. This mass will be used to determine a loss of sand after it has been used to fill the excavated hole and cone.
2. Prepare the surface of the location to be tested so that it is a level plane.
3. Seat the inverted apparatus on the prepared plane surface and mark the outline of the funnel. Alternately, place the base plate on the level surface.
4. Step 4 is not listed in AASHTO T 191; it is adopted from ASTM D 1556-90. Remove the soil from the area outlined by the cone or within the area bounded by the base plate hole. Take care not to disturb the soil that will bound the hole while removing the soil from the volume of the test hole. The volume of the hole is dependent upon maximum particle size of the material being tested in conformance to AASHTO T 191, Table 1. A larger jar and cone may be needed when the volume exceeds 0.1 cubic feet.

   “The walls of the hole should slope slightly inward and the bottom should be reasonably flat or concave. The hole should be kept as free as possible of pockets, overhangs, and sharp obtrusions since these affect the accuracy of the test. Soils that are essentially granular require extreme care and may require digging a conical shaped test hole. Place all excavated soil, and any soil loosened during digging, in a moisture tight container that is marked to identify the test number. Take care to avoid loss of any materials. Protect this material from any loss of moisture until the mass has been determined and a specimen has been obtained for a water content determination” (ASTM D 1556, 7.1.5).

5. Weigh and record the material removed from the test hole. Retain a representative portion of the sample to determine the moisture content of the soil, making sure that the moisture sample conforms to the minimum mass requirements in Table 1. Determine the moisture content of the soil using AASHTO T 265 or another acceptable rapid dry method.

Minimum Particle Size, (mm)	Minimum Test Hole Volume (cm^3)	Minimum Mass for Moisture Content, (g)
4.75	708	100
12.5	1416	250
25	2124	500
50	2832	1000

Table 1. Minimum volume of test hole for maximum particle size.

6. Seat the apparatus in the hole or on the base plate and open the valve. Allow the sand to flow from the cone, filling the hole and the cone apparatus. Once the sand has ceased flowing, close the valve sharply. There should be no vibration in the immediate area during this operation.
7. Weight the apparatus with the remaining sand and subtract this from the original weight of the apparatus filled with sand. This is the mass of the sand used for the test. Subtract the mass of the sand previously determined to fill the cone from the mass of the sand used for the test. This is the mass of sand used to fill the excavated hole.

5.0 Calculations

Moisture content (w)=

$$\frac{(W_3 - W_4)\ X\ 100}{W_4}$$

Calculate W to the nearest 0.1 percent.

Dry mass of material removed from the hole (W_6)=

$$\frac{W_5}{(1 + \frac{W}{100})}$$

Calculate the dry mass of the material removed from the test hole to the nearest 0.01 g.

Dry density of the material (W)

$$V = \frac{(W_7 - W_8)}{W_1}$$

$$W = (\frac{W_6}{V})\ X\ 1000$$

Calculate the in-place dry density of the material tested to the nearest 0.1 kg per cubic meter.

Where:

w = percentage of moisture content, in material from test hole

W_3 = moist mass of moisture sample, in g

W_4 = dry mass of moisture sample, in g

W_5 = moist mass of the material from the test hole, in g

W_6 = dry mass of material from the test hole, in grams

V = volume of test hole, in cubic centimeters

W_7 = grams of sand used

W_8 = grams of sand in funnel

W = dry density of the tested material, in kg per cubic meters

Percent compaction(%C)

$$\%C = (\frac{W}{L})\ X\ 100$$

Where:

%C = percent of maximum dry density, determined by AASHTO T 99 or T 180

L = laboratory maximum dry density, determined by AASHTO T 99 or T 180

W = dry density of tested material, in kg per cubic meter

L ***NOTE: <u>Keep units straight during calculations</u>***

6.0 Example Calculation

<u>Given</u>: Moist mass of moisture sample = 271.6 g

Dry mass of moisture sample = 257.9 g

Moist mass of sample from test hole = 2864.9 g

Sand used to fill hole = 2150.0 g

Sand to fill cone = 240.0 g

Optimum laboratory dry density = 2273.16 kg per cubic meter

Bulk density of sand = 1568.16 kg per cubic meter

<u>Find</u>: w , W_6, W, and %C

<u>Solution</u>:

$$w = \frac{(271.6 \;\; 257.9) \; x \; 100}{257.9} = 5.3$$

$$W_6 = \frac{2864.9}{1 \; (\frac{5.3}{100})} = 2720.70 \; g = 2.72 \; kg$$

$$Convert \; W_1 \; to \; \frac{g}{m^3} = 1.571 \; x \; 10^6 \; \frac{g}{m^3}$$

$$V = \frac{(2150 \quad 240)}{1.571 \; x \; 10^6} = .00122 \; m^3$$

$$W = \frac{2.72}{.00122} = 2229.5 \; \frac{kg}{m^3}$$

$$\%C = (\frac{2229.5}{2280.7}) \; x \; 100 = 98.2$$

Sample Test

True or False

1. The bulk density of the sand cone needs to be determined in order to determine the in-place density of the soil.
2. The volume of the density apparatus needs to be determined by filling it with water at a known temperature.
3. Slight changes in moisture or degradation of the sand during storage and transport may affect the sand density determination.
4. The bulk density of the sand must be determined with the container provided for testing. Other volumetric containers are not acceptable.
5. The amount of sand needed to fill the funnel of the sand cone apparatus must be determined in order to accurately reflect the amount of sand required to fill the test hole during the test procedure.
6. Soil excavated from the test hole may be discarded immediately.
7. When digging the test hole, take care to avoid creating pockets, overhangs, and sharp obtrusions since they affect the accuracy of the test.
8. The mass of sand required to fill the test hole is used to determine the volume of the test hole.
9. Calculate the moisture content of the material under test to the nearest whole percent.
10. Density is determined on a wet basis first and a dry basis after the moisture content of the material has been determined.

Project____________________ County____________________ Date____________

Inspector____________________

WORK SHEET FOR DENSITY TESTS

		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Station							
Dist.]							
Elevation (minus rod from final grade)							
Wet wt. soil in hole, (g)	W_3						
Dry wt. soil in hole, (g)	W_4						
% of moisture	*w*						
Initial wt. sand (g) or Final vol. reading	W_7						
Final wt. sand (g) or Initial vol. reading	W_8						
Volume of hole (m^3)	V						
Dry density (kg/m^3)	W						
Compaction curve							
Std. density	L						
% of Std. density =(W/L) X 100	%C						

W_2 = Wt. of sand in apparatus= ___________

V_1 = Vol. of sand in apparatus =____________

W_1 = Wt. cubic feet of sand = _____________

Determination of Moisture by Means of a Calcium Carbide Gas Pressure Tester

AASHTO T 217

1.0 Purpose

This method is intended to determine the moisture content of soils using a calcium carbide gas pressure tester. The tester is also referred to as the "Speedy Meter."
The apparatus is very portable and no electricity is required, making the method particularly useful. The tester determines the moisture content as part of a chemical reaction between water and calcium carbide.

Note: This tester uses potentially dangerous chemicals which react to produce acetylene gas. Care should be taken when performing this test. Avoid breathing the acetylene gas and avoid running the test where potential for ignition might cause a fire.

Figure 1. Calcium carbide moisture testing kit with associated equipment.

2.0 Apparatus

Calcium Carbide Pressure Moisture Tester (See Figure 1): The Speedy Meter will usually include the reagent calcium carbide. AASHTO states that the shelf life of the reagent is limited and that it should be used in accordance with the manufacturer's recommendations. The meter is a simple pressurized chamber with a special cap holding the sample and a chamber where the carbide is placed. The cap should fit tightly seated on the chamber, usually with a rubber gasket to ensure an adequate seal during testing.

Balance: The balance must conform to the requirements of AASHTO M 231, Class G-2 (samples are 2 kg or less and the scale is sensitive to the nearest 0.1 g). Some models contain a scale built-in to the unit to the meter.

Cleaning Brush and Cloth: Used to clean the tester after each use.

Scoop: Used to measure the calcium carbide reagent.

Figure 2. Placing calcium carbide into moisture tester chamber.

3.0 Procedure

(1) If using the 20 g or 26 g testers, place three scoops (~24 g) of calcium carbide into the tester (Figure 2). If using the super 200 D tester, place six scoops (~48 g) into the tester.

(2) Weigh a sample of soil of the exact mass specified by the manufacturer of the instrument in the balance provided and place the soil into the cap of the instrument (Figure 3). When using the 20 g or 26 g testers, place two 31.75 mm (1.25 in) steel balls in the body of the tester with the calcium carbide.

Figure 3. Placing moist soil sample inside the cap of meter.

NOTE 5 in AASHTO T 217 indicates that if the moisture content of the sample exceeds the limit of the pressure gage (20% moisture for soil tester), a one-half size sample must be used and the dial reading must be multiplied by 2. This proportional method is not directly applicable to the dry mass percent scale on the super 200 D tester.

(3) With the instrument in a horizontal position (to ensure that the calcium carbide does not come into contact with the soil) seal the cap and tighten down on the clamp. A complete seal must be achieved in order to obtain accurate results from the instrument (Figure 4).

Figure 4. Ensure that seal is made between cap and chamber.

(4) Raise the instrument and allow the soil to fall from the cap into the pressure vessel. Shake the instrument vigorously (60 seconds for granular soils, 180 seconds for other soils) to permit a complete reaction between the soil and the calcium carbide.

Note: If steel balls are used in the tester, shake in a rotating motion to avoid damaging the instrument.

(5) When the needle stops moving, read the dial gauge while holding the unit in a horizontal position at eye level (Figure 5).

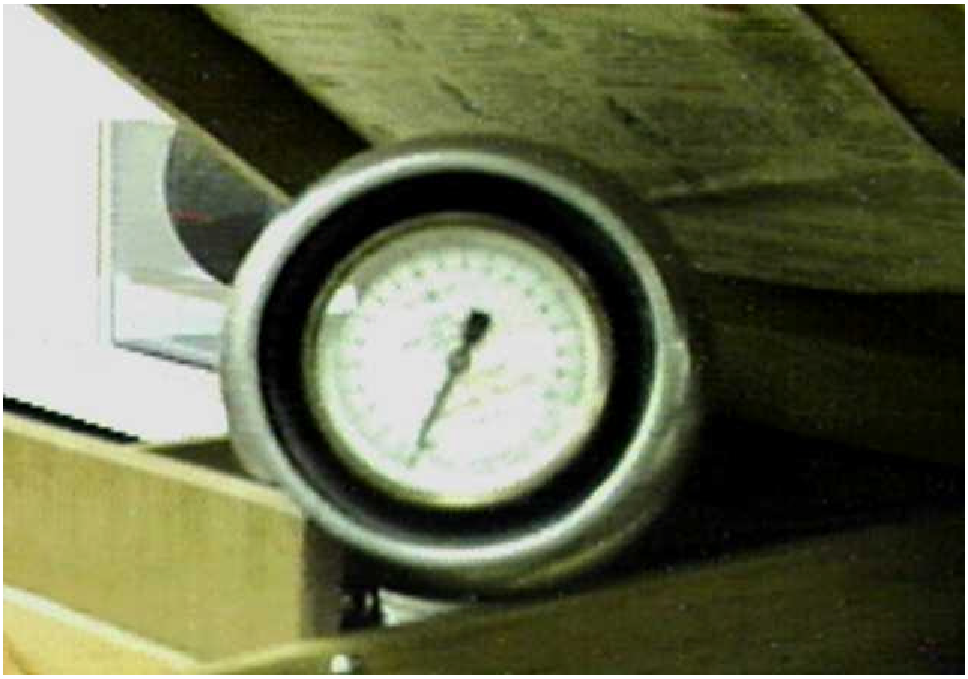


Figure 5: Dial reading on the speedy meter.

(6) Record sample mass and dial reading

(7) Position the instrument so that the cap is away from the user and slowly release the gas from the pressure chamber. Inspect the sample remaining inside the pressure chamber. If it is not completely pulverized then a new sample must be obtained and tested after the instrument has been thoroughly cleaned.

(8) The speedy moisture tester determines moisture content based on the wet mass of the soil. The percentage of moisture based on the dry mass of the material is read from the conversion curve which should be supplied with each instrument.

Note 8 in AASHTO T 217 recommends that users check the accuracy of the gauge and the conversion curve by testing samples of a known moisture content and developing correction factors (if necessary) for the instrument. The moisture content should be determined to the nearest whole percent in this method.

4.0 Calculation

The percentage of moisture by dry mass of soil can be determined by a conversion curve or from the given conversion chart .

Speedy Reading, (Wet mass %)	**Dry Mass, %**	**Speedy Reading, (Wet mass %)**	**Dry Mass, %**	**Speedy Reading, (Wet mass %)**	**Dry Mass, %**
1.0	1.0	20.5	25.8	35.5	55.0
2.0	2.1	21.0	26.5	36.0	56.2
3.0	3.2	21.5	27.4	36.5	57.4
4.0	4.3	22.0	28.2	37.0	58.7
5.0	5.4	22.5	29.0	37.5	60.0
6.0	6.5	23.0	29.8	38.0	61.2
7.0	7.6	23.5	30.7	38.5	62.6
8.0	8.7	24.0	31.5	39.0	63.9
9.0	9.8	24.5	32.4	39.5	65.2
10.0	11.0	25.0	33.3	40.0	66.6
10.5	11.7	25.5	34.2	40.5	68.0
11.0	12.3	26.0	35.3	41.0	69.4
11.5	13.0	26.5	36.0	41.5	70.9
12.0	13.6	27.0	36.9	42.0	72.4
12.5	14.2	27.5	37.9	42.5	73.8
13.0	14.9	28.0	38.8	43.0	75.4
13.5	15.6	28.5	39.8	43.5	76.9
14.0	16.3	29.0	40.8	44.0	78.5
14.5	16.9	29.5	41.8	44.5	80.1
15.0	17.6	30.0	42.8	45.0	81.8
15.5	18.3	30.5	43.9	45.5	83.4
16.0	19.0	31.0	44.9	46.0	85.1
16.5	19.7	31.5	45.9	46.5	86.9
17.0	20.4	32.0	47.0	47.0	88.6
17.5	21.2	32.5	48.1	47.5	90.6
18.0	21.9	33.0	49.2	48.0	92.3
18.5	22.7	33.5	50.3	48.5	94.1
19.0	23.4	34.0	51.5	49.0	96.0
19.5	24.2	34.5	52.6	49.5	98.0
20.0	25.0	35.0	53.8	50.0	100.0

Sample Test

True or False

1. The calcium carbide moisture tester determines the moisture content of soils as a chemical reaction between water and calcium carbide.
2. Calcium carbide has a short shelf life and should be used in conjunction with manufacturer’s recommendations.
3. Calcium carbide should be placed in the cap of the moisture gage.
4. Most speedy moisture content gauges read moisture as a percent of the dry weight.
5. A complete seal is necessary between the cap and chamber to get accurate results.
6. The percentage of moisture in the soil sample is based on the dry mass of the material, and is read from a conversion curve supplied with the instrument.
7. If the anticipated moisture content of the soil exceeds the capacity of the instrument in use, the result of the test should be divided by two.
8. The moisture gauge should be shaken well for three minutes for granular soils or one minute for other soils to ensure a complete reaction between the soil and calcium carbide.

