Comparison of Various Methods to Determine Bulk Specific Gravity of Cores

An Investigation of High Values Using AASHTO T275 – Paraffin Coated Method

Prepared by: Joe Schroer, PE

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By

Joe Schroer, PE
Field Materials Engineer

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16. Abstract

A report from a MoDOT asphalt paving project was that unexpected results were obtained when adhering to the standard for determination of bulk specific gravity of compacted asphalt mixture (Gmb) specimens, AASHTO T 166. The test method requires specimens with water absorption greater than 2.0 percent be retested according to either AASHTO T 275, bulk gravity using paraffin-coated specimens, or T 131, bulk gravity using the automatic vacuum sealing method (CoreLok.) The contractor chose to perform T 275 and obtained bulk specific gravities of the cores higher than originally obtained. A limited investigation into the method was performed. The result of this investigation confirmed the contractor's results and a recommendation that specimens dipped in paraffin be prohibited as an allowable test method. It was determined that paraffin entering the pore structure of the cores resulted in falsely high bulk specific gravity values.

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It was reported from the Southwest District that unexpected results were obtained when adhering to the standard for determination of bulk specific gravity of compacted asphalt mixture (Gmb) specimens, AASHTO T 166. The test method requires specimens with water absorption greater than 2.0 percent be retested according to either AASHTO T 275, bulk gravity using paraffin-coated specimens, or T 131, bulk gravity using the automatic vacuum sealing method (CoreLok.) The contractor chose to perform T 275 and obtained higher bulk specific gravities of cores which is counter to the theory and practice of using paraffin-coated specimens. A limited investigation into the method was performed. The result of this investigation confirmed the contractor's results and a recommendation that specimens dipped in paraffin be prohibited as an allowable test method. It was determined that more paraffin entered the pore structure of the cores than intended, therefore skewing the results.

When using AASHTO T 166, Archimedes' principle is employed to establish the mass/volume relationship for the specific gravity. It is used to determine the volume of the compacted specimens by using the difference in the dry mass and the mass submerged in water. The specimen is soaked in the water bath for 3 to 5 minutes, quickly patted dry and the mass determined for a saturated surface-dry (SSD) mass. This corrects the volume measurement for absorbed water. If the water absorption exceeds 2.0 percent, then the specimen is considered to have interconnected air voids that will allow the water to freely flow in and out of the specimen. Water in the specimen, when determining the submerged mass and not included in the SSD mass, results in artificially higher specific gravities by lowering the measured volume. Paraffin-coated specimens are used with the idea being to coat the outside while preventing water infiltration of the internal voids and allowing an accurate volume measurement.

The investigation began by obtaining the contractor's data to determine correct application of the test method and calculation of results. There appeared to be no irregularities and the inspector that had reported the discrepancy was able to repeat their results. The contractor's results shown in Table 1 reveal that the bulk specific gravity of the cores (Gcb) was higher with T 275 yielding an increase in density up to 2.7 percent due to using paraffin coated specimens. Differences in paraffin specific gravity and other factors were reviewed but nothing was found that would explain the differences.

Contractor's Results						
	T 166			T 275		
Core	Gcb	Density %	Air Voids %	Gcb	Density %	Air Voids %
1AJ	2.137	88.7	11.3	2.188	90.7	9.3
1CJ	2.171	90.0	10.0	2.240	92.7	7.3
1DJ	2.142	88.9	11.1	2.159	89.6	10.4

Table 1

The investigation was continued by preparing specimens with all cut faces. Cored specimens from performance testing were sawn to the approximate dimensions of a

typical roadway core. These cores were tested in accordance with AASHTO T 166, T 269, T 275 and T 131. A description for dimensional analysis of air voids is included in T 269. The results of the tests are shown in Table 2. Since these are smooth sided specimens, accuracy was verified as the dimensional analysis and vacuum sealing methods were in close agreement and yielded the lowest Gcb values. Paraffin-coated specimens, which should have compared closely to the dimensional analysis values, were the heaviest or most dense confirming the contractor's results. As a side note, the Gcb values for the CoreLok were calculated with the old method developed to correlate with T 166. These matched closely with T 166 giving further confidence in the measured values of the different methods. Comparison of the different methods to T 166 is found in Table 3. The paraffin-coated specimens were originally cooled by refrigeration to 5C (40F) then dipped in paraffin but the paraffin coating curled away from the specimen. The specimens were allowed to warm closer to room temperature before coating was successful.

