Bulk Specific Gravity of Laboratory Compacted Asphaltic Concrete Specimens

Lab Experiment #8

Submitted to:

Matthew Church

CE 361: Highways Materials Laboratory

Prepared by:

Christopher M. Smemoe
Thursday, 8:00 AM

Brigham Young University
Provo, UT 84602

May 26, 1994

Table of Contents

II. Results

Table 2.1-Bulk Specific Gravities of tested Asphalt Concrete Specimens: Results from 6.5% Asphalt Cement Content

Sample Number:	Weight of Specimen In Air (g)	Weight of Specimen In Water (g)	Weight of saturated, Surface-dry Specimen In Air (g)	Bulk Specific Gravity	Unit Weight (lbs./ft^3)
1	1138.8	625.0	1140.0	2.21	137.98
2	1203.1	663.1	1204.1	2.22	138.76
3	1198.8	658.2	1200.8	2.21	137.86
4	1164.7	642.6	1167.7	2.22	138.42

Table 2.2-Data and Bulk Specific Gravities of Asphalt Concrete Specimens

Percent Asphalt Cement	Specific Gravity of Specimen A	Specific Gravity of Specimen B	Specific Gravity of Specimen C	Average Specific Gravity	Unit Weight (lbs/ft^3)
4	2.12	2.13	2.16	2.13	132.8
4.5	2.15	2.11	2.13	2.13	132.8
5	2.18	2.19	2.2	2.19	136.7
5.5	2.2	2.18	2.19	2.19	136.7
6	2.23	2.18	2.21	2.21	137.7
6.5	2.22	2.21	2.22	2.22	138.3

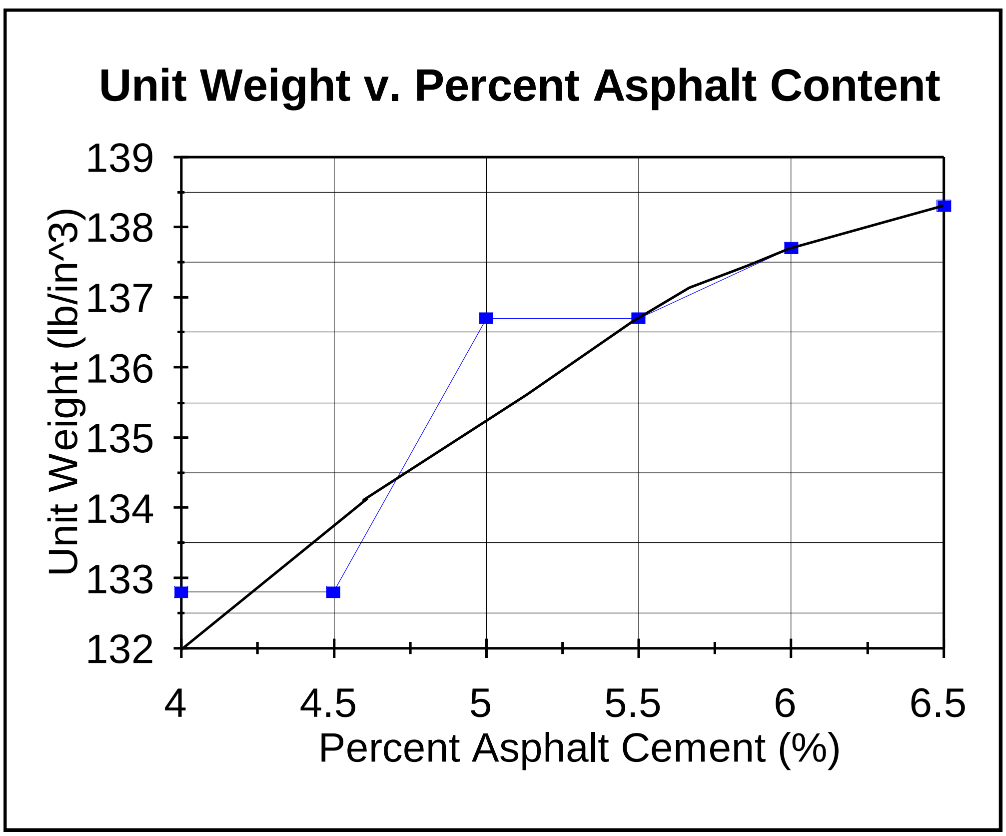

Figure 2.1-Unit Weight v. Percent Asphalt Content for all tested Specimens

By observation of table 2.2 and fig. 2.1, the maximum specific gravity was found to have a value of 2.22. If this value is multiplied by 62.4, a value of 138.3 lbs/in^3 is obtained. This represents the maximum unit weight of the asphaltic concrete specimens tested.

