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# 3

## SAMPLING AND TESTING AGGREGATES

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### Testing

As stated in the previous chapter, the Producer shall furnish and maintain a plant laboratory, meeting the requirements of Section 106.07 of the Road and Bridge Specifications.

### Test and Equipment

Test procedures shall be conducted in accordance with the standards referenced in the current specifications. Testing for Gradation and Atterberg Limits will be conducted on the Department's verification samples. To accommodate the testing requirements, a field or plant laboratory shall be furnished and contain the following equipment:

- 1 - Motorized screen shaker for fine and coarse grading analysis.
- 1 - Set of sieves for the motorized shaker. The screen sizes shall include the specification sizes for the type of material being produced.
- 1 - Balance having a capacity of at least 45 lbs. (20 kg), with a sensitivity of one ounce (28 grams) or less.
- 1 - Balance having a capacity of at least 2.5 lbs. (1 kg), with a sensitivity of 0.1 gram or less.
- 1 - Drying apparatus.
- 1 - Set of liquid and plastic limit devices.

Producers shipping only coarse open-graded aggregate shall not be required to obtain Atterberg Limit equipment.

Under the QA program, a certified technician must be present at all times during the mixing of the final product. Such technician shall be capable of designing, sampling, testing and adjusting the mixture.

## Sieve Analysis

Aggregate gradation (sieve analysis) is the distribution of particle sizes expressed as a percent of the total dry weight. Gradation is determined by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom and weighing the material retained on each sieve. Sieve numbers and sizes most often used in grading aggregates for aggregate paving mixtures are given in the table below.

**Nominal Dimensions**  
of U. S. Standard Sieves AASHTO M 92

Sieve Designation Alternate Inches	Standard mm	Nominal Sieve Opening inches
3	75.0	3.00
2	50.0	2.00
1 ½	37.5	1.50
1	25.0	1.00
¾	19.0	0.750
3/8	9.5	0.375
No. 4	4.75	0.187
No. 10	2.00	0.0787
No. 20	0.850	0.0331
No. 40	0.425	0.0165
No. 60	0.250	0.0098
No. 80	0.180	0.0070
No. 100	0.150	0.0059
No. 200	0.075	0.0029

Sieve sizes to be checked for compliance for the various mixtures are designated in the specifications. See the Road and Bridge Specifications. Gradations are expressed on the basis of the total percent passing, which indicates the total percent of aggregate by weight that will pass a given size sieve.

Some of the descriptive terms used in referring to aggregate gradation are:

- (a) Coarse aggregate – all of the material retained on the No. 10 sieve (2.00 mm).
- (b) Fine aggregate or soil mortar – all of the material passing the No. 10 (2.00 mm) sieve.

## **Procedure for Sieve Analysis of Dense Graded Aggregates**

Dry sieve analysis and washed sieve analysis are two methods of determining proportions of various particle sizes in a mineral aggregate. In Virginia, however, a combination of both methods is used in performing a sieve analysis on aggregates. Standard procedures for performing the sieve analysis are given in VTM-25. The steps are as follows:

1. Obtain a representative sample of the material from a 30 to 40 lbs. (13.6 to 18.1 kg) field sample by either a sample splitter or the quartering method. (See Paragraphs (a) and (b) below.) The sample of material should be reduced to a test sample weighing not less than 5000 grams dry weight.
  - (a) Sample Splitter - A suitable riffle sampler or sample splitter for proportional splitting of the material which is capable of obtaining representative portions of the sample without loss of fines.
  - (b) Quartering Method – The following method of sample - size reduction by quartering is outlined for use when a conventional sample splitter is not available.
    - (1) Uniformly distribute a shovel full of the aggregate over a wide, flat area on a tight weave canvas or other smooth surface. Continue to distribute shovelfuls of material in layers until all the sample is used to make a wide, flat pile that is reasonably uniform in thickness and distribution of aggregate sizes. Do not permit coning of the aggregate.
    - (2) Divide the pile cleanly into equal quarters with a square-end shovel or straight piece of sheet metal. When a canvas is used, the division may be conveniently made by inserting a thin stick (or rod) under the canvas and raising it to divide the sample equally, first into halves, then into quarters.
    - (3) Remove two opposite quarters and set aside.

- (4) Repeat the foregoing procedure with the remaining portion of the aggregate until a test sample of desired size is obtained.
  - (5) Store the portion that has been set aside for possible check testing.
2. Accurately weigh the wet sample. Record this wet weight on a moisture worksheet. This material will not only be used for the gradation test but also for the moisture test.  
Example: 5922 grams.
3. Dry aggregate sample thoroughly. The sample is dried to a constant weight at a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).
4. To complete the required tests it will also be necessary to take a small sample from the remaining material; this sample must be dried at a temperature of no more than  $140^{\circ}\text{F}$  ( $60^{\circ}\text{C}$ ). From this small sample the material passing the No. 40 ( $425\ \mu\text{m}$ ) sieve will be extracted to run Atterberg Limits.
5. After the sample that was taken for the gradation test and moisture test is dried to a constant weight and cooled, accurately weigh the dried sample. In weighing and handling the sample, extreme care must be taken to avoid any loss of material, as this will affect the accuracy of the results. Also, do not adjust the weight of the sample to an even figure, such as 5000 g, 5500 g, etc. Use the entire reduced and dried sample.
6. Record the weight of the dried sample. This weight is used for two purposes. First, it is recorded on the moisture worksheet and used to determine the percent of total moisture in the sample and, second, it is used as the weight of the total sample for computing the gradation of the sample obtained by either a sample splitter or quartering method.

7. Calculate the moisture content in the sample. We can determine the percent of total moisture of the sample by the following formula.

$$\% \text{ Moisture} = \frac{(\text{wt. of wet mat'l}) - (\text{wt. of dry mat'l.})}{\text{wt. of dry mat'l}} \times 100$$

$$\text{wt. of wet mat'l} = 5922$$

$$\text{wt. of dry mat'l} = 5640$$

$$\% \text{ moisture} = \frac{(5922 - 5640)}{5640} \times 100$$

$$\% \text{ moisture} = \frac{282}{5640} \times 100$$

$$\% \text{ moisture} = .05 \times 100 = 5.0$$

Note: When calculating the moisture content, round answer to the nearest 0.1 percent

8. Shake the sample in a mechanical shaker. If no clay and silt is sticking to the aggregate there is not a problem. If this is a problem, buff the entire test sample. The sample is usually by a mechanical device in which a scoopful of the aggregate is placed into a metal bowl and a rotating hard rubber mall is lowered into the material removing the dust from the stone. If the total test sample is made up of hard, fairly clean material, then the buffing of the test sample can be eliminated.

Note: Prior to running a sieve analysis for either coarse or fine aggregates, using a mechanical shaker, the shaker should be calibrated annually as outlined in VCM-20.

9. Separate the + No. 10 (+ 2.00 mm) (coarse) portion of the test sample into individual sizes using large sieves mounted in frames. These sieves are arranged with the more coarse sieve at the top 3 inch (75 mm); each sieve below is finer; and the finest sieve, a + No. 10 (2.00 mm) is at the bottom. It will take approximately seven to ten (10) minutes of shaking to separate the material.
10. Weigh and record the weights of the + No. 10 (+ 2.00 mm) material retained on each sieve. Suppose, upon examination of the sieves, that the first sieve we found material retained on was the 1 inch (25.0 mm) sieve. The material is carefully removed, placed on the balance and the weight recorded on the 1 inch (25.0 mm) under grams retained. This material is then removed from the balance and the next sieve examined for material retained.

The material from the next sieve in this example the 3/4 inch (19.0 mm) sieve is carefully removed and placed on the balance and the weight recorded on the 3/4 inch (19.0 mm) under grams retained. This procedure is done for each successive sieve.

