MoDOT TM 79
AASHTO T 89 & T90

Plasticity Index
(Aggregate Specific)

MoDOT TM 79
AASHTO T 89 & T 90

Aggregate Preparation
Liquid Limit
Plastic Limit
Plasticity Index

Atterberg Limits

- Atterberg limits are simple tests to determine the moisture contents of a material at which the material moves from a solid to a semi-solid to a plastic and to a liquid state.
- Shrinkage Limit
- Plastic Limit
- Liquid Limit

Shrinkage Limit

- The point at which a material changes from a solid to a semi-solid.
- Shrinkage Limit will not be taught at this training.

Plastic & Liquid Limit

- Each material becomes less stable as the moisture increases.
- A material whose percent moisture content is greater than the Liquid Limit is soft and unstable.

AASHTO T 89 & T90 4

Plastic & Liquid Limit

- Plastic Limit is the point at which a material moves from a semi-solid to a plastic state.
- Liquid Limit is the point at which a material moves from a plastic to a liquid state.
- Both are used to determine Plasticity Index.

AASHTO T 89 & T90 5

Plasticity Index

- Plasticity Index is a number that is derived from subtracting the Plastic Limit from the Liquid Limit.
- Plasticity Index is not an Atterberg limit.

AASHTO T 89 & T90 6

Aggregate Preparation Procedure - Bases

- Prepare sample in accordance with MoDOT TM 79
- Obtain representative sample (30 to 40 lbs.)
- Reduce sample down to 500 to 2500 g (dependant on maximum aggregate size).

AASHTO T 89 & T90 7

Aggregate Preparation Procedure - Bases

- This process will produce 3 parts which will be used to make up the final sample.
- Sieve the material over the #40 (0.425 mm) sieve, set this minus #40 fraction aside. It is your **first part** of the final sample.
- Continue the next steps with the plus #40 fraction.

AASHTO T 89 & T90 8

Aggregate Preparation Procedure – Bases

- Place the plus #40 fraction in a pan and cover with water.
- Scrub the material to break up lumps.
- Wash over a # 40 sieve and retain wash water.
- Remainder of plus # 40 fraction will be oven dried @ 140°F (60°c) or less (may air dry).

AASHTO T 89 & T90 9

Aggregate Preparation Procedure - Bases

- When the plus # 40 fraction is dry, shake over a # 40 sieve to remove any additional minus # 40 material. Set this minus #40 material aside. This is your **second part** of the final sample.
- Allow the wash water to settle until clear
- Siphon off the majority of clear water and oven dry @ 140°F (60°c) or less (may air dry).

AASHTO T 89 & T90 10

Aggregate Preparation Procedure – Bases

- Note the low oven temperature which assures that any organic material in the sample remains intact.
- When dry, break material with mortar and pestle to pass # 40 sieve. This is your **third part** of the final sample.

AASHTO T 89 & T90 11

Aggregate Preparation Procedure – Bases

- The final sample is the combination of three minus #40 parts.
- The three parts are:
  - Minus #40 material when first sieved.
  - Minus # 40 material dry sieved off the scrubbed and dried plus #40 fraction.
  - Minus #40 material retrieved from the wash water.

  Mix these three parts thoroughly.

AASHTO T 89 & T90 12

Sample Preparation Procedure – Soils

- Soil preparation for PI will not be covered in this training.
- Refer to AASHTO Test Method T-87 for this procedure.

Plastic Limit

AASHTO T 90

Plastic Limit Scope

- As the moisture content of a material moves below the Liquid Limit, it becomes more plastic.
- The minimum moisture content at which a material begins to behave as a plastic is called the Plastic Limit.

Plastic Limit Scope

- The Plastic Limit is determined by a simple test where the material is repeatedly rolled into threads 3 mm (1/8”) in diameter.
- The moisture content at the point where the test specimen begins to break up is the Plastic Limit.

AASHTO T 89 & T90 16

Plastic Limit Equipment

- Dish
- Spatula (3-4” long by ¾” in width)
- Surface for rolling
- Containers
- Balance capable of weighing to the nearest 0.01 gram
- Oven 230° F ± 9° (110° ± 5°C)

AASHTO T 89 & T90 17

Plastic Limit Procedure

- From the thoroughly wet and mixed Liquid Limit sample, obtain about 8 grams for a test sample, anytime during mixing procedure.
  - Alternatively mix 20 grams of material and obtain 8 gram test specimen.
- Take 1.5 – 2 grams from the 8 gram test specimen and squeeze into an ellipsoidal mass.
  - Protect remaining sample from further drying.

AASHTO T 89 & T90 18

Plastic Limit Procedure

- Place 1.5 – 2 gram specimen on rolling surface, applying just enough pressure to move the specimen back an forth.
- Roll it back and forth with your hand till it forms a uniform diameter.
- Roll it back and forth at a rate of 80-90 strokes per minute being sure to apply pressure uniformly during the procedure.

AASHTO T 89 & T90 19

Plastic Limit Procedure

- When the diameter of the thread becomes 3 mm (1/8 in.), stop rolling.
- Break into 6 or 8 equal pieces and repeat the process.

AASHTO T 89 & T90 20

Plastic Limit Procedure

- Repeat until thread crumbles under the pressure required for rolling and the specimen can no longer be rolled into a thread.
  - **Note:** The test specimen may crumble when the thread diameter is greater than 3 mm (1/8”). It is acceptable to end the rolling procedure at this point.

AASHTO T 89 & T90 21

Plastic Limit Procedure

- Repeat rolling process for remaining sample until all 8 grams is used.
- Gather pieces, weigh to the nearest 0.01 gram, and oven dry @ 230 ± 9°F (110° ± 5°C)
- Calculate percent moisture to the nearest whole number.
- Moisture content is the Plastic Limit.

AASHTO T 89 & T90 22

Plastic Limit Common Testing Errors

- Improperly blended sample
- Too thin or too thick threads
- Applying too much pressure
- Non-uniform rolling
- Rolling on the wrong type surface
- Non-uniform mixing of material and water
- Contaminated water

AASHTO T 89 & T90 23

Liquid Limit

AASHTO T 89

Liquid Limit Equipment

- Dish
- Cover
- Spatula (3-4” long by ¾” in width)
- Liquid Limit device
- Grooving tool
- Gauge

Equipment

- Balance, capable of weighing to the nearest 0.01 grams
- Oven 230 ± 9°F (110 ± 5°c)
- Distilled or de-mineralized water
  - Note: May use tap water if proven not to effect test results.
- Stable flat surface
- Sample containers

Liquid Limit Summary

- Liquid Limit test is performed on material passing the 0.425mm (#40) sieve.
- There are two methods approved by AASHTO, we will only be teaching Method B.
- Blow count must be within 22-28 blows.
- Liquid Limit is a calculation based on moisture content and number of blows to closure.

Liquid Limit Procedure

- Inspect the Liquid Limit device and grooving tool.
  - Check the pin (connecting the cup) to verify it is not worn.
  - Check the screws connecting the cup to the hanger arm are tight.
  - Check the point of contact on the cup and base are not excessively worn.

AASHTO T 89 & T90 28

Liquid Limit Procedure

- Check the center of the cup to ensure that use has not worn a groove into the cup.
- Check the cam follower.
- Check the adjusting screws.
- Check the dimensions of the grooving tool.

- Adjust the height of the drop so that the point on the cup that contacts the base rises to a height of 10.0mm ± 0.2mm.

AASHTO T 89 & T90 29

Liquid Limit Procedure

- Place sample (50 to 100 g) in mixing dish and add desired amount of water.
- Mix thoroughly by alternately stirring, chopping and kneading with the spatula.
- Mix each increment of water thoroughly into the sample before adding the next increment.
- Do not mix the sample in the Liquid Limit cup.

AASHTO T 89 & T90 30

Liquid Limit Common Concerns

- Some materials are slow to absorb water.
- When testing such materials, allow additional mixing time to ensure water absorption.
- It is possible to obtain a false value for Liquid Limit.

Liquid Limit Procedure

- If too much water is added, either discard the test specimen or continue mixing and kneading the material until natural evaporation lowers the moisture content to the proper consistency.
- **DO NOT ADD ADDITIONAL DRY MATERIAL TO THE TEST SPECIMEN AFTER STARTING TEST!!**

Liquid Limit Procedure

- Place representative specimen of mixed material into the Liquid Limit cup directly above the point where the cup rests on the base.
- Use spatula to spread and level the specimen so that the material is 10 mm deep and is centered as close as possible over the contact point of the cup.

Liquid Limit Procedure

- Use as few spatula strokes as possible.
- Do not trap air bubbles within the mass.
- Trim excess material from the specimen and return to mixing dish, and cover to prevent moisture loss.

AASHTO T 89 & T90 34

Liquid Limit Procedure

- Use grooving tool to make a smooth firm stroke through sample.
- Do not allow the sample to tear or slide in the cup while making the groove.
- Use no more than 6 strokes to complete the division. (May touch cup on last pass only)
- The curved portion of the grooving tool is 10 mm high.

AASHTO T 89 & T90 35

Liquid Limit Procedure

- For automatic device, set counter at zero and turn on.
- For manual device, turn crank at a rate of approximately 2 revolutions per second.
- Do not hold the base of the device with the free hand while applying blows.

AASHTO T 89 & T90 36

Liquid Limit Common Concerns

- Some materials tend to slide on the surface of the cup instead of flowing together. If this occurs, remix the material with additional water and repeat the procedure. If the sample continues to slide at fewer than 22 blows, the Liquid Limit test is not applicable.
- Record that the Liquid Limit could not be determined.

