Test Procedure for

THEORETICAL MAXIMUM SPECIFIC GRAVITY OF BITUMINOUS MIXTURES

TxDOT Designation: Tex-227-F

Effective Date: July 2019

1. SCOPE

1.1 Use this test method to determine the theoretical maximum specific gravity (commonly referred to as "Rice gravity") of a bituminous mixture. The theoretical maximum specific gravity of a bituminous mixture is the bulk specific gravity of that mixture when compacted to the point of zero air voids. Use the specific gravity obtained to calculate the percent air voids and percent voids in mineral aggregates (VMA) contained in compacted samples as described in Tex-207-F. The theoretical maximum specific gravity is also used to calculate the effective specific gravity (G_e) of aggregates as described in Tex-204-F.

1.1.1 Part I is no longer an approved method. Refer to Part II of the test procedure.

1.1.2 Use Part II to perform the test using the 4,500 mL metal vacuum pycnometer and vibrating table.

1.1.3 Part III is no longer an approved method. Refer to Part II of the test procedure.

1.2 Refer to Table 1 for Superpave and conventional mix nomenclature equivalents. Replace conventional nomenclature with Superpave nomenclature when required.

Table 1
Nomenclatures and Definitions

Nomenclatures		Definitions
Conventional	**Superpave**	
G_e	G_{se}	Effective Specific Gravity of Aggregates
G_r	G_{mm}	Theoretical maximum specific gravity
G_{rc}	G_{mm}	Theoretical maximum specific gravity corrected for water absorption during test

1.3 Use Table 2 to achieve sample size requirements.

Table 2
Sample Size

Nominal Maximum Size of Aggregate in Mixture, in. (mm)[1]	Minimum Weight of Sample, g (lb.)
1 (25.0)	2,500 (5.5)
3/4 (19.0)	2,000 (4.4)
1/2 (12.5)	1,500 (3.3)
3/8 (9.5)	1,000 (2.2)
#4 (4.75)	500 (1.1)

1. Nominal maximum aggregate size is one sieve size larger than the first sieve that retains more than 10% of the total aggregate.

1.4 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

PART I—USING HAND-HELD GLASS PYCNOMETER

2. SCOPE

2.1 The hand-held glass pycnometer is no longer an accepted process.

2.2 Refer to Part II of this test procedure.

PART II—USING A METAL VIBRATORY PYCNOMETER

3. SCOPE

3.1 This procedure measures the theoretical maximum specific gravity of bituminous mixtures using a metal vibratory pycnometer.

4. APPARATUS

4.1 *Metal vacuum pycnometer*, 150 fl. oz. (4,500 mL), with a clear poly (methyl methacrylate) (PMMA) lid for applying vacuum (Humbolt H-1750, Gilson SG-16A, or equal).

4.2 *Vibrating table*, Humbolt H-1755, Gilson SGA-5RT, or equal.

4.3 *Vacuum hoses, connections, tapered stoppers, and valves*, suitable to apply and control the specified vacuum level within the assembly. A vacuum flask or moisture trap needs to be inline between the vacuum pump and the metal vacuum pycnometer to prevent water vapor from entering the vacuum pump.

4.4 *Manometer or vacuum gauge*, able to determine the level of pressure (vacuum) within the assembly.

4.4.1 Do not keep a manometer in the system during routine testing, as a sudden vacuum loss can break it.

4.4.2 Use the manometer to qualify vacuum pumps and water aspirators and check the accuracy of vacuum gauges.

4.5 *Vacuum pump or water aspirator*, to evacuate air from the assembly.

4.5.1 It must be able to reduce residual pressure to 2.0 in. (50 mm) Hg or less before completion of the evacuation process of the procedure. (See Section 10.)

4.5.2 A quick check to determine the adequacy of a vacuum source is possible without the use of a manometer, should the vacuum gauge reading be suspect.

4.5.2.1 Place water in the vacuum flask at slightly above 102°F (39°C) so that the water will be at 102°F (39°C) at the time the maximum degree of evacuation is achieved by the vacuum source.

4.5.2.2 Begin applying vacuum.

4.5.2.3 If the vacuum source is capable of causing a vigorous boil to occur in water at 102°F (39°C) or less, the residual pressure within the system is 2.0 in. (50 mm) Hg or less and the vacuum source meets the requirements for this test method.

4.6 *Balance*, Class G2 in accordance with Tex-901-K, with a minimum capacity of 2,500 g.