**Example - Recorded weights of Coarse gradation (+10) material:**

MECHANICAL ANALYSIS OF TOTAL SAMPLE				MECHANICAL ANALYSIS OF SOIL MORTAR			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING	SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)				63.0 mm (2 ½)			
50.0 mm (2)				50.0 mm (2)			
37.5 mm (1 ½)				37.5 mm (1 ½)			
25.0 mm (1)	<b>1155</b>			25.0 mm (1)			
19.0 mm (3/4)	<b>470</b>			19.0 mm (3/4)			
9.50 mm (3/8)	<b>860</b>			9.50 mm (3/8)			
4.75 mm (4)	<b>540</b>			4.75 mm (4)			
2.0 mm (10)	<b>445</b>			2.0 mm (10)			
.850 mm (20)				.850 mm (20)			
.425 mm (40)				.425 mm (40)			
.250 mm (60)				.250 mm (60)			
.180 mm (80)				.180 mm (80)			
.150 mm (100)				.150 mm (100)			
.075 mm (200)				.075 mm (200)			
Total	<b>5640</b>			Total	<b>166.1</b>		

11. Obtain a representative sample of the material passing the No. 10 (2.00 mm) sieve (fine material). The material passing the No. 10 (2.00 mm) sieve is thoroughly mixed and, using a small sample splitter, is reduced until a fine gradation sample weighing between 125 - 200 grams is obtained.
12. Weigh the reduced fine gradation sample. Again, care must be exercised in weighing and handling the sample, as any loss of material will affect the accuracy of the results. Use the entire reduced sample.
13. Record the weight of the fine gradation sample. This weight is recorded and used as the total weight for computing the gradation of the soil mortar. The weight should be recorded to the nearest 0.1 gram

14. Place the fine gradation material on a No. 200 (75  $\mu\text{m}$ ) sieve and gently wash by passing running water through the sample. When the wash water passing through the sample is clear, the sample is considered clean. The washed material is then transferred to a drying dish and dried at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).
15. Separate the fine gradation -10 (2.00 mm) material into individual sizes using the standard 8 in. (200 mm) diameter sieves. The sieves normally used are: No. 20 (850 $\mu\text{m}$ ), No. 40 (425  $\mu\text{m}$ ), No. 60, (250  $\mu\text{m}$ ), No. 80 (180  $\mu\text{m}$ ), No. 100 (150  $\mu\text{m}$ ), and No. 200 (75  $\mu\text{m}$ ) . These sieves are arranged with the coarser sieve at the top; each sieve below is finer; and the finest sieve, a No. 200 (75  $\mu\text{m}$ ), is at the bottom. A pan is placed below to retain any fine material that may pass this sieve.

The dried sample is placed on the top sieve, and the entire nest of sieves is placed in a shaker that produces a circular and tapping motion, or in other approved shaking devices. This motion assists gravity in settling the individual aggregate particles on the sieve which will properly identify the size of that particular particle.

Note: Prior to running a sieve analysis for either coarse or fine aggregates, using a mechanical shaker, the shaker should be calibrated annually as outlined in VCM-20.

16. Weigh and record the weights of the fine gradation sample No. 200 (75  $\mu\text{m}$ ) retained on each sieve to the nearest 0.1 gram. Suppose upon examination of the sieves, that the first sieve we found material retained on was the No. 20 sieve (850  $\mu\text{m}$ ) . The material is carefully removed, placed on the balance and the weight recorded under the “mechanical analysis of soil mortar” as grams retained for the +No. 20 sieve (+ 850  $\mu\text{m}$ ). This material is then removed from the balance and the next sieve examined for material retained. The material from the next sieve in this example No. 40 (425  $\mu\text{m}$ ) sieve is carefully removed and placed on the balance and the weight recorded on + No. 40 (+425  $\mu\text{m}$ ) sieve under “grams retained”. This procedure is done for each successive sieve. The weights should be recorded to the nearest 0.1 gram.

**Example – Recorded weights of fine gradation ( -10) material:**

MECHANICAL ANALYSIS OF TOTAL SAMPLE				MECHANICAL ANALYSIS OF SOIL MORTAR			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING	SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)				63.0 mm (2 ½)			
50.0 mm (2)				50.0 mm (2)			
37.5 mm (1 ½)				37.5 mm (1 ½)			
25.0 mm (1)	<b>1155</b>			25.0 mm (1)			
19.0 mm (3/4)	<b>470</b>			19.0 mm (3/4)			
9.50 mm (3/8)	<b>860</b>			9.50 mm (3/8)			
4.75 mm (4)	<b>540</b>			4.75 mm (4)			
2.0 mm (10)	<b>445</b>			2.0 mm (10)			
.850 mm (20)				.850 mm (20)	<b>36.9</b>		
.425 mm (40)				.425 mm (40)	<b>26.6</b>		
.250 mm (60)				.250 mm (60)	<b>15.9</b>		
.180 mm (80)				.180 mm (80)	<b>7.8</b>		
.150 mm (100)				.150 mm (100)	<b>5.8</b>		
.075 mm (200)				.075 mm (200)	<b>19.8</b>		
Total	<b>5640</b>			Total	<b>166.1</b>		

17. Determine the percent retained on each sieve. Up to this point we have made entries for the weight of the total sample, weight of each +No. 10 (2.00 mm) sieve, weight of the fine gradation sample -No. 10 (2.00 mm) material and weight of each - No. 10 (2.00 mm) sieve. In order to determine the percent retained, we must divide the grams retained on each sieve by the total dry weight of the sample (5640) for the +No. 10 (2.00 mm) sieves and the total dry weight of the sample (166.1) for the -No. 10 (2.00 mm) sieves.



## Coarse Gradation Computation

$\frac{\text{Grams Retained}}{\text{Total Weight}} \times 100 = (\%) \text{ Retained}$

MECHANICAL ANALYSIS OF TOTAL SAMPLE			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)			
50.0 mm (2)			
37.5 mm (1 ½)			
25.0 mm (1)	<b>1155</b>	<b>20.5%</b>	
19.0 mm (¾)	<b>470</b>	<b>8.3%</b>	
9.50 mm (¾)	<b>860</b>	<b>15.2%</b>	
4.75 mm (4)	<b>540</b>	<b>9.6%</b>	
2.0 mm (10)	<b>445</b>	<b>7.9%</b>	
.850 mm (20)			
.425 mm (40)			
.250 mm (60)			
.180 mm (80)			
.150 mm (100)			
.075 mm (200)			
Total	<b>5640</b>		

$\frac{\text{Grams Retained}}{\text{Total Weight}} \times 100 = (\%) \text{ Retained}$

$$\frac{1155}{5640} \times 100 = 20.5\%$$

5640

$$\frac{470}{5640} \times 100 = 8.3\%$$

5640

$$\frac{860}{5640} \times 100 = 15.2\%$$

5640

$$\frac{540}{5640} \times 100 = 9.6\%$$

5640

$$\frac{445}{5640} \times 100 = 7.9\%$$

5640

## Fine Gradation Computation

MECHANICAL ANALYSIS OF SOIL MORTAR			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)			
50.0 mm (2)			
37.5 mm (1 ½)			
25.0 mm (1)			
19.0 mm (¾)			
9.50 mm (3/8)			
4.75 mm (4)			
2.0 mm (10)			
.850 mm (20)	<b>36.9</b>	<b>22.2%</b>	
.425 mm (40)	<b>26.6</b>	<b>16.0%</b>	
.250 mm (60)	<b>15.9</b>	<b>9.6%</b>	
.180 mm (80)	<b>7.8</b>	<b>4.7%</b>	
.150 mm (100)	<b>5.8</b>	<b>3.5%</b>	
.075 mm (200)	<b>19.8</b>	<b>11.9%</b>	
Total	<b>166.1</b>		