AASHTO T 89 & T90 37

Liquid Limit Procedure

- Apply blows until the 2 sides of the material come in contact at the bottom of the groove along a distance of about 13mm (0.5 in.)
- If this is not achieved in 22 – 28 blows, adjust sample moisture and run again.
  - If blows are less than 22, continue to stir, chop and knead, which will allow moisture to evaporate.
  - If blows are more than 28, add water and mix thoroughly. Allow time for water to absorb.

AASHTO T 89 & T90 38

Liquid Limit Procedure

- After obtaining a preliminary closure in the 22 –28 blow range.
- Immediately return remaining sample to mixing dish and, without adding any additional water, repeat procedure.
- Number of blows shall be within ± 2 of preliminary closure, however the final closure must be in the 22 – 28 blow range.
- Record the number of blows.

AASHTO T 89 & T90 39

Liquid Limit Procedure

- Take a slice of the sample that includes the closure, approximately the width of the spatula (¾”) from the specimen cup.
- Remove the slice from edge to edge of the specimen at right angles to the groove.

AASHTO T 89 & T90 40

Liquid Limit Procedure

- Place in container, weigh to the nearest 0.01 gram, and record.
- Place in oven to dry at 230° F ± 9°(110 ± 5°c)

AASHTO T 89 & T90 41

Liquid Limit Procedure

- Put remaining part of the specimen back into the mixing dish and cover. This material is used to complete the Plastic Limit test while the Liquid Limit sample is drying.
- Determine the moisture content to the nearest 0.1% according to AASHTO T 265.

AASHTO T 89 & T90 42

Liquid Limit Calculations

$$LL = kW^N$$

LL = Liquid Limit
W^N = Moisture content
k = Correction Factor for blows

Report to nearest whole number

Liquid Limit Correction Factors

BLOWS	FACTOR
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014

Liquid Limit Common Testing Errors

- Improperly adjusted or maintained Liquid Limit device
- Miss-counting blows
- Restraining the base to the Liquid Limit device during testing
- Trapping air bubbles in the test specimen
- Material cake of improper thickness

Liquid Limit Common Testing Errors

- Non-uniform moisture content in sample
- Performing test before moisture content in the specimen is equalized
- Contaminated water used for testing
- Adding water too quickly for the material to absorb it during the mixing process

AASHTO T 89 & T90 46

Plasticity Index

Plasticity Index Scope

- The Plasticity Index (PI) of a material is a measure of the cohesive properties of a material.
- It represents the range of moisture contents in which a cohesive material is plastic.
- Plasticity Index is a calculated value derived by subtracting the Plastic Limit from the Liquid Limit.

AASHTO T 89 & T90 48

Plasticity Index Scope

- PI is an indicator of the suitability of the clay fraction of soil-aggregate for use in highway construction.
- Pavements constructed with soil-aggregates having a high PI tend to have problems with rutting, shifting, and shoving.

AASHTO T 89 & T90 49

Plasticity Index Scope

- When the Plasticity Index is too low or the fraction is non-plastic, material will tend to become friable (crumbles readily) in dry weather.
- It is possible for the calculations to result in a zero number, if the plastic and liquid limit are the same.
- Such a material is considered and reported as non-plastic, not zero.

AASHTO T 89 & T90 50

Plasticity Index Calculations

- Plasticity Index is the Liquid Limit minus the Plastic Limit.

$$PI = LL - PL$$

- Round to the nearest whole number.

AASHTO T 89 & T90 51

200 [75 µm] sieve plus the amount retained in the "PAN". The quantity retained on the smallest sieve is then added to the quantity in the "PAN + LOSS" and is to be recorded on the line designated as "TOTAL". The "TOTAL" should equal the original dry weight [mass] within a tolerance of one gram for each sieve that the material passed through. The difference between the "TOTAL" and the "ORIGINAL DRY WEIGHT [MASS] is recorded on the line designated "DIFFERENCE". Tolerance for the sieving is plus or minus 1 gram per sieve. In the example in Exhibit 1001-B, the tolerance should be equal to or less than plus or minus 5 grams (five sieves were used, beginning with the smallest sieve through which 100 percent passed). This tolerance is to be recorded on the line designated as "SIEVE ACCURACY".

The total amount of material finer than the smallest sieve shall be determined by adding the weight [mass] of material passing the smallest sieve obtained by dry sieving to that lost by washing. In the example, the amount lost by washing as recorded on the "LOSS" line was found to be 442 grams. The 7 on the "PAN" line shows that 7 additional grams were obtained in the dry sieving operation. This total quantity, 449 grams, is recorded on the "PAN + LOSS" line.

Except for the smallest sieve used, the percent passing is determined by dividing the quantity shown for each sieve by the original dry weight [mass] and subtracting the percentage from 100. The percentage passing the smallest sieve is found by dividing the quantity shown on the "PAN + LOSS" line by the original dry weight [mass]. The percentage for the smallest sieve is shown on the line for that sieve.

After entering information from Form T-630R in SiteManager, the box at the bottom of the column may be checked and the database "RECORD NO." entered at the top of the column. (NOTE: The record number may change due to deletion of files, therefore this could only be used as a short-term reference for recalling a gradation. After this number becomes invalid, the gradation would have to be located in the database by using the date of testing.

Exhibit 1001-C shows Form T-630R being used to record the gradation of a material produced to meet Section 1003 specifications.

1001.5.2 Plasticity Index.

1001.5.2.1 The frequency of plastic index Quality Assurance tests shall be in accordance with the specifications. This includes retained samples from quality control tests and independent samples for quality assurance. The plasticity index is defined as the numerical difference between the liquid limit and the plastic limit. The liquid limit is that moisture content, expressed as a percentage of the weight [mass] of the oven-dried material, at which the soil will flow together ½ inch (13mm) at 22-28 blows. The plastic limit is the minimum moisture content, expressed as a percentage of the weight [mass] of the oven dried material, at which soil thread can no longer be rolled into 1/8 in (3mm) diameter thread. All original weights [masses] and calculations shall be recorded on Form T-630R.

1001.5.2.2 Apparatus.

(a) Apparatus for liquid limit shall conform to Section 3 of AASHTO T89. Liquid limit device may be either mechanically or manually operated. A curved grooving tool shall be used per Method B. All measurements, calibrations and adjustments shall be made in accordance with AASHTO T89 Method B. An example of material at the liquid limit is shown in Exhibit 1001-D, of this Section.

(b) Apparatus for plastic limit shall conform to Section 3 of AASHTO T90. A Plastic Limit Rolling Device shall not be used. Material shall be rolled using the Hand Rolling Method. An example of the crumbling of the thread is shown in Exhibit 1001-D, of this Section.

1001.5.2.3 Procedures. The liquid limit shall be determined in accordance with AASHTO T89 Method B, with the exception of material preparation. Material preparation shall be in accordance with MoDOT Test Method TM 79.

1001.5.2.4 Calculations. Plasticity index is calculated per AASHTO T90, as the difference between the liquid limit and plastic limit. Reported to the nearest whole number.

1001.5.2.5 Report. All original weights [masses] and calculations shall be recorded on Form T-630R. If the material is such that the plastic limit cannot be determined, the material is to be considered non-plastic. A SiteManager sample record for independent samples is to be filled out in accordance with Automation Sec 3510 of this Manual. The record shall indicate that the sample type is "Quality Assurance", Acceptance Method is "Accepted/Complete", the QA data for tests should be entered on test templates as follows: Plasticity Index on SAA008AB*.

*The last letter of this template is subject to change if the template is revised. The most current template should have the designation 'NEWEST' before its description.

1001.5.3 Percent Deleterious Substances in Coarse Aggregate.

1001.5.3.1 The inspector shall determine the percent of deleterious substances in coarse aggregate, when required, in accordance with MoDOT Test Method TM 71. Determination of deleterious is required for Source Approval samples.

1001.5.3.2 Deleterious shall be determined on the combined aggregate for Hot Mix Asphalt sampled from the cold feed belt at the asphalt plant. The test data shall be recorded on the Plant Inspector's Excel Worksheet.

1001.5.3.3 Deleterious shall be determined on individual fractions for material produced for Portland Cement Concrete Masonry. A SiteManager record shall be created that represents the specific product code and producer/supplier source of the coarse aggregate. The sample type shall be "Material Approval". One test per 500 cu yds of concrete, regardless of class of concrete, is required per fraction of aggregate. One test may represent multiple projects. The test data should be reported in conjunction with gradation, absorption and thin/elongated. Contracts should be attached on the SiteManager record.

1001.5.3.4 Deleterious shall be determined on individual fractions for material produced for Portland Cement Concrete Pavement. A SiteManager record shall be created that represents the specific product code and producer/supplier source of the coarse aggregate. The sample type shall be "Quality Assurance". Testing frequency shall comply with specifications.

1001.5.4 Lightweight [Low Mass Density] Particle Content including Coal and Lignite in Fine Aggregate.

1001.5.4.1 The inspector shall determine the lightweight particle content in accordance with MoDOT Test Method TM 71. The test shall be performed according to AASHTO T113 except that lightweight [low mass density] sand particles are not considered deleterious lightweight [low mass density] particles.