Field Density and Moisture Tests of Soils By Nuclear Gauge – Troxler 3411-B

Kansas Test Method KT – 51

1.0 Scope

This test method covers the procedure for measuring the "in-place" (wet) density and moisture of soils. The moisture content of the soil is used in conjunction with the "in-place" density measurement to determine dry density. Procedures for Kansas Test Methods KT-51 and KT-52 reflect testing procedures found in AASHTO T-238 and T-239. Kansas Test Methods KT-51 and KT-52 are being used in lieu of the regional standards which are AASHTO T 238 and T 239.

Procedures for KT-51 and KT-52 are similar except that each utilizes a different nuclear gauge. KT-51 utilizes the Troxler 3411-B while KT-52 utilizes the Troxler 3440. This training module shall be applicable to both test methods.

The nuclear gauge uses a gamma source and gamma detector to measure the "in-place" (wet) density of soils at depths ranging from 50 mm (2 in) to 300 mm (12 in). The intensity of the radiation detected upon return to the gamma detector is dependent in part upon the density of the soil. To determine moisture content, the nuclear gauge uses a fast neutron source and a thermal neutron detector, which determines the intensity of slow or moderated neutrons. Moisture is then determined by the relationship of nuclear count to mass of water per unit volume of soil.

Caution should be exercised when operating the nuclear gauge. This equipment utilizes radioactive materials, which may be hazardous to the health of users unless proper precautions are taken.

2.0 Apparatus

Nuclear Gauge: Troxler 3411-B; see Figure 1.

Probe: Either the gamma source or the gamma detector shall be housed in the probe for insertion into a pre-formed hole of the material to be tested. Probes shall be marked in increments of 50 mm (2 in) with depths ranging from 50 mm (2 in) to a maximum of 300 mm (12 in). The probe shall be mechanically held in place when it is manually moved to the desired depth.

Housing: The source, detector, readout device, probe, and power supply shall be in housings of rugged construction that are moisture and dust proof.

Guide: Used for the hole-forming device to make a hole normal to the prepared surface.

Hole-forming Device: An auger, pin, or similar device for forming a hole in the soil to accommodate the probe. The hole-forming device shall have a nominal diameter equal to or up to 3 mm(1/8 in) greater than the probe diameter.

Reference Standard Block: Uniform, non-changing density block shall be provided with each gauge for the purpose of checking equipment operation and background count.

3.0 Gauge Preparation

Warm up the nuclear gauge in accordance with the manufacturer’s recommendations.

3.1 Take Reference Standard Count

Set the time switch in the SLOW (4 minute) position and take a reading on the reference standard block. This reading should be within one (1) standard count. The two numbers should land within two machine for malfunction.

3.2 Check Density Calibration Curves

Calibration curves are generated by determining the nuclear count rate for several materials of different densities and plotting the count ratio versus the known material density. The calibration curves for newly acquired gauges should be checked. All 3411-B gauges shall be subjected to a “factory” calibration at least once each year. KDOT gauges shall be calibrated at the Materials and Research Center.

3.3 Determining Moisture Correction Factor

Determinations by the nuclear method are to be compared with moisture quantities described under AASHTO T 217. A determination represents three one-minute or one four-minute wet density (WD) count readings from the gauge at one location. Moisture samples shall be extracted from the same location the nuclear gauge readings are taken. At least six separate locations are required. Discard the location(s) with the greatest deviation to leave five pair of samples for analysis. Prepare the test site and proceed as stated in Section 4.0, entitled Test Procedure.

Compare the six or more sample pairs of oven dry and nuclear gauge results from the locations mentioned above. Discard the sample pair(s) that deviate the greatest from the remaining five. Oven dry samples are to be at least 1000 g and are to be taken under the center of the gauge to a depth of 150 to 200 mm (6 to 8 in). Nuclear tests are to be taken with the Moisture Correct set at 00 on the 3411-B scaler. Prepare a chart of sample pairs as shown below:

Sample No.	**% M Oven Dry**	**%M Gauge**	**Moisture Difference (% M Oven Dry - % M Gauge)**
1	4.5	8.6	-4.1
2	4.0	5.9	-1.9
3	7.2	9.7	-2.5
4	6.7	8.6	-1.9
5	3.9 *	9.5 *	-5.6
6	4.7	8.6	-3.
Average	5.4	8.3	-2.9 #

Note: “ * ” Represents the discarded sample pair

Note: “ # “ If the Average Moisture Difference exceeds +/- one percent, a Moisture Correction Factor will be required for that soil type.

To determine the correction factor, calculate the average difference value and proceed as follows:

Calculate the Moisture Correction Factor using the average difference values

$$MoistureCorrectionFactor = \frac{1000(Avg\_\%\_M\_OvenDry - Avg\_\%\_M\_Gauge)}{100 + Avg\_\%\_M\_Gauge}$$

In the example above, the moisture correction would be as follows:

$$MoistureCorrectionFactor = \frac{1000(5.4 - 8.3)}{100 + 8.3} = -27$$

The correction is independent of dry density and adjusts the apparent moisture to a true moisture regardless of dry density. Dial the value into the Moisture Correction switches on the 3411-B scaler, paying particular attention to the algebraic sign. This value can be used for all future tests on the same soil type. Each soil type will have a moisture correction factor.

4.0 Test Procedure

Determine the number of soil types to be encountered on the project. If the number is substantial, then use AASHTO T 217 to determine the correct moisture content of the soil instead of calibrating the nuclear density gauge to moisture.

Randomly select a test site where the gauge will be at least 300 mm (12 in) away from any slight vertical projection. If the vertical projection is significant, then maintain a distance of 3 m (10 ft) including all stationary vehicles and equipment. Vehicles and construction equipment in motion should maintain a minimum distance of 1 to 1.5 m (3 to 4 ft) from the gauge.

4.1 Site Preparation

1) Prepare the test site by removing all loose and disturbed material as necessary to expose the top of the material to be tested.
2) Plane an area of sufficient size to a smooth condition so as to have maximum contact between the gauge and the material being tested.
3) The maximum void space beneath the gauge shall not be more than 3 mm (1/8 in). Use native soils or fine sand to fill these voids and smooth the surface with a rigid plate or other suitable tool. The depth of the filler should not exceed approximately 3 mm (1/8 in).

4) Make a hole perpendicular to the prepared surface using the guide and the hole-forming device. The hole shall be of such depth and alignment that insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.

4.2 Procedure

1) Tilt the gauge and extend the probe to the position required for the desired depth of the test.
2) Insert probe in the hole.
3) Seat the gauge firmly by moving it about the probe with a back and forth motion.
4) Pull gently on the gauge in the direction that will bring the side of the probe which faces the center of the gauge into contact with the side of the hole.
5) Set the POWER/TIME switch to the "Normal" position.
6) Turn the moisture correction switches to "00" or to the previously determined correction factor setting.
7) Press "Measure" key. After one minute the counting procedure will stop.
8) Press "WD" and record the Wet Density in kg/m3 (PCF)
   Press "M" and record the Moisture in kg/m3 (PCF)
   Press "DD" and record the Dry Density = (WD-M)
   Press %M and record percent moisture = (100*M)/DD

4.3 Gauge Reading

Secure and record three one-minute readings: Record the kg/m^3 (PCF) on Wet Density (WD) and Moisture (M) for each reading. If any individual Wet Density reading is not within +/- 16 kg/m^3 (+/- 1.0 PCF) of the average, eliminate it along with its Moisture reading from the average. Take another one-minute reading to replace the eliminated values and these values with the non deviant values. If two dry densities are not within +/- 16 kg/m^3 (+/- 1.0 PCF) of the average, discard all three readings and start over again. When three readings meet the above criteria, record the average WD and the average M of the soil.

5.0 Soil Identification

A selection of the soil type is necessary in order to set the moisture correction factor for the 3411-B. Nonhomogeneous soils may be encountered in which differences between the gauges and oven are inconsistent between samples. In this case, the use of AASHTO T 217 is the proper method for analyzing the moisture content of the soil.

Sample Test

True or False

1. The nuclear gauge uses a gamma source and gamma detector to measure the “in-place” density of soils.

2. Procedures for KT-51 and AASHTO T-238 are identical, including the use of identical nuclear gauges.

3. The selected test site must be at least 300 mm(12 in) away from any vertical projection.

4. Moving equipment or vehicles should maintain a distance of least 5 m from the gauge.

5. The maximum void space beneath the gauge should not exceed 3 mm(1/8 in)

6. When making the hole for the source rod, make sure it is perpendicular to the prepared surface area.

Field Density and Moisture Tests of Soils By Nuclear Gauge – Troxler 3440

Kansas Test Method KT – 52

Procedures for Kansas Test Methods KT-51 and KT-52 reflect testing procedures found in AASHTO T-238 and T-239. Kansas Test Methods KT-51 and KT-52 are being used in lieu of the regional standards which are AASHTO T 238 and T 239.

Procedures for KT-51 and KT-52 are similar except each utilizes a different nuclear gauge. The training module for KT-51 is applicable to both tests.

Standard Practice for Description and Identification of Soils, Visual/Manual Procedure

ASTM D 2488

1.0 Scope

The procedure is used to describe the composition of soil particles below cobble size (passing 75 mm size). This procedure is used in the field as a quick way to identify and classify soils into distinct categories. It can also be used in the laboratory as a supplement to ASTM D 2487. In cases where exact soil identification is necessary, ASTM recommends the use of ASTM D 2487.

This method assumes a basic understanding of the mechanical characteristics of soils in relation to appearance. ASTM D 2488 (Note 4) states that "the ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics."

2.0 Definitions

This method relies on a basic understanding of particle definitions. The following terms are used throughout the specification. The following terms are defined according to ASTM D 2488.

Cobble: particles of rock that will pass a 300 mm square opening and be retained on a 75 mm sieve.

Boulder : particles of rock that will not pass a 300 mm square opening.

<u>*Clays*</u>: soil passing a 0.075 mm sieve that can be made to exhibit plasticity within a range of water contents, and that exhibits considerable strength when air dry. For classification, a clay is a fine-grained soil, or the fine-graded portion of a soil, with a plasticity index equal to or greater than four, and the plot of plasticity index versus liquid limit falls on or above the "A" line (Figure 1).

<u>*Silt*</u>: soil passing a 0.075 mm sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than four, or the plot of plasticity index versus liquid limit falls below the "A" line (Figure 1).

<u>*Organic Silt*</u>: a silt with sufficient organic content to influence soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75% of its liquid limit value before oven drying.

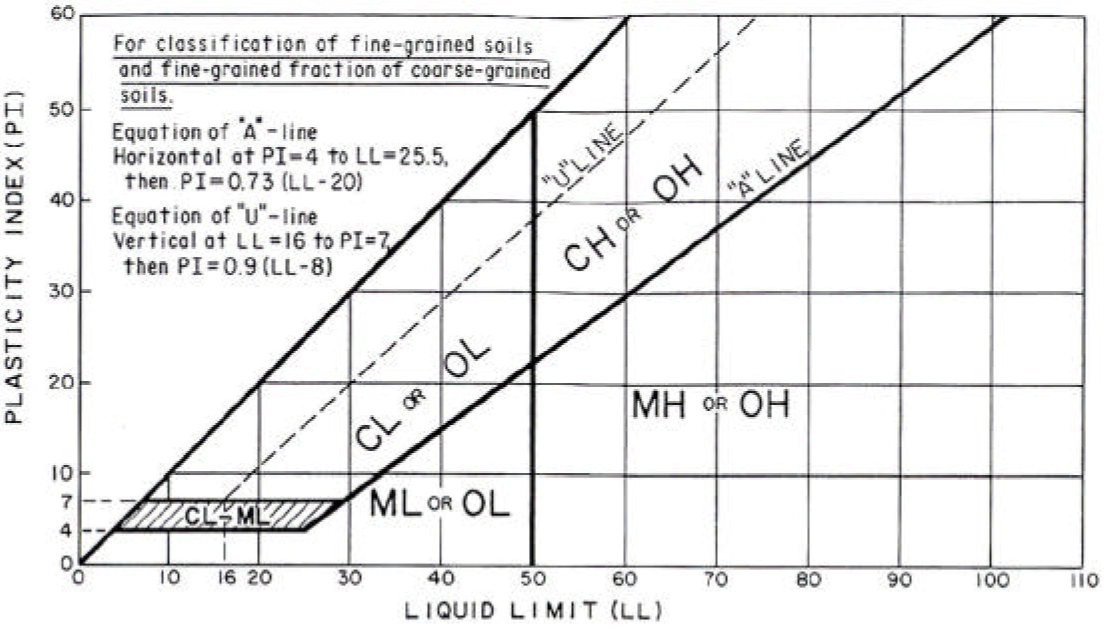


Figure 1: Plasticity Chart (Reprinted from ASTM D 2487).

Coarse Gravel: particles of rock that will pass a 75 mm sieve and be retained on a 19 mm sieve.

Fine Gravel: particles of rock that will pass a 19 mm sieve and be retained on 4.75 mm sieve.

Coarse Sand: particles of rock that will pass a 4.75 mm sieve and be retained on a 2.00 mm sieve.

Medium Sand: particles of rock that will pass a 2.00 mm sieve and be retained on a 0.425 mm sieve.

Fine Sand: particles of rock that will pass a 0.425 mm sieve and be retained on a 0.075 mm sieve.

Organic Clay: clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as clay, except that its liquid limit value after oven drying is less than 75% of its liquid limit value before oven drying.

Peat: soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.0 Sampling

Materials sampled for identification should be obtained under a recognized sampling specification. The origin (location) of the sample as it existed in the field should be duly noted on reporting forms. This includes station number or offset associated with a stated centerline, depth of exploration, location description with respect to a permanent monument, etc.

4.0 Procedure

Assigning group symbols and names to soil samples: Use the appropriate flow chart (Figures 2-4), adapted from ASTM D 2488, to determine soil type by gradation. This method assumes that the technician estimates the percentage of fines, sand, and gravel to the nearest 5%. Appendix X4 in ASTM D 2488 outlines several means for estimating the percentages of particles in a soil sample. Using the "jar method," the technician mixes the sample with water in a jar and allows the contents to settle. The larger particles will settle first, followed later by small particles. The volume that each particle size occupies within the jar can be used to estimate percentages.

