ATT-19/22 MOISTURE-DENSITY RELATION,
Standard Compaction, + 5 000 µm Material

1.0 SCOPE

This method describes the laboratory compaction procedures for determining the relationship between the Dry Density and Moisture Content (compaction curve) of soil-aggregate, and soil-aggregate-asphalt mixtures, with less than 30% retained on the 20,000 µm sieve, compacted in a 152.4-mm (6") diameter mold with a 2.5 kg rammer dropped from a height of 305-mm (12") producing a compactive effort of 600 kN-m/m^3.

2.0 EQUIPMENT

Proctor Mold Assembly: Each mold shall have a base plate and an extension collar assembly, both made of metal and constructed so they can be securely attached and easily detached from the mold. The extension collar assembly shall have a height extending above the top of the mold of at least 50.8mm (2.0"). The extension collar shall align with the inside of the mold. The bottom of the base plate and bottom of the centrally recessed area that accepts the cylindrical mold shall be planar.

Mold Specifications	ASTM D 698
Mold Height	116.4 ± 0.5 mm
Mold Diameter	152.4 ± 0.7 mm
Mold Volume	2124 ± 25 cm^3

Manual Rammer: The mass of the rammer shall be 2.5 ± 0.01 kg, with a diameter of 50.80 ± 0.13 mm. The rammer shall be equipped with a guide sleeve that has sufficient clearance that the free fall of the rammer shaft and head is not restricted. The guide sleeve shall have at least four vent holes at each end (eight holes total) located with centres 19.0 ± 1.6mm (¾" ± 1/16") from each end and spaced 90 degrees apart. The minimum diameter of the vent holes shall be 9.5mm (3/8")

Electronic Balance: capable of reading to 0.1 grams.
The balance must be operated as per manufacturer's recommendations.
Balances must be inspected, cleaned, and calibrated annually.

Sample Extruder: (optional), for extruding compacted specimens from the proctor mold.

Conventional Oven: thermostatically controlled oven capable of maintaining a temperature of 110 ± 5ºC throughout the drying chamber.

Straight Edge: A stiff metal straight edge of any convenient length but not less than 254 mm (10"). The total length of the straight edge shall be machined straight to a tolerance of ± 0.01 mm (± 0.005"). The scraping edge shall be bevelled if it is thicker than 3 mm (⅛").

Water Bottle: Trigger spray bottle, hand pump sprayer with wand, or graduated water bottle with sprinkler top

Sieves: 5,000 µm and 20,000 µm.

Mixing Tools: Miscellaneous tools such as a grinding mill, large mixing pan, putty knives, large butcher knife, sampling containers (plastic pails or plastic bags), mixing spoons, plastic cover sheets, grocer scoops (large & small), drying pans, etc.

Zero Air Voids Table (Relative Density of 2.65)

Data Sheet: Moisture-Density Test (such as MAT 6-22)

3.0 PROCEDURE

The following procedure is performed on materials with more than 70% passing the 20,000 µm sieve. Compaction of each specimen is performed in a 152 mm diameter mold.

If testing minus 5,000 µm material with more than 7% oversize, or + 5,000 µm material with more than 90% passing the 20,000 µm sieve, proceed with Section 3.2.

If the mixture has between 70% and 90% passing the 20,000 µm sieve, the + 20,000 µm material is substituted by an equivalent weight of – 20,000 µm to + 5,000 µm material. The proportioning is described in Section 3.4.

3.1 Percent Passing 5,000 µm Sieves

Determine the percent passing the 5,000 µm and 20,000 µm sieves as follows:

1. Obtain approximately 15 kg of representative mixture and weigh the sample.

2. Sieve entire sample through the 5,000 µm sieve into a tared mixing pan.

3. Weigh the material passing the 5,000 µm sieve.

4. Calculate the cumulative percent passing 5,000 µm sieve using the formula:

$$\textit{Cumulative \% Passing 5 000 } \mu m \ (\%) = \frac{\textit{Wt. Passing 5 000 } \mu m \textit{ Sieve}}{\textit{Total Wt. of Sample}} \times 100\%$$

If the result is higher than 93%, this test procedure should be replaced with ATT-23.