PLASTIC INDEX DETERMINATION

MATERIAL _____ PRODUCT OR SPEC NO. _____

FACILITY CODE _____ PRODUCER _____

BLOWS	FACTOR	BLOWS	FACTOR
22	0.985	25	1.000
23	0.990	26	1.005
24	0.995	27	1.009
		28	1.014

REC.NO./PAGE								
DATE								
INSPECTOR								
LOCATION								
	L.L.	P.L.	L.L.	P.L.	L.L.	P.L.	L.L.	P.L.
BLOWS								
CORR.FACTOR								
WET WT + CAN								
DRY WT + CAN								
MOISTURE								
DRY WT + CAN								
CAN WT								
DRY WT								
% MOISTURE								
PLASTIC INDEX								

REPORT DATA AND REMARKS

_____.
_____.
_____.
_____.

REC.NO./PAGE								
DATE								
INSPECTOR								
LOCATION								
	L.L.	P.L.	L.L.	P.L.	L.L.	P.L.	L.L.	P.L.
BLOWS								
CORR.FACTOR								
WET WT + CAN								
DRY WT + CAN								
MOISTURE								
DRY WT + CAN								
CAN WT								
DRY WT								
% MOISTURE								
PLASTIC INDEX								

REPORT DATA AND REMARKS

_____.
_____.
_____.
_____.

EXHIBIT 1001-A (PAGE 2)

FORM T-630R PLANT INSPECTION AGGREGATE WORKSHEET

MATERIAL CRUSHED WINTERSET LIMESTONE PRODUCT OR SPEC. NO TYPE 5 BASE

FACILITY CODE 3014902112 PRODUCER BIG STONE COMPANY

PURCHASE ORDER NO. PLANT LOCATION 0.6 MI. SW/O MID TOWN, MO

CONSIGNED TO LEDGE 1-4

DESGINATION QUARRY STOCKPILE

MECHANICAL SIEVE ANALYSIS

RECORD NO.	485		486								
DATE	3/19/96		3/20/96								
INSPECTOR	R.K.		R.K.								
ORIG/WET WT.	3215	%	3314	%		%		%		%	
ORIG.DRY WT.	3171		3252								
WASHED DRY WT.	2729		2981								
LOSS	442		271								
FIELD MOIST.	44	1.4	62	1.9							SPEC
	*										LIMIT
37.5 mm (1 ½")											100
25 mm (1")	0	100	0	100							
19 mm (3/4")											
12.5 mm (1/2")	378	88	350	89							60-90
9.5 mm (3/8")											
4.75 mm (# 4)	1537	52	1468	55							40-60
2.36 mm (# 8)											
2.0 mm (#10)											
1.18 mm (#16)											
850 µm (# 20)											
600 µm (# 30)	2458	22	2412	26							15-35
425 µm (# 40)											
300 µm (# 50)											
150 µm (#100)											
75 µm (#200)	2719	14	2971	8.5							0-15
PAN	7		6								
PAN + LOSS	449		277								
TOTAL	3168		3248								
DIFFERENCE	-3		-4								
SIEVE ACCURACY	±5		±5								
TONS ACC/REJ.	1380		925								
QUALITY DETERMINATION											
ORIG.WT.											
DELT											
SHALE											
CHERT											
OTHER											
TOTAL DELT											
PLASTICITY INDEX											
IN COMPUTER	☐		☐		☐		☐		☐		

REPORT DATA AND REMARKS

*Stockpile was originally tested for Type 1 Base. retested for Type 5.

EXHIBIT 1001-B

PLASTIC INDEX DETERMINATION

MATERIAL _____ PRODUCT OR SPEC NO. _____

FACILITY CODE _____ PRODUCER _____

BLOWS	FACTOR	BLOWS	FACTOR
22	0.985	25	1.000
23	0.990	26	1.005
24	0.995	27	1.009
		28	1.014

REC.NO./PAGE	485 / 1							
DATE	3/19/96							
INSPECTOR	R.K.							
LOCATION	BIG STONE@MIDTOWN							
	L.L.	P.L.	L.L.	P.I.	L.L.	P.I.	L.L.	P.I.
BLOWS	25							
CORR.FACTOR								
WET WT + CAN	17.89	11.64						
DRY WT + CAN	16.21	11.12						
MOISTURE	1.68	0.52						
DRY WT + CAN	16.21	11.12						
CAN WT	8.23	8.13						
DRY WT	7.98	2.99						
% MOISTURE	21	17						
PLASTIC INDEX	4							

REPORT DATA AND REMARKS

_____.
_____.
_____.
_____.

REC.NO./PAGE								
DATE								
INSPECTOR								
LOCATION								
	L.L.	P.L.	L.L.	P.I.	L.L.	P.I.	L.L.	P.I.
BLOWS								
CORR.FACTOR								
WET WT + CAN								
DRY WT + CAN								
MOISTURE								
DRY WT + CAN								
CAN WT								
DRY WT								
% MOISTURE								
PLASTIC INDEX								

REPORT DATA AND REMARKS

_____.
_____.
_____.
_____.

EXHIBIT 1001-B (PAGE 2)

FORM T-630R PLANT INSPECTION AGGREGATE WORKSHEET

MATERIAL CRUSHED WINTERSET LIMESTONE PRODUCT OR SPEC. NO 1003.1 GR. 3

FACILITY CODE 3014902112 PRODUCER BIG STONE COMPANY
PURCHASE ORDER NO. PLANT LOCATION 0.6 MI. SW/O MID TOWN, MO

CONSIGNED TO LEDGE 1-4

DESGINATION QUARRY STOCKPILE

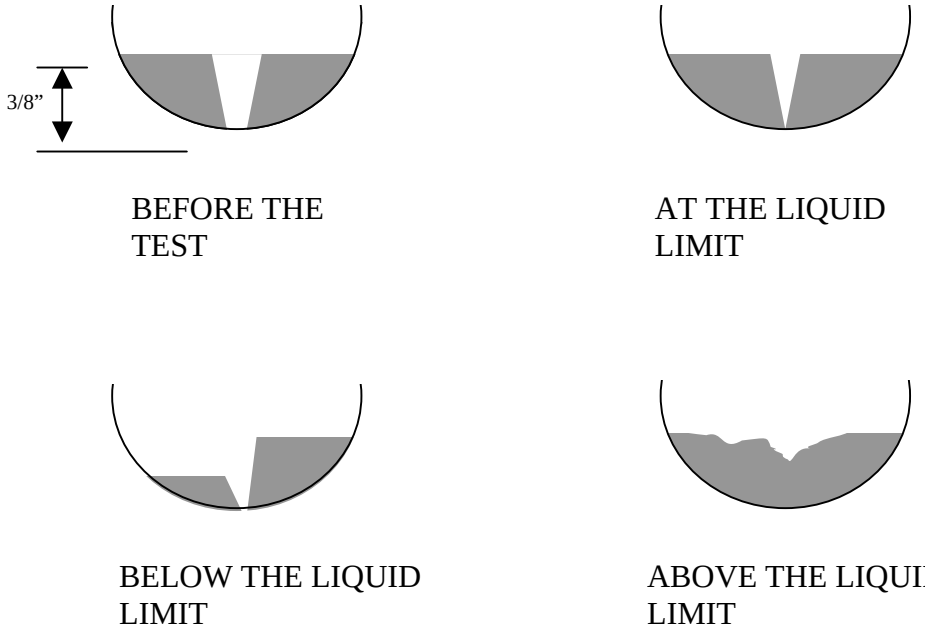
MECHANICAL SIEVE ANALYSIS

RECORD NO.	486										
DATE	3/28/96										
INSPECTOR	R.K.										
ORIG/WET WT.	1651	%		%		%		%		%	
ORIG.DRY WT.	1544										
WASHED DRY WT.											
LOSS											
FIELD MOIST.	107	6.9									SPEC LIMIT
37.5 mm (1 ½")											
25 mm (1")											
19 mm (3/4")											
12.5 mm (1/2")	0	100									100
9.5 mm (3/8")	281	82									80-100
4.75 mm (# 4)	1472	5									0-5
2.36 mm (# 8)											
2.0 mm (#10)											
1.18 mm (#16)											
850 µm (# 20)											
600 µm (# 30)											
425 µm (# 40)											
300 µm (# 50)											
150 µm (#100)											
75 µm (#200)											
PAN	70										
PAN + LOSS	70										
TOTAL	1542										
DIFFERENCE	-2										
SIEVE ACCURACY	±3										
TONS ACC/REJ.	1380	ACC.									
QUALITY DETERMINATION											
ORIG.WT.											
DELT											
SHALE											
CHERT											
OTHER											
TOTAL DELT											
PLASTICITY INDEX											
IN COMPUTER	☐		☐		☐		☐		☐		

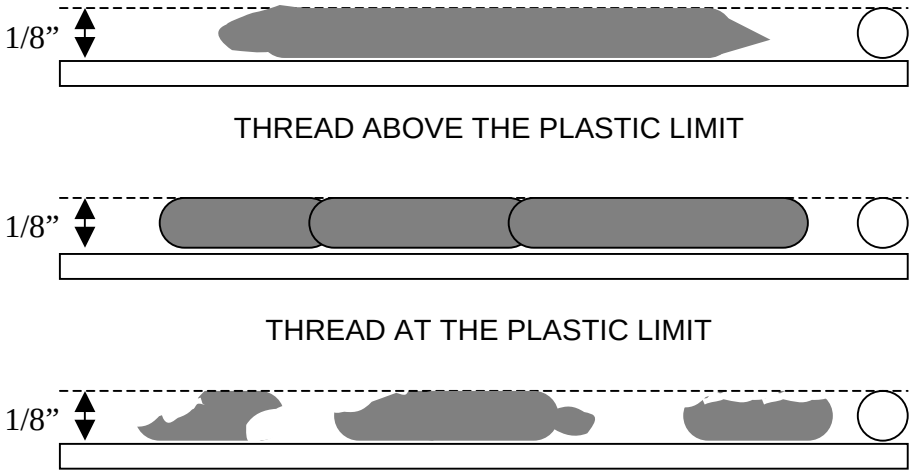
REPORT DATA AND REMARKS

*Stockpile was originally tested for Type 1 Base. retested for Type 5.