In addition to particle size classification, ASTM D 2488 outlines several tests to be performed on soils to further describe them. Table 13 in ASTM D 2488 presents a checklist for Description of soils. Not all criteria are applicable to all samples. Consult ASTM D 2488 when classifying soil beyond a particle-size definition.

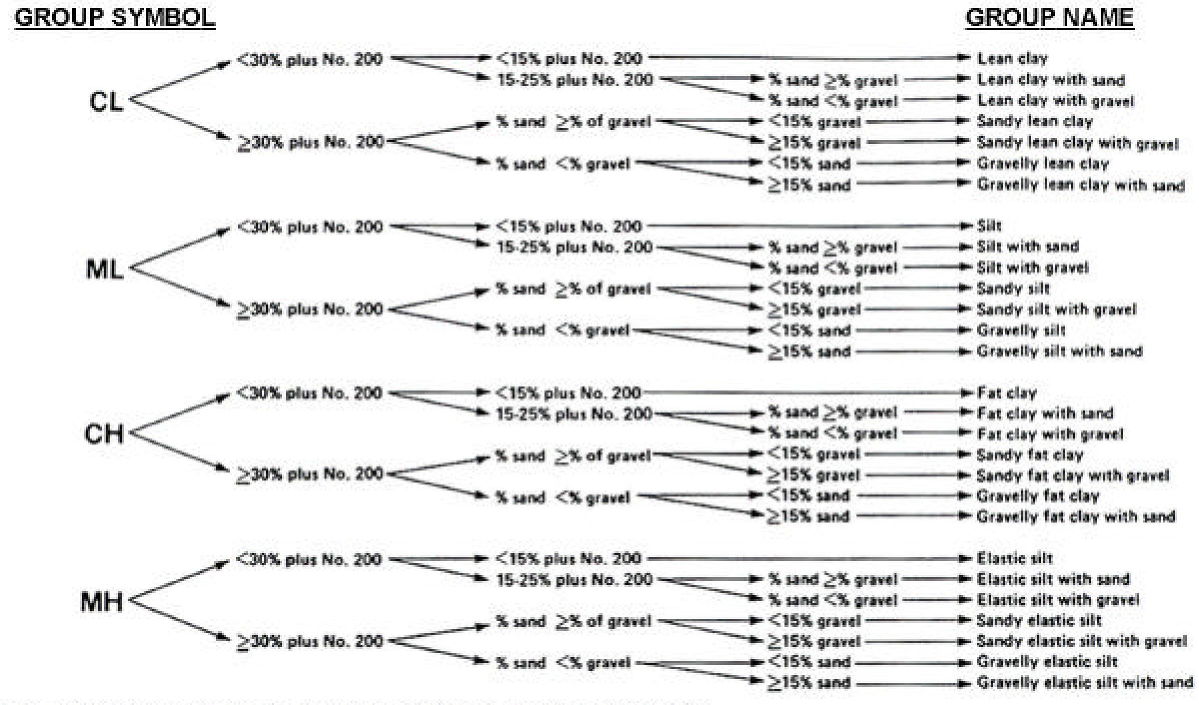
Some of the less obvious properties explored when performing a soils identification include:

(1) the soil hardness or reaction to a hammer blow (a soil is hard if the gravel portion does not crack, fracture, or crumble under a hammer blow)

(2) the dry strength of 12.5 mm balls crushed between the fingers (none, low, medium, high, very high)

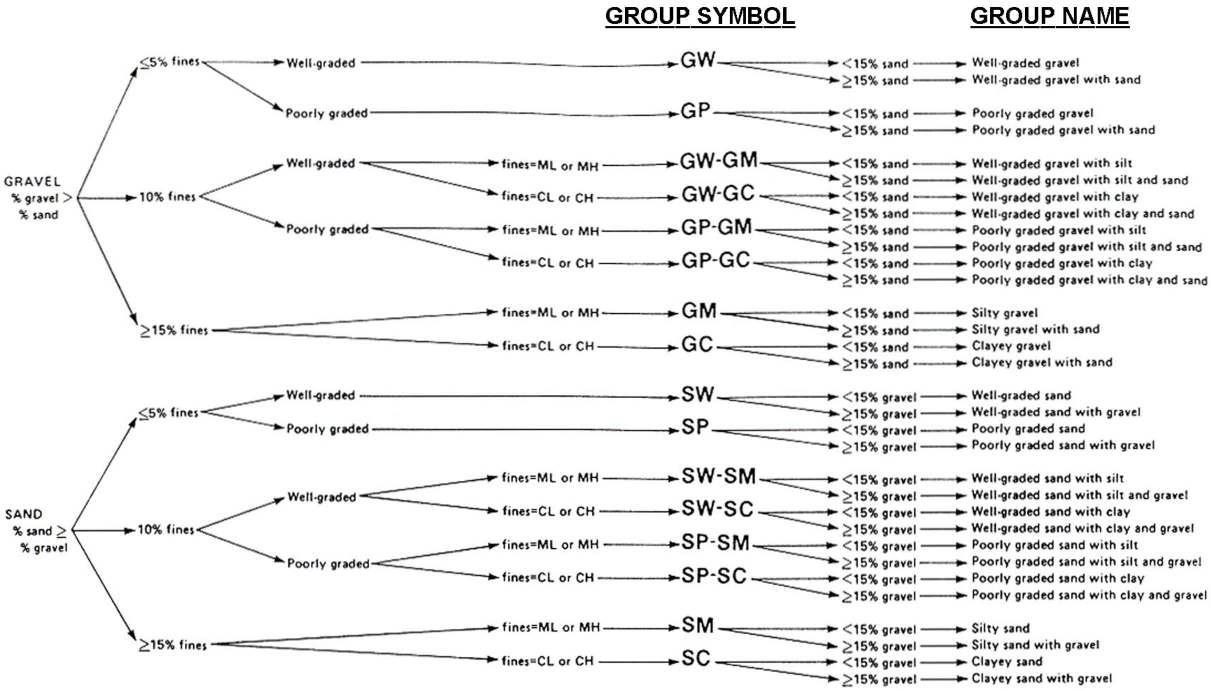
(3) the dilatancy of a 12.5 mm ball smoothed onto the palm of one hand and shaken horizontally against the other to note the tendency of water to form on the surface and then to be reabsorbed into the soil when squeezed (reaction noted as none, slow, or rapid)

(4) the toughness or relative pressure required to roll the soil into a 3 mm thread near the plastic limit (low, medium, or high)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

Figure 2: Reproduction of Flow Chart (Fig 1a in ASTM D 2488) to be used when identifying Inorganic Fine Grained Soils (50% or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

Figure 3: Reproduction of Flow Chart (Fig. 2 in ASTM D 2488) to be used when identifying Coarse Grained Soils (less than 50% fines)

Sample Test

True or False

1. This test procedure is used when classifying soils for precise determinations.
2. This practice is limited to identification of particles smaller than 75 mm.
3. By definition, gravel passes a 75 mm sieve and is retained on a 4.75 mm sieve.
4. Plasticity in general and the plasticity index specifically is used in the classification of certain types of soil.
5. By definition, sand passes a 9.5 mm sieve and is retained on a 0.075 mm sieve.

Family of Curves -- One Point Method

AASHTO T 272

1.0 Purpose

This procedure is useful for the quick determination of optimum moisture content and maximum dry density of a soil. It utilizes a family of curves and a one-point determination.

“A family of curves is a group of typical moisture-density relationships determined using AASHTO T 99, which reveal certain similarities and trends characteristic of the soil type and source. Soils from one source will have many different moisture-density curves, but if a group of these curves are plotted together certain relationships usually apparent. In general it will be found that higher unit mass soils assume steeper slopes with maximum dry densities at lower optimum moisture contents, while the lower unit mass soils assume flatter more gently sloped curves with higher optimum moisture contents” (AASHTO T 272, 2.1).

One-point determinations are made by compacting a mold of soil with a 2.5 kg rammer and a drop of 305 mm. There are four alternative procedures.

Method	**Requirements**
A	101.6 mm diameter mold*; soil material passing a 4.75 mm sieve
B	152.4 mm diameter mold*; soil material passing a 4.75 mm sieve
C	101.6 mm diameter mold*; soil material passing a 19.0 mm sieve
D	152.4 mm diameter mold*; soil material passing a 19.0 mm sieve
*Height: 116.43 +/- 0.13 mm (4.584 +/ .005 in)	

The preceding methods correspond to methods used in AASHTO T 99. For instance, if AASHTO T 99 Method C is used to form the family of curves, then Method C must be used for the one-point determination.

2.0 Apparatus

See AASHTO T 99, Section 2

3.0 Method A

3.1 Sample

See AASHTO T 99, Section 3

3.2 Procedure

1. Dampen the selected representative sample to approximately 4% below the optimum moisture content. Mix the sample thoroughly with water.
2. Compact the prepared soil in a 101.6 mm mold (with collar attached).

   ** Compact in three equal layers giving a total compacted depth of approximately 125 mm.

   ** Compact each layer by applying 25 uniformly distributed blows from the rammer.

   ** Rammer drop should be 305 mm above the elevation of the compacted soil.

   ** See Note 2 in AASHTO T 99 concerning the foundation to perform compaction on.

3. Remove extension collar. Use a straightedge to trim the compacted soil even with the top of the mold.
4. Determine the mold mass and moist soil mass in kilograms to the nearest 5 grams.
5. Determine the wet density (W_1) of the compacted in kilograms per cubic meter.

$$W_1 = (\text{Mass of compacted specimen and mold - mass of the mold}) \times 1060$$

6. Remove the material from the mold and slice vertically through the center
7. Obtain a representative sample from one of the cut faces and determine its mass immediately.
8. Determine the moisture content by drying the sample in an oven at 110 +/- 5°C (230 +/- 9°F) for a minimum of 12 hours or to a constant mass.

   ** The moisture sample must not have a mass less than 100 g.

4.0 Method B

4.1 Sample

Select the sample in accordance with AASHTO T 99, Section 4.3 with the exception that it must have a mass of approximately 7 kg.

4.2 Procedure

The procedure for Method B is identical to the Method A procedure with the following exceptions:

1. Use the 152.40 mm mold instead of the 101.6 mm mold.
2. Compact each layer with 56 uniformly distributed blows.

3. Determine W_1 (in kilograms per cubic meter of compacted soil by the following formula:

$$W_1 = (\text{Mass of compacted specimen and mold - Mass of mold}) \times 471$$

5.0 Method C

5.1 Sample

1. If the field sample is damp, dry under a trowel until it is friable.
2. Break up the aggregations throughly without reducing the natural size of individual particles.
3. Sieve the pulverized soil over the 19.0 mm sieve and discard any material that is retained. See Note 3 in AASHTO T 99, Sec. 8.2.
4. Select a representative sample from the material obtained in steps 1-3. The sample should have a mass of 5 kg or more.

5.2 Procedure

The procedure for Method B is identical to the Method A procedure with the following exception in Step 8: the moisture sample mass can not be less than 500 g.

6.0 Method D

6.1 Sample

Following the sample selection process as outlined in section 5.1 with one exception; the sample mass shall be approximately 11 kg.

6.2 Procedure

Follow the procedure for Method A (or C) with the following exceptions:

1. Use the 152.40 mm mold instead of the 101.6 mm mold.
2. Compact each layer with 56 uniformly distributed blows.
3. Determine W_1 (in kilograms per cubic meter of compacted soil by the following formula:

$$W_1 = (\text{Mass of compacted specimen and mold - Mass of mold}) \text{ x } 471$$

7.0 Calculations

The calculations proceed in the same manner as the AASHTO T 99 calculations.

1. Calculate the wet density (W_1) in kilograms per cubic meter

   Methods A and C: (mass of mold and soil - mass of mold) x 1060

   Methods B and D: (mass of mold and soil - mass of mold) x 471

2. Calculate the moisture content for each compacted sample by dividing the water content (loss between wet mass and dry mass for moisture sample) by the dry mass of the sample by multiplying by 100.

$$w = (\frac{M_1\ M_2}{M_2})\ X\ 100$$

w = moisture content of sample
M_1 = wet mass of soil
M_2 = dry mass of soil

3. Calculate the dry density (W) for each compacted sample in kilograms per cubic meter.

W=

$$(\frac{W_1}{w\ 100})\ x\ 100$$

4. Determine the moisture-density relationship by plotting density as the ordinates and the corresponding moisture contents as the abscissas.
5. Connect the points drawn on the moisture-density graph with a smooth curve. The moisture content corresponding to the peak of the curve will be termed the optimum moisture content.
6. The dry density at the optimum moisture content is the maximum dry density.

8.0 Optimum Moisture Content/Maximum Dry Density

The objective of the preceding calculations is to determine the moisture content and corresponding oven-dry density of the specimen. The dry density (y-axis) should be plotted against the corresponding moisture content (x-axis). This plot will define one point within or on the family of curves (See Figure 1 in AASHTO T 272).

See Appendix I for complete AASHTO T 272 test method for developing a moisture-density family of curves.

CHAPTER III

Soil Laboratory Technician

Specific Gravity of Soils

AASHTO T 100

1.0 Purpose

This method is used to determine the specific gravity of a soil mass. The main use of specific gravity information is for hydrometer calculation which determines particle size distribution of grain sizes too small to measure with standard sieves. Other uses include: computation of the void ratio and soil density.

The specific gravity of any substance is defined as the density of the material divided by the density of distilled water at a stated temperature. The density of gas free distilled water at STP (standard temperature and pressure) is 1.000g/cc. The mass of the displaced water is used to indirectly measure the volume of the mass under question. Density is then calculated as the mass to volume ratio.

2.0 Apparatus

Pycnometer: AASHTO allows either a volumetric flask (Figure 1) or a stoppered bottle. The volumetric flask needs to have a capacity of at least 100 ml. A 500 ml capacity flask is required for samples of clay that contain their natural moisture. Stoppered bottles must have a capacity of least 50 ml. The stopper must be made of the same material as the bottle, and must be of a size that "it can be easily inserted to a fixed depth in the neck of the bottle, and shall have a small hole through its center to permit the emission of air and surplus water" (AASHTO T 100, 5.1.1).