4.7 *Masonry trowel and flat scoop.*

4.8 *Sample splitter or quartering machine.*

4.9 *Mercury thermometer*, marked in 2°F (1°C) divisions or less, or digital thermometer capable of measuring the temperature specified in the test procedure.

4.10 *Air circulating fan.*

4.11 *Large, flat-bottom pans.*

4.12 *Vacuum flasks*, of any capacity found suitable to condense water vapor and trap moisture to protect vacuum pump (optional).

4.13 *Stopwatch or timer.*

4.14 *Gloves.*

4.15 *Water bath with a Tank Heater and Circulator*, for calibration of metal pycnometer and for immersing the metal pycnometer and sample in water, while suspended. It should be equipped with an overflow outlet for maintaining a constant water level.

4.16 *Standard U.S. sieves,* as specified in procedure, meeting the requirements of Tex-907-K.

5. CALIBRATING METAL VACUUM PYCNOMETER

5.1 Perform this calibration procedure each day that the pycnometer is used.

5.2 Prepare and calibrate the metal pycnometer as follows, to assure that it is of definite and constant volume.

5.3 Determine the water temperature.

5.3.1 A water temperature of 77 ± 3°F (25 ± 2°C) is a standard calibration and test temperature.

5.3.2 The water temperatures used during the pycnometer calibration and the final weighing of the pycnometer containing evacuated mixture must be within 2°F (1°C).

5.4 Unplug or turn off the water circulator in the water bath while obtaining the submerged pycnometer weight. Tare the scale with the weighing apparatus suspended in water.

Note 1—Equip the scale with a suitable apparatus to permit weighing the metal pycnometer with sample while suspended in water.

5.5 Submerge the metal pycnometer in water by placing it into the water bath at an angle. This will prevent any air from remaining under the bottom of the metal pycnometer. Hang the metal pycnometer from the weighing apparatus and allow the scale to stabilize.

5.6 Weigh and record the weight to the nearest 0.1 g. Record weight as *D* in Section 7.

6. PROCEDURE

6.1 Obtain a representative sample. Minimum sample size requirements are given in Table 2.

6.2 Place sample in a large flat pan and warm in an oven until it becomes workable.

6.3 Heat sample to the minimum temperature and for the least amount of time necessary to separate the mix into individual aggregate particles. If using the theoretical maximum specific gravity in the calculation of laboratory molded density, cure the sample at the same temperature and for the same length of time as the sample used for molding.

6.4 Use a circular motion with a masonry trowel while exerting downward pressure to roll the aggregate and effectively break apart individual coated aggregates. It is important to separate the aggregates, particularly the fine material, to the greatest extent possible without fracturing particles in the process.

6.5 If the aggregate larger than 3/4 in. (19.0 mm) was removed from the laboratory-molded specimens, then sieve aggregate larger than 3/4 in. (19.0 mm) out of the sample.

Note 2–If a Rice gravity is needed to calculate the percent density of road cores for mixes that contain aggregate larger than 3/4 in. (19.0 mm), then perform an additional Rice gravity without removing the aggregate larger than 3/4 in. (19.0 mm).

6.6 Reduce the mix using a quartering machine or by thoroughly blending the material and taking small portions from several places from the entire area of the pan to achieve a sample size conforming to the requirements in Table 2.

6.7 *Alternative One for Determining the Weight of the Sample:*

6.7.1 Weigh the prepared sample at room temperature to the nearest 0.1g

6.7.2 Record the weight as *A* in Section 7.

6.7.3 Transfer the weighed sample into the metal pycnometer.

6.7.4 Take care not to lose any of the material

6.7.5 Proceed to Section 6.9.

6.8 *Alternative Two for Determining the Weight of the Sample:*

6.8.1 Fill the metal pycnometer approximately one third full with water at approximately the temperature used for calibration.

6.8.2 Place the metal pycnometer on the scale.

6.8.3 Zero out or tare the scale.

6.8.4 After the sample has cooled to room temperature, pour the sample into the metal pycnometer.

6.8.5 Record the weight as *A* in Section 7.

6.8.6 Remove the metal pycnometer from the scale and proceed to Section 6.9.

6.9 Cover the sample with water at approximately the temperature used for calibration.

6.9.1 As some cooling can occur during the evacuation procedure, a water temperature a few degrees above that used for calibration may help provide the desired water temperature at the time of weighing the evacuated pycnometer.

6.9.2 The water level must be adequate to submerge the entire sample (by approximately 1 in. [25 mm]) yet not be so high as to cause water to siphon into the vacuum lines during the test.