5. Sieve the +5,000 µm material through the 20,000 µm sieve into a tared mixing pan.

6. Weigh the material passing the 20,000 µm sieve.

7. Calculate the cumulative percent passing the 20,000 µm sieve as follows:

$$\% = \frac{\text{(Wt. Passing 20 000}\mu\text{m Sieve) + (Wt. Passing 5 000}\mu\text{m Sieve)}}{\text{Total Wt. of Sample}} \times 100\% \quad \text{or}$$

$$\% = \frac{\text{(Total Wt. of Sample) - (Wt. Retained on 20 000}\mu\text{m Sieve)}}{\text{Total Wt. of Sample}} \times 100\%$$

8. If the result is 90% or higher, proceed with Section 3.2.

   If the percent passing the 20,000 µm sieve is between 70% and 90%, keep the - 20,000 µm + 5,000 µm aggregate separate, in case this fraction is required when proportioning. Then proceed with Section 3.4.

3.2 Material With More than 90% Passing the 20,000 µm Sieve

1. Obtain a sample of at least 30 kg of representative material.
2. Sieve entire sample through the 20,000 µm sieve into large mixing pans.
3. Discard the material retained on the 20,000 µm sieve.
4. Dry the minus 20,000 µm material until the material is friable; that is, the material can be passed through the 5,000 µm sieve.
5. Tare a mixing pan.
6. Thoroughly mix the – 20,000 µm sample.
7. Weigh 5,300 grams of – 20,000 µm material into the mixing pan.
8. Add water to the 5,300 grams of material as follows:
   a) Fill the spray bottle with water.
   b) Spray some water onto the soil in the wash basin, at the same time working the soil, so that no portion becomes excessively damp.
   c) Mix the soil thoroughly by hand, or by using a mixing spoon, ***until the moisture is uniformly distributed***.
9. Continue to add water until the sample reaches a moisture content of approximately 3% below optimum moisture. This approximate moisture condition is reached when a squeezed handful of the fines portion of the sample (-5,000 µm soil) barely holds together when dropped 0.5 metres into the soil.
10. Record the weight of water used.
11. Place the sample (first run) into a plastic bag.

12. Add the same amount of water recorded in step 10 to four additional 5,300 gram samples by following step 8 above. Also place each of the four samples into a sealed plastic bag.

3.3 Forming the Specimens

1. Add water to each of the above samples in 80 gram increments. Gradually spray in and blend the required weight of water into the first 4 samples (runs) as shown in Table 1 (5300 g. soil x (1.5% M.C. / 100) = 80 grams water).

   Do not add water to the fifth run. This sample is kept at the estimated 3% below optimum moisture content until the other four runs have been compacted. If it is determined that a fifth point is required on the wet side of the moisture-density relation curve, 400 grams of water is then added to the fifth sample. If run number 5 is required on the dry side of the curve, the sample will be compacted at its present moisture condition (-3%).

TABLE 1

RUN NUMBER	WEIGHT OF WATER ADDED (g)	ESTIMATED MOISTURE CONTENT INCREASE (%)
1	80	+1.5
2	160	+3.0
3	240	+4.5
4	320	+6.0
5	0	0

2. Empty one of the plastic bags into a mixing pan and add water for Run #1 as directed in Sec 3.2, step 8.

3. Place the sample in a plastic bag. Repeat steps 2 and 3 for runs 2, 3 and 4. The samples should remain in the plastic bags until the water is evenly distributed.