Bulk Specific Gravity (Gcb)					
	AASHTO	Paraffin	Dimensional	CoreLok	Old CoreLok
	T 166	T 275	T 269	T 331	InstroTek
1	2.318	2.350	2.291	2.288	2.317
2	2.308	2.331	2.274	2.277	2.306
3	2.313	2.336	2.282	2.277	2.308
4	2.347	2.368	2.326	2.314	2.344
5	2.293	2.316	2.271	2.264	2.294
6	2.314	2.334	2.280	2.282	2.313
Air Voids					
1	6.37	5.11	7.46	7.59	6.42
2	6.78	5.87	8.16	8.04	6.85
3	6.58	5.66	7.85	8.04	6.80
4	5.20	4.36	6.08	6.54	5.35
5	7.39	6.48	8.27	8.56	7.36
6	6.54	5.72	7.93	7.84	6.58

Table 2

Difference in Gcb from T 166					
	AASHTO	Paraffin	Dimensional	CoreLok	Old CoreLok
	T 166	T 275	T 269	T 331	InstroTek
1	0.000	-0.031	0.027	0.030	0.001
2	0.000	-0.022	0.034	0.031	0.002
3	0.000	-0.023	0.031	0.036	0.005
4	0.000	-0.021	0.022	0.033	0.004
5	0.000	-0.023	0.022	0.029	-0.001

6	0.000	-0.020	0.035	0.032	0.001
Difference in Air Voids from T 166					
1	0.00	1.27	-1.09	-1.22	-0.04
2	0.00	0.91	-1.38	-1.26	-0.07
3	0.00	0.92	-1.27	-1.46	-0.22
4	0.00	0.85	-0.87	-1.34	-0.15
5	0.00	0.91	-0.87	-1.17	0.03
6	0.00	0.81	-1.40	-1.30	-0.05

Table 3

Mostly anecdotal evidence of inaccuracies in the paraffin-coated specimens could be found in a literature search. Becky McDaniel, Technical Director, of the North Central Superpave Center found that the laboratory for the Indiana DOT had experienced similar results to MoDOT's findings on occasion. Most studies when referring to paraffin-coated specimens had employed the use of Parafilm as described in ASTM D1188 for the coating. Only two studies could be found that actually documented the use of dipped specimens. A study at the University of California - Berkley investigating compacted specimens for performance testing ranked from heaviest to lightest with equivalent AASHTO methods shown in parenthesis are as follows: Unsealed or SSD (T 166), paraffin (T 275,) Parafilm (D1188,) then vacuum membrane (similar to T 331.)[1] The results of this study were in line with the expected results when reasoning through the test methods. The other study from the Mediterranea University of Reggio Calabria provided an examination of the differences in procedures.[2] This study ranked the specimens in a similar order to MoDOT as follows: Paraffin (T 275,) CoreLok (T 331,) Parafilm (D1188,) with the lightest being dimensional analysis (T 269.) The study mentioned inaccuracies of the SSD (T 166) method; however, they did not carry out testing of the specimens by this procedure. The paraffin-coated specimens produced significantly higher bulk specific gravities than the other methods. These studies highlighted the differences discussed in other publications on the variability of paraffin-coated specimens.

Figures 1 through 3 illustrate the difference in the methods. Figure 1 shows the volume measured by dimensional analysis which includes the voids on the surface in the total volume. This should result in the largest volume or lowest Gcb possible. When the volume is measured by T 166, the surface voids are excluded from the volume since it is patted dry for the SSD condition. The end result is a smaller volume and higher Gcb. When the core is sealed with a membrane, such as the CoreLok plastic bag or Parafilm, as shown in Figure 2, the voids on the surface are included in the total volume effectively producing a similar Gcb to the dimensioned core. The paraffin-dipped specimen as shown in Figure 3 excludes the paraffin filled voids from the core volume. It is assumed the paraffin will only fill the external voids. However, paraffin penetrating deeper into the core through interconnected voids will exclude those voids from the volume calculation, reduce the volume and erroneously produce a higher Gcb.