6.10 Place the flat plexiglass vacuum lid with O-ring on the metal pycnometer and place on vibrating table. Clamp to hold in place. Turn on the vacuum pump or water aspirator and lower the residual pressure within the system to 2.0 in. (50 mm) Hg pressure. This equates to a vacuum gauge reading of 27.9 in. (710 mm) Hg at normal sea level atmospheric pressure.

6.11 Turn the vibrating table on and maintain the residual pressure and agitation for 10 to 15 minutes.

Note 3—Water can suck into the aggregate, so the minimum time required to remove air from the sample is best.

6.11.1 If the mix looks lightly coated or the aggregate is absorptive, use 10 min.

6.11.2 If the mix looks well coated and has a thick film of asphalt, use 15 min.

6.12 After the 10 to 15 min. of agitation and evacuation, turn the vibrating table off, turn the vacuum or water aspirator off, and gently release the vacuum. Remove the metal pycnometer from the vibrating table and then remove the flat plexiglass vacuum lid.

6.13 Check the water temperature. It must be within 2°F (1°C) of the calibration temperature.

6.14 Unplug or turn off the water circulator in the water bath while obtaining the submerged sample weight. Tare the scale with the weighing apparatus suspended in water.

6.15 Submerge the metal pycnometer with sample in water by placing it into the water bath at an angle. This will prevent any air from remaining under the bottom of the metal pycnometer. Hang the metal pycnometer from the weighing apparatus and allow the scale to stabilize.

6.16 Weigh and record the weight to the nearest 0.1 g. Record weight as *E* in Section 7.

6.17 Perform the instructions in Sections 6.18–6.26 if the aggregate absorbs water during the test. This can occur when the surfaces of any absorptive aggregate are not completely coated or are coated very thinly with asphalt. This problem may increase when highly effective vacuum pumps are used and if the samples

remain exposed to this vacuum for an excessive time. Very porous aggregates, such as lightweight aggregates, are particularly prone to absorb water during this test.

6.18 Tare a large flat pan.

6.19 Pour the contents of the pycnometer into the pan. Rinse particles clinging to the wall of the pycnometer into the pan.

6.20 Decant the water from the pan over a No. 200 (75 µm) sieve, taking care to avoid loss of any of the sample.

6.21 Tilt the sample pan to further drain water to the bottom and place in front of an electric fan to remove surface moisture. Set the fan so that it will not cause movement of the fine particles of the mixture.

6.22 Remove water draining to the bottom of the pan with a suction bulb.

6.23 Stir the sample intermittently with a trowel until the sample is almost surface dry.

6.24 Increase the drying cycle to 15min. intervals, stirring for two min. every interval. Weigh after every other stirring. When the loss in mass is 0.5 g or less, the sample is surface dry. Record this weight as A_{sd} in Section 7.

6.25 Verify the validity of the end-point by drying for an additional 30min. period when practical.

6.26 If a loss greater than 0.5 g occurs, continue drying until the new endpoint is reached. Record this new value as A_{sd} in Section 7.

6.27 See notes in Section 10 for additional information.

7. CALCULATIONS

7.1 Calculate theoretical maximum specific gravity:

$$G_r = \frac{A}{D + A - E}$$

Where:

G_r = theoretical maximum specific gravity

A = weight of dry sample in air, g

D = weight of calibrated pycnometer submerged in water, g

E = weight of pycnometer containing sample while submerged in water, g

7.2 Calculate theoretical maximum specific gravity (corrected for water absorption during test):

$$G_{rc} = \frac{A}{D + A_{sd} - E}$$

Where:

G_{rc} = theoretical maximum specific gravity corrected for water absorption during test

A = weight of dry sample in air, g

A_{sd} = weight of surface dry sample in air, g

D = weight of calibrated pycnometer submerged in water, g

E = weight of pycnometer containing sample while submerged in water, g

PART III—USING A WIDE-MOUTH HAND-HELD GLASS PYCNOMETER

8. SCOPE

8.1 The wide-mouth hand-held glass pycnometer is no longer an accepted process.

8.2 Refer to Part II of this test procedure.

9. TEST RECORD FORMS

9.1 Use the following Excel forms (in conjunction with hot mix specifications) to calculate and report theoretical maximum specific gravity results:

- HMAC Properties and Gradation,
- HMAC Mixture Design,
- HMAC Mix Properties, and
- Quality Control/Quality Assurance (QC/QA) test data worksheets for 2004 Specifications or for 2014 Specifications.