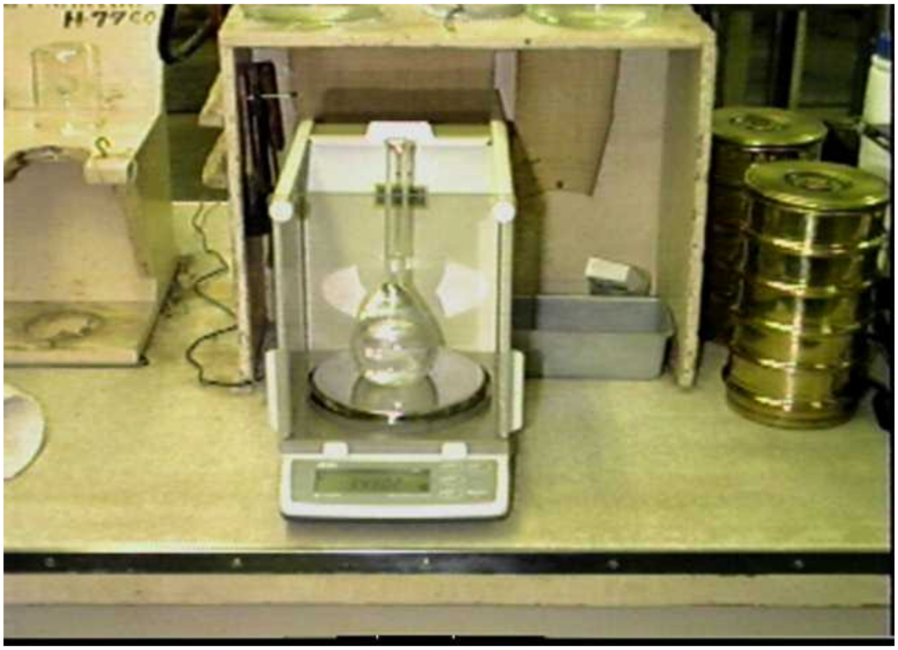


Figure 1: Weighing pycnometer.

Balance: For volumetric flasks, an AASHTO M 231 Class C balance sensitive to 0.01 g must be used. For stoppered bottles, and AASHTO M 231 Class B balance sensitive to 0.001 g must be used.

Oven: Drying oven capable of maintaining a consistent temperature of 110 +/- 5° C.

Thermometer: Must cover the range of 0 to 50° C readable and accurate to 1° C.

3.0 Sample Preparation

This method is for particles passing the 4.75 mm sieve. If the material to be tested contains particles larger than the 4.75 mm sieve, then that portion of the sample should be run using AASHTO T 85, Test for Specific Gravity and Absorption of Coarse Aggregate. Note 1 in T 100 indicates a weighted average formula to be used when combining the T 85 procedure for material retained on the 4.75 mm sieve and the T 100 procedure for material passing the 4.75 mm sieve.

When determining the specific gravity of soils for the hydrometer analysis, this method is run on the material passing the 2.00 mm sieve.

This method is to be used on samples where the particles are relatively insoluble to water. Materials which contain “extraneous matter (such as cement, lime, etc.), water-soluble mater (such as sodium chloride), and soils containing matter with a specific gravity of less than one, typically require special treatment or a qualified definition of specific gravity” (AASHTO T 100, 4.2).

4.0 Calibration of Pycnometer

1. Clean, dry, and weigh the pycnometer and record its mass, W_f.
2. Fill the pycnometer with distilled water at room temperature. The mass of the pycnometer and the water (W_a) should be determined and recorded.

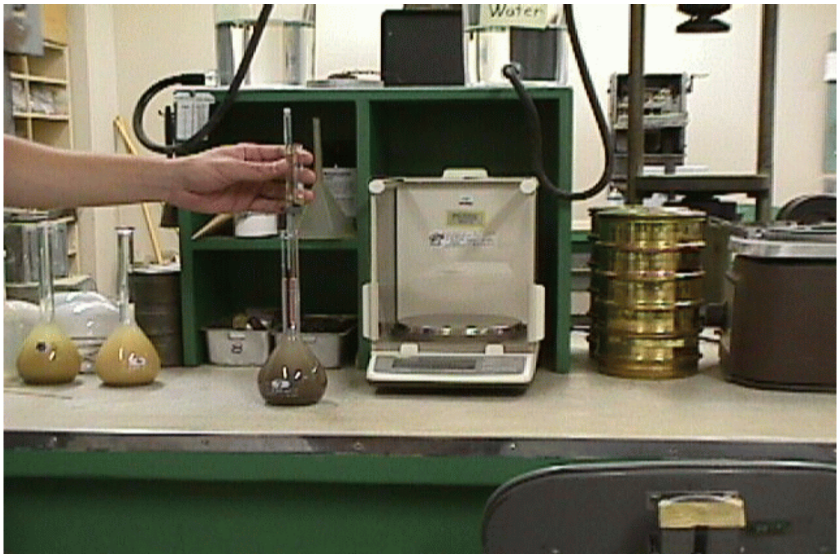


Figure 2: Measuring temperature of pycnometer.

3. Take the temperature of the water in the pycnometer (Figure 2). This observed temperature (T_i) will be used as the temperature reference. Table 1 indicates the relative density of water to be used in determining the variation in the mass of the pycnometer and water over the expected range of temperatures.

$$W_a@T_x = \frac{density\ of\ water\ @T_x}{density\ of\ water\ @T_i}\ x\ (W_a@T_i - W_f) + W_f$$

Where: Wa = mass of pycnometer and water, in grams

Wf = mass of pycnometer, in grams
T_i = observed temperature of water, in degrees C
T_x = any other observed temperature, in degrees C

Temperature, deg C	Relative density of water	Correction Factor, K
18	0.9986244	1.0004
19	0.9984347	1.0002
20	0.9982343	1.0000
21	0.9980233	0.9998
22	0.9978019	0.9996
23	0.9975702	0.9993
24	0.9973286	0.9991
25	0.9970770	0.9989
26	0.9968156	0.9986
27	0.9965451	0.9983
28	0.9962652	0.9980
29	0.9959761	0.9977

Table 1: Correction factors used to determine the density of water at various temperatures.

Calibration Example:

Determine the mass of the pycnometer at 29°C. With W_a @ T_i = 679.73; T_i = 24°C; W_f = 178.93. Calculate W_a @ T_x for a single pycnometer over the range of expected test temperatures.

Wa @ 29°C = (0.9959761/0.9973286) x (679.3-178.93) + 178.93 = 679.0508537

Wa @ 29°C = 679.05

5.0 Sample Preparation

1. The sample used for this test may be oven-dried or contain its natural moisture. The mass on an oven-dry basis should be at least 25 g when using the volumetric flask, or 10 g when using the stoppered bottle.
2. If the sample contains its natural moisture, determine its oven dry mass at the end of the procedure by drying it in an oven maintained at 110 +/- 5°C (230 +/- 9°F). Drying some soils at lower pressures and temperatures may be necessary to reduce the potential for hydration. Clay samples that contain a natural moisture content should be dispersed in distilled water prior to placement in the 500 mL flask using the dispersing equipment specified in AASHTO T 88 (Hydrometer Test). Clay samples need to be dispersed completely in order to obtain an accurate determination of specific gravity.
3. When using oven dried samples, the sample should be dried for a minimum of 12 hours in an oven maintained at 110 +/- 5°C (230 +/- 9°F), cooled to room temperature, weighed and placed into the pycnometer, or placed into the pycnometer and weighed.

4. Add distilled water at room temperature to the pycnometer so that the sample is completely covered and approximately 3/4 full for the volumetric flask, or about ½ full for the stoppered bottle. Allow the sample to soak for a minimum of 12 hours before proceeding with the test.
5. Remove the entrapped air from the sample using either the boiling method or the partial vacuum method.

Figure 3: **Boiling soil in pycnometer on hot-plate.**

<u>Boiling Method:</u>

Place the pycnometer on a hot plate (see Figure 3) and gently boil the sample for 10 minutes, while occasionally rolling the pycnometer to assist in the removal of air. Samples boiled will be cooled to room temperature before proceeding with the test.

Vacuum Method:

Subject the contents of the pycnometer to a partial vacuum of 13.33 kPa or less absolute pressure by connecting to an aspirator or vacuum pump or by use of a bell jar. It may be necessary to reduce the pressure for some soils since they will boil violently under vacuum. Notes 7 and 8 in AASHTO T 100 indicate that water may be added in layers when using the vacuum in order to remove air from the water in stages. Samples with natural moisture and high plasticity may take 6 to 8 hours to deair. Samples with low plasticity may take 4 to 6 hours to deair. Oven dried samples generally take 2 to 4 hours to deair. During the vacuum phase, samples should be agitated gently at intervals to assist in the removal of air.

6. Fill the pycnometer to its calibrated capacity at room temperature, dry off the surface of the pycnometer, and weigh. Record the temperature of the pycnometer, and weigh. Record the temperature of the pycnometer and its content to the nearest °C and use the previously determined calibration procedure to determine the mass of the pycnometer and sample (W_a) at the measured temperature (T_i).

6.0 Calculations

Calculating the specific gravity of the soil at T_x:

$$\textit{Specific Gravity, } \frac{T_x}{T_x} \quad \frac{W_o}{[W_o\ (W_a\ W_b)]}$$

Where: W_o = mass of oven-dried soil, g
W_a = mass of pycnometer filled with water @T_x, g
W_b = mass of pycnometer filled with water and soil @T_x, g
T_x = temperature of the water @W_b

Correction of the specific gravity at Tx to 20°C:

$$Specific\ Gravity,\ \frac{T_x}{20°C} = K\ x\ (Specific\ Gravity,\ \frac{T_x}{T_x})$$

Where: K = value from Table 1. K is determined by dividing the relative density of water @T_x by the relative density of water at 20°C

Example Calculation:

Wo = 25.687 g

Wa @ 25°C = 679.732

Wb @ 25°C = 696.091

Specific Gravity @ 25°C = 25.687/[25.687+(679.732 - 696.091)]

Specific Gravity @ 25°C = 2.754

Correction @ 25°C to 20°C = 0.9989(2.754)

Specific Gravity @ 20°C = 2.751

When using the volumetric flask, report specific gravity values to the nearest 0.01. When using the stoppered bottle, report specific gravity values to the nearest 0.001. Indicate on the reporting form whether of not any of the original samples was discarded to perform the test.

Sample Test

True or False

1. Specific gravity is defined as the ratio of a mass of a given volume of a material at a stated temperature to the mass in air of the same volume of gas-free distilled water at a stated temperature.
2. The specific gravity of soils is performed on particles passing the 2.36 mm sieve.
3. This method is equally applicable for soils that contain water soluble materials.
4. The volumetric flask must be used for this test method. Other types of containers are not acceptable.
5. The pycnometer must be calibrated in order to determine its volume.
6. The standard test temperature for the water used in this test is 20°C (68°F).
7. Samples with natural moisture and high plasticity will deair more quickly than samples that are oven dried with low plasticity.
8. When using the volumetric flask, report the specific soil gravity to the nearest 0.001.
9. When performing the specific gravity on clay samples, special consideration needs to be followed, such as drying the material at a lower temperature or using dispersing equipment when adding the water to the sample.
10. If a non-standard temperature is measured at the conclusion of the test (anything other than 20°C), then the test needs to scrapped and rerun.

Sample Test

Calculation

Calculate the Specific Gravity for the following sample. Be sure to correct the specific gravity to the standard reading at 20°C.

W_o = 25.275 g

W_a @ 28°C = 583.825

W_b @ 25°C = 598.535

Particle Size Analysis of Soils by Hydrometer

AASHTO T 88

1.0 Purpose

This procedure makes a quantitative determination of the distribution of particle sizes in soils based on their rate of fall in liquid. The procedure is intended for particles passing the 0.075 mm (# 200) sieve. The data are plotted on a semi-log plot of percent finer vs. particle diameters and may be combined with data from the mechanical analysis. One important result of this test is to obtain the clay fraction (percent < 0.002 mm). The test is also valuable in identifying particle sizes (<0.02 mm) which could be susceptible to frost. The analysis is based on Stoke's Law.

In Stoke's Law, the rates of settling of spherical particles in a fluid are expressed by:

$$V = C\, r^2$$

V = velocity (cm/s)
r = particle's radius (cm)
C = constant

The prepared sample is dispersed and placed into a sedimentation cylinder. Then, the specific gravity of the solution with suspended particles is measured by the hydrometer. Measurements of specific gravity with correction for temperature and the specific gravity of the particles involved determine the percentage of the sample which has not yet settled. Measurement of the elapsed time, adjusted for depth of measurement, temperature, and specific gravity of the soil determines the maximum diameter of the particles still suspended at the effective depth.

2.0 Apparatus

Oven: Capable of maintaining a temperature of 110 +/- 5°C (230 +/-9°F) for drying the sieve analysis samples.

Balance: Conforming to the requirements of AASHTO M 231, general purpose balance

Stirring Apparatus: Mechanically operated apparatus (shake mixer), capable of turning the vertical paddle shaft at a rate of at least 10000 rpm. The shaft should be of such length so that the mixing paddle is between 19 mm and 37.5 mm from the bottom of the dispersion cup. Air jet dispersion devices may also be used and are discussed in further detail in AASHTO T 88.

Hydrometer: ASTM hydrometer, calibrated to read either in units of specific gravity or in grams per liter in suspension, conforming to requirements for hydrometers 151H or 152H, measuring grams per liter in suspension, since these calculations are slightly less involved than those used with hydrometer 151H.

Sedimentation Cylinders: Glass cylinder approximately 460 mm in height and 60 mm diameter and marked for a volume of 1000 mL.

Thermometer: Calibrated and readable to 0.5°C.

Sieves: Series of sieves conforming to the requirements of AASHTO M 92. The normally required sieves are as follows: 75 mm, 50 mm, 25 mm, 9.5 mm, 4.75 mm, 2.00 mm, 0.425 mm, 0.075 mm.

Water bath or constant temperature room: Either needs to be capable of maintaining a temperature as near 20°C as possible.

Beaker: 250mL, and a Graduated cylinder to measure 125 mL.

Timing device: Clock or watch that indicates seconds.

Containers: For moisture content determination.

Miscellaneous: Glass rod for stirring sample mixture, jars for soaking samples in solution, wash bottles.

Dispersing agent: Solution of sodium hexametaphosphate and distilled water, at the rate of 40 g of sodium hexametaphosphate per liter of solution. Solution should be prepared frequently and should be adjusted to a pH of 8 or 9 by use of sodium carbonate in order to prevent a decrease in dispersing action.

3.0 Sample Preparation

The test sample for this procedure should be prepared using the dry prep method (AASHTO T 87).

The sample mass used for the sieve analysis is dependent on nominal maximum size of particles (see table below). The sieve analysis is performed on particles larger than the 2 mm sieve in accordance with AASHTO T 27 (Sieve Analysis of Fine and Coarse Particles, Sections I, pgs 31-42).

Nominal Maximum Size of Particles	Approximate Minimum Mass of Sample
75 mm	5 kg
50 mm	4 kg
25 mm	2 kg
9.5 mm	0.5 kg

AASHTO also stipulates alternate procedures for separating the larger particles from the finer particles using either a 4.75 mm or 0.425 mm sieve in lieu of the usual 2 mm sieve. Local specifications may dictate which sieve to use for the separation, but normally the 2 mm sieve is used and therefore this manual will discuss the procedure using only the 2 mm sieve.