EXHIBIT 1001-C



THE LIQUID LIMIT TEST



THE PLASTIC LIMIT TEST

EXHIBIT 1001-D

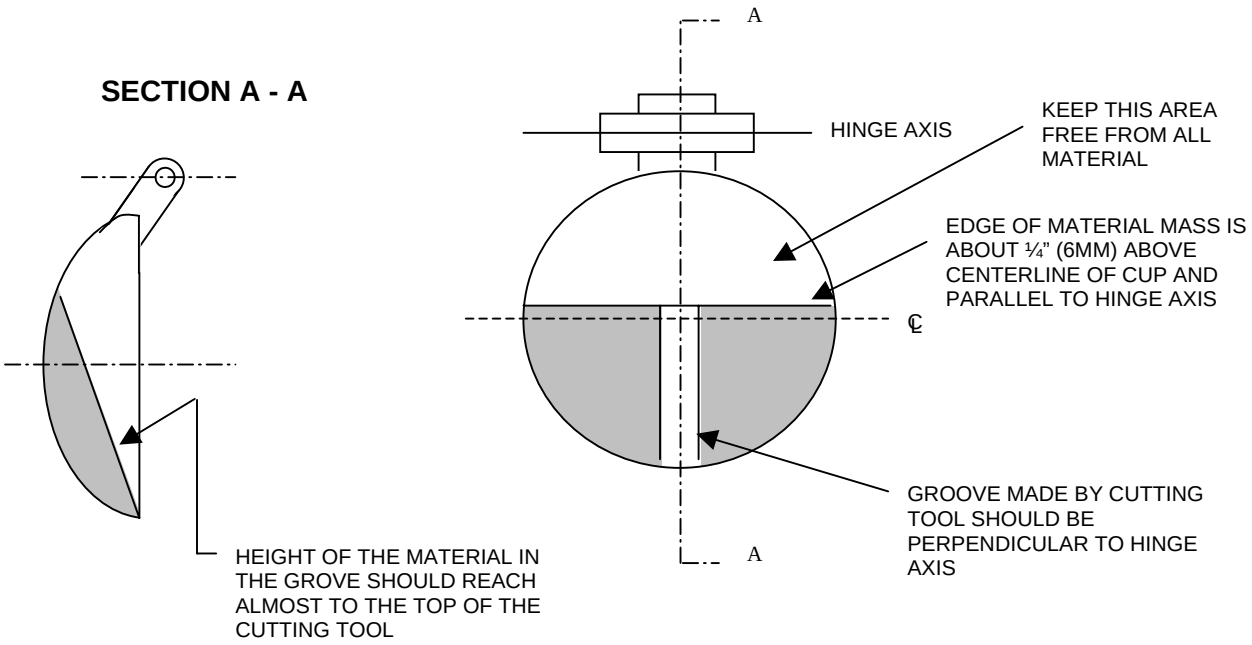


EXHIBIT 1001-E

Example of Calibration Procedure Exhibit 1001-H

Date created xx/xx/xx **Date revised xx/xx/xx (if applicable)** **(PAGE 1 OF 2)**

VERIFICATION PROCEDURE FOR A LIQUID LIMIT DEVICE
Procedure #XX

PURPOSE: This method provides instruction for checking the physical characteristics of a manual or electric Liquid Limit device.

VERIFICATION EQUIPMENT REQUIRED:
1. Caliper readable to 1 mm
2. Gage
3. Stopwatch
4. Resilience Device

TOLERANCE: Equipment will meet dimensional tolerances in AASHTO T89 and applicable interims.

PROCEDURE:
1. Record the laboratory inventory number of the equipment used in the appropriate space provided on the form. Record the information applicable to this piece of equipment in the lines provided on the verification form. Complete the line for the previous and next verification date.
2. Using the caliper measure the thickness of the base unit of the Liquid Limit device and record on Line 1.
3. Using the caliper measure the length of the base unit of the Liquid Limit device and record on Line 2.
4. Using the caliper measure the width of the base unit of the Liquid Limit device and record on Line 3.
5. Using the resilience device, check the resilience of the base unit according to AASHTO T-89. If the base meets specifications record ok on line 4.
6. Using the gage check the drop of the cup according to the specifications in AASHTO T89. If satisfactory record so on line 5. If not, adjust drop to meet specifications.
7. Using the stopwatch check the Mechanical Liquid Limit device's rate of drops per second and record on Line 6. If the Device is a Manual device record N/A on Line 6.
8. Check the pin connecting the cup to make sure it is not worn sufficiently to allow side play, if OK record OK on line 7.
9. Using the caliper, measure the contact point of the base and the cup at the widest point on the base surface, and record on line 8.
10. Date and initial in the labeled locations at the bottom of the form. Record any comments, If rejected, note in comment area.

Date created xx/xx/xx **Date revised xx/xx/xx (if applicable)** **(PAGE 2 OF 2)**

VERIFICATION RECORD OF Lab No #_____

VERIFICATION PROCEDURE # - XX - Liquid Limit Device

MANUFACTURER: _____ SERIAL # _____

SOURCE: _____ MODEL #_____

INTERVAL: 12 Months

Previous Verification Date _____

Next Due Date For Verification _____

VERIFICATION EQUIPMENT USED:

Caliper _____

Gage _____

Stopwatch _____

Resilience Device_____

MEASUREMENTS:

1. Thickness _____ 2. Length _____

3. Width _____ 4. Resilience _____

5. Drop _____ 6. # of drops/second _____

7. Side Play _____ 8. Contact Point _____

DATE_____ **TECHNICIAN** _____

Comments_____

REVIEWED BY: _____ **DATE:** _____

EXHIBIT 1001-H

DETERMINING THE LIQUID LIMIT OF SOILS

AASHTO T 89

Developed by
FHWA Multi-Regional Soils Training & Certification Group

August 1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation, are prerequisites for this training package.

- AASHTO T265, Laboratory Determination of Moisture Content of Soils
- AASHTO T87, Standard Method of Preparing Disturbed Soil Samples

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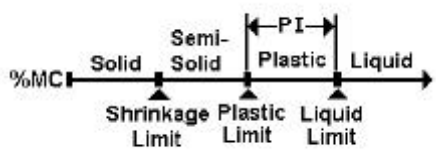
ATTERBERG LIMITS

Soils form the foundation of all transportation facilities. The final structure will be no more durable than the foundation upon which it rests. In order to ensure that the soils which support structures will function as intended in the design, it is necessary for all designers to have basic information about them. Designers use this information to decide if a naturally occurring soil can support the anticipated traffic load or if it will require chemical modification (e.g., cement stabilization, lime treatment or treatment with fly ash) to enable it to perform as a highway foundation. The strength of the soil foundation is also used in determining the type of surface course the designer will choose for a pavement structure.

Several tests are performed in the laboratory that provide information to the designer about soils which may be used as the foundation for a roadway. The determination of Atterberg Limits are among these tests. In 1911, a Swedish scientist, A. Atterberg, developed some simple tests for determining the moisture contents of a soil at which the soil moves from a solid to a semisolid, to a plastic and to a liquid state. The numbers generated by these tests are used to quantitatively describe the effect of varying water contents on a soil. As the moisture content of a soil increases, the soil will eventually change from a solid to a liquid state.

The Atterberg Limits are:

- Shrinkage Limit - The point at which a soil changes from a solid to a semisolid.
- Plastic Limit - The point at which a soil moves from a semisolid to a plastic state.
- Liquid Limit - The point at which a soil moves from a plastic to a liquid state.



Each soil becomes less stable as the moisture increases (moving from left to right on the diagram) after it exceeds the moisture needed for compaction. A soil whose percent moisture content is greater than the Liquid Limit is, therefore, soft and unstable.

Two of these numbers (Liquid Limit and Plastic Limit) are used to determine the Plasticity Index. The Plasticity Index is **not** an Atterberg Limit. It is a number that is derived by subtracting the Plastic Limit of a soil from its Liquid Limit.

$$PI = LL - PL$$

The Plasticity Index of a soil is a measure of the cohesive properties of a soil. It is the numerical range of moisture contents in which a cohesive soil is plastic. Many state highway departments specify Plasticity Index values for soils to be used in construction.

The Shrinkage Limit is not used in determining the Plasticity Index. It is not one of the original Atterberg Limits and is not used as widely in highway construction specifications. The point at which a soil moves from a solid to a semisolid state is not as significant as the Liquid Limit in determining the a soil's suitability for highway construction.

When soil samples are received by the laboratory, they may be identified by a field classification (e.g., plastic, nonplastic, hard, friable, etc.) based on moisture content and consistency at the time of sampling. This field classification provides an indication of a soil's suitability for use in construction. However, a more accurate determination of the soil's behavior at varying moisture contents is needed to ensure that the soils will be able to perform in a pavement structure. Therefore, it is critical that the tests for Atterberg Limits be properly performed. They are one of the criteria used to classify a soil in terms of its suitability for a specific design use and for determining if a soil meets specifications for use in construction projects.