In fig. 2.1, one may observe that as the asphalt cement content of the compacted asphaltic concrete specimens increase, the unit weight will increase as well. But the unit weight will eventually obtain a maximum value, after which the unit weight of the it will decrease with the addition of asphalt cement. The maximum asphalt content to be used in the Marshall mix design procedure was determined in this test to be 6.5%. If a specimen with a higher percentage of asphalt cement was tested, the pavement may obtain a greater density, and this percentage of asphalt cement would be used.

III. Discussion

Procedure

Preparation of the specimens

Before preparing the asphalt concrete specimens for testing, an aggregate was obtained and dried at a temperature of approximately 230 degrees. The aggregate mixture and the test equipment were kept at this temperature throughout the test. Since a Sinclair AC-10 asphalt cement was used in the test procedures, specifications for this material were used in determining the specific gravity of the paving mixture. The specifications used in the test include the following*:

Asphalt grade	Discharge Temperature	Laboratory Compaction Temp	Minimum Compaction Temp
AC-10	235-265 F	235-245 F	190 F

*obtained from Budge, ***Highway Materials Laboratory***.

So the asphaltic hot mix materials were kept at a temperature between 235 and 245 F throughout the entire test. The only variation from this was when testing specimen number 4, which was compacted at 205 F due to the fact that it could not be warmed to the desired 235 F within a reasonable time by simply using the oven.

An 1150 gram sample of hot aggregate mix, obtained from the hot oven, was weighed out. After forming a "crater" in the aggregate material so the calculated asphalt cement mass would completely mix with the aggregate, the asphalt cement was combined with the aggregate. The total mass of the specimen, including 6.5% asphalt cement, was calculated to be 1229.95 grams.

After weighing out and combining the appropriate portions of asphalt cement and mineral aggregates, the mixture was placed in the mixing machine and mechanically stirred for a period of 1 minute, 45 seconds. The temperature of the specimen was then determined to insure that the specimen was at compaction temperature.

The asphaltic concrete mixture was then compacted. First, after placing filter paper on the bottom of the preheated mold, the mixture was poured into the mold. The asphalt mixture was then spaded with a heated trowel 25 times. 15 standard blows were applied to the specimen around the inside of the mold. The hammer was then centered over the top of the specimen and 10 more blows were applied, followed by 50 blows on the same side. The base plate and top mold collar were removed, and the assembly was reversed. 50 standard blows were then applied to the opposite side. The specimen was then allowed to cool, marking it for later identification. Three asphaltic specimens were prepared in this manner. In all four were prepared because the first specimen was prepared incorrectly. To examine details from the preparation of each specimen, see the section entitled ***possible errors***.

Testing for specific gravity of the specimens

A day after all four specimens had been prepared, the specific gravities of each laboratory compacted asphaltic concrete specimen were determined.

After freeing each of the specimens from the mold they were contained in by the use of the compaction hammer, the dry weight of each specimen was found. Using a string-board-and weight mechanism, and resetting the scale to zero, each specimen was immersed in water for one minute and the weight of the specimen in water was obtained and recorded. Finally, each asphaltic concrete specimen was dried on the surface and the mass of each saturated specimen was obtained.

The bulk specific gravity of each specimen (F) was calculated by dividing the weight of the dry specimen (B) by the difference between the weight of the specimen in water (D) and the weight of the saturated surface-dry specimen (C). (F=B/(C-D)). By multiplying the average specific gravity of specimens 2, 3, and 4 by 62.4, the average unit weight of the specimen was obtained.

Answers to "Observations and Discussion"

1. Define Bulk Specific Gravity.

Bulk specific gravity is defined as *"the ratio of the weight of a given volume of material to the weight of a volume of water equal to the total volume of the material. The total volume includes the combined volume of solid matter, permeable voids, and impermeable voids."* (California Dept. of Public Works, Division of Highways. ***Definitions of Terms Relating to Specific Gravity***). In other words, the bulk specific gravity of an asphaltic concrete specimen is just the weight of the solid specimen divided by the weight of water contained in the total volume of material, including all cracks and pore spaces:

$$G_b = \frac{\text{Weight of asphaltic specimen.}}{\text{Weight of water contained in total volume of asphaltic specimen.}}$$

If the density of water is assumed to be exactly 1 gram/cm^3, then the bulk specific gravity of the asphaltic specimen is equal to its bulk density in gram/cm^3.