Make the separation on the 2 mm sieve and obtain sub-samples from the portion passing the 2 mm sieve for hygroscopic moisture and hydrometer analysis. Sample mass for hygroscopic moisture should be a minimum of 10. Sample mass for the hydrometer portion of the test should be approximately 100 for sandy soils and approximately 50 for silty or clayey soils. Sample masses should be determined immediately or placed in air-tight containers until tested.

4.0 Determination of Composite Correction for Hydrometer Reading

Hydrometer readings are affected by the specific gravity of the solution, the temperature of the solution, and where the scale is read (top or bottom of the meniscus). All these considerations necessitate a “composite” correction on hydrometer readings for the sample in question. AASHTO T 88 recommends preparing a “blank” sample in a sedimentation cylinder (using the same proportion of solution and distilled water as would normally prevail for the sample cylinder) at a controlled (or several controlled) temperature(s) in order to ascertain what the “correction” factor for the reading on the scale should be. This may be done over an anticipated range of temperatures in order to determine the effect on actual readings during the test, or a companion blank may be tested at the same time as the test sample.

Hydrometer scales are designed to be read at the bottom of the meniscus. Because this is not possible with soil suspensions (the discolored water does not allow you to read the scale on the hydrometer at the bottom of the meniscus), the top of the meniscus should be read and a correction factor applied. When using hydrometer 152 H, the composite correction is the reading at the top of the meniscus in the "blank" sample minus zero.

5.0 Hygroscopic Moisture Determination

Determine the mass of a subportion of the material passing the 2 mm sieve for hygroscopic moisture content. Hygroscopic moisture is simply the moisture in equilibrium with that in the atmosphere to which the soil is exposed. All associated masses for hygroscopic moisture should be recorded to the nearest 0.01 g. Follow AASHTO T 265 (Laboratory Determination of Moisture Content of Soils, Sect I, pgs 25-30) in order to determine the moisture content.

6.0 Dispersion of Soil Sample

After weighing, samples for the hydrometer test need to be dispersed by being placed into a 250 mL beaker, covered with 125 mL of stock solution (prepared concentration of sodium hexametaphosphate, 40 grams per liter), stirred thoroughly with a glass rod and allowed to soak for a minimum of 12 hours.

After the 12 hour soaking period, empty the contents of the beaker into the dispersion cup. Make sure all of the sample in the beaker is washed into the dispersion cup. Add distilled water into the dispersion cup so that it is at least half full. Disperse the contents in the cup mechanically for a period of 60 seconds.

7.0 Hydrometer Procedure

1. After the 60 second dispersion, place the contents of the dispersion cup into the sedimentation cylinder. Be sure to rinse off the cup and paddles of the dispersion apparatus completely in order to obtain the entire sample.

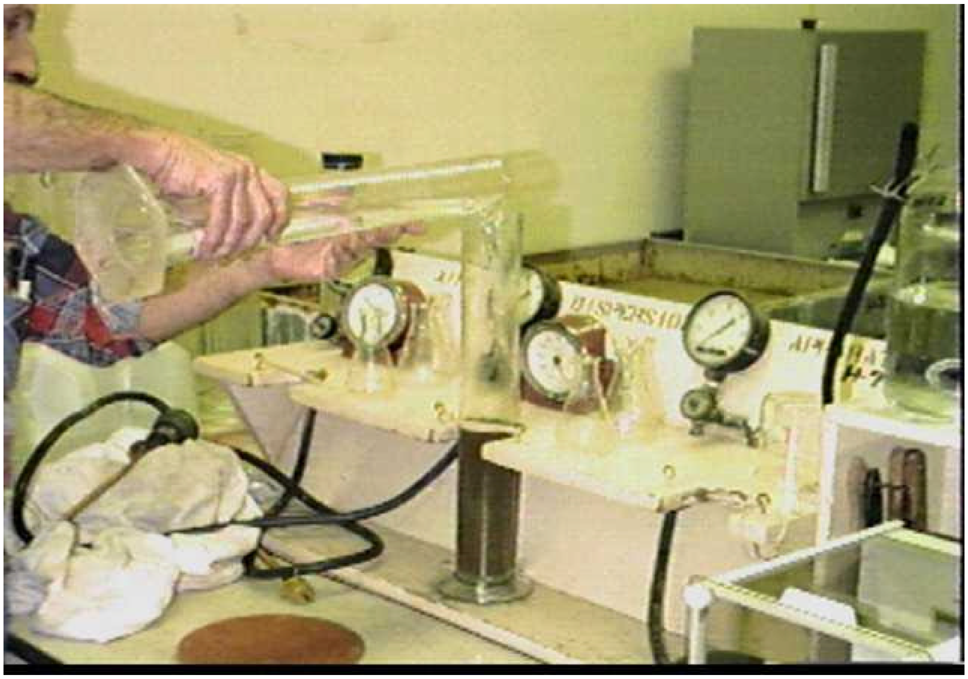


Figure 1: Adding distilled water to sample in sedimentation cylinder.

2. Add distilled water to the sample in the sedimentation cylinder (Figure 1). Make sure that the temperature of the distilled water and the sample are regulated at the test temperature, 20°C (68°F). This can be accomplished by controlling the temperature of the test room or using a constant temperature bath. Deviations from 20°C (68°F) can be compensated for but should not be so great as to make readings suspect with large correction factors.

Figure 2: Adding water to the calibration mark on the cylinder.

Add enough water so that the final volume of the specimen and the solution is 1 liter. Take care in adding water to the mark as the cylinder fills up (Figure 2). It is a good idea to use the eyedropper in order to achieve the proper height in the sedimentation cylinder.

3. Once the proper volume of the sample with solution is obtained, agitate the cylinder by covering one end with the palm of one hand and turn the cylinder upside down and back for a period of 60 seconds to agitate the slurry (Figure 3). Note 5 in AASHTO T 88 indicates that the number of turns during 60 seconds should be approximately 60, counting the turn upside down and back as two turns. Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

Figure 3: Agitating slurry in the sedimentation cylinder.

4. At the conclusion of the shaking, place the sedimentation cylinder on a level, firm surface, record the time, and allow the sample to settle. From this point to the completion of the test it is crucial to disturb the sedimentation cylinder as little as possible in order to allow the particles to fall naturally without any undue vibration. The sedimentation cylinder should also be placed in the constant temperature bath or be located in an area where temperature can be controlled for the duration of the test.

5. After 120 seconds have elapsed from the cessation of agitation, take the first reading of the sample using the hydrometer 152H.

   Some considerations when taking hydrometer reading: lower the hydrometer into the sample slowly, avoid disturbing the sample as much as possible. Do not drop the hydrometer into the cylinder, causing it to bob up and down through the sample. Do not allow the hydrometer to touch the sides of the sedimentation cylinder. The hydrometer should be placed into the sample several seconds prior to the required reading time in order to take an accurate reading at the prescribed time.

The hydrometer reading should be taken at the top of the meniscus formed by the suspension around its stem. The temperature of the sample should also be determined and recorded each time a hydrometer reading is taken.

6. Readings should be taken and recorded at the following times after the start of the test: 2 minutes, 4 minutes, 15 minutes, 30 minutes, 60 minutes, 250 minutes, and 1440 minutes. After each reading the hydrometer should be carefully removed from the sample and placed with a spinning motion into clear water in order to clean the hydrometer stem and bulb (Figure 4). Alternately, clean the hydrometer stem and bulb using a spray bottle.

Figure 4: Clean hydrometer stem and bulb between uses.

The number of readings taken and the length of time necessary to take those readings will depend upon the specific gravity of the particles in the sample and the requirements for determination of the minimum particle size. Samples which necessitate a determination down to the 0.001 mm particle size will take four times as long as determinations down to the 0.002 mm particle size. Readings are technically possible down to the 0.00024 mm size, below which particles are colloidal (smaller than clay) and will remain in suspension indefinitely. Practically, readings below the 0.001 mm size using this procedure are not normally taken and are not usually required by specifications.

7. At the conclusion of the hydrometer analysis, empty thoroughly wash the contents of the sedimentation cylinder over a 0.075 mm sieve (Figure 5). Dry the retained material in an oven maintained at 110 +/- 5°C (230 +/-9°F) to a constant mass in order to run a sieve .

Figure 5: Pouring finished hydrometer from sedimentation over 0.075 mm sieve.

analysis on materials passing the 2 mm and retained on the 0.075 mm sieve. Determination of particle percentages on particular sieve sizes should be specified by the specifying agency

8.0 Calculation Steps

1. Calculating percentage of hygroscopic moisture in sample (%M):

$$\%M = \left(\frac{W - W_1}{W_1}\right) 100$$

Where: W = mass of air dried soil

W_1 = mass of oven dried soil

2. Calculating percentage of soil in suspension(for Hydrometer 152H):

$$P = \left(\frac{Ra}{w}\right) 100$$

Where: P = percent of originally dispersed soil in suspension

R = corrected hydrometer reading

w = mass of dispersed soil (oven-dried basis)

a = value for density of suspension, use a value from Table 1 for nearest G of soil

Values of a for different specific gravities

Specific gravity, G (apparent)	Constant, a
2.95	0.94
2.85	0.96
2.75	0.98
2.65	1.00
2.55	1.02
2.45	1.04
2.35	1.06

Table 1. Specific gravity-suspension density constant

3. *Express percentage of soil in suspension as part of total sample mass:*

% of total mass = P x (100 - % retained on 2 mm sieve/100)

4. *Determine diameters of particles in soil suspension:*

$$D = K\sqrt{\frac{L}{T}}$$

Where: L = effective depth of hydrometer, from Table 2

T = time interval from beginning of test

K = constant based on test temperature and material specific gravity, from Table 3

Values of Effective Depth Based on Hydrometer 152H

Actual Hydrometer Reading	Effective Depth (L) (cm)	Actual Hydrometer Reading	Effective Depth (L) (cm)
0	16.3	31	11.2
1	16.1	32	11.1
2	16.0	33	10.9
3	15.8	34	10.7
4	15.6	35	10.6
5	15.5	36	10.4
6	15.3	37	10.2
7	15.2	38	10.1
8	15.0	39	9.9
9	14.8	40	9.7
10	14.7	41	9.6
11	14.5	42	9.4
12	14.3	43	9.2
13	14.2	44	9.1
14	14.0	45	8.9
15	13.8	46	8.8
16	13.7	47	8.6
17	13.5	48	8.4
18	13.3	49	8.3
19	13.2	50	8.1
20	13.0	51	7.9
21	12.9	52	7.8
22	12.7	53	7.6
23	12.5	54	7.4
24	12.4	55	7.3
25	12.2	56	7.1
26	12.0	57	7.0
27	11.9	58	6.8
28	11.7	59	6.6
29	11.5	60	6.5
30	11.4		

Table 2

Values for K for use in Particle Diameter Equation

Specific Gravity									
Temp °C	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.1374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.01323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01225	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

Table 3

Example Form and Grain Size Accumulation Curve

Temp, °C	Hydro. Reading	Hydro. Correction	Period of Sedimentation(minutes)	Max. Grain size (mm)	Actual Grain Size (mm)	Percent in suspension	
20	38	8	0.0				
20	35	8	0.5	0.112			
20	34	8	1.0	0.078			
20	31	8	2.0	0.055			
20	31	8	5.0	0.035			
20	29	8	15.0	0.020			
20	28	8	30.0	0.014			
20	28	8	60.0	0.010			
20	22	8	250.0	0.005			
20	20	8	1440.0	0.002			

Table 4

Sample Test

True or False

1. The particle size analysis of soils determines particle sizes below the 0.00024 mm diameter range.
2. The hydrometer reading should be taken at the top of the meniscus formed by the suspension around its stem.
3. When agitating the slurry by turning the sedimentation cylinder, a turn upside down and back counts as one turn.
4. Standard test temperature for the hydrometer test is 20°C (68°F).
5. Sodium hexametaphosphate solution should be prepared in concentration of 60 grams of sodium hex per liter of distilled water.
6. Sample size for the hydrometer portion of the grain size analysis should be minimum of 100 grams for sandy soils and a minimum of 50 grams for silty or clayey soils.
7. Composite corrections for hydrometer readings are a combination of corrections which correct for temperature, where the scale is read on the hydrometer, and the specific gravity of the suspension.
8. The settling of spherical particles falling through a fluid is described by Stoke’s Law.
9. Disperse the contents in the dispersion cup mechanically for 60 seconds.
10. Particle sizes determined by this method are measured in inches.

Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test

AASHTO T 87

1.0 Purpose

This method involves the preparation of soil samples, received from the field, for mechanical analysis, physical testing, or any other desired test. The practice is intended to provide qualitative information.

2.0 Apparatus

Balance: Must conform to the requirements of AASHTO M 231, general purpose balance.

Drying Apparatus: Any suitable device capable of drying samples at a temperature not exceeding 60°C.

Sieves: Series of sieves conforming to the requirements of AASHTO M 92. The following sizes are normally used: 19.0 mm, 4.75 mm, 2.00 mm, 0.425 mm. Other sizes may be required depending on the specific test (see Note 1 in AASHTO T 87).

Pulverizing Apparatus: Either a mortar and rubber-covered muller or a mechanical device (power-driven rubber-covered muller) suitable for breaking up aggregations of soil particles without reducing individual grain sizes.

Sample Splitters: A suitable riffle sampler or sample splitter for proportional splitting of the sample and capable of obtaining representative portions of the sample without appreciable loss of fines.

3.0 Sample Size

For AASHTO T88: For particle size analysis, material passing a 2.00 mm sieve is required in amounts equal to 110 g for sandy soils and 60 g for silty or clayey soils. A sufficient amount of material retained on either the 4.75 mm or 2.00 mm sieve is required (See Note 4 in AASHTO T 88) to obtain a representative gradation, and depending on the maximum particle size, shall not be less than amounts in the following table.

Diameter of largest particle (mm)	Approximate minimum mass of portion (kg)
9.5	0.5
25	2.0
50	4.0
75	5.0

For AASHTO T100: For the specific gravity test performed in conjunction with AASHTO T 88, material passing the 2.00 mm sieve is required in the following oven-dry amounts: 25 g when the volumetric flask is used and 10 g when the stoppered bottle is used.

For physical tests: For the physical tests, at least 300 g of the material passing the 0.425 mm sieve is required, allocated as follows:

Test	Approximate Mass (g)
Liquid limit (T 89)	100
Plastic limit (T 90)	20
Shrinkage factors (T 92)	30
Field moisture equivalent (T 93)	50
Check and referee tests	100

For other tests: For quantity of material required for testing, refer to the specific method of test.