LIQUID LIMIT

The Liquid Limit is the moisture content at which a specific soil moves from a plastic to a liquid state. Generally, soils with high Liquid Limits are clays with poor engineering properties. Soils with a high clay content are cohesive (stick together), plastic (moldable), compressible (able to be consolidated), and nearly impervious (impenetrable by water). Their compressibility leads to rutting under load and can even cause the soil structure to collapse under its own weight, causing embankment failure.

Clay soils become unstable when they react with water. Soils with high clay content also are subject to swelling and shrinking during normal changes in moisture content. The swell/shrinkage cycle will also lead to foundation failure. Swelling and shrinkage are directly related to shear failure. When clay soils are disturbed by construction processes, they lose their shear strength and are, therefore, subject to failure.

Therefore, the Liquid Limit is used to analyze the clay content of a soil. The Liquid Limit is used in conjunction with the Plasticity Index to identify soils with a clay content high enough to keep them from performing well in embankment construction.

SUMMARY OF TESTING

There are two methods approved by AASHTO to determine the Liquid Limit of a soil. The basic test steps are the same for both methods. The differences are in the initial quantity of water added to the test specimen; the number of specimens which are tested; the mandatory blow count range; and the calculations involved. When the results of Method B or the use of tap water cause questionable test results, there is also a reference method that must be used to establish the validity of the values. This reference method uses Method A with special parameters to ensure exacting testing standards.

The Liquid Limit test is performed on material passing the 0.425 mm (No. 40) sieve. First mix the test specimen with water, alternately stirring and chopping the soil and adding water until the soil is at a uniform stiff consistency. You will need some experience to recognize when you have reached the correct consistency for each soil type. Place some of the test specimen in the cup of the Liquid Limit device. Then use the spatula to press and spread the material to the correct thickness. Be careful not to trap air bubbles in the test specimen when spreading it in the cup.

Use the grooving tool to divide the test specimen in the cup through its center moving the tool from back to front only one time for each stroke. Be sure to form a clean, sharp groove. Use no more than six strokes of the grooving tool to divide the specimen; only the last stroke of the grooving tool is to scrape the bottom of the cup.

If you are using a manual device, turn the crank at approximately 2 revolutions per second. If you are using an automatic device, turn on the machine. Count the number of blows of the machine or use the automatic counter if the device is equipped with one. When the groove closes to 13 mm (0.5 inch), stop the device. Record the number of blows the device needed to close the groove.

For Method A, repeat these steps at least three times until you have blow counts within the following ranges:

- 25 - 35
- 20 - 30
- 15 - 25

There must be a difference of at least ten blows between the high and low blow count for the test result to be valid.

For Method B, the blow count must be within the range of 22-28, inclusive, and only one specimen is used for testing. A second specimen is run to verify the blow count.

From each test specimen, remove a slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove. Be sure to take that portion of the groove in which the soil flowed together. Then, determine the moisture content of each specimen in accordance with AASHTO T265. The Liquid Limit is a mathematical calculation based on the moisture content and number of blows at closure.

TYPICAL TEST RESULTS

Liquid Limits vary widely. It is possible to obtain values as high as 80 - 100. Values between 40 - 60 are typical of clay soils. For silty soils, typical values are between 25 - 50. The Liquid Limit test will not produce a result for sandy soils; sandy soils are termed nonplastic.

COMMON TESTING ERRORS

- Improperly adjusted Liquid Limit device.
- Loose adjusting screws.
- Excessively worn pin.
- Excessively worn base or cup.
- Worn grooving tool.
- Automatic counter not zeroed.
- Miscounting blows on manual device.
- Restraining the base of the Liquid Limit device during testing.
- Trapping air bubbles in the test specimen.
- Soil cake of improper thickness.
- Moisture content test specimen not representative of Liquid Limit test specimen.
- Plotting or calculation errors.
- Nonuniform moisture content in sample.
- Performing test before moisture content in soil specimen is equalized.
- Contaminated water used for testing.
- Adding water too quickly for the soil to absorb it during the mixing process

TEST METHODOLOGY - METHOD A

Before beginning any procedure, you must first assemble all the equipment you will need to perform the test. To determine the Liquid Limit of a soil specimen, you will need the following.

- Dish - An unglazed porcelain dish (or similar mixing dish), approximately 115 mm (4 ½ inches) in diameter
- Cover - A cover to be used over the dish to prevent moisture loss during testing
- Spatula - A spatula or pill knife with a blade approximately 75 - 100 mm (3 - 4 inches) long and approximately 20 mm (3/4-inch) wide
- Liquid Limit Device - Manual or mechanically operated conforming to AASHTO T89
- Grooving Tool - Conforming to AASHTO T89, Figure 1
- Gage - Conforming to AASHTO T89, Figure 1 or a metal bar 10.0 ±0.2 mm (0.394 ±0.008 inches) thick and approximately 50 mm (2 inches) long
- Containers - Enough containers with close-fitting lids to provide one container for each moisture content determination. Containers must be resistant to corrosion and not subject to change in mass with repeated heating and cooling.
- Balance - Conforming to AASHTO M231, Class C
- Oven - A thermostatically controlled oven capable of maintaining a temperature of 110 ±5°C (230 ±9°F)
- Distilled or Demineralized Water or Tap Water, if approved
- Semi-logarithmic Graph Paper
- AASHTO T265 (For the Determination of Moisture Content)
- Stable, flat surface - Support for testing apparatus to ensure uniform impact and base stability of device

Testing Apparatus

Test Specimen

Prepare a soil sample in accordance with AASHTO T87, Standard Method of Preparing Disturbed Soil Samples, or in accordance with AASHTO T146, Standard Method of Wet Preparation of Disturbed Soil Samples. Separate the material passing the 0.425-mm (No. 40) sieve. Obtain a representative portion of approximately 100 grams from this material.

Weighing Test Specimen

Procedure Preparation

1. Inspect the Liquid Limit device and grooving tool.

A. Check that the pin connecting the cup is not worn to the point of allowing side play.

B. Check that the screws connecting the cup to the hanger arm are tight. Loose screws allow excessive cup movement and cause erratic blow counts.

C. Check that the points of contact on the cup and base are not excessively worn. Excessive wear is defined as approximately 13 mm (0.5 inches) in diameter. Check the lip of the cup for excessive wear. Excessive wear is defined as when any point on the cup rim is worn to approximately ½ the original thickness.

D. Check the center of the cup to ensure that use has not worn a groove into the cup. (Replace any cup in which there is a pronounced groove.)

E. Check the cam follower. It should not be worn beyond the tolerance allowed or allow any rocking on the height gage when checking height of drop.

F. Check the adjusting screws. All screws in the adjusting assembly must be tight with no noticeable movement.

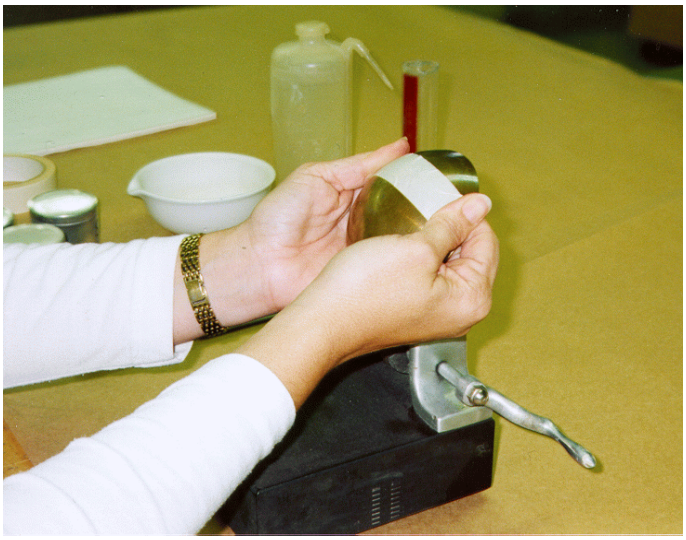
G. Check the dimensions of the grooving tool to ensure that the tool continues to conform to the tolerances of AASHTO T89, Figure 1.

2. Adjust the height of drop so that the point on the cup that contacts the base rises to a height of 10.0 ±0.2 mm (0.394 ±0.008 in.)

A. Mark the point of contact of the cup with the base. Facing the front of the cup, raise the cup by hand. Place a piece of masking tape across the outside bottom of the cup. Place the tape parallel to the pivot pin with the top edge of the tape bisecting the wear mark on the cup where it contacts the base.

NOTE

When a cup is new, place a piece of carbon paper on the base, carbon side up, then allow the cup to drop several times to mark the contact spot.



Placing Masking Tape on Cup Bottom

B. Lower cup into position**.**

> NOTE
>
> You may remove the cup from the device to apply the tape. If this was done, place cup on device and install pivot pin.

C. Turn the crank and raise the cup to its maximum height.

D. Slide the height gage under the cup from the front until the gage contacts the edge of the tape on the cup. If the gage contacts the cup at the edge of the tape, the adjustment is approximately correct.

Checking Contacts with Height Gage

E. If the gage does not contact the cup at the edge of the tape, use the adjusting screw device to adjust the height until the cup is in proper position. Lock the adjustment assembly into proper position.

F. Leave the gage in position. Check the adjustment by turning the handle at two revolutions per second. If the cup does not move and a ringing or clicking sound is heard, the adjustment is correct. If no sound is heard or if the cup rises from the gage, re-adjust the height of drop.