Grams Retained x 100 = (%) Retained

Total Weight

$$\frac{36.9}{166.1} \times 100 = 22.2\%$$

166.1

$$\frac{26.6}{166.1} \times 100 = 16.0\%$$

166.1

$$\frac{15.9}{166.1} \times 100 = 9.6\%$$

166.1

$$\frac{7.8}{166.1} \times 100 = 4.7\%$$

166.1

$$\frac{5.8}{166.1} \times 100 = 3.5\%$$

166.1

$$\frac{19.8}{166.1} \times 100 = 11.9\%$$

166.1

18. Determine the percent passing for the +No. 10 (2.00 mm) material (coarse gradation). We must first place the figure 100.0 (%) in the “percent passing” column above the screen having the first entry of grams retained. By subtracting the percent retained from the percent passing the next larger sieve, we obtain the percent passing. This process is repeated for each sieve until the percent passing the No. 10 (2.00 mm) is obtained. All calculations should be recorded to the nearest 0.1 percent

### Calculations for Percent Passing

MECHANICAL ANALYSIS OF TOTAL SAMPLE			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)			
50.0 mm (2)			
37.5 mm (1 ½)			<b>100.0</b>
25.0 mm (1)	<b>1155</b>	<b>20.5%</b>	<b>79.5</b>
19.0 mm (3/4)	<b>470</b>	<b>8.3%</b>	<b>71.2</b>
9.50 mm (3/8)	<b>860</b>	<b>15.2%</b>	<b>56.0</b>
4.75 mm (4)	<b>540</b>	<b>9.6%</b>	<b>46.4</b>
2.0 mm (10)	<b>445</b>	<b>7.9%</b>	<b>38.5</b>
.850 mm (20)			
.425 mm (40)			
.250 mm (60)			
.180 mm (80)			
.150 mm (100)			
.075 mm (200)			
Total	<b>5640</b>		

**% Passing - % Retained = % Passing**

NOTE: 100% is always placed in the percent passing column one line above the screen having the first entry of grams retained.

100.0 - 20.5 = 79.5

79.5 - 8.3 = 71.2

71.2 - 15.2 = 56.0

56.0 - 9.6 = 46.4

46.4 - 7.9 = 38.5

19. Determine the percent passing for the fine gradation sample -No. 10 (2.00 mm) material).  
 Again, we must first place the figure 100.0 (%) in the “percent passing” column above the screen having the first entry of grams retained. By subtracting the percent retained from the percent passing the next larger sieve, we obtain the percent passing. This process is repeated for each sieve until the percent passing the No. 200 (75 μm) is obtained. All calculations should be recorded to the nearest 0.1 percent.

MECHANICAL ANALYSIS OF SOIL MORTAR			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)			
50.0 mm (2)			
37.5 mm (1 ½)			
25.0 mm (1)			
19.0 mm (¾)			
9.50 mm (3/8)			
4.75 mm (4)			
2.0 mm (10)			<b>100.0</b>
.850 mm (20)	<b>36.9</b>	<b>22.2%</b>	<b>77.8</b>
.425 mm (40)	<b>26.6</b>	<b>16.0%</b>	<b>61.8</b>
.250 mm (60)	<b>15.9</b>	<b>9.6%</b>	<b>52.2</b>
.180 mm (80)	<b>7.8</b>	<b>4.7%</b>	<b>47.5</b>
.150 mm (100)	<b>5.8</b>	<b>3.5%</b>	<b>44.0</b>
.075 mm (200)	<b>19.8</b>	<b>11.9%</b>	<b>32.1</b>
Total	<b>166.1</b>		

**% Passing - % Retained = % Passing**  
 NOTE: 100% is always placed in the percent passing column one line above the screen having the first entry of grams retained.

100.0 - 22.2 = 77.8  
 77.8 - 16.0 = 61.8  
 61.8 - 9.6 = 52.2  
 52.2 - 4.7 = 47.5  
 47.5 - 3.5 = 44.0  
 44.0 - 11.9 = 32.1

20. **Determine the percent retained for the -No. 10 (2.00 mm) material of the total sample.** By multiplying the percent passing the No. 10 (2.00 mm) of the total sample by the percent retained on each of the sieves of the fine gradation -No. 10 (2.00 mm) sample and then dividing by 100 , we can calculate the percent retained on each sieve of the -No. 10 (2.00 mm) material for the total sample.

$$\% \text{ Passing (No.10)} \times \% \text{ Retained Soil Mortar} / 100 = \% \text{ Retained Total Sample}$$

MECHANICAL ANALYSIS OF TOTAL SAMPLE				MECHANICAL ANALYSIS OF SOIL MORTAR			
SIEVE SIZES	GRAMS RETAIN	PERCENT RETAINED	PERCENT PASSING	SIEVE SIZES	GRAMS RETAIN	PERCENT RETAIN	PERCENT PASSING
63.0 mm (2 ½)				63.0 mm (2 ½)			
50.0 mm (2)				50.0 mm (2)			
37.5 mm (1 ½)			100.0%	37.5 mm (1 ½)			
25.0 mm (1)	1155	20.5%	79.5%	25.0 mm (1)			
19.0 mm (3/4)	470	8.3%	71.2%	19.0 mm (3/4)			
9.50 mm (3/8)	860	15.2%	56.0%	9.50 mm (3/8)			
4.75 mm (4)	540	9.6%	46.4%	4.75 mm (4)			
2.0 mm (10)	445	7.9%	38.5%	2.0 mm (10)			100.0%
.850 mm (20)		8.5%		.850 mm (20)	36.9	22.2%	77.8%
.425 mm (40)		6.2%		.425 mm (40)	26.6	16.0%	61.8%
.250 mm (60)		3.7%		.250 mm (60)	15.9	9.6%	52.2%
.180 mm (80)		1.8%		.180 mm (80)	7.8	4.7%	47.5%
.150 mm (100)		1.3%		.150 mm (100)	5.8	3.5%	44.0%
.075 mm (200)		4.6%		.075 mm (200)	19.8	11.9%	32.1%
Total	5640			Total	166.1		

**% Passing (No.10) × % Retained Soil Mortar / 100 = % Retained Total Sample**

38.5 x 22.2 = 854.7 / 100 = 8.54 8.5%

38.5 x 16.0 = 616.0 / 100 = 6.16 6.2%

38.5 x 9.6 = 369.6 / 100 = 3.69 3.7%

38.5 x 4.7 = 180.9 / 100 = 1.80 1.8%

38.5 x 3.5 = 134.8 / 100 = 1.34 1.3%

38.5 x 11.9 = 458.2 / 100 = 4.58 4.6%

21. **Determine the percent passing for the -No. 10 (2.00 mm) material of the total sample.** Again, by subtracting the percent retained from the percent passing the next larger sieve, we obtain the percent passing. This process is repeated for each sieve until the percent passing the No. 200 (75 μm) is obtained. All calculations should be recorded to the nearest 0.1 percent. For a quick check of your computations, remember that the percent retained and the percent passing the -No. 200 (75μm) sieve of the total sample should agree within 0.1 percent.