10. NOTES

10.1 Values for G_r and G_{rc} are rarely equal, even when no water absorption occurs. The determination of the surface dry condition is usually, to some degree, inaccurate because moisture commonly contained inside fine aggregate conglomerates. For this reason, some values will tend to indicate more correction than is justified. The decision on which value to use must be based on the following factors:

10.1.1 *Aggregate Potential for Water Absorption:*

Other factors being equal, if the average aggregate water absorption is lower than accepted parameters during mixture design, the probability for absorption during this test diminishes.

10.1.2 *Asphalt Film Thickness:*

10.1.2.1 Mixtures with high asphalt contents will rarely require absorption correction.

10.1.2.2 High vacuum levels applied to highly absorptive aggregates may overcome this factor.

10.1.2.3 Lean mixtures will often require correction.

10.1.3 *Number of Fractured Aggregates:*

10.1.3.1 Some absorption will always occur when uncoated aggregate remains exposed to vacuum saturation procedures.

10.1.3.2 Consider both the number of these particles and their potential for absorption.

10.1.4 *Vacuum Level applied:*

10.1.4.1 Other factors being equal, highly effective vacuum pumps will cause more water absorption than less effective pumps or water aspirators.

10.1.5 *Difference Between G_r and G_{rc} Values:*

10.1.5.1 As the difference between G_r and G_{rc} values increases, confidence that significant water absorption has occurred also increases.

10.1.5.2 Make corrections when values vary by more than 1.0%.

10.1.5.3 Corrections of less than 0.3% are usually insignificant and exist only because of the inadequacy of the correction procedure.

10.1.5.4 Base decisions concerning variations between G_r and G_{rc} ranging from 0.3–1.0% on the first four factors.

10.1.5.5 Calculate the percentage difference:

$$\frac{G_r - G_{rc}}{G_{rc}} \times 100 = \%$$

10.2 When using a vacuum pump to create a partial vacuum on the sample contained in the pycnometer, close the system for periods during the test by closing the valve in the line leading from the vacuum pump. This will protect the pump from water vapors and it can be turned off if necessary. Restart the pump and reopen the valve when leaks in the system cause the absolute pressure to rise above 2.0 in. (50 mm) Hg.

10.3 Vacuum sources applying absolute pressure considerably below 2.0 in. (50 mm) Hg may reach the end-point more quickly than less effective pumps.

10.4 Treat mix used to perform Rice gravity calculations identically to mix used for molding for density.

10.5 The vacuum pump or water aspirator must be able to reduce the residual (absolute) pressure in the system to 2.0 in. (50 mm) Hg or less before the completion of the air evacuation process of the procedure. This equates to a vacuum gauge reading of 27.9 in. (710 mm) Hg or more at normal sea level atmospheric pressure. When a gauge is used, it is necessary to use a mercury manometer to establish the point on a vacuum gauge that equates to 2.0 in. (50 mm) Hg of residual (absolute) pressure.

10.5.1 This can be accomplished by pulling a residual (absolute) vacuum of 2.0 in. (50 mm) Hg as read on a mercury manometer that is placed in line with the vacuum gauge.

10.5.2 At this point, make a mark on the vacuum gauge and use this point as the minimum vacuum that must be pulled.

10.5.2.1 Vacuum gauges are not as precise as manometers and as such, the vacuum gauge should be calibrated with a manometer on a regular basis.

Table 3
Pressure Conversions

% Vacuum	Absolute Pressure (mmHg)	Absolute Pressure (inHg)	Gauge Pressure (inHg)
0.0	760.0	29.92	0.00
7.9	700.0	27.56	2.36
21.1	600.0	23.62	6.30
34.2	500.0	19.68	10.24
47.4	400.0	15.75	14.17
60.5	300.0	11.81	18.11
73.7	200.0	7.87	22.05
86.8	100.0	3.94	25.98
88.2	90.0	3.54	26.38
89.5	80.0	3.15	26.77
90.8	70.0	2.76	27.16
92.1	60.0	2.36	27.56
93.3	51.3	2.02	27.90
94.7	40.0	1.57	28.35
96.1	30.0	1.18	28.74
97.4	20.0	0.79	29.13
98.7	10.0	0.39	29.53
99.3	5.0	0.20	29.72
99.7	2.5	0.10	29.82
99.9	1.0	0.04	29.88
100.0	0.0	0.00	29.92

11. ARCHIVED VERSIONS

11.1 Archived versions are available.