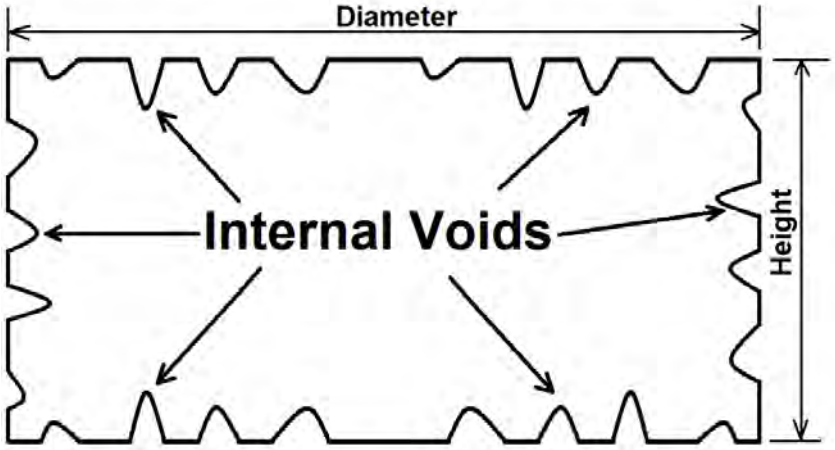

Figure 1

Measured by T 166 - Internal voids on surface excluded from total volume
Measured by T 269 -
Internal voids included in total volume

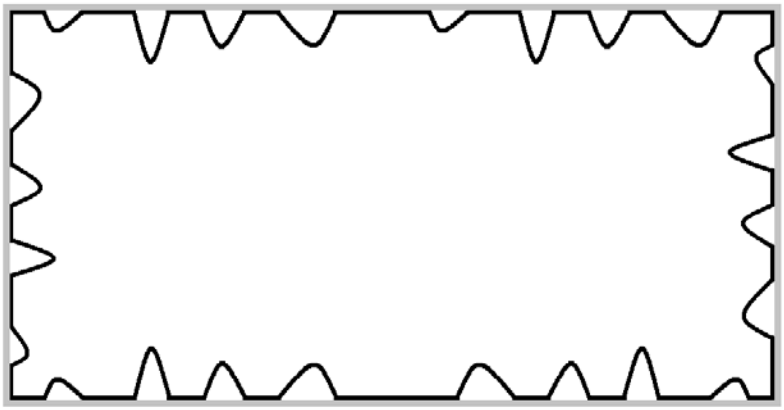

Figure 2

Measured by vacuum sealing (and Parafilm) -
Internal voids on surface included in total volume

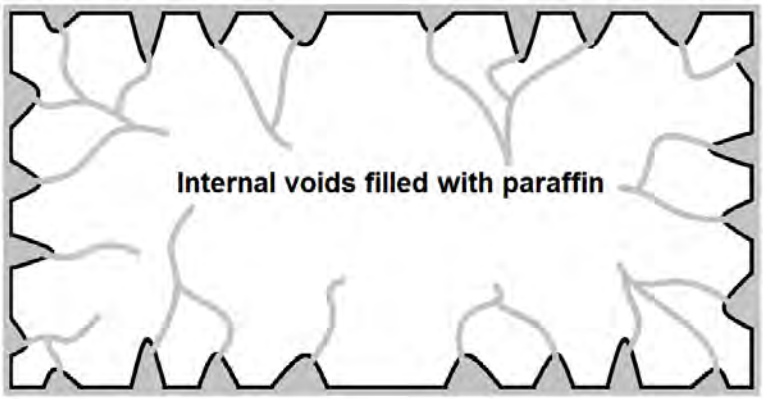

Figure 3
Measured by paraffin -Internal voids on surface and paraffin saturated voids excluded from total volume

It was determined from reviewing the data and other literature that paraffin infiltration of the internal voids caused the unexpectedly high Gcb values. The test method, T 275, does not describe a method of coating specimens but in a note suggests that cooling specimens and dipping them in the warmed paraffin is acceptable. Other methods suspected to limit ingress of the paraffin into the interconnected voids may include brushing the paraffin onto the specimen. The amount of paraffin absorbed by the specimens was estimated by calculating the difference in volume between the dimensional analysis and paraffin-coated specimens. Assuming the volume difference is occupied by paraffin, the result of 6.9 cubic centimeters was multiplied by the specific gravity of the paraffin, 0.818, to produce 5.8 grams of absorbed paraffin. To test this, specimen No. 4 had paraffin scraped from the surface as shown in Figure 4. The difference between the dry and scraped specimen is 2.2 grams. That is the amount of paraffin represented on the card at the forefront of Figure 4. Although unexpected, it is believed that this illustrates the error produced by absorbed paraffin. Specimen No. 3 is also shown as an example of a paraffin-coated specimen.