4.0 Initial Preparation of Test Samples

1. Thoroughly dry the field sample in air or using a drying apparatus at a temperature not exceeding 60°C (140°F).
2. Obtain a representative test sample, required by the test, using the sampler or by splitting or quartering.
3. Break up the aggregation of soil particles using the pulverizing apparatus.
4. Weigh the portion of the dried sample selected for testing. Record the mass as the mass of total sample uncorrected for hygroscopic moisture.
5. Separate this portion of the sample into fractions using one of the following methods:

   Alternate Method 1: 2.00 mm sieve

   1) Separate the dried sample into two fractions using a 2.00 mm sieve.
   2) Ground the fraction retained on the 2.00 mm sieve using the pulverizing apparatus. Continue until the aggregations of soil particles are broken into individual grains.
   3) Separate the ground soil into two fractions using the 2.00 mm sieve.

   Alternate Method 2: 4.75 mm and 2.00 mm sieve

   1) Separate the dried sample into two fractions using a 4.75 mm sieve.
   2) Ground the fraction retained on the 4.75 mm sieve using the pulverizing apparatus. Continue until the aggregations of soil particles are broken into individual grains.
   3) Separate the ground soil into two fractions using the 4.75 mm sieve.

4) Thoroughly mix the fraction passing the 4.75 mm sieve by the use of the sampler or by splitting and quartering.
5) Obtain a representative sample adequate for the desired tests and weigh it.
6) Separate the split-off portion using the 2.00 mm sieve and process it as in Alternate Method 1.
7) Weigh the material from the split-off portion retained on the 2.00 mm sieve. This will be used for coarse sieve analysis computations.

5.0 Samples For Particle Size Analysis and Specific Gravity

1. Set aside the fraction retained on the 2.00 mm sieve or 4.75 mm sieve (Alternate Methods 1 or 2), after the second sieving, for use in the sieve analysis of the coarser material.
2. Thoroughly mix the fraction passing the 2.00 mm sieve (from Alternate Methods 1 or 2) using the sampler or by splitting or quartering. Obtain representative samples as follows:
   ** For hydrometer analysis and sieve analysis of the fraction passing the 2.00 mm sieve, obtain 110 g for sandy soil and 60 g for silty/clayey soil.

   ** For specific gravity, obtain 25 g when using the volumetric flask and 10 g when using the stoppered bottle.

6.0 Samples For Physical Tests

1. Using the 0.425 mm sieve, separate the remaining portion of the material passing the 2.00 mm sieve into two parts.

2. Using the pulverizing apparatus, ground up the fraction passing the 0.425 mm sieve. This should be done in a manner as not to break up the individual grains while breaking up the aggregations.
3. Separate the ground soil into two fractions using the 0.425 mm sieve. Then reground the material as before

   ** If the grinding process produces little material passing the 0.425 mm sieve, discard the material retained on the sieve.
4. Retain, for testing purposes, the several fractions passing the 0.425 mm sieve obtained from the grinding and sieving operations described previously.

7.0 Samples For Moisture Density Relations

1. Separate the portion of dried soil, selected for the moisture density relations test, using the sieve required by Section 3.0.
2. Break up the aggregations of soil particles retained on the specified sieve, if necessary.
3. Separate the ground soil into two fractions using the required sieve
4. The fractions passing the required sieve in both sieve operations should then be thoroughly mixed and used for the moisture density test.

Unified Classification System of Soils

ASTM D 2487

1.0 Purpose

This standard describes the arrangement of different soils with similar properties into groups and subgroups based on applications. The method is based on the following factors: liquid limit, plastic limit, and grain size distribution curve. It is to be used when precision classification is required. The standard is a useful first step in any field or lab investigation of soil.

The use of this method will almost always yield a single classification group symbol and group name. Exceptions to this include: when a soil contains 5 to 12% fines or when the plot of liquid limit and plasticity index values fall into the area of cross-hatched area on the plasticity chart. In these cases, dual symbols are used. For borderline cases, where results indicate that a soil is close to another soil classification group, two symbols separated by a slash should be used. The borderline cases are particularly important when trying to establish expansive potential.

2.0 Terminology

Cobbles: particles of rock that will pass a 300 mm sieve and be retained on 75 mm sieve.

Boulders: particles of rock that will not pass a 300 mm sieve.

Gravel: particles of rock that will pass a 75 mm sieve and be retained on 4.75 mm sieve.

Types of gravels:

1) ***Coarse***: passes a 75 mm sieve and retained on 4.75 mm sieve.

2) ***Fine***: passes a 19 mm sieve and retained on 4.75 mm sieve.

Sand: particles of rock that will pass 4.75 mm sieve and be retained on a 0.075 mm sieve.

Types of sand:

1) ***Coarse***: passes 4.75 mm sieve, retained on 2.00 mm sieve.

2) ***Medium***: passes 2.00 mm sieve, retained on 0.425 mm sieve.

3) ***Fine***: passes 0.425 mm sieve, retained on 0.075 mm sieve.

Clay: soil passing a 0.075 mm sieve that can be made to exhibit plasticity or putty-like properties. Clay exhibits a high degree of strength when air-dry.

Silt: soil passing the 0.075 mm sieve that is nonplastic or only slightly plastic. Silt exhibits little or no strength when air dry

Organic Clay: clay with sufficient organic content to influence the soil's properties.

Organic Silt: silt with sufficient organic content to influence the soil's properties

3.0 Preparation for Classification

Prior to classification by this standard, other tests must be run on the soil. The following information must be determined before the figures and tables in this standard can be used: (1) particle size distribution, (2) liquid limit (AASHTO T 89), (3) Plastic limit and plasticity index (AASHTO T 90).

4.0 Procedure

With the information obtained in section 3.0, classification is a simple matter of entering the figures and tables on the following pages.

1. Go to Figure 1 or 2. This will depend on how much material passes the 0.075 mm sieve.

   For soils with 50% or more passing 0.075 mm sieve:

   2. Determine whether or not the liquid limit falls above or below 50.
   3. Identify whether or not the soil is organic or inorganic.
   4. The PI will determine the group symbol.
   5. Follow the remaining of diagram or go to Figure 3 (Classifying Organic Soil) to determine a group name.

   For soils with 50% or more retained on 0.075 mm sieve:

   2. Determine whether the material is gravel (%gravel > %sand) or sand (%sand > %gravel).
   3. Use %fines, c_u and c_c values to determine a group symbol.
   4. Follow remainder of diagram to group name.

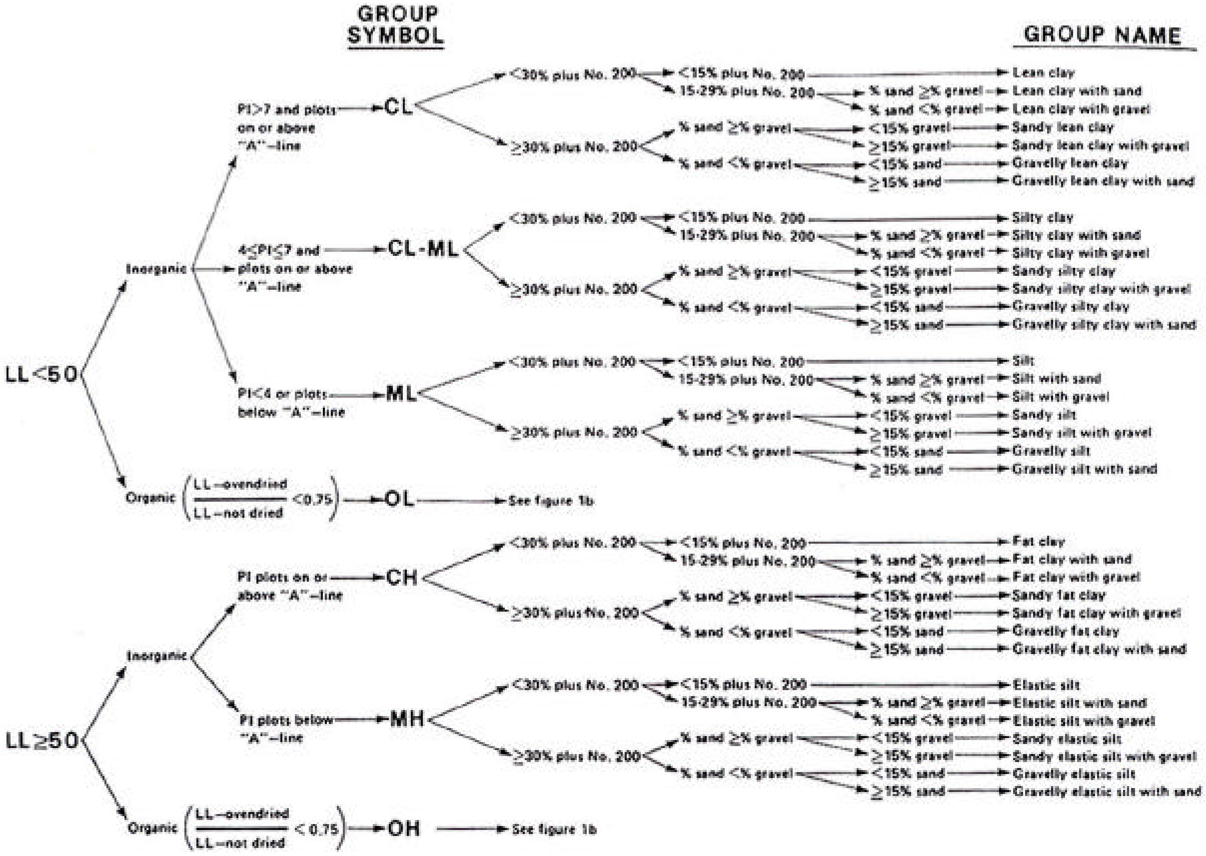


Figure 1: Flow Chart for Classifying Fine-Grained Soil (Reproduced from ASTM D 2487)

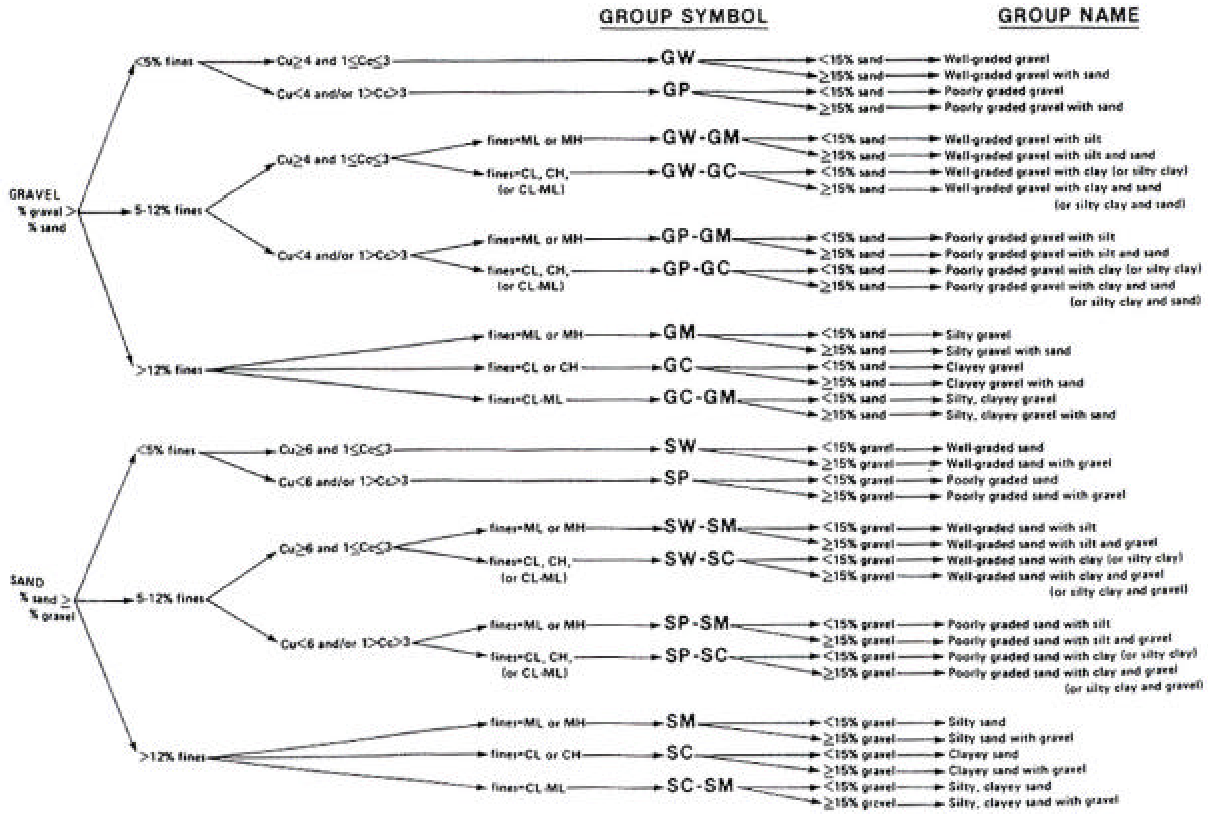


Figure 2: Flow Chart for Classifying Coarse Grained Soil (Reproduced from ASTM D 2487)

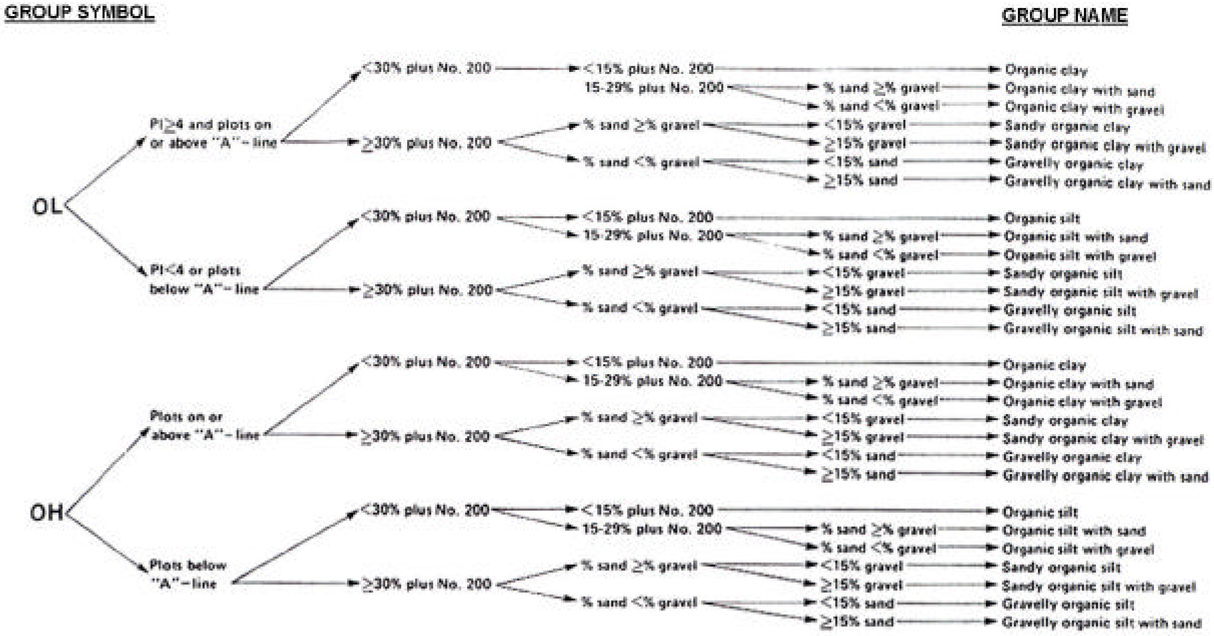


Figure 3: Flow Chart for Classifying Organic Fine-Grained Soil (Reproduced from ASTM D 2487)