MECHANICAL ANALYSIS OF TOTAL SAMPLE			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)			
50.0 mm (2)			
37.5 mm (1 ½)			<b>100.0%</b>
25.0 mm (1)	44.55	33.5%	70.5%
19.0 mm (¾)	11.5	8.5%	62.0%
9.5 mm (¾)	4.7	3.5%	58.5%
4.75 mm (No. 40)	2.0	1.5%	57.0%
2.0 mm (No. 10)	0.85	0.6%	56.4%
0.85 mm (No. 20)	0.42	0.3%	56.1%
0.425 mm (No. 40)	0.21	0.15%	55.9%
0.18 mm (No. 100)	0.18	0.13%	55.8%
0.15 mm (No. 100)	0.15	0.11%	55.7%
0.075 mm (No. 200)	0.0	0.0%	55.7%
Total			

**% Passing - % Retained = % Passing**

NOTE: 100% is always placed in the percent passing column one line above the screen having the first entry of grams retained.

$38.5 - 8.5 = 30.0$   
 $30.0 - 6.2 = 23.8$   
 $23.8 - 3.7 = 20.1$   
 $20.1 - 1.8 = 18.3$   
 $18.3 - 1.3 = 17.0$   
 $17.0 - 4.6 = 12.4$

<b>COMPLETED MECHANICAL SIEVE ANALYSIS</b>							
<b>MECHANICAL ANALYSIS OF TOTAL SAMPLE</b>				<b>MECHANICAL ANALYSIS OF SOIL MORTAR</b>			
<b>SIEVE SIZES</b>	<b>GRAMS RETAINED</b>	<b>PERCENT RETAINED</b>	<b>PERCENT PASSING</b>	<b>SIEVE SIZES</b>	<b>GRAMS RETAINED</b>	<b>PERCENT RETAINED</b>	<b>PERCENT PASSING</b>
63.0 mm (2 ½)				63.0 mm (2 ½)			
50.0 mm (2)				50.0 mm (2)			
37.5 mm (1 ½)			<b>100.0%</b>	37.5 mm (1 ½)			
25.0 mm (1)	<b>1155</b>	<b>20.5%</b>	<b>79.5%</b>	25.0 mm (1)			
19.0 mm (3/4)	<b>470</b>	<b>8.3%</b>	<b>71.2%</b>	19.0 mm (3/4)			
9.50 mm (3/8)	<b>860</b>	<b>15.2%</b>	<b>56.0%</b>	9.50 mm (3/8)			
4.75 mm (4)	<b>540</b>	<b>9.6%</b>	<b>46.4%</b>	4.75 mm (4)			
2.0 mm (10)	<b>445</b>	<b>7.9%</b>	<b>38.5%</b>	2.0 mm (10)			<b>100.0%</b>
.850 mm (20)		<b>8.5%</b>	<b>30.0%</b>	.850 mm (20)	<b>36.9</b>	<b>22.2%</b>	<b>77.8%</b>
.425 mm (40)		<b>6.2%</b>	<b>23.8%</b>	.425 mm (40)	<b>26.6</b>	<b>16.0%</b>	<b>61.8%</b>
.250 mm (60)		<b>3.7%</b>	<b>20.1%</b>	.250 mm (60)	<b>15.9</b>	<b>9.6%</b>	<b>52.2%</b>
.180 mm (80)		<b>1.8%</b>	<b>18.3%</b>	.180 mm (80)	<b>7.8</b>	<b>4.7%</b>	<b>47.5%</b>
.150 mm (100)		<b>1.3%</b>	<b>17.0%</b>	.150 mm (100)	<b>5.8</b>	<b>3.5%</b>	<b>44.0%</b>
.075 mm (200)		<b>4.6%</b>	<b>12.4%</b>	.075 mm (200)	<b>19.8</b>	<b>11.9%</b>	<b>32.1%</b>
Total	<b>5640</b>			Total	<b>166.1</b>		

NOTE: When reporting results, percentages should be reported to the nearest whole number, except if the percentage passing the No 200 (75 µm) sieve is less than 10 percent, it shall be reported to the nearest 0.1 percent.

## Atterberg Limits

### Liquid Limit

**Definition:** The amount of water (percent of moisture) that it takes for a soil to pass from a plastic to a liquid state.

The Atterberg Limits provide a measure of the consistency of the soil. With the gradation test completed, we now return to the small sample that has been drying at a maximum of 140°F (60°C). From this sample we must obtain the -No. 40 (-425 µm) material on which the Liquid Limit and Plastic Limit will be run. VDOT uses the procedure outlined in AASHTO T-89 Method B, except as modified by VTM-7, to perform routine liquid limit tests. AASHTO T-89 Method A except as modified by VTM-7 is used for referee testing.

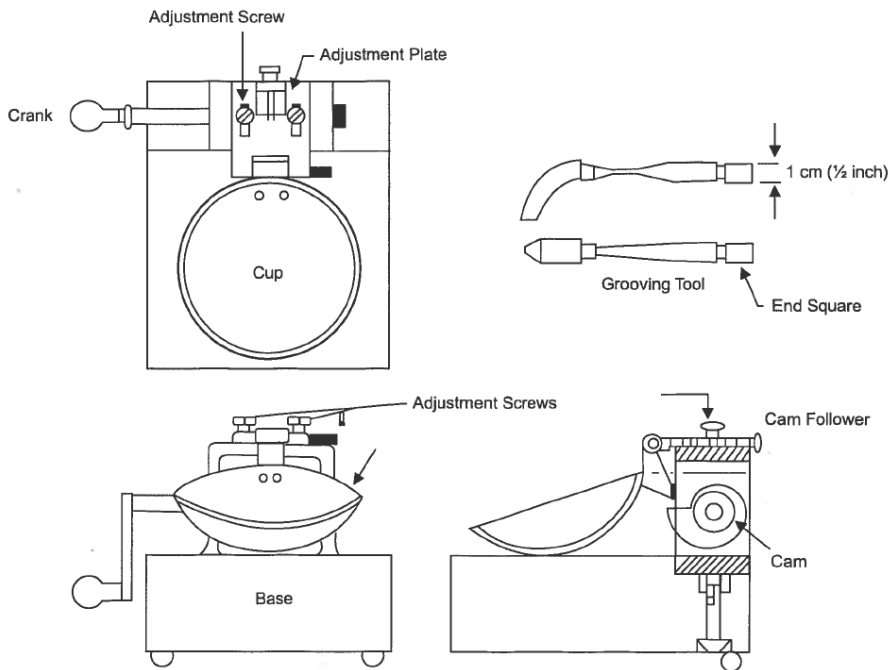
The modification to the test method regards the sensitivity of the balance used. AASHTO T-89 requires that the balance conform to M 231, Class G1. A Class G1 balance has a readability of 0.01 grams. VTM-7 states that a balance with a sensitivity of 0.10 grams may be used.

The steps for the tests procedures are outlined as follows:

1. Buff and sieve the entire sample using a No. 10 (2.00 mm) sieve. Buff the sample using the same procedure as outlined for the gradation sample. The material retained on the No. 10 (2.00 mm) sieve may be discarded.
2. Buff and sieve a representative sample of the material passing the No. 10 (2.00 mm) sieve using a No. 40 (425 µm) sieve with a sieve pan under it. Again use the same procedure for buffing as outlined for the gradation sample. The material retained on the No. 40 (425 µm) should be rebuffed and resieved until little or no material is passing the No. 40 (425 µm) sieve. The No. -40 (-425 µm) material is used for the Atterberg Limits.
3. The Liquid Limit device should be inspected to determine that the device is in good working order. There should be no excessive wear in the pin connecting the cup, nor a groove cut in the cup through long usage. The Liquid Limit Cup should be inspected for proper thickness. The grooving tool should be inspected to determine if there is excessive wear on the cutting edge. It is essential that the Liquid Limit cup be adjusted so that, when it is raised, the contact point of the cup is 10.0 mm ± 2 mm above the base (the back end of the grooving tool is 10.0 mm in thickness). The adjustment plate is manipulated back and forth by loosening the screws in its tip and turning the set screw at the back. With the 10.0 mm gauge held in place, the adjustment plate is moved so that when the crank is revolved, there is a slight ringing



sound when the cam strikes the cam follower. If the cup is raised off the gauge or no sound is heard, further adjustments are necessary.