Figure 4
Paraffin scraped from Core 4 to determine internal paraffin content

The validity of the results was proved on roadway cores with the same battery of test methods with the addition of Parafilm-coated specimens, ASTM D1188. Figure 5 shows

an example of a core with the Parafilm wrapping. Three cores were chosen with known in-place permeability. One core was tested with typical permeability and two with high permeability. Permeability test results were 23.3 ft./day for 1AA, 107.6 ft./day for 2AA and 101.1 ft./day for 1AAJ. The results as shown in Table 4 and Table 5 ranked the test

methods in the same order as the sawn specimens. The Parafilm cores produced gravities very close to the vacuum sealing method as expected. Dimensional analysis yielded the highest air voids due to the irregular top and bottom surfaces. Cores were correctly ranked by permeability for each test method except for T 275. This fits the theory that the more interconnected the voids in the specimens, the more error that is produced.

Bulk Specific Gravity (Gcb)					
	AASHTO	Paraffin	Parafilm	Dimensional	CoreLok
	T 166	T 275	D1188	T 269	T 331
1AA	2.296	2.330	2.257	2.214	2.243
2AA	2.220	2.272	2.149	2.081	2.142
1AAJ	2.239	2.265	2.177	2.120	2.175
Air Voids					
1AA	6.38	4.99	7.95	9.72	8.52
2AA	9.46	7.33	12.35	15.14	12.64
1AAJ	8.70	7.61	11.22	13.52	11.30

Table 4

Difference in Gcb from T 166					
	AASHTO	Paraffin	Parafilm	Dimensional	CoreLok
	T 166	T 275	D1188	T 269	T 331

Figure 5
Parafilm-coated specimen

1AA	0.000	-0.034	0.039	0.082	0.053
2AA	0.000	-0.052	0.071	0.139	0.078
1AAJ	0.000	-0.027	0.062	0.118	0.064
Difference in Air Voids from T 166					
1AA	0.00	1.39	-1.57	-3.35	-2.15
2AA	0.00	2.13	-2.88	-5.68	-3.18
1AAJ	0.00	1.09	-2.52	-4.83	-2.60

Table 5

The inconsistency of paraffin-coated specimens, AASHTO T 275, reported from the field was confirmed by the MoDOT Central Laboratory. The high degree of error produced by this test method can give the appearance of acceptable compactive effort when removal by MoDOT's specifications would be required as shown by core No. 2AA when compared to the CoreLok results. It is recommended that a change be added to the specifications that would disallow T 275 as an option when cores have greater than 2% absorption when using T 166. This would leave T 331 or the vacuum sealing method as the acceptable option for these cores. Since vacuum sealing is not available in all of the contractors' laboratories, ASTM D1188 will be added as an alternate method. It is more time consuming and has a potential for rupture of the Parafilm membrane. However, a check in the test method would reveal any breaches of the membrane.

[1] Harvey, J., Mills, T., Scheffy, C., Sousa, J., and Monismith, C.L., **"An Evaluation of Several Techniques for Measuring Air-void Content in Asphalt Concrete Specimens,"** *Journal of Testing and Evaluation*, JTEVA,Vol. 22, No. 5, September 1994, pp. 424-430.

[2] Praticó, F.G., Moro, A., Ammendola, R., **"Comparing Different Procedures for the Measurement of the Bulk Specific Gravity for Compacted HMA Samples,"** 4th Italian Society of Road Infrastructures International Conference, Palermo, Italy, September 12-14, 2007.

Missouri Bulk Specific Gravity Calculation

AASHTO T 166

Updated 05/11/2012

Sample ID	Dry Sample Mass **A** (g)	Mass Sample in Water B (g)	Mass of SSD Sample **C** (g)	T 166 Bulk **Gmb**	Mixture T 209 **Gmm**	Air Voids (%)	Water Absorbed (%)
1	902.7	515.4	904.8	2.318	2.476	6.4	0.5
2	866.5	493.0	868.4	2.308	2.476	6.8	0.5
3	823.0	470.6	826.4	2.313	2.476	6.6	1.0
4	915.4	527.2	917.2	2.347	2.476	5.2	0.5
5	844.5	479.1	847.4	2.293	2.476	7.4	0.8
6	834.7	476.1	836.8	2.314	2.476	6.5	0.6
1AA	764.9	436.7	769.9	2.296	2.452	6.4	1.5
2AA	645.8	368.0	658.9	2.220	2.452	9.5	4.5
1AJ	609.4	345.3	617.5	2.239	2.452	8.7	3.0