2. How does bulk specific gravity differ from the general term specific gravity?

The term *specific gravity* refers to refers to the weight of a given volume of material divided by the weight of an equal volume of water. The volume of water used would not include any voids in the material. The bulk specific gravity, however, refers to the weight of a given volume of material *divided by the weight of water contained in a volume equal to the total volume of voids in a material + the total volume of the material itself*. In other words, there is an excess of water used in determining the *bulk specific gravity* which is equal to the total volume of voids in the material.

3. How is Bulk Specific Gravity used in designing asphaltic concrete mixes?

The unit weight in lbs/ft^3 of a material may be obtained by multiplying its bulk specific gravity by 62.4. By testing and averaging the specific gravities for a series of asphaltic concretes, the average unit weight can be obtained for several asphalt cement - mineral aggregate concentrations. A graph of unit weight v. percent asphalt cement is constructed. (such as the one in figure 2.1). The percent asphalt content at the maximum unit weight of the specimen is taken from the graph. Then, the stability test is performed on the specimen. From the stability test, the flow and Marshall stability of the asphaltic concrete specimen are obtained. The flow and stability versus percent asphalt cement curves can be drawn. Finally, if the specific gravity of the mineral aggregates and the specific gravity of the asphalt cement are known, the percent air voids in the compacted mixture and percent voids in the compacted mineral aggregates (%VMA) can be calculated by using equations **17.5, 17.8, 17.11,** and **17.12** on pages 764-767 in ***Traffic and Highway Engineering***, by Garber and Hoel. After calculating the %VMA and the percent air voids in the compacted mixture for each variation of asphalt cement content tested, the %VMA and the percent air voids in the compacted mixture versus percent asphalt cement content may be constructed.

All of these graphs are then used to select the asphalt contents for maximum stability, maximum unit weight, and percent voids in total mix within the limits specified. A typical void space used to determine asphalt content would be 4% voids. In this case, the asphalt contents at maximum stability, maximum unit weight, and 4 percent voids are averaged. This indicates the optimum asphalt cement content to be used in the pavement mixture.

4. What precautions must be met when determining bulk specific gravity?

1. Care should be taken to avoid distortion, bending, or cracking of the asphaltic specimens during and after removal of the specimen from the mold. A damaged specimen will cause errors when determining the bulk specific gravity.

2. It is necessary to keep the specimens at the proper compaction temperature when mixing and compacting. Otherwise, the aggregates will not completely mix and bind to the asphalt, causing a loose pavement mixture and a loss of fine aggregates. In addition, pavement mixtures at different temperatures will cause variations in the amount of compaction of the materials. These phenomenons will cause errors in the bulk specific gravity.

3. The specimens tested should be free of paper or excess material, as this will cause an error in the determination of the bulk specific gravity.

4. The specimen must be completely immersed in water when placed in the water bath. This is necessary because the specimen will have a different weight out of the water than in the water, thus distorting the specific gravity calculation.

5. The exact number of blows must be given to each side of each specimen. In this case, the number of blows was 75 on one side and 50 on the other side. If the exact number of compacting hammer blows is not used, then the specific gravity will be different than its intended value.

6. All weights measured must be exact.

7. The asphalt cement should not touch the sides of the mixing container before mixing, or some cement will not mix with the aggregates.

Uses of the test

The bulk specific gravity test is used to determine the bulk specific gravity of asphaltic concrete specimens. When combined with results from the Marshall stability test, the optimum asphalt and aggregate mix can be determined. The process of determining the optimum asphalt and aggregate mix is outlined in question 3 of the ***Answers to "Observations and Discussion"*** section above.

The unit weight is calculated from the bulk specific gravity. When the density of water is assumed to be 1 g/cm^3, the unit weight (in g/cm^3) is equal to the bulk specific gravity of the specimen. A specimen with high unit weight will have high density, and a specimen with low unit weight will have low density. The density obtained in the laboratory can act as a comparison of quality between asphaltic concrete mixtures. And the density and composition of the asphaltic specimen may be compared with density and quality of specimens already in place on the roadway.

Advantages/Disadvantages

Advantages:

Nuclear methods are also available to determine the specific gravity of asphaltic pavements, but the fastest, easiest, and least expensive way of determining the specific gravity of *laboratory compacted* asphalt specimens appears to be the test method described in this study.

If the test is performed properly and at least 3 specimens are used in determining the specific gravity for each asphalt cement content, relatively accurate results of the bulk specific gravity may be obtained.

Disadvantages:

The use of laboratory specimens in determining the specific gravity of asphaltic concrete may not always be representative of the compacting and mixing conditions used in the field. For testing the specific gravity of field specimens, either destructive or non-destructive tests may be used. The test described in this study would be classified as a destructive test, where the removal of pavement from a road surface is required before testing the specimen. A more desirable (and possibly more accurate) method of testing a field specimen would be to use nuclear equipment, where the in-situ density could be obtained.