4. Obtain a sample weighing approximately 50 grams from the thoroughly mixed portion of the material passing the No. 40 (425  $\mu\text{m}$ ) sieve. Place this material in a mixing dish and mix with 8-10 ml of distilled or demineralized water. The material is mixed by alternately and repeatedly stirring, kneading, and chopping with a spatula. If additional water is needed in the mixture, it shall be added increments of 1-3 ml. It shall then be thoroughly mixed in stiff consistency.

NOTE: The cup of the Liquid Limit device shall not be used for mixing soil and water.

5. Place a portion of this mixture in the cup of the Liquid Limit device above the spot where the cup rests on the base and, with a spatula, squeeze and spread the material with as few strokes as possible. The material is then leveled and at the same time trimmed to a depth of 1/2 inch (1.0 cm) at the point of maximum thickness.
6. Divide the soil in the cup by firm strokes of the grooving tool along a diameter of the centerline of the cam follower. To avoid tearing the side of the groove or slipping the soil cake on the cup, up to six (6) strokes may be permitted to form this groove. A stroke is considered one motion from back-to-front or front-to-back. The depth of the groove shall be increased with each stroke, and only the last stroke shall scrape the bottom of the cup.

7. The cup containing the soil sample shall be lifted and dropped by turning the crank at the rate of two (2) revolutions per second until the two sides of the sample make contact at the bottom of the groove along a distance of about 1/2 inch (12.5 mm) . The groove must be closed between 22 and 28 blows. If the closure is met between the required blows, remove the material from the cup and return it to the bowl. Do not add any additional water. Repeat steps 5 and 6. If the second closure is between 22 and 28 blows and within 2 blows of the first closure record the number as directed in step 8.

If the groove closes before 22 blows, the material is too wet and must be discarded or returned to the mixing dish and mixed and kneaded until enough evaporation has taken place for the closure point to fall within an acceptable range . If it takes more than 28 blows to close the groove, the material is too dry and must be returned to the mixing dish. Then add a small increment of water and remix thoroughly.

NOTE: While the crank is being turned, the base of the machine should not be held.

8. Record the number of blows to close the groove 1/2 inch (12.5 mm) on the worksheet in the “Liquid Limit Section”.
9. Remove and place in a suitable container with a close-fitting lid, a slice of soil approximately the width of the spatula (3/4 inch) extending from edge-to-edge of the soil cake, and at right angles to the portion of the groove in which the soil flows together. The covered container and soil shall then be weighed to the nearest 0.1 gram and recorded on the form.

NOTE: The weight of the empty container and lid should already be recorded on the form in the space marked “Dish”.

10. Dry the soil in the container to a constant weight at 230 ± 9°F (110 ± 5°C) and record the weight of the covered container and dry soil. Again, the weight should be recorded to the nearest 0.1 gram.

Liquid Limit	
Dish No. <b>160</b>	No. of Blows <b>28</b>
Dish & Wet Soil <b>42.4</b>	Dish & Dry Soil <b>38.6</b>
Dish & Dry Soil <b>38.6</b>	Dish <b>19.4</b>
Mass of Water	Dry Soil
% Moisture = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 =$	
L.L. =	=

11. Calculate the Liquid Limit of the material. First we must determine the weight of the water. To determine the weight of the water, we must subtract the weight of the dish and dry soil from the weight of the dish and wet soil. Record the weight of the water on the form in the space marked "Mass of Water"
12. Secondly, we must determine the weight of the dry soil. To determine the weight of the dry soil, we must subtract the weight of the dish from the weight of the dish and dry soil. Record the weight of the dry soil on the form in the space marked "Dry Soil".
13. We are now ready to calculate the percent moisture or limit at which the soil becomes liquid. To determine the percent of moisture, we divide the weight of the water by the weight of the dry soil and multiply by "100". Record this in the space marked "% Moisture". Since our Liquid Limit Test is based on a standard of 25 blows to close the groove, and if we had a number other than 25, we must use a factor to convert the moisture to what it would have been if the groove had closed at 25 blows.

A chart of correction factors is supplied to all pugmill laboratories (See page 3-20). By multiplying the percent of moisture by the correction factor, we determine the true Liquid Limit. The Liquid Limit is first recorded to the nearest 0.1 gram on the worksheet, but reported in PLAID to the nearest whole number. 5 or above - round up, 4 or below - round down.

Liquid Limit	
Dish No. 160	No. of Blows 28
Dish & Wet Soil 42.4	Dish & Dry Soil 38.6
Dish & Dry Soil 38.6	Dish 19.4
Mass of Water 3.8	Dry Soil 19.2
$\% \text{ Moisture} = \frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 = \frac{3.8}{19.2} \times 100 = 19.8$	
L.L. = 20.1 = 20	

**Step (1)** 42.4  
- 38.6  
3.8

**Step (2)** 38.6  
- 19.4  
19.2

**Step (3)** % Moisture = 3.8 x 100 = 19.8  
19.2

**Step (4)** L.L. = 19.8 x 1.014 (factor for 28 blows) = 20.1 = 20

## Liquid Limit Chart

$$L. L. = M(f)$$

Where : L. L. = Liquid Limit

M = % Moisture

f = Correction Factor

N = Number of Blows

N	f
15	0.940
16	0.947
17	0.954
18	0.961
19	0.967
20	0.973
21	0.979
22	0.985
23	0.990
24	0.996
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022
31	1.026
32	1.030
33	1.034
34	1.038
35	1.042
36	1.045
37	1.049
38	1.052
39	1.055
40	1.059

Example : % Moisture at 22 blows = 42.3

From Table for 22 blows, f = 0.985

$$L. L. = 42.3 \times 0.985$$

$$L. L. = 41.7 = 42$$

## Plastic Limit

**Definition: The amount of water (percent of moisture) that it takes for a soil to pass from a semi-solid to a plastic state.**

VDOT uses the procedure outlined in AASHTO T-90, except as modified by VTM-7, to perform determine the plastic limit and plasticity index of soils. The modification to the test method regards the sensitivity of the balance used. AASHTO T-90 requires that the balance conform to M 231, Class G1. A Class G1 balance has a readability of 0.01 grams. VTM- 7 states that a balance with a sensitivity of 0.10 grams may be used.

1. To determine the plastic limit, remove an 8-gram portion of the thoroughly mixed material that is to be used for the liquid limit test. The sample may be removed at any time after the material becomes plastic enough to be easily shaped into a ball without sticking excessively to the fingers when squeezed, or at the completion of the liquid limit test.
2. From the 8-gram mass of mixed material, break off a 1.5 - 2.0 gram portion. Squeeze and form the sample into an ellipsoidal-shaped mass and roll this mass between the fingers and a piece of glass or unglazed paper lying on a smooth horizontal surface, with just enough pressure to roll the mass into a thread of uniform diameter throughout its length. 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. This operation shall continue until the thread becomes 1/8 inch (3.0 mm) in diameter. At no time shall the operator attempt to produce failure at exactly 1/8 inch (3.0 mm) by either reducing the rate of rolling or increasing the pressure. If a sample cannot be rolled to a thread of 1/8 inch (3.0 mm) on the first attempt, it shall be considered non-plastic and no further testing is necessary. Record NP for non-plastic under "Plastic Limit".
3. Should the sample roll down to 1/8 inch (3.0 mm), break the thread into 6 to 8 pieces and squeeze the pieces together between the thumb and fingers of both hands. Again, shape the material into a uniform mass roughly ellipsoidal shaped and re-roll. Continue this alternate rolling to a thread 1/8 inch (3.0 mm) in diameter, gathering together, kneading, and re-rolling until the thread crumbles under pressure required for rolling the soil no longer can be rolled into a thread. The crumbling may occur when the thread is of a diameter greater than 1/8 inch (3.0 mm). This shall be considered a satisfactory end point, provided this has previously been rolled into a 1/8 inch (3.0 mm) thread.