Alberta Transportation

MAT 6-22/13

MOISTURE - DENSITY TEST

FIELD TEST PROCEDURE ATT 19/13

Project :	Hwy 58:02	Test No. :	10
Contract # :	12354	Date :	6-Sep-1995
Source :	Stockpile	Tech :	J. Jones

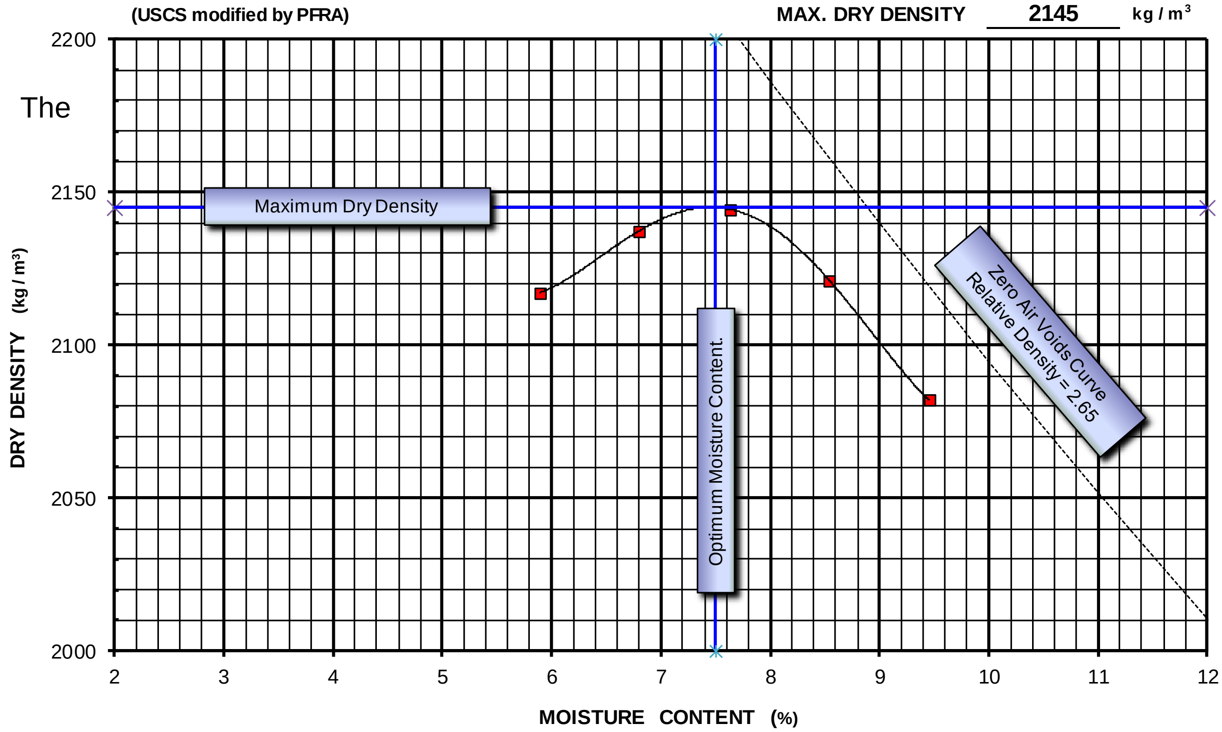
DENSITY	A. VOLUME OF MOLD		cm^3	2113	2113	2113	2113	2113	
	B. Wt OF WET SAMPLE + MOLD		g.	10962.3	11047.6	11101.8	11090.0	11040.0	
	C. Wt OF MOLD		g.	6225.0	6225.0	6225.0	6225.0	6225.0	
	D. Wt OF WET SAMPLE	B - C	g.	4737.3	4822.6	4876.8	4865.0	4815.0	
	E. WET DENSITY	(D/A) x 1000	kg / m^3	2242	2282	2308	2302	2279	
	F. DRY DENSITY	(100 x E) / (100+N)	kg / m^3	**2117**	**2137**	**2144**	**2121**	**2082**	
MOISTURE CONTENT	G. MOISTURE ADDED / RUN NO.			80 g / run #1	160 g / run #2	240 g / run #3	320 g / run #4	400 g / run #5	
	H. CONTAINER NO.			A	B	C	D	E	
	I. Wt OF WET SAMPLE + TARE		g.	5347.2	5463.3	5518.6	5503.8	5483.0	
	J. Wt OF DRY SAMPLE + TARE		g.	5085.2	5157.0	5173.1	5121.3	5065.0	
	K. TARE OF CONTAINER		g.	640.2	647.3	642.6	642.5	642.5	
	L. Wt OF WATER	I - J	g.	262.0	306.3	345.5	382.5	418.0	
	M. Wt OF DRY SOIL	J - K	g.	4445.0	4509.7	4530.5	4478.8	4422.5	
	N. MOISTURE CONTENT	(L / M) x 100	%	**5.9**	**6.8**	**7.6**	**8.5**	**9.5**	