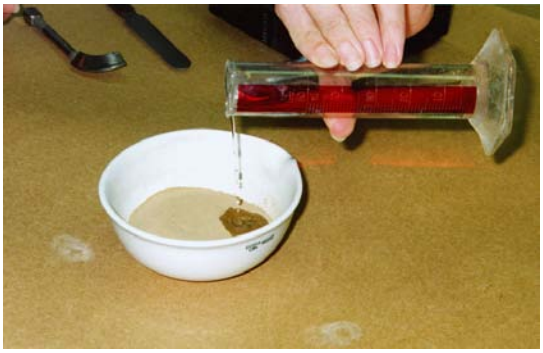
G. Remove the tape as soon as the check procedure is completed.

Testing Procedure

I. Prepare Test Specimen

A. Place the test specimen in the mixing dish. Add 15 - 20 mL of water. Mix thoroughly by alternately stirring, kneading, and chopping with the spatula. Add enough water to form a soil mass with a stiff consistency. After the initial addition of 15 - 20 mL of water, add subsequent water in increments of 1 - 3 mL. Mix each increment of water thoroughly into the soil mass before adding the next increment.

> **NOTE**
>
> It is permissible to use tap water for routine testing, if comparative tests indicate no difference in test results.



Adding Water

Blending Water and Soil

B. If too much water is added, either discard the test specimen or continue mixing and kneading the material until natural evaporation lowers the moisture content to the proper consistency.

C. Do not add additional dry material to the test specimen.

> **NOTE**
>
> Do not use the cup of the Liquid Limit device to mix the soil and water.

NOTE

Some soils (fine silts and clays) are slow to absorb water.
When testing such soils, allow additional mixing time to ensure water absorption. If water is added too quickly to these soils, it is possible to obtain a false value for the liquid limit.

II. Perform Test

A. Use the spatula to scoop a representative specimen of the mixed material about the size of a golf ball. Immediately cover mixing dish to eliminate moisture loss.

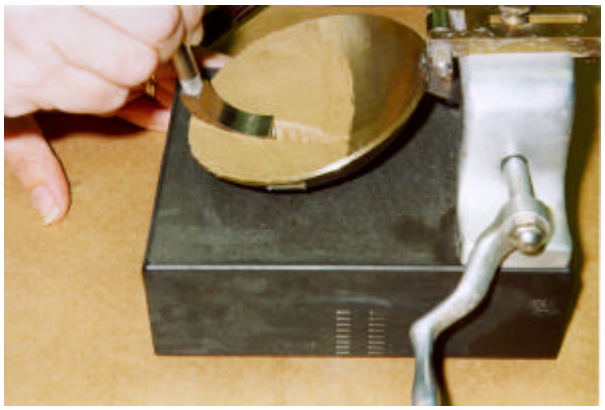
B. Place this specimen in the cup of the liquid limit device directly above the point where the cup rests on the base.

C. Use the spatula to press, spread, and level the specimen so that the material is no more than 10 mm thick at its maximum thickness and is centered as close as possible over the contact point of the cup and the base. Use as few spatula strokes as possible. Do not trap air bubbles within the mass.

Spreading Specimen in Liquid Limit Cup

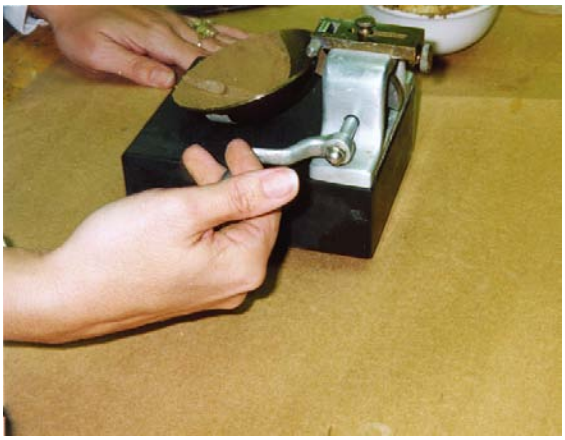
D. Trim excess soil from the specimen during Step C, return the excess to the mixing dish and immediately cover to prevent moisture loss.

E. Use the grooving tool to make a smooth firm stroke through the soil pat. Move the grooving tool from back to front though the center of the soil pat. Do not allow the soil pat to tear or slide in the cup while making the groove. (If the soil pat tears or slides, the soil is too dry or may be nonplastic. You will have to add more water and try again.) Increase the depth of the groove with each stroke, but do not allow the tool to touch the bottom of the cup, except on the last stroke. Use no more than six strokes to complete the division. While grooving the material, you can use the curved end of the grooving tool to determine if the pat is the proper thickness. When the grooving tool touches the cup, the top of the soil cake should be level with the top of the curved portion of the grooving tool. The curved portion of the grooving tool is 10 mm (0.4 inch) high.



Grooving the Soil Specimen

F. Apply blows. If the device is automatic, turn on the device. If the device is manual, turn the crank at approximately two revolutions per second. Continue applying blows until the two sides of the material come in contact at the bottom of the groove along a distance of about 13 mm (0.5 in.).



Applying Blows by Turning the Handle

NOTE

Do not hold the base of the device with the free hand while turning the crank.

NOTE

Some soils tend to slide on the surface of the cup instead of flowing together. If this occurs, remix the material with additional water and repeat the procedure. If the soil continues to slide at fewer than 25 blows, the Liquid Limit test is not applicable. Record that the Liquid Limit could not be determined.

G. Record the number of blows needed to close the groove to 13 mm (0.5 in.)

III. Determine Moisture Content

A. Use the spatula to take a slice of soil from the specimen in the cup. Remove the slice from edge to edge of the soil cake at right angles to the groove. Include that portion of the groove where the soil has flowed together. Place the slice in a drying container.

Removing the Moisture Content Specimen

Placing Specimen in Drying Container

B. Determine the moisture content of the slice in accordance with AASHTO T 265.

C. Put the remaining part of the soil cake back into the mixing dish and cover it.

D. Wash and dry the cup and grooving tool.

E. Add more water to the material in the mixing dish and remix, making the material more fluid. The intent is to increase the fluidity of the soil by 5 shocks (blows).

F. Repeat Steps II.A. - II. F. at least twice, until at least one determination is made in each of the following ranges. The range of the three determinations must be at least 10 blows.

- 25 - 35
- 20 - 30
- 15 - 25

G. Determine the percentage of moisture to the nearest 0.1% for each test specimen in accordance with AASHTO T 265.

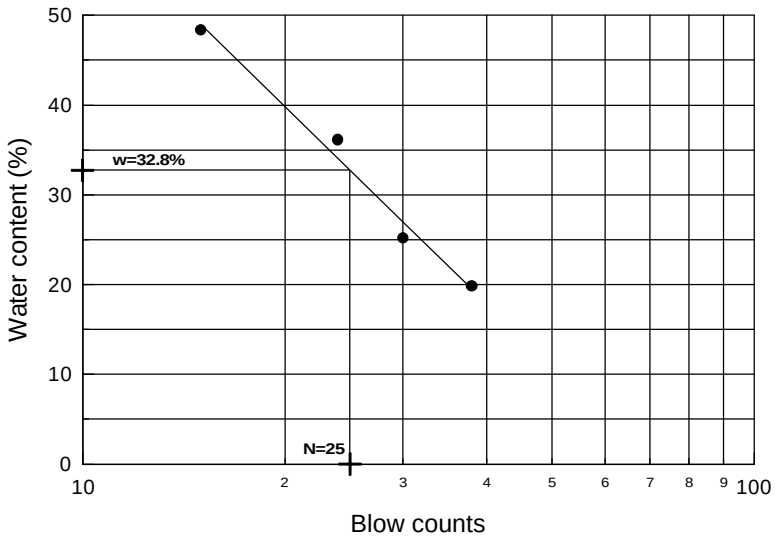
IV. Flow Curve Preparation

A. Prepare semi-logarithmic graph paper by labeling the x and y axes for moisture content and number of shocks.

B. For each test specimen, plot the point corresponding to the blow count and moisture content.

C. Draw a flow curve (as straight a line as possible passing through all plotted points).

Example



> NOTE
>
> The lower point, although recorded, was outside the 25 - 35 range. The course developers, unlike AASHTO directions, prefer that all points be recorded.

V. Determine the Liquid Limit

Identify the moisture content at which the flow curve intersects the 25-blow line. The moisture

content at the intersection of the flow curve and the 25-blow line is the Liquid Limit. Record the Liquid Limit to the nearest whole number.

REFERENCE TESTS

When performing Method A as a reference test, use the following time schedule.

1. Mixing of soil with water: **5 - 10 minutes**

   The more plastic the soil, the longer the mixing time should be.

2. Seasoning in the humidifier: **30 minutes**

3. Remixing the material before placing it in the brass cup:
   Add 1 mL of water and mix: **1 minute**

4. Placing the material in the brass cup: **3 minutes, maximum**

5. Adding water and remixing: **3 minutes**

6. Do not add dried soil to the seasoned soil during the test.

DETERMINING THE PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

AASHTO T 90

Developed by
FHWA Multiregional Soils Training & Certification Group

August 1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation, are prerequisites for this training package.