The crumbling will manifest itself differently with the various types of soils. Repeat steps 2 and 3 until the 8-gram portion of material is completely tested.

4. At the conclusion of the rolling when the sample has finally crumbled, gather the soil, place in a suitable container with a close-fitting lid and weigh. This weight must be recorded to the nearest 0.1 gram on the form in the space marked "Dish & Wet Soil".

NOTE: The weight of the empty container and lid should already be recorded on the form in the space marked "Dish".

5. Dry the soil in the container to a constant weight at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ) and re-weigh. Record the weight in the space marked "Dish and Dry Soil". Again, the weight must be recorded to the nearest 0.1 gram.

Plastic Limit	
Dish No. 136	
Dish & Wet Soil 36.1	Dish & Dry Soil <b>33.7</b>
Dish & Dry Soil <b>33.7</b>	Dish 20.0
Mass of Water	Dry Soil
P. L. = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 =$	

6. Calculate the Plastic Limit of the Material. First, we must determine the mass of the water. To determine the weight of the water, we must subtract the weight of the dish and dry soil from the weight of the dish and wet soil. Record the weight of the water on the form in the space labeled, **Mass of Water.**

Secondly, as for the Liquid Limit, we must determine the weight of the dry soil. To determine the weight of the dry soil, we must subtract the weight of the dish from the weight of the dish and dry soil. Record the weight in the space labeled **Dry Soil** on the form.

We are now ready to calculate the percent of moisture or limit at which the soil becomes plastic. To determine the percent moisture, we divide the weight of the water by the weight of the dry soil and multiply by "100". **A conversion factor is not needed to compute the Plastic Limit.**

The Plastic Limit is first recorded to the nearest 0.1 gram on the work sheet, then round to the nearest whole number. 5 or above - round up, 4 or below - round down.

Plastic Limit			
Dish No. 136			
Dish & Wet Soil 36.1	Dish & Dry Soil 33.7		
Dish & Dry Soil 33.7	Dish	20.0	
Mass of Water 2.4	Dry Soil	13.7	
P. L. = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 = \frac{2.4}{13.7} \times 100 = 17.5 = 18$			

**Step (1)** 36.1  
- 33.7  
2.4

**Step (2)** 33.7  
- 20.0  
13.7

**Step (3) % Moisture =  $\frac{2.4}{13.7} \times 100 = 17.5 = 18$**

## Plasticity Index

Definition: The numerical difference between the Liquid Limit and the Plastic Limit, we simply subtract the Plastic Limit from the Liquid Limit. If a material is non-plastic, the Plastic Limit is recorded as 0.

Liquid Limit	20%
Plastic Limit	- <u>18%</u>
Plasticity Index	<b>2 %</b>

## Optimum Moisture

### Dense Graded Aggregates

Optimum moisture content is defined as the water content at which an aggregate mixture will achieve maximum density for a particular compaction method. Even with an understanding of the definition of optimum moisture as stated above, the words optimum moisture have little meaning to a Producer Technician or Inspector unless a measurable value can be found to express optimum moisture. VDOT uses the procedures outlined in AASHTO T-99 Method A, except as modified by VTM-1, to determine the optimum moisture content of aggregate mixtures. Like other moisture contents, optimum moisture is expressed as a percentage.

It is not necessary for the Producer Technician or Inspector to understand the laboratory test method or memorize the test procedure. However, it is very important that they understand the laboratory test results as reported and how they apply to the production and inspection of central-mix mixtures.

A moisture content of optimum moisture plus or minus two (2) percentage points is required by the Virginia Department of Transportation Road and Bridge Specifications in the production of central-mix aggregate mixtures. With this requirement, a need arises for the Producer Technician and Inspector to understand some of the descriptive terms used in referring to optimum moisture.

Note: CMA used for pipe backfill and Hydraulic Cement Stabilized CMA may only have a moisture content of optimum to + two (2) percentage points.



Some of the descriptive terms used are:

- (a) Plus 4 material (4.75 mm) - All the material in an aggregate mixture retained on the No. 4 (4.75 mm) sieve.
- (b) Minus 4 material (4.75 mm) - All the material in an aggregate mixture passing the No. 4 (4.75 mm) sieve.
- (c) Minus 4 (4.75 mm) optimum moisture - optimum moisture of the minus 4 (4.75 mm) material is determined by District Laboratory proctor test (AASHTO T-99).
- (d) Plus 4 (4.75 mm) optimum moisture - Optimum moisture of the plus 4 (4.75 mm) material is one percent (1%) of the percentage of the plus 4 (4.75 mm) material, or as directed by the Engineer.
- (e) Absorption - Percent of moisture in an aggregate in a saturated surface dry condition (SSD).
- (f) Total optimum moisture - The sum of the weighted optimum moistures of the minus 4 (4.75 mm) material and plus 4 (4.75 mm) material.
- (g) Moisture Range - Total optimum moisture plus or minus two (2) percentage points.

AASHTO T-99 utilizes only the minus 4 (4.75 mm) portion of an aggregate mixture and may be reported as that of the minus 4 (4.75 mm) material only. In all specifications for dense graded aggregate there must be a percentage of plus 4 (+4.75 mm) material, so it is necessary for the Producer Technician to calculate the total optimum moisture for any type of central mix aggregate mixture.

## To Find Total Optimum Moisture

Use this formula  $(P_c W_c + P_f W_f) 100$

### Obtain the required data.

$P_c$  = % +4 Material expressed as a decimal.

Determine the percent of +4 material by subtracting the percentage of - 4 material (found in the Mechanical Sieve Analysis of Total Sample) from 100 (total sample).

$$100.0 - 46.4 = 53.6 \% \quad + 4 \text{ material}$$

Expressed as decimal = **0.536**

$W_c$  = Absorption of +4 Matl. plus 1% expressed as a decimal

Absorption is obtained from the Plant or the Materials Section. 1% moisture is allowed for the + 4 material or as directed by the Engineer.

**Absorption = 0.3%**

Expressed as decimal  $0.003 + 0.01 = \mathbf{0.013}$

$P_f$  = % -4 Material expressed as a decimal (from Sieve Analysis)

-4 material = **46.4**

Expressed as a decimal = **0.464**

$W_f$  = Optimum Moisture of -4 Material expressed as a decimal

**Optimum moisture = 10.5%**

Expressed as decimal = **0.105**

### Calculate the Total Optimum Moisture Content

$$(P_c W_c + P_f W_f) 100$$

$$[(\underline{0.536} \times \underline{0.013}) + (\underline{0.464} \times \underline{.105})] 100$$

$$[ \underline{0.007} + \underline{0.049} ] 100$$

$$0.056 \times 100 = \mathbf{5.6}$$

### Calculate Moisture Range:

$$\begin{array}{r} 5.6 \\ - 2.0 \\ \hline 3.6 \end{array} \quad \text{to} \quad \begin{array}{r} 5.6 \\ + 2.0 \\ \hline 7.6 \end{array}$$