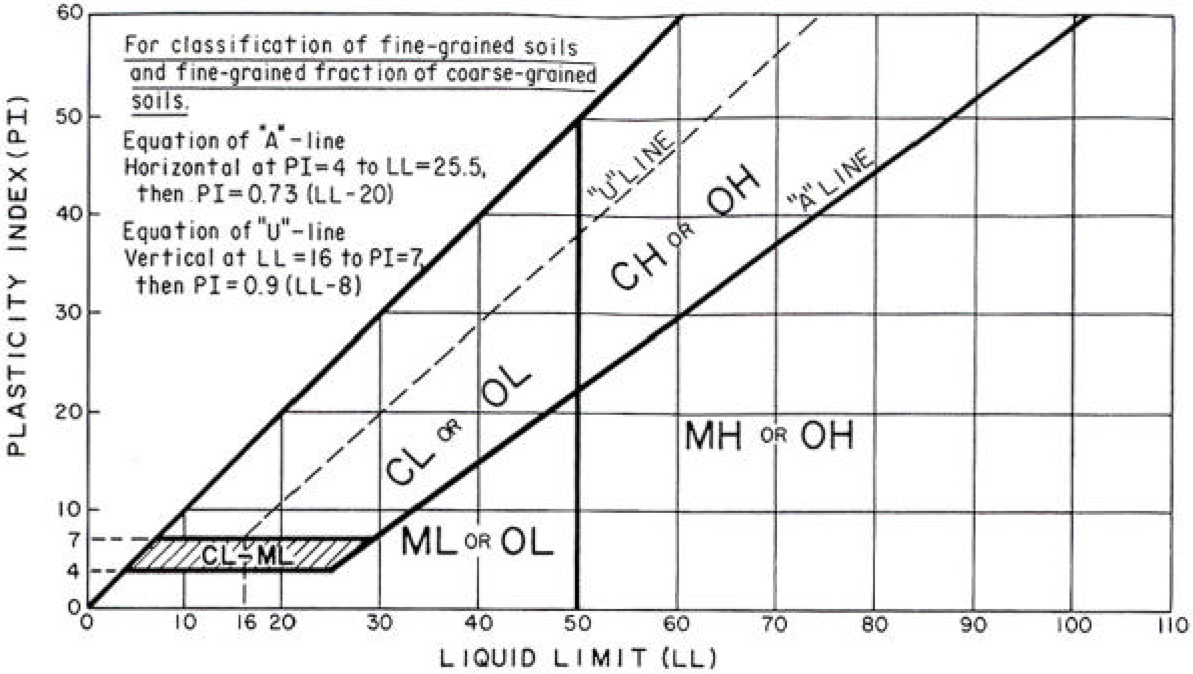


Figure 4: Plasticity Chart (Reproduced from ASTM D 2487)

Sample Test

True or False

1. The Unified classification system is based on the following factors: liquid limit, plastic limit and particle size distribution.

2. This method will always yield a single classification group symbol and group name.

3. The Unified system classifies soils into two broad categories, fine-grained and coarse-grained soils.

Given the following values, classify the soil by the ASTM D 2487 method giving the group symbol and group name:

- ☐ Gravel fraction (retained on No. 4 sieve) = 10%
- ☐ Sand fraction (passing No. 4 sieve, but retained on No. sieve) = 82%
- ☐ Silt and Clay (passing No. 200 sieve) = 8%
- ☐ Liquid limit = 39
- ☐ Plasticity Index = 8
- ☐ Cu = 3.9
- ☐ Cc = 2.1

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APPENDIX I

AASHTO/ASTM/KT Standards

5.16.51 FIELD DENSITY AND MOISTURE TESTS OF SOILS BY NUCLEAR GAUGE - TROXLER 3411-B (Kansas Test Method KT-51)

a. SCOPE

This method of test covers the procedure for measuring the "in-place" density and moisture of soils by the attenuation of gamma and neutron radiation. The intensity of the radiation detected is dependent in part on the density of the material being tested. It should be recognized that the density and moisture determined by this method is not necessarily the average value within the measured volume at any one location. KT-51 reflects testing procedures found in AASHTO T-238 and T-239. **The equipment utilizes radioactive materials which may be hazardous to the health of users unless proper precautions are taken (SOM 1.13.2).**

b. APPARATUS

b.1. General.

b.1.a. *Probe*. Either the gamma source or the gamma detector shall be housed in a probe for insertion into a preformed hole of the material to be tested. The probe shall be marked in increments of 50 mm (2 in) for tests with probe depths from 50 mm (2 in) to a maximum of 300 mm (12 in). The probe shall be mechanically held in place when it is manually moved to the desired depth.

b.1.b. *Housing*. The source, detector, readout device, probe, and power supply shall be in housings of rugged construction that are moisture and dust proof.

b.1.c. *Guide*. A guide used for the hole forming device to make a hole normal to the prepared surface.

b.1.d. *Hole-forming Device*. An auger, pin, or similar device for forming a hole in the soil to accommodate the probe. The hole-forming device shall have a nominal diameter equal to or up to 3 mm (1/8 in) greater than the probe diameter.

b.2. Standardization.

b.2.a. Standardization of the nuclear gauge on a reference standard block is required at the start of each day's use and when test measurements are suspect.

b.2.b. Warm up the nuclear gauge in accordance with the manufacturer's recommendations.

c. GAUGE PREPARATIONS

c.1. Taking Reference Standard Count.

Put the time switch in the SLOW (4 minute) position and take a reading on the reference standard block. This reading should be within 1standard count. The two numbers should be within 1and within 2machine for malfunction.

c.2. Checking Density Calibration Curves.

The calibration curves for newly acquired gauges should be checked. **All 3411-B gauges shall be subjected to a "factory" calibration at least once each year.** KDOT gauges shall be calibrated at the Materials and Research Center.

NOTE a: If KT-11 is used for moisture determination instead of the nuclear gauge, then skip **c.3.** Determining Moisture Correction Factor Using the Nuclear Gauge.

c.3. Determining Moisture Correction Factor Using the Nuclear Gauge.

c.3.a. Determinations* by the nuclear method are to be compared with moisture quantities described under KT-11 **b. CONSTANT WEIGHT METHOD**. Moisture samples shall be extracted from the same location the nuclear gauge readings are taken. At least 6 separate locations are required. Discard the location(s) with the greatest deviation to leave 5 pair of samples for analysis. Prepare the test site and proceed as stated in **d. TEST PROCEDURE** of this test method.

* A determination represents 3 one-minute or 1 four-minute wet density (WD) count readings from the gauge at one location.

c.3.b. Compare the six or more sample pairs of oven dry and nuclear gauge results from the locations listed above in **c.3.a.** Discard the sample pair(s) that deviates the greatest from the remaining five. Oven dry samples are to be at least 1 000 g and are to be taken under the center of the gauge to a depth of 150 to 200 mm (6 to 8 in). Nuclear tests are to be taken with the Moisture Correct set at 00 on the 3411-B scaler.

c.3.c. Prepare a chart of sample pairs as shown below:

Sample No.	%M Oven Dry (%M OD)	%M Gauge (% G)	Moisture Diff. (%M OD - %M G)
1	4.5	8.6	-4.1
2	4.0	5.9	-1.9
3	7.2	9.7	-2.5
4	6.7	8.6	-1.9
5 *	3.9 *	9.5 *	-5.6 *
6	4.7	8.6	-3.9
Average	5.4	8.3	-2.9 #

NOTE: "*" represents the discarded sample pair.
 # NOTE: If the Average Moisture Diff. exceeds +/- one percent, a Moisture Correction Factor will be required for that soil type.

c.3.d. The difference between the expected to vary from sample to sample due to normal variation. To determine the correction factor, calculate the average difference value and proceed as follows:

Calculate the Moisture Correction Factor using the average difference values, as follows:

$$\text{Moisture Corr. Factor} = \frac{1{,}000\ (\text{Avg. \%M Oven dry - Avg. \%M Gauge}}{100 + \text{Avg. \%M Gauge}}$$

In the example above, the moisture correction would be as follows:

$$\text{Moisture Corr. Factor} = \frac{1{,}000\left(5.4 - 8.3\right)}{100 + 8.3} = -27$$

The correction is independent of dry density and adjusts the apparent moisture to a true moisture regardless of dry density. **Dial this value into the Moisture Correction switches on the 3411-B scaler, paying particular attention to the algebraic sign.** This value can be used for all future tests on the same soil type.

NOTE b: Each soil type will have a moisture correction factor.

d. TEST PROCEDURE

d.1. Determine the number of soil types to be encountered on the project. If the number is substantial, then use KT-11 MOISTURE TESTS to determine the correct moisture content of the soil instead of calibrating the nuclear density gauge to moisture. **KT-11 c. GAS PRESSURE "SPEEDY" METHOD** can be used if the Speedy was calibrated within the last year.

d.2. Randomly select a test site where the gauge will be at least 300 mm (12 in) away from any slight vertical projection. If the vertical projection is significant, then maintain a distance of 3 m (10 ft) including all stationary vehicles and construction equipment. Vehicles and construction equipment in motion should maintain a **minimum** distance of 1 to 1.5 m (3 to 4 ft) from the gauge.

d.3. Prepare the test site in the following manner:

d.3.a. Remove all loose and disturbed material, and remove additional material as necessary to expose the top of the material to be tested.

d.3.b. Prepare a horizontal area, sufficient in size to accommodate the gauge by planing a level area to a smooth condition. This will create a maximum contact surface between the nuclear gauge and material being tested.

d.3.c. The maximum void beneath the gauge shall not exceed approximately 3 mm (1/8 in). Use native soil or fine sand to fill the voids and smooth the surface with a rigid plate or other suitable tool. The depth of the filler should not exceed approximately 3 mm (1/8 in).

d.3.d. Make a hole perpendicular to the prepared surface using the guide and the hole-forming device. The hole shall be of such depth and alignment that insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.

d.4. Proceed with testing in the following manner:

d.4.a. Tilt the gauge and extend the probe to the position required for the desired depth of test.

d.4.b. Insert the probe in the hole.

d.4.c. Seat the gauge firmly by moving it about the probe with a back and forth motion.

d.4.d. Pull gently on the gauge in the direction that will bring the side of the probe which faces the center of the gauge into intimate contact with the side of the hole.

d.4.e. Set the Power/Time switch to the "Normal" position (one minute position).

d.4.f. Turn the moisture correction switches to "00" or to the previously determined correction factor setting.

d.4.g. Press "Measure" key. After one minute the counting procedure will stop.

d.4.h. Press WD and record the Wet Density in kg/m^3 (PCF)
Press M and record the Moisture in kg/m^3 (PCF)
Press DD and record the Dry Density = (WD - M)

Press %M and record Percent Moisture = $\frac{100(M)}{DD}$

d.5. Take Gauge Reading

Secure and record 3 one-minute readings: Record the kg/m^3 (PCF) on Wet density (WD) and Moisture (M) for each reading. If any individual WD is not within ± 16 kg/m^3 (± 1.0 PCF) of the average, eliminate it along with its M reading from the average. Take another one-minute reading (to replace the values eliminated) and average these values with the non-deviant values. Test this new set of values by the above criteria. If two dry densities are not within ± 16 kg/m^3 (± 1.0 PCF) of the average, discard all three readings and start over again. When three readings meet the above criteria, record the average WD and the average M of the soil.

NOTE c: With the Troxler 3411-B series gauge, 1 four-minute count
(slow position) can be used instead of 3 one-minute counts (normal position). No averaging is then needed.

d.6. Determining Moisture Readings Using KT-11

Determine the moisture content of soil directly under the gauge according to KT-11.

If the soil fails to meet the designated compaction at a single location, rotate the gauge 180 degrees and take new readings. If the soil compaction still fails, then the compaction is inadequate.

e. CALCULATIONS WHEN USING KT-11

Calculate the Moisture in kg/m^3 (PCF) and subtract that quantity from the Wet Density (WD) determined by the gauge. This will yield the Dry Density (DD):

$$M = \frac{WD(\%M)}{(100 + \%M)}$$

$$DD = WD - M$$

$$\%PR = \frac{100(DD)}{SD}$$

where: M = Moisture content in kg/m^3 (PCF)
DD = Dry Density in kg/m^3 (PCF)
WD = Wet Density in kg/m^3 (PCF)
%PR = Percent of Proctor Density (also referred to as the Percent of Standard Density)
SD = Standard Density kg/m^3 (PCF)

f. SOIL IDENTIFICATION

f.1. Identification of the soil is required for several reasons. These include the comparison to the standards for optimum moisture content and target density which are required in order to determine compliance with the specifications; determining the proper moisture correction factors to be applied for the soil under test; and the reporting of the moisture and density tests results.

f.2. A selection of soil type is necessary in order to set the moisture correction factor for the 3411-B.

f.3. Nonhomogeneous soils may be encountered in which differences between gauges and oven are not consistent between samples. In this case, the use of KT-11 MOISTURE TESTS is the proper method for analyzing the moisture content of the soil.

TESTING:

Wet density and moisture are the only items the density gauge is capable of reading. All other values are calculated from wet density, moisture, and initialized information in the gauge.