- AASHTO T 265, Laboratory Determination of Moisture Content of Soils
- AASHTO T 87, Standard Method of Preparing Disturbed Soil Samples
- AASHTO T 89, Determining the Liquid Limits of soils

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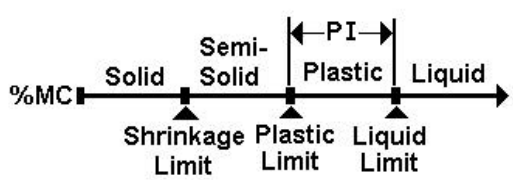
ATTERBERG LIMITS

Soils form the foundation of all transportation facilities. The final structure will be no more durable than the foundation upon which it rests. In order to ensure that the soils which support structures will function as intended in the design, it is necessary for designers to have basic information about them. Designers use this information to decide if a naturally occurring soil can support the anticipated traffic load or if it will require chemical modification (e.g., cement stabilization, lime treatment or treatment with fly ash) to enable it to perform as a highway foundation. The strength of the soil foundation is also used in determining the type of surface course the designer will choose for a pavement structure.

Several tests are performed in the laboratory that provide information to the designer about soils which may be used as the foundation for a roadway. The determination of Atterberg Limits are among these tests. In 1911, a Swedish scientist, A. Atterberg, developed some simple tests for determining the moisture contents of a soil at which the soil moves from a solid to a semisolid, to a plastic and to a liquid state. The numbers generated by these tests are used to quantitatively describe the effect of varying water contents on a soil. As the moisture content of a soil increases, the soil will eventually change from a solid to a liquid state.

Atterberg Limits are the:

- Shrinkage Limit - The point at which a soil changes from a solid to a semisolid.
- Plastic Limit - The point at which a soil moves from a semisolid to a plastic state.
- Liquid Limit - The point at which a soil moves from a plastic to a liquid state.



Each soil becomes less stable as the moisture increases (moving left to right on the diagram) after it exceeds the moisture needed for compaction. A soil whose percent moisture content is greater than the Liquid Limit is, therefore, soft and unstable.

Two of these numbers (Liquid Limit and Plastic Limit) are used to determine the Plasticity Index. The Plasticity Index is **not** an Atterberg Limit. It is a number that is derived by subtracting the Plastic Limit of a soil from its Liquid Limit.

$$PI = LL - PL$$

The Plasticity Index of a soil is a measure of the cohesive properties of a soil. It represents the range of moisture contents in which a cohesive soil is plastic. Many state highway departments specify Plasticity Index values for soils to be used in construction.

The Shrinkage Limit is not used in determining the Plasticity Index. It is not one of the original Atterberg Limits and is not used as widely in highway construction specifications. The point at which a soil moves from a solid to a semisolid state is not as significant as the Liquid Limit in determining the shear strength and compressibility of a soil.

When soil samples are received by the laboratory, they may have a field classification (e.g., plastic, nonplastic, hard, friable, etc.) based on their moisture content and consistency at the time of sampling. This field classification provides an indication of a soil's suitability for use in construction. However, a more accurate determination of the soil's behavior at varying moisture contents is needed to ensure that the soils will be able to perform in a pavement structure. Therefore, it is critical that the tests for Atterberg Limits be properly performed. They are one of the criteria used to classify a soil in terms of its suitability for a specific design use and for determining if a soil meets specifications for use in construction projects.

PLASTIC LIMIT

As the moisture content of a soil moves below the Liquid Limit, it becomes more plastic. External force is needed to make the soil deform. Its bearing capacity begins to increase. The soil becomes more cohesive and can be molded by hand into a ball or other shape. The minimum moisture content at which a soil begins to behave as a plastic is called the Plastic Limit. The Plastic Limit is determined by a simple test in which the soil is repeatedly rolled into threads approximately 3 mm in diameter. During the repeated rollings, the soil gradually loses moisture until it reaches the point where it will no longer hold together and breaks into short pieces. The moisture content at the point where the soil begins to break up is the Plastic Limit.

PLASTICITY INDEX

The range of moisture contents at which a soil is considered to be plastic are those which fall between the Liquid Limit and the Plastic Limit. This range is identified as an engineering property by the Plasticity Index (PI). The Plasticity Index is a calculated value derived by subtracting the Plastic Limit from the Liquid Limit.

$$PI = LL - PL$$

The Plasticity Index is an indicator of the suitability of the clay fraction of a soil or soil-aggregate for use in highway construction. It is used as a specification by many highway departments to determine the usability of a soil. When the Plasticity Index of the binder fraction of a material containing clay is too high, the material will tend to soften under wet conditions. Pavements constructed with soils or soil-aggregates having a high PI tend to have problems with rutting, shifting and shoving. They may develop a washboard surface or other failures that are caused by foundation failures. When such materials are used as surfacings,

they tend to become slippery in wet weather. When the Plasticity Index is too low or the soil fraction is nonplastic, the material will tend to become friable in dry weather. It may ravel at the edges and abrade under traffic. Pavement surfacings constructed with low PI material tend to be dusty and may lose much of their binder during dry periods. The Plasticity Index is one of the factors considered in determining the classification of soils.

Since the Plasticity Index is the numerical range of moisture contents through which a soil remains plastic, each soil becomes less stable as the moisture content increases (moves left to right on the graph) after it exceeds the moisture content needed for proper compaction. A soil the natural moisture content of which exceeds the Liquid Limit is, therefore, soft and unstable.

It is possible for a soil to have a PI of zero, if the Plastic Limit and Liquid Limit are the same. Such a soil is considered plastic, although the range of moisture contents at which the material behaves as a plastic is so severely limited that the range cannot be determined by standard laboratory tests. Soils with a PI of zero should not be confused with nonplastic soils. Nonplastic soils (generally sands) are almost totally free of clay particles. Nonplastic soils never reach a cohesive state, but move abruptly from a viscous liquid state to a dry granular state. A nonplastic soil will not solidify. It will not form clods or other solid masses. It cannot be rolled into a thread as small as 3.2 mm (1/8 inch) and, therefore, cannot be tested for a Plastic Limit.

AASHTO T90 defines a PI of zero to be considered non-plastic.

SUMMARY OF TESTING

To determine the Plastic Limit of a soil, you will first add water to a dried soil sample and mix it thoroughly. When the moisture content is uniform, place the test specimen on a flat, smooth, impermeable surface and, with the heel of the hand, roll it into a thin thread. Remold the test specimen, without adding additional water. Repeat the procedure until the specimen crumbles. Then, you determine the moisture content of the test specimen in accordance with AASHTO T 265. The moisture content is the Plastic Limit. You can then determine the Plasticity Index by subtracting the Plastic Limit from the Liquid Limit, determined in accordance with AASHTO T 89.

TYPICAL TEST RESULTS

Plastic Limit tests are conducted on silts and clays. Normally, silty soils have lower Plastic Limits than clay soils. The Plastic Limit usually falls in the range of 5 - 30. Nonplastic materials (e.g., sand) cannot be tested by this procedure. Nonplastic materials lack the cohesiveness to be rolled into a thread.

The Plasticity Index can range as high as 70 or 80 for very plastic clays. However, most clays have a PI of 20 - 40 and silts have a PI of 10 - 20.

COMMON TESTING ERRORS

- Nonuniform mixing of soil and water
- Contaminated water
- Improperly blended sample
- Too thin or too thick soil threads
- Errors in determining mass
- Applying too much pressure or nonuniform pressure in rolling
- Rolling on the wrong type surface

CRUMBLING

Different types of soils exhibit different styles of breaking up during rolling. Some soils fall apart in many small aggregations; others form a tubular layer on the outside that splits at both ends. When this occurs, the splitting tends to progress toward the middle until the thread falls apart in many small platy particles. Heavy clays require a lot of pressure to deform the soil, especially as it approaches the Plastic Limit. With clay soils, the thread often breaks into a series of barrel-shaped segments about 6.4 - 9.5 mm (1/4 - 3/8 inch) in length.

The technician is never to attempt to produce failure at exactly 3.2 mm (1/8 inch) by reducing the rate of rolling or modifying hand pressure. It is acceptable to reduce the amount of rolling required for soils with low plasticity by making the initial diameter of the ellipsoidal test specimen near the 3.2 mm (1/8 inch) final diameter.

TEST METHODOLOGY

Before beginning any procedure, you must first assemble all the equipment you will need to perform the test. To determine the Plastic Limit of a soil specimen, you will need the following.

- ♦ Dish - An unglazed porcelain dish (or similar mixing dish), approximately 115 mm (4 ½ inches) in diameter
- ♦ Spatula - A spatula or pill knife with a blade approximately 75 - 100 mm (3 - 4 inches) long and approximately 20 mm (3/4-inch) wide
- ♦ Surface for Rolling - Glass Plate or Smooth, Unglazed Paper
- ♦ Containers - Enough containers with close-fitting lids to provide one container for each moisture content determination. Containers must be resistant to corrosion and not subject to change in mass with repeated heating and cooling.
- ♦ Balance - Conforming to AASHTO M231, Class C
- ♦ Oven - A thermostatically controlled oven capable of maintaining a temperature of 110 ±5°C (230 ±9°F)

Figure 1: Equipment for Plastic Limit

Test Specimen

Prepare a soil sample in accordance with AASHTO T 87, Standard Method of Preparing Disturbed Soil Samples. Separate the material passing the 0.425-mm (No. 40) sieve. Obtain a representative portion of approximately 20 grams from this material if you are only going to perform the test to determine the Plastic Limit.

Place the air dried soil in a mixing dish and thoroughly mix with water until it can be easily shaped into a ball. Knead the material into plastic mass until the moisture content and texture are uniform. Take a ball of approximately 8 g to perform the test.