### Gradation Worksheet

MECHANICAL ANALYSIS OF TOTAL SAMPLE				MECHANICAL ANALYSIS OF SOIL MORTAR			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING	SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)		%		63.0 mm (2 ½)		%	
50.0 mm (2)		%		50.0 mm (2)		%	
37.5 mm (1 ½)		%	<b>100.0%</b>	37.5 mm (1 ½)		%	
25.0 mm (1)	<b>1155</b>	<b>20.5%</b>	<b>79.5%</b>	25.0 mm (1)		%	
19.0 mm (3/4)	<b>470</b>	<b>8.3%</b>	<b>71.2%</b>	19.0 mm (3/4)		%	
9.50 mm (3/8)	<b>860</b>	<b>15.2%</b>	<b>56.0%</b>	9.50 mm (3/8)		%	
4.75 mm (4)	<b>540</b>	<b>9.6%</b>	<b>46.4%</b>	4.75 mm (4)		%	
2.0 mm (10)	<b>445</b>	<b>7.9%</b>	<b>38.5%</b>	2.0 mm (10)		%	<b>100.0%</b>
.850 mm (20)		<b>8.5%</b>	<b>30.0%</b>	.850 mm (20)	<b>36.9</b>	<b>22.2%</b>	<b>77.8%</b>
425 mm (40)		<b>6.2%</b>	<b>23.8%</b>	425 mm (40)	<b>26.6</b>	<b>16.0%</b>	<b>61.8%</b>
.250 mm (60)		<b>3.7%</b>	<b>20.1%</b>	.250 mm (60)	<b>15.9</b>	<b>9.6%</b>	<b>52.2%</b>
.180 mm (80)		<b>1.8%</b>	<b>18.3%</b>	.180 mm (80)	<b>7.8</b>	<b>4.7%</b>	<b>47.5%</b>
.150 mm (100)		<b>1.3%</b>	<b>17.0%</b>	.150 mm (100)	<b>5.8</b>	<b>3.5%</b>	<b>44.0%</b>
.075 mm (200)		<b>4.6%</b>	<b>12.4%</b>	.075 mm (200)	<b>19.8</b>	<b>11.9%</b>	<b>32.1%</b>
Total	<b>5640</b>	<b>12.4%</b>		Total	<b>166.1</b>	<b>32.1%</b>	

Liquid Limit		Plastic Limit		Physical Characteristics of Soil	
Dish No. <b>160</b>	No. of Blows <b>28</b>	Dish No. <b>136</b>		Liquid Limit	<b>20</b> %
Dish & Wet Soil <b>42.4</b>	Dish & Dry Soil <b>38.6</b>	Dish & Wet Soil <b>36.1</b>	Dish & Dry Soil <b>33.7</b>	Plastic Limit	<b>18</b> %
Dish & Dry Soil <b>38.6</b>	Dish <b>19.4</b>	Dish & Dry Soil <b>33.7</b>	Dish <b>20.0</b>	Plasticity Index	<b>2</b> %
Mass of Water <b>3.8</b>	Dry Soil <b>19.2</b>	Mass of Water <b>2.4</b>	Dry Soil <b>13.7</b>		
% Moisture = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 = \underline{19.8}$		P.L. = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 = \underline{17.5} = \underline{18}$		Optimum Moisture Content	
				Total Soil	<b>5.6</b> %
				-4.75 mm (-4) Portion	<b>10.5</b> %
				Maximum Density	
				Total Soil	kg/m <sup>3</sup> (lbs/ft <sup>3</sup> )
				-4.75 mm (-4) Portion	kg/m <sup>3</sup> (lbs/ft <sup>3</sup> )
L.L. = <b>20.1 = 20</b>					

**Wet Weight = 5922 grams    % Moisture 5.0    Moisture Range 3.6 – 7.6    Absorption 0.3**

## Knowledge Check

### Chapter 3 Sampling and Testing Aggregates

1. The fine gradation is washed over the:
  - A. No. 10 (2.00 mm) sieve
  - B. No. 40 (425  $\mu\text{m}$ ) sieve
  - C. No. 100 (150  $\mu\text{m}$ ) sieve
  - D. No. 200 (75  $\mu\text{m}$ ) sieve
  
2. The sieve size that separates the coarse material from the fine material is the:
  - A. No. 40 (425  $\mu\text{m}$ ) sieve
  - B. No. 10 (2.00 mm) sieve
  - C. No. 80 (180  $\mu\text{m}$ ) sieve
  - D. No. 100 (150  $\mu\text{m}$ ) sieve
  
3. The fine gradation sample should weigh between:
  - A. 75 and 100 grams
  - B. 100 and 125 grams
  - C. 125 and 200 grams
  - D. 200 and 300 grams
  
4. A process in which an aggregate is separated into its various sizes by passing it through screens of various openings for the purpose of determining the distribution of the quantities separated is:
  - A. Fineness Modulus
  - B. Sieve analysis
  - C. Moisture analysis
  - D. Yield

5. The minimum dry weight of a sample of central mix aggregate that contains +19.0 mm (3/4 inch) material should be:
- A. 2000 grams
  - B. 4000 grams
  - C. 5000 grams
  - D. 8000 grams
6. Two acceptable ways of splitting a sample are by a sample splitter and by the quartering method.
- A. True
  - B. False
7. What is the temperature range at which the fine gradation is dried?
8. The fine material is shaken for how many minutes?
9. The total sample is computed to the nearest \_\_\_\_\_ percent?
10. The numerical difference between the liquid limit and plastic limit is the plasticity index.
- A. True
  - B. False
11. The liquid limit and plastic limit tests are run on material passing the:
- A. No. 10 (2.00 mm) sieve
  - B. No. 40 (425  $\mu$ m) sieve
  - C. No. 80 (180  $\mu$ m) sieve
  - D. No. 200 (75  $\mu$ m) sieve

12. The moisture content at which a soil changes from a semi-solid to a plastic state is the liquid limit.
- A. True  
B. False
13. In determining the liquid limit and plastic limit, the portion of the wet sample used must be dried at a temperature not to exceed 140°F (60°C) .
- A. True  
B. False
14. Which tests are performed on dense graded aggregates?
15. What are the requirements for water used in the liquid limit and plastic limit test?
16. How many blows per second is the cup on the liquid limit device dropped?
17. To determine the moisture content in the liquid limit test 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, and including that portion that flowed together must be taken.
- A. True  
B. False
18. When determining the plastic limit, the soil is rolled to a thread of \_\_\_\_.
19. VDOT Specifications require that central mixed aggregate be shipped at optimum moisture  $\pm$  percentage points.
- A. 5  
B. 4  
C. 3  
D. 2

**Problem No. 1****Moisture Calculation**

Complete the following moisture determination problem and give the moisture content in percent.

Dish & Wet Material    700 grams

Dish & Dry Material    680 grams

Dish                        200 grams

**Problem No. 2****Moisture Calculation**

In an effort to determine the moisture content of a material, a sample of the material was taken and found to weigh 1346 grams. The sample was then dried to a constant weight and reweighed. The dried sample was found to have a weight of 1240 grams. Using this information, calculate the percent of moisture.

### Problem No. 3

Below is a sample of an Aggregate Subbase Material, Type I, Grading No. 21A. Complete the worksheet for gradation, liquid limit, plastic limit, plasticity index, optimum moisture content and moisture range.