ESTIMATED SOIL CLASSIFICATION **SC**

(USCS modified by PFRA)

OPTIMUM MOISTURE **7.5** **%**

MAX. DRY DENSITY **2145** **kg / m^3**



REMARKS :	80% passing the 5 000 µm sieve.	Degree of Saturation = 84.4 %
		Soil Relative Density = 2.65 %

FIGURE 1

The time to allow for water distribution is:

a) A minimum of 12 hours for "highly plastic" silts (MH), clays (CI or CH), organic clays and silts (OH) and peat (Pt).

b) A minimum of 3 hours for soils with “low plasticity”, such as clays (CL), silts (ML), organic silts and organic silty clays (OL), clayey gravels (GC) and clayey sands (SC).

c) A minimum of 1 hour for silty gravels (GM) and silty sands (SM).

There is no time requirement for clean gravels (GW or GP) and clean sands (SW or SP).

4. Compact Run No. 1 as directed in ATT-23, steps 1 to 19 of Section 3.3 with the following changes:

a) Use the 152 mm diameter mold to compact the samples.

b) Compact each lift with 56 blows.

c) Rod each lift several times with the scoop in order to uniformly distribute the coarse and fine aggregate, thus avoiding large void spaces and erroneous results.

d) During the trimming operation, remove all particles that extend above the top level of the mold. Hand tamp fine material into any irregularities in the surface, and level the specimen again with the straight edge.

e) The weight of the moisture content sample should be approximately 1 000 grams.

5. Weigh the moisture content sample immediately and record as “Wt. of Wet Sample + Tare” on line "I", as shown in Figure 1. Remove the mix from the mold, and then thoroughly clean the mold.

6. Dry the sample in the oven at 110^oC ± 5^oC, until it reaches a constant dry weight, as directed in ATT-15, MOISTURE CONTENT, Oven Method.

7. Weigh the hot sample and record on line "J", the “Weight of Dry Sample + Tare”.

8. Repeat steps 4 to 7 for run numbers 2, 3 and 4.

9. Calculate the wet density of each run as follows:

$$\textit{Wet Density } (kg/m^3) = \frac{(\textit{Wt. of Wet Sample \& Mold - Wt. of Mold})}{\textit{Volume of Mold}} \times 1000$$

10. If the wet density of run no. 4 has increased over the wet density of run no. 3, add 400 grams of water to run no. 5, as directed in steps 8 (a) to (c) of Section 3.2 and step 3 of this section. If the wet density of run no. 4 has decreased or remained the same as run no. 3, compact the 5^{th} run as is, at the estimated 3% below optimum moisture content.

    NOTE: The five point moisture-density curve should have at least two points on the dry side of optimum and two points on the wet side of optimum.

11. Compact run no. 5 as described in steps 4 to 7 and calculate the wet density as outlined in step 9.

12. Calculate the moisture content and dry density of each run as directed in ATT-23, Section 3.4.

13. Plot the 5 point moisture-density relation curve and determine the maximum dry density and optimum moisture content of the aggregate as directed in ATT-23, Section 3.5.