5.16.52 FIELD DENSITY AND MOISTURE TESTS OF SOILS BY NUCLEAR GAUGE TROXLER 3440 (Kansas Test Method KT-52)

a. SCOPE

This method of test covers the procedure for measuring the "in-place" density and moisture of soils by the attenuation of gamma and neutron radiation. The intensity of the radiation detected is dependent in part on the density of the material being tested. It should be recognized that the density and moisture determined by this method is not necessarily the average value within the measured volume at any one location. KT-52 reflects testing procedures found in AASHTO T-238 and T-239. **The equipment utilizes radioactive materials which may be hazardous to the health of users unless proper precautions are taken (SOM 1.13.2).**

b. APPARATUS

b.1. General.

b.1.a. *Probe***.** Either the gamma source or the gamma detector shall be housed in a probe for insertion into a preformed hole of the material to be tested. The probe shall be marked in increments of 50 mm (2 in) for tests with probe depths from 50 mm (2 in) to a maximum of 300 mm (12 in). The probe shall be mechanically held in place when it is manually moved to the desired depth.

b.1.b. *Housing*. The source, detector, readout device, probe, and power supply shall be in housings of rugged construction that are moisture and dust proof.

b.1.c. *Guide*. A guide used for the hole forming device to make a hole normal to the prepared surface.

b.1.d. *Hole-forming Device*. An auger, pin, or similar device for forming a hole in the soil to accommodate the probe. The hole-forming device shall have a nominal diameter equal to or up to 3 mm (1/8 in) greater than the probe diameter.

b.2. Standardization.

b.2.a. Standardization of the nuclear gauge on a reference standard is required at the start of each day's use and when test measurements are suspect.

b.2.b. Warm up the nuclear gauge in accordance with the manufacturer's recommendations.

c. GAUGE PREPARATIONS

c.1. Taking Reference Standard Count.

c.1.a. Place the Reference Block on a flat surface at least 2 m (6 ft) from any building or structure and a minimum of 10 m (33 ft) from any other radioactive source. The surface can be asphalt or concrete pavement, compacted aggregate or a similar surface with density not less than 1,600 kg/m^3 (100 PCF). Do not use truck beds, tailgates, table tops, etc. The gauge automatically compares the new standard count to the average of the last four (4) STD Counts. The new standard will "pass" if it is not more (or less) than 1the moisture average of the last four counts. After taking the count, be sure to enter it in the log.

The "P" indicated to the right of the percentage figures indicates that the new counts are within the 1% percent density and the 2% moisture limits. If the percentages are not within these limits, an "F" will be displayed. If you do get an "F", or fail display, take a look around. Are any other gauges close by? Is the gauge seated correctly on the reference block? Are the gauge base and reference block top both clean? Is the reference block on a recommended surface? If all other conditions are normal, do not accept the standard count just taken. Press **NO** and take another standard count.

NOTE a: If the second count also fails, the old Standard Count sets should be replaced. This is accomplished by continuing to run and accept new Standard Counts until a PASS condition exist for both Density and Moisture.

Press **YES** to accept the new standard and enter it into memory. If "NO" is pressed, the new count is not accepted and the display returns to show the old values.

c.2. Checking Density Calibration Curves.

c.2.a. The calibration curves for newly acquired gauges should be checked. **All 3440 gauges shall be subjected to a "factory" calibration at least once each year.** KDOT gauges shall be calibrated at the Materials and Research Center.

NOTE b: If KT-11 is used for moisture determination instead of the nuclear gauge, then skip **c.3.** Determining Moisture Correction Factor Using the Nuclear Gauge and **c.4.** Enabling the Correction Factor. Go to **c.5.** Enabling Proctor Densities.

c.3. Determining Moisture Correction Factor Using the Nuclear Gauge.

c.3.a. Determinations* by the nuclear method are to be compared with moisture quantities described under KT-11 **b. CONSTANT WEIGHT METHOD**. Moisture samples shall be extracted from the same location the nuclear gauge readings are taken. At least 6 separate locations are required. Discard the location(s) with the greatest deviation to leave five pair of samples for analysis. Prepare the test site and proceed as stated in **d. TEST PROCEDURE** of this test method.

* A determination represents a four-minute count reading from the gauge at one location.

c.3.b. Compare the six or more sample pairs of oven dry and nuclear gauge results from the locations listed above in **c.3.a.** Discard the sample pair(s) that deviates the greatest from the remaining five. Oven dry samples are to be at least 1000 g and are to be taken under the center of the gauge to a depth of 150 to 200 mm (6 to 8 in). Nuclear tests are to be taken without ENABLING the Moisture Correction on the 3440 scaler.

c.3.c. Prepare a chart of sample pairs as shown below:

Sample No.	%M Oven Dry (%M OD)	%M Gauge (%M G)	Moisture Diff. (%M OD - %M G)
1	4.5	8.6	-4.1
2	4.0	5.9	-1.9
3	7.2	9.7	-2.5
4	6.7	8.6	-1.9
5 *	4.2 *	5.5 *	-1.3 *
6	4.7	8.6	-3.9
Average	5.4	8.3	-2.9 #

NOTE c: "*" represents the discarded sample pair.

 # NOTE: If the Average Moisture Diff. exceeds +/- one percent, a Moisture Correction Factor will be required for that soil type.

c.4. Enabling the Correction Factor

The difference between the %M Oven Dry and the %M Gauge is expected to vary in each soil type due to normal variation. To enable the correction factor, calculate the average moisture values for the Oven Dry and Gauge, and proceed as follows:

The Troxler 3440 Gauge is factory calibrated for soils, asphalts and concretes. On occasions when the gauge is to be used on materials that are not covered by the original calibration, the gauge may be adjusted to read these materials. This adjustment, or shift, is known as an **OFFSET**.

NOTE: When an Offset has been enabled, all future readings will automatically be adjusted with the offset regardless of the test site. It is very important that the operator DISABLE the offset function prior to taking readings on materials that <u>do not require an offset</u>.

Offset functions will be disabled if the gauge is turned off for more than 10 seconds.

Offsets will be required for an accurate measurement if the material to be measured has a density outside the range of 1100 to 2700 kg/m^3 (70 to 170 PCF) or if the material is high in a hydrogen-rich material such as cement, gypsum, coal or lime.

To Enable a "Moisture OFFSET" press number **2** on the original offset display.

```
- OFFSET - Select:
1 - Dens.  - OFF -
2 - Moist. - OFF -
3 - Trench - OFF -
```

After pressing number **2** the display will be:

```
Moisture Offset
  DISABLED
Do you want to
  ENABLE?
```

Press **YES** for the display:

```
Moisture Offset-
K = _._
Do you want a
new M - Offset?
```

To change press **YES**. (Pressing **NO** leaves the factors unchanged)

The display is:

```
    Select source
    of Offset
1 - gauge derived
2 - stored value
```

At this time, the user may select a previously stored offset or a gauge-derived value. The gauge-derived value may be a new value input via the keypad or an actual value recorded from a measurement.

From the last display, select **1** for the display:

```
SELECT:
1 - True M __ %
2 - Gauge M __ %
ENTER to enable
```

For a true gauge-derived offset two (2) values must be input. The *True Moisture* value which is the Average %M Oven Dry must be input. The *Gauge Moisture* which is the Average %M Gauge must also be input.

If the above values are correct, press ENTER.

To input a new *True Moisture* value, press **1** for the display:

True Moisture -
_____ %
Press ENTER
when completed

Input the Average %M Oven Dry value and press **ENTER.** To input a new *Gauge Moisture* value, press **2** for the display:

Gauge Moisture -
Select
1 - Keypad entry
2 - Measurement

To input the Average press %M Gauge from the table above via the keypad, press **1**.

The display is:

Gauge Moisture -
_____ %
Press Enter
when completed

Input the Average %M Gauge from the table above via the keypad, and press **ENTER.** The offset will be enabled and the display will return to **<READY>**.

Moisture Offset - Stored Value

To recall a previously stored moisture offset, press **2** from the last display.

The display will be:

Enter desired
memory location
of M - offset:
(1-4)

Input any number from **1** to **4** and press **ENTER** for the display:

```
   Moisture Offset
     ENABLED
    K = ________
```

The offset will be enabled and the display will return to **<READY>**.

NOTE d: Each soil type will have a unique moisture correction factor.

c.5. Enabling Proctor Densities.

The 3440 gauge will calculate the Proctor percent (%PR) automatically once Enabled. Up to 4 different Proctor values can be stored for later use.

To select or change a Proctor value press the **PROCTOR/MARSHALL** key for the display:

```
    MA=
    PR=
    VD=
Want to change?
```

If a value is to be enabled or a new value added or changed, press **YES**.

The display is:

```
    Select:
1 - MA
2 - PR
3 - Voidless
```

Marshall and Proctor functions are identical as far as operations are concerned. For this test procedure, only Proctor is of interest. To change a Proctor value, press **2** for:

```
Select source of
Proctor value:
1 - Stored value
2 - New Value
```

At this time, the user may select a previously stored Proctor or a new value. If no previously stored values exist then select **2** for the display:

Proctor:
0.0 PCF
Press ENTER
when completed

Input the Proctor value and press **ENTER**. The following display will be:

PR= **0.0** PCF
Do you want to
save this value
for later use?

Press **YES** for the following display:

Select Proctor
Memory Cell:
1= 0.0 2= 0.0
3= 0.0 4= 0.0

Select a memory cell location, enter the Proctor density, and press **ENTER**. The display will return to **<READY>**.

d. TEST PROCEDURE

d.1. Determine the number of soil types to be encountered on the project. If the number is substantial, then use **KT-11 MOISTURE TESTS** to determine the correct moisture content of the soil instead of calibrating the nuclear density gauge to moisture. **KT-11 c. GAS PRESSURE "SPEEDY" METHOD** can be used if the Speedy was calibrated within the last year.

d.2. Randomly select a test site where the gauge will be at least 300 mm (12 in) away from any slight vertical projection. If the vertical projection is significant, then maintain a distance of 3 m (10 ft) including all stationary vehicles and construction equipment. Vehicles and construction equipment in motion should maintain a minimum distance of 1 to 1.5 m (3 to 4 ft) from the gauge.

d.3. Prepare the test site in the following manner:

d.3.a. Remove all loose and disturbed material, and remove additional material as necessary to expose the top of the material to be tested.

d.3.b. Prepare a horizontal area, sufficient in size to accommodate the gauge by planing a level area to a smooth condition. This will create a maximum contact surface between the nuclear gauge and material being tested.

d.3.c. The maximum void beneath the gauge shall not exceed approximately 3 mm (1/8 in). Use native soil or fine sand to fill these voids and smooth the surface with a rigid plate or other suitable tool. The depth of the filler should not exceed approximately 3 mm (1/8 in).

d.3.d. Make a hole perpendicular to the prepared surface using the guide and the hole-forming device. The hole shall be of such depth and alignment that insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.

d.4. Proceed with testing in the following manner:

d.4.a. Tilt the gauge and extend the probe to the position required for the desired depth of test.

d.4.b. Insert the probe in the hole.

d.4.c. Seat the gauge firmly by moving it about the probe with a back and forth motion.

d.4.d. Pull gently on the gauge in the direction that will bring the side of the probe which faces the center of the gauge into intimate contact with the side of the hole.

d.4.e. Make sure the gauge is in the soils mode. To check this function, press shift and mode. Press **1** for **SOILS**. After a short delay, the display will return to **<READY>**.

d.5. Take Gauge Reading

Secure and record 1 four-minute reading: Record the kg/m^3 (PCF) on Wet Density (WD), Moisture (M), and percent of Proctor (%PR) of the soil. By entering the Standard Density of the soil into the gauge, **c.5.** Enabling Proctor Densities, the %PR will be calculated by the gauge.

d.6. Determining Moisture Readings Using KT-11

Determine the moisture content of soil directly under the gauge according to KT-11.

d.7. If the soil fails to meet the designated compaction at a single location, rotate the gauge 180 degrees and take new readings. If soil compaction still fails, then compaction is inadequate.

e. CALCULATIONS WHEN USING KT-11

Calculate the Moisture in kg/m^3 (PCF) and subtract that quantity from the Wet Density (WD) determined by the gauge. This will yield the Dry Density (DD):

$$M = \frac{WD(\%M)}{(100 + \%M)}$$

$$DD = WD - M$$

$$\%PR = \frac{100(DD)}{SD}$$

where: M = Moisture content in kg/m^3 (PCF)
%M = Percent of Moisture
DD = Dry Density in kg/m^3 (PCF)
WD = Wet Density in kg/m^3 (PCF)
%PR = Percent of Proctor Density (also referred to as the Percent of Standard Density)
SD = Standard Density (PCF)

f. SOIL IDENTIFICATION

f.1. Identification of the soil is required for several reasons. These include the comparison to the standards for optimum moisture content and target density which are required in order to determine compliance with the specifications; determining the proper moisture correction factors to be applied for the soil under test; and the reporting of the moisture and density tests results.

f.2. A selection of soil type is necessary in order to set the moisture correction factor for the 3440.

f.3. Nonhomogeneous soils may be encountered in which differences between gauges and oven are not consistent between samples. In this case, the use of **KT-11 MOISTURE TESTS** is the proper method for analyzing the moisture content of the soil.

TESTING:

Wet density and moisture are the only items the density gauge is capable of reading. All other values are calculated from wet density, moisture, and initialized information in the gauge.

APPENDIX II

Acronyms Used in the Soils Industry

Commonly Used Acronyms In The Soils Industry

AASHTO: American Association of State Highway and Transportation Officials

ASTM: American Society for Testing and Materials

LL: Liquid Limit

PI: Plasticity Index

PL: Plastic Limit

QA: Quality Assurance

QC: Quality Control

SSD: Saturated Surface Dry

APPENDIX III

Conversions from Metric to English Units

Conversions From Metric To English Units

Length:

1 m = 3.281 ft

1 cm = 3.281×10^{-2} ft

1 mm = 3.281×10^{-3} ft

1 m = 39.37 in

1 cm = 0.3937 in

1 mm = 0.03937 in

Area:

1 m^2 = 1550 in^2

1 cm^2 = 10.764×10^{-4} ft^2

1 mm^2 = 10.764×10^{-6} ft^2

1 m^2 = 10.764 ft^2

1 cm^2 = 0.155 in^2

1 mm^2 = 0.155×10^{-2} in^2

Force:

1 N = 0.2248 lb

1 kN = 224.8 lb

1 kgf = 2.2046 lb

1 kN = 0.2248 kip

1 N/m = 2204.6 lb

Volume:

1 m^3 = 35.32 ft^3

1 cm^3 = 35.32 x 10^{-4} ft^3

1 m^3 = 61023.4 in^3

1 cm^3 = 0.061023 in^3

Temperature:

Convert From	To	Equation
deg Fahrenheit (F)	deg Celsius (C)	(C) = [(F) - 32] + 1.8
Deg Celsius (C)	deg Fahrenheit (F)	(F) = [1.8 (C)] + 32

Sieves (Metric to English):

0.075 mm → No. 200

0.180 mm → No. 80

0.425 mm → No. 40

0.60 mm → No. 30

1.18 mm → No. 16

2.36 mm → No. 8

2.00 mm → No. 10

4.75 mm → No. 4

9.5 mm → 3/8 in

12.5 mm → ½ in

19.0 mm → 3.4 in

25.0 mm → 1.0 in

37.5 mm → 1 ½ in