MECHANICAL ANALYSIS OF TOTAL SAMPLE				MECHANICAL ANALYSIS OF SOIL MORTAR			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING	SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)		%		63.0 mm (2)		%	
50.0 mm (2)		%		50.0 mm		%	
37.5 mm (1 ½)		%		37.5 mm (1)		%	
25.0 mm (1)		%		25.0 mm		%	
19.0 mm (3/4)	<b>252</b>	%		19.0 mm		%	
9.50 mm (3/8)	<b>2352</b>	%		9.50 mm		%	
4.75 mm (4)	<b>1241</b>	%		4.75 mm		%	
2.0 mm (10)	<b>1017</b>	%		2.0 mm		%	
.850 mm (20)		%		.850 mm	<b>39.7</b>	%	
425 mm (40)		%		425 mm	<b>23.2</b>	%	
.250 mm (60)		%		.250 mm	<b>13.4</b>	%	
.180 mm (80)		%		.180 mm	<b>9.2</b>	%	
.150 mm (100)		%		.150 mm	<b>6.4</b>	%	
.075 mm (200)		%		.075 mm	<b>18.8</b>	%	
Total	<b>9334</b>	%		Total	<b>174.2</b>	%	

Liquid Limit		Plastic Limit		Physical Characteristics of Soil	
Dish No. <b>14</b>	No. of Blows <b>26</b>	Dish No. <b>19</b>		Liquid Limit	%
Dish & Wet Soil <b>87.1</b>	Dish & Dry Soil <b>84.1</b>	Dish & Wet Soil <b>80.1</b>	Dish & Dry Soil <b>78.0</b>	Plastic Limit	%
Dish & Dry Soil <b>84.1</b>	Dish <b>72.8</b>	Dish & Dry Soil <b>78.0</b>	Dish <b>69.4</b>	Plasticity Index	%
Mass of Water	Dry Soil	Mass of Water	Dry Soil		
% Moisture = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 =$		P.L. = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 =$		Optimum Moisture Content	
L.L. =				Total Soil	%
				-4.75 mm (-4) Portion	<b>10.3</b> %
				Maximum Density	
				Total Soil	_____ kg/m <sup>3</sup> (lbs/ft <sup>3</sup> )
				-4.75 mm (-4) Portion	_____ kg/m <sup>3</sup> (lbs/ft <sup>3</sup> )

Wet Weight = **9847 grams**      % Moisture \_\_\_\_      Moisture Range \_\_\_\_\_      Absorption = **0.3**



### Chapter 3 Sampling and Testing Aggregates

#### Problem No. 4

Below is a sample of an Aggregate Subbase Material, Type I, Grading No. 21A. Complete the worksheet for gradation, liquid limit, plastic limit, plasticity index, optimum moisture content and moisture range.

MECHANICAL ANALYSIS OF TOTAL SAMPLE				MECHANICAL ANALYSIS OF SOIL MORTAR			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING	SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)		%		63.0 mm (2 ½)		%	
50.0 mm (2)		%		50.0 mm (2)		%	
37.5 mm (1 ½)		%		37.5 mm (1 ½)		%	
25.0 mm (1)		%		25.0 mm (1)		%	
19.0 mm (3/4)	<b>357</b>	%		19.0 mm (3/4)		%	
9.50 mm (3/8)	<b>1448</b>	%		9.50 mm (3/8)		%	
4.75 mm (4)	<b>913</b>	%		4.75 mm (4)		%	
2.0 mm (10)	<b>1011</b>	%		2.0 mm (10)		%	
.850 mm (20)		%		.850 mm (20)	<b>57.8</b>	%	
425 mm (40)		%		425 mm (40)	<b>24.8</b>	%	
.250 mm (60)		%		.250 mm (60)	<b>16.0</b>	%	
.180 mm (80)		%		.180 mm (80)	<b>8.7</b>	%	
.150 mm (100)		%		.150 mm (100)	<b>6.3</b>	%	
.075 mm (200)		%		.075 mm (200)	<b>19.5</b>	%	
Total	<b>6136</b>			Total	<b>190.0</b>		

Liquid Limit		Plastic Limit		Physical Characteristics of Soil	
Dish No. <b>21</b>	No. of Blows <b>28</b>	Dish No. <b>10</b>		Liquid Limit	%
Dish & Wet Soil <b>52.1</b>	Dish & Dry Soil <b>48.9</b>	Dish & Wet Soil <b>79.9</b>	Dish & Dry Soil <b>77.8</b>	Plastic Limit	%
Dish & Dry Soil <b>48.9</b>	Dish <b>33.7</b>	Dish & Dry Soil <b>77.8</b>	Dish <b>67.4</b>	Plasticity Index	%
Mass of Water	Dry Soil	Mass of Water	Dry Soil		
% Moisture = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 =$		P. L. = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 =$		Optimum Moisture Content	
				Total Soil	%
				-4.75 mm (-4) Portion	<b>10.5</b> %
				Maximum Density	
L.L. =				Total Soil	_____ kg/m <sup>3</sup> (lbs/ft <sup>3</sup> )
				-4.75 mm (-4) Portion	_____ kg/m <sup>3</sup> (lbs/ft <sup>3</sup> )

Wet Weight = **6449** grams      % Moisture \_\_\_\_\_      Moisture Range \_\_\_\_\_      Absorption = **0.6**

### Chapter 3 Sampling and Testing Aggregates

#### Problem No. 5

Below is a sample of an Aggregate Subbase Material, Type I, Grading No. 21A. Complete the worksheet for gradation, liquid limit, plastic limit, plasticity index, optimum moisture content and moisture range.

MECHANICAL ANALYSIS OF TOTAL SAMPLE				MECHANICAL ANALYSIS OF SOIL MORTAR			
SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING	SIEVE SIZES	GRAMS RETAINED	PERCENT RETAINED	PERCENT PASSING
63.0 mm (2 ½)		%		63.0 mm (2 ½)		%	
50.0 mm (2)		%		50.0 mm (2)		%	
37.5 mm (1 ½)		%		37.5 mm (1 ½)		%	
25.0 mm (1)		%		25.0 mm (1)		%	
19.0 mm (3/4)	<b>267</b>	%		19.0 mm (3/4)		%	
9.50 mm (3/8)	<b>2650</b>	%		9.50 mm (3/8)		%	
4.75 mm (4)	<b>1343</b>	%		4.75 mm (4)		%	
2.0 mm (10)	<b>1103</b>	%		2.0 mm (10)		%	
.850 mm (20)		%		.850 mm (20)	<b>44.6</b>	%	
425 mm (40)		%		425 mm (40)	<b>28.4</b>	%	
.250 mm (60)		%		.250 mm (60)	<b>15.8</b>	%	
.180 mm (80)		%		.180 mm (80)	<b>10.2</b>	%	
.150 mm (100)		%		.150 mm (100)	<b>7.6</b>	%	
.075 mm (200)		%		.075 mm (200)	<b>21.2</b>	%	
Total	<b>8893</b>			Total	<b>200.0</b>		

Liquid Limit		Plastic Limit		Physical Characteristics of Soil	
Dish No. <b>3</b>	No. of Blows <b>22</b>	Dish No. <b>5</b>		Liquid Limit	%
Dish & Wet Soil <b>88.2</b>	Dish & Dry Soil <b>85.4</b>	Dish & Wet Soil <b>80.2</b>	Dish & Dry Soil <b>78.2</b>	Plastic Limit	%
Dish & Dry Soil <b>85.4</b>	Dish <b>72.0</b>	Dish & Dry Soil <b>78.2</b>	Dish <b>68.1</b>	Plasticity Index	%
Mass of Water	Dry Soil	Mass of Water	Dry Soil		
% Moisture = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 =$		P. L. = $\frac{\text{Mass of Water}}{\text{Dry Soil}} \times 100 =$		Optimum Moisture Content	
L.L. =				Total Soil	%
				-4.75 mm (-4) Portion	<b>10.8</b> %
				Maximum Density	
				Total Soil	_____ kg/m <sup>3</sup> (lbs/ft <sup>3</sup> )
				-4.75 mm (-4) Portion	_____ kg/m <sup>3</sup> (lbs/ft <sup>3</sup> )

Wet Weight = 9418 grams    % Moisture \_\_\_\_\_    Moisture Range \_\_\_\_\_    Absorption = **0.7**