14. Plot the zero air voids curve using a relative density of 2.65 as directed in ATT-23, Section 3.6, steps 2 to 4.

3.4 Material With 70% to 90% Passing the 20,000 µm Sieve

1. Obtain approximately 50 kg of representative material, as directed in ATT-38, SAMPLING, Gravel and Sand.

2. Sieve the entire sample through the 20,000 µm sieve into large mixing pans.

3. Discard the material retained on the 20,000 µm sieve.

4. Dry the -20,000 µm mixture until friable, that is, until the material can be passed through the 5,000 µm sieve.

    NOTE: If the oven or burner is used, the drying temperature should not exceed $60^{o}C$. Stop drying before the sample reaches the friable condition, as the heated sample will continue to lose moisture. Cool the sample before proceeding with the test. Continuously stir the sample while drying or cooling off. Do not dry the sample in the microwave oven.

5. Sieve the remaining – 20,000 µm material through the 5,000 µm sieve.

6. Keep the material retained and the material passing the 5,000 µm sieve in separate mixing pans.

7. Obtain the cumulative percent passing the 5 000 µm determined in Section 3.1, step 4.

8. Calculate the amount of each size of material required to make up a 5,300 gram combined sample as follows:

   a) $$\text{Req'd Wt. of -5000 µm Material} = \frac{\text{5300 g x Percent Passing 5 000 µm Sieve}}{100\%}$$

   b) $$\text{Req'd Wt. of +5000 µm Material} = \text{5300 g - (Req'd Wt. of - 5 000 µm Material)}$$

   e.g., Cumulative % Passing 5,000 µm Sieve = 57%

   $$\text{Req'd Wt. of -5000 µm Material} = \frac{5300 \times 57\%}{100\%} = 3\,021 \text{ g}$$

   $$\text{Req'd Wt. of +5000 µm Material} = 5\,300 - 3\,021 = 2\,279 \text{ g} \quad ; \quad \text{or}$$

   $$\text{Req'd Wt. of +5000 µm Material} = \frac{5300 \times (100\% - 57\%)}{100\%} = 2\,279 \text{ g}$$

9. Tare a mixing pan.

10. Thoroughly mix the – 20,000 µm, + 5,000 µm, material.

11. Weigh the required weight of + 5,000 µm material into the mixing pan.

12. Thoroughly mix the material which passed the 5,000 µm sieve.

13. Add the required weight of – 5,000 µm material to the + 5,000 µm material to obtain a 5,300 gram sample.

14. Add water by weight, or volume, as follows:

    a) Insert the sprinkler top into the mouth of the graduated medicine bottle.

    b) Shake the bottle so that the water sprays out onto the soil in the mixing pan, at the same time working the soil so that no portion becomes excessively damp.

    c) Mix the soil thoroughly by hand until the moisture is uniformly distributed.

15. Continue to add water until the sample is approximately 3% below optimum which is the recommended moisture content for the first run. This approximate moisture condition is reached when a squeezed handful of the fines portion of the sample (-5,000 μm soil) barely holds together when dropped 0.5 metres onto the soil.

16. Record the weight, or volume, of water that was required to prepare the first sample because the same amount of water will later be added to four additional 5,300 gram samples.

17. Place the sample in a plastic bag.

18. Prepare 4 additional duplicate samples by following steps 9 to 17 above.

19. Form five moisture-density relation specimens as directed in Section 3.3.

4.0 HINTS AND PRECAUTIONS

1. A grinding mill may be required to break the dry lumps of material so that all fines will pass through the 5,000 μm sieve, but do not crush individual soil particles.

2. The plastic limit test may be performed on the fines portion of the sample to estimate the optimum moisture content of the material.

3. ***Ensure that all proctor molds and proctor hammers, have been calibrated, on a yearly basis***, as per ASTM D 698. Molds that meet the requirements should be labelled with the calibration date, mold volume, and calibration technologist. Proctor hammers should be labelled to show the calibration date, and calibration technologist.

4. ***Each lab should have a book with all the equipment calibrations recorded***. Equipment used in testing Soils, GBC, and Asphalt Materials must be calibrated for accuracy on a regular basis to assure the equipment is producing reliable results. Equipment and apparatus that may be affected by movement must be re-calibrated after relocation.

5. It is recommended that Balance Check Weights be used at the start of each day, and the results recorded, to identify if calibration drift has occurred. Drift can occur for any number of reasons: such as temperature changes, being moved, or aging electronics.

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