Missouri Paraffin Core Specific Gravity Calculation

AASHTO T 275

Updated 05/11/2012 Enter Paraffin Density F: 0.819

Sample ID	Dry Sample Mass **A** (g)	Dry Sample + Paraffin Mass B (g)	Mass of Sealed Sample 2 in Water **C** (g)	CoreLok Bulk **Gmb**	Mixture T 209 **Gmm**	Air Voids (%)
1	902.6	913.2	516.1	2.350	2.476	5.1
2	866.5	893.3	488.8	2.331	2.476	5.9
3	823.0	838.2	467.3	2.336	2.476	5.7
4	915.4	932.8	525.0	2.368	2.476	4.4
5	844.5	855.3	477.4	2.316	2.476	6.5
6	834.7	847.9	474.2	2.334	2.476	5.7
4*	915.4	917.6	527.3	2.362	2.467	4.3
1AA	764.7	783.0	432.4	2.330	2.452	5.0
2AA	645.7	675.3	355.0	2.272	2.452	7.3
1AJ	609.8	638.4	334.3	2.265	2.452	7.6

Missouri Parafilm Core Specific Gravity Calculation

ASTM D1188

Updated 05/11/2012 Enter Parafilm Density F: 0.838

Sample ID	Dry Sample Mass **A** (g)	Dry Sample + Paraffin Mass B (g)	Mass of Sealed Sample 2 in Water **C** (g)	CoreLok Bulk **Gmb**	Mixture T 209 **Gmm**	Air Voids (%)
1AA	764.6	767.4	425.3	2.257	2.452	8.0
2AA	645.6	648.3	344.7	2.149	2.452	12.3
1AJ	609.4	612.3	328.9	2.177	2.452	11.2

Gmb=A/(B-C-(B-A)/F)

Missouri CoreLok Core Specific Gravity Calculation

AASHTO T 331

Updated 12/02/2011

Enter Plastic Bag Density F: 0.932 0.903 InstroTek yellow bag
0.932 InstroTek green bag

Sample ID	Dry Sample Mass A (g)	Bag Mass (g)	Sealed Sample Mass B (g)	Final Sample Mass (Removed from Bag) C (g)	Mass of Sealed Sample 2 in Water E (g)	CoreLok Bulk Gmb	Mixture T 209 Gmm	Air Voids (%)	Specimen Mass Check Repeat (%)
1	902.6	25.8	928.4	902.6	506.3	2.288	2.476	7.6	0.00
2	866.5	25.7	892.0	866.4	484.0	2.277	2.476	8.0	-0.01
3	823.0	25.7	848.6	823.0	459.7	2.277	2.476	8.0	0.00
4	915.4	25.9	941.2	915.4	518.0	2.314	2.476	6.5	0.00
5	844.5	25.9	870.3	844.4	469.5	2.264	2.476	8.6	-0.01
6	834.7	25.9	860.5	834.6	467.0	2.282	2.476	7.8	-0.01
1AA	764.6	25.8	790.4	764.6	421.9	2.243	2.452	8.5	0.00
2AA	645.6	25.7	671.3	645.6	342.3	2.142	2.452	12.6	0.00
1AAJ	609.4	25.8	635.2	609.4	327.3	2.175	2.452	11.3	0.00
1AAJ*	609.9	25.9	635.8	609.8	327.5	2.175	2.452	11.3	-0.02
1AAJ*	609.9	25.6	635.5	610.5	327.3	2.168	2.452	11.6	0.10

Dimensional Specific Gravity

unit:	g	in	in	in	in	in	cm^3			
	Weight	**Thickness**	**Thickness**	**Thickness**	**Diameter**	**Diameter**	**Volume**	**Bulk Sp. G.**		
1	902.6	1.94	1.93	1.94	3.98	3.98	393.9329	2.291	2.476	7.5
2	866.5	1.87	1.88	1.87	3.98	3.98	381.0504	2.274	2.476	8.2
3	823	1.77	1.78	1.77	3.98	3.98	360.7096	2.282	2.476	7.9
4	915.4	1.94	1.94	1.94	3.97	3.98	393.62	2.326	2.476	6.1
5	844.5	1.81	1.83	1.83	3.98	3.99	371.8125	2.271	2.476	8.3
6	834.7	1.79	1.79	1.78	3.99	4.00	366.1663	2.280	2.476	7.9
1AA	764.6	1.961	1.961	1.971	3.700	3.701	345.4118	2.214	2.452	9.7
2AA	645.6	1.751	1.762	1.755	3.708	3.711	310.2819	2.081	2.452	15.1
1AJ	609.4	1.625	1.622	1.635	3.707	3.710	287.3918	2.120	2.452	13.5