Figure 2: Test Specimen for Plastic Limit

PROCEDURE

I. Squeeze the 8 g test specimen into an ellipsoidal mass.

II. Place the test specimen on the rolling surface. Applying just enough pressure to cause the specimen to move, roll it back and forth with your hand until it forms a thread of uniform diameter throughout its length. Roll it back and forth at a speed of approximately 80 - 90 strokes per minute being sure to apply pressure uniformly during the procedure. A stroke equals one complete motion back and forward to the starting point.

Figure 3: Rolling the Test Specimen

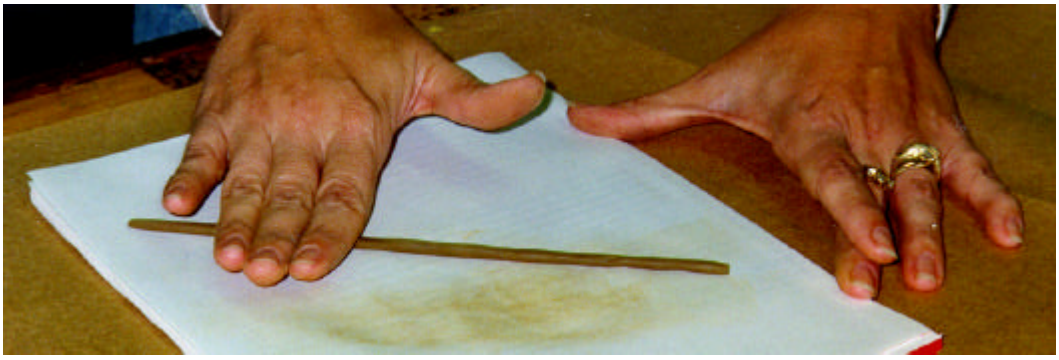


Figure 4: Continuing to Roll the Test Specimen

III. When the diameter of the thread becomes 3.2 mm (1/8 inch), stop rolling. Break the thread into six or eight reasonably equal-sized pieces.

Figure 5: Individual Pieces

IV. Squeeze the pieces between the thumbs and fingers to create a uniform ellipsoidal mass.

V. Repeat Steps II - IV, until the thread crumbles under the pressure required for rolling and the specimen can no longer be rolled into a thread.

NOTE

The test specimen may crumble when the thread has a diameter greater than 3.2 mm (1/8 inch). It is acceptable to end the rolling procedure at this point if the specimen has previously been rolled to the 3.2 mm-diameter.

VI. Gather the pieces of the crumbled thread together. Place them in a tared container that is suitable for drying to determine the moisture content.

VII. Determine the moisture content in accordance with AASHTO T 265 and record the results.

CALCULATIONS

I. Determine the Plastic Limit using the following formula and report the result to the nearest whole number.

$$PL = \frac{\text{Mass of Water}}{\text{Mass of Oven - Dry Soil}} \times 100$$

Example

Mass of Water = 5.3 g
Mass of Oven Dry Soil = 22.0 g

$$PL = \frac{5.3}{22.0} \times 100$$

$$PL = 0.2409 \times 100$$

$$PL = 24.09 = 24$$

II. Determine the Plasticity Index using the following formula and report the result to the nearest whole number.

$$PI = LL - PL$$

Example LL = 70
PL = 24

PI = 70 - 24
PI = 46

GLOSSARY

Atterberg Limits - Tests designed by A. Atterberg. Used to identify the limits at which a soil passes from a solid, semisolid, plastic, and liquid states. Atterberg Limits are the Plastic Limit, Liquid Limit and Shrinkage Limit. The Plastic Limit and Liquid Limit are used to determine the Plasticity Index.

Cohesive - Tending to stick together

Compressibility - Able to be reduced in volume through compaction.

Friable - A noncohesive material which crumbles readily.

Liquid Limit - An Atterberg Limit. The moisture content at which a soil moves from a plastic to a liquid state.

Plastic - Capable of being molded into a sustainable shape.

Plastic Limit - An Atterberg Limit. The moisture content at which a soil moves from a semisolid to a plastic state.

Plasticity Index - A measure of the cohesive properties of a soil. Determined by subtracting the Plastic Limit from the Liquid Limit.

Nonplastic - Not capable of being molded into a sustainable shape.

Shrinkage Limit - An Atterberg Limit. The moisture content at which a soil changes from a solid to a semisolid.

MoDOT TM 79: Aggregate Base Prep for PI
Prep of Aggregates for Liquid Limit & Plastic Limit Test
PROFICIENCY CHECKLIST

Applicant_____

Employer_____

Trial#	1	2
1. Reduce sample to required size		
2. Split sample over No. 40 sieve		
3. Wash plus No. 40 material, retaining wash water		
4. Allow particles in wash water to settle and decant off water		
5. Dry remaining material in 140° F oven (may air dry)		
6. Shake dried washed plus No. 40 material over a No. 40 sieve		
7. Combine the 3 minus No. 40 components: Original separated minus No. 40 material Dried material from washing Minus No. 40 material shaken from washed plus No. 40 material		
	Pass	Pass
	Fail	Fail

Examiner:_____Date:_____

AASHTO T 89: Determining the Liquid Limit of Soils
PROFICIENCY CHECKLIST

Applicant_____

Employer_____

Sample Preparation Trial#	1	2
1. Sample obtained by T 87 or TM 79		
2. Sample consists of about 50-100g of soil passing # 40 sieve		
3. Soil mixed with about 8-10mL of distilled or demineralized water in mixing dish (other than brass cup) **Note:** Tap water may be used for routine testing if comparative tests indicate no difference in Results using tap and distilled water		
4. Mixing done by stirring, kneading and chopping with spatula		
5. Additional increments of water added (1-3mL) until mass is uniform and has still consistency		
6. No additional dry material added to wet sample once testing has begun		
7. If too wet, sample either discarded or mixed to evaporate water		
Procedure		
1. Liquid limit device previously inspected for wear and height of cup drop checked		
2. Part of mixture put in cup and spread with spatula until 10mm deep at maximum thickness		
3. As few strokes of spatula as possible used		
4. Care taken to avoid entrapment of air bubbles		
5. Excess soil returned to mixing dish		
6. Unused wet soil in storage dish covered during test		
7. (Using curved grooving tool): Material in dish divided through centerline of follower with no more than 6 strokes of curved tool and only last stroke of grooving tool scrapes bottom of cup		
8. Material in dish divided through centerline of follower with no more than 6 strokes of curved tool		
9. Only last stroke of grooving tool scrapes bottom of cup		
10. Tearing along groove and slippage of cake avoided		
11. Cup lifted and dropped twice per second until bottom of groove closes about 0.5” (13mm) in 22-28 blows		
13. Material in cup immediately returned to mixing dish, and no additional water added		
14. Steps 2 through 10 repeated		
15. Closure in 22 to 28 blows		
16. Number of blows recorded for second closure		
17. Moisture specimen is taken after second groove closure (if closure is in acceptable range and within ± 2 blows of the first closure)		
18. Slice of sample, width of spatula, extending across cake at right angles to groove and including portion that flowed together removed from dish and placed in container		

AASHTO T 89: Determining the Liquid Limit of Soils
PROFICIENCY CHECKLIST
(cont.)

19. Container and material weighed to 0.01g		
20. Water content determined according to T 265		
21. Water content calculated to nearest whole percent by: $\% \text{ moisture} = \frac{\text{mass of water}}{\text{mass of oven dry material}} \times 100$		
22. Liquid limit calculated by $\text{Liquid Limit} = \frac{\text{Moisture Content}}{\text{Correction Factor for Blows}}$		

Pass Pass

Pass Pass

Examiner:_____Date:_____

AASHTO T 90: Determining the Plastic Limit & Plastic Index of Soils
PROFICIENCY CHECKLIST

Applicant_____

Employer_____

Trial#	1	2
1. Sample is either 20g of minus # 40 material obtained by T 87 or by TM 79, or 8g of liquid limit material		
2. If 20g sample of dry material - a. Mixed with distilled or demineralized water in mixing dish b. Approximately 8g ball formed		
3. A 1.5 to 2g portion of 8g ball selected and formed into ellipsoidal mass		
4. Mass rolled between fingers or palm and plate/paper (or between top and bottom plate of rolling device to form 1/8" diameter thread		
5. Rate of rolling between 80-90 strokes per minute (counting stroke as one complete motion of hand forward or back to the starting position)		
6. Mass rolled for no more than 2 minutes to obtain thread diameter of 1/8"		
7. When thread diameter is 1/8", thread broken into several pieces		
8. Pieces squeezed together between thumbs and fingers into ellipsoidal mass		
9. Steps 4 through 9 repeated until thread crumbles and soil can no longer be rolled into a thread **Note:** Crumbling may occur when thread diameter is greater than 1/8"		
10. Operator does not attempt to produce failure at exactly 1/8"		
11. Crumbled pieces placed in tared container and container immediately covered		
12. Steps 3 through 12 repeated until the 8g specimen is completely tested		
13. Mass of specimen and container determined to 0.01g		
14. Specimen dried and water content determined according to T 265		
15. Plastic Limit calculated from: $PL = \frac{\text{mass of water}}{\text{mass of oven dry soil}} \times 100$		
16. Plastic Limit reported to at least the nearest whole number		
17. Plasticity index calculated from: PI = Liquid Limit – Plastic Limit		
	Pass	Pass
	Fail	Fail

Examiner:_____Date:_____