In addition, variations in the methods of preparation of laboratory asphaltic specimens may result in different specific gravities for the same asphalt cement content. But inaccurate bulk specific gravities may be avoided by preparing several specimens with the same asphalt content and averaging the values of their specific gravities.

Possible Errors

The possible errors include the following:

Specimen #1: After the specimen was specimen was mixed and compacted into its mold, it was discovered that the incorrect mold had been used in the preparation of the asphaltic specimen. When the time came to test the specimen, it was exceedingly difficult to remove the specimen from its mold. Force was required, which caused cracking of the specimen and possibly further compaction. This may have resulted in an increase in the density of the specimen, but the increase was not significant because in the **ASTM D 2726-73**, describing the standard test method for determining the bulk specific gravity states, "Duplicate specific gravity results by the same operator should not be considered suspect unless they differ by more than 0.02." The specific gravities of all specimens were all within 0.02 of each other.

Specimen #2: In both specimens 1 and 2, the mixer did not completely mix the aggregate with the asphalt cement. The result was that the specimens were not as completely compacted as they may have otherwise been. This may have caused specimens 1 and 2 to have lower specific gravities than they may have had if they had been completely mixed.

Specimen #3: The specific gravity obtained from specimen #3 appeared to be the most exact value. Some of the paper, however, stuck to the specimen when compaction occurred. The paper sticking to the specimen may have resulted in a slightly inaccurate reading for the bulk specific gravity. The filter paper stuck to the other specimens as will, however.

Specimen #4: When preparing specimen number 4 for testing, a small amount of asphalt cement did not mix with the pavement mixture because it became stuck to the stirring mechanism. In addition, the compaction temperature for specimen #4 was below 210 F. These factors may have caused specimen #4 to have a lower specific gravity than the expected specific gravity. But specimen #4 turned out to have a specific gravity similar to specimen #2, of 2.22. The more dense aggregate mixture used for specimen number 4 may have resulted in the higher specific gravity. But the specific gravity results were close enough that all the values may be considered valid.

Further possibilities for error may have occurred, and these are discussed in question number 4 in the section, ***Answers to "Observations and Discussion"***.

Limitations of this Lab

One of the main limitations of this lab is that when the bulk specific gravity of pre-existing pavement structures is desired, pavement specimens must be cut out of the pre-existing pavement. If many tests are required, this could cause destruction to pavement. The holes made would need to be patched. When testing for the bulk specific gravity of in-place pavements, the nuclear method may be the most desirable.

IV. Conclusions

Properties of the paving material

From the data on specific gravity, the unit weight of the tested pavement mixture compared to other pavement mixtures can be determined.

The average unit weight of the of the 6.5% asphalt specimens tested was determined to be 138.3 lbs per cubic ft. This specific gravity was the maximum average unit weight of all design specimens tested. By observing figure 2.1, the graph of unit weight versus percent asphalt content, one can observe that 128.3 lb/in^3 is the maximum unit weight of the asphaltic specimen. The percent asphalt content at this unit weight, 6.5%, will be used in averaging the optimum asphalt contents of the specimen in the Marshall pavement design procedure.

There existed a continuous rise in the unit weights of the asphaltic concrete mixes ranging from 4 to 6.5% asphalt. At higher percentages of asphalt, even greater unit weights of the asphalt concrete may occur, but these unit weights will decrease after the optimum unit weight is obtained. In other words the optimum unit weight may occur at an asphalt cement content greater than 6.5%.

Numerous possibilities for error occurred while preparing and testing the specific gravities of the specimens, but the use of 3 asphalt concrete specimens for each %AC and the attempt to maintain laboratory standards resulted in reasonably accurate data.

Engineering Significance of this lab

As mentioned in the section, ***Answers to Observations and Discussion***, the specific gravity is used to determine the maximum unit weight of a material. On a graph of unit weight v. percent asphalt content, the asphalt content which corresponds to the maximum unit weight is observed. In conjunction with the Marshall stability and other specific gravity tests, the optimum content of asphalt cement in the pavement mixture may be determined. This pavement mixture may then be mixed at an asphalt plant and used for construction of flexible pavement structures.

V. Appendix

The following books were used for reference:

American Society for Testing and Materials. ***1978 Annual Book of ASTM Standards.*** Part 15. American Society for Testing and Materials, 1978.

Garber, Nicholas and Lester A. Hoel. ***Traffic and Highway Engineering***. West Publishing Company, 1988.

Calculations and Data on Next Page.