

Maximum Specific Gravity of Bituminous Paving Mixtures

Lab Experiment #9

Submitted to:

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CE 361: Highways Materials Laboratory

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II. Results

Table 2.1: Test data and Maximum Specific Gravity Calculations for 6.5% asphalt cement content.

Weight of Pycnometer Filled with Water (grams)	Weight of Mix in Air (grams)	Weight of combined Pycnometer, Mix, and Water (grams)	Volume of Voidless Mix (cm ³)	Maximum Specific Gravity
6267.30	1229.90	6962.30	534.90	2.30

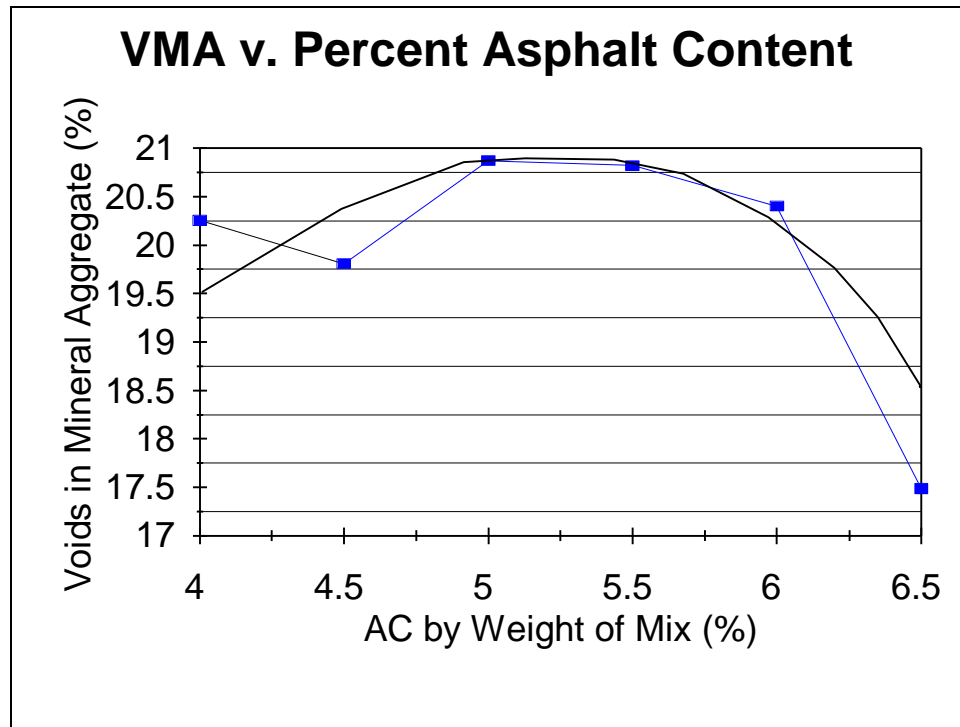


Figure 2.1: VMA versus Asphalt Content

In table 2.1, one can observe the test data and calculations for the maximum specific gravity of the asphaltic paving mixture. The maximum specific gravity was determined by performing the ASTM test entitled *Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures*. (ASTM D 2041 - 78). The methods used will be discussed in the section entitled **procedure**.

The percent voids in the mineral aggregate versus percent asphalt content curve may be observed in fig. 2.1. The results from voids in the mineral aggregate were scattered, with the lowest amount of void spaces in the mineral aggregate occurring in the compacted specimen containing 6.5% asphalt.

From the maximum specific gravity found in this study, as well as the properties obtained in other labs, the total voids in the mix, the voids in the mineral aggregate, the unit weights of all asphaltic specimens, and other properties were calculated. This information is located in table 2.2. Sample calculations are located in the appendix. Bulk specific gravity and unit weight were determined from Lab Experiment no. 8 and adjusted average Marshall stability and Flow were determined from Lab Experiment no. 10.

In figure 2.2, one may observe a curve showing the voids in total mix versus percent asphalt cement content. As the asphalt content rose, the percent voids in total mix decreased, due to asphaltic concrete filling the

void spaces. The only specimen which met the criterion of 3-5% voids in total mix was the sample containing 6.5% asphalt, which had 3.5% air voids.

Table 2.2: Combined Specific Gravity and Test Data*

Asphalt Cement Content (%)	Bulk Specific Gravity	Maximum Specific Gravity	Total Voids in mix (%)	Specific Gravity of Asphalt Cement (%)	Voids in Mineral Aggregate (VMA) (%)	% VMA Filled (%)	Unit Weight (lb/ft ³)	Adjusted Average Marshall Stability (lbs.)	Flow (1/100 in.)
4.0	2.13	2.42	11.98	1.03	20.26	40.84	132.80	1783	9.7
4.5	2.13	2.38	10.50	1.03	19.81	46.98	132.80	902	9.4
5.0	2.19	2.44	10.25	1.03	20.88	50.92	136.70	1925	8.0
5.5	2.19	2.41	9.13	1.03	20.82	56.16	136.70	1751	11.7
6.0	2.21	2.39	7.53	1.03	20.41	63.09	137.70	1543	10.6
6.5	2.22	2.30	3.48	1.03	17.49	80.11	138.30	1643	7.8

* These calculations were made according to the plan set forth by the Utah Department of Transportation's bituminous pavement design procedure, found in Budge's Highway Materials Laboratory. A copy of this sheet and Sample calculations with data are located in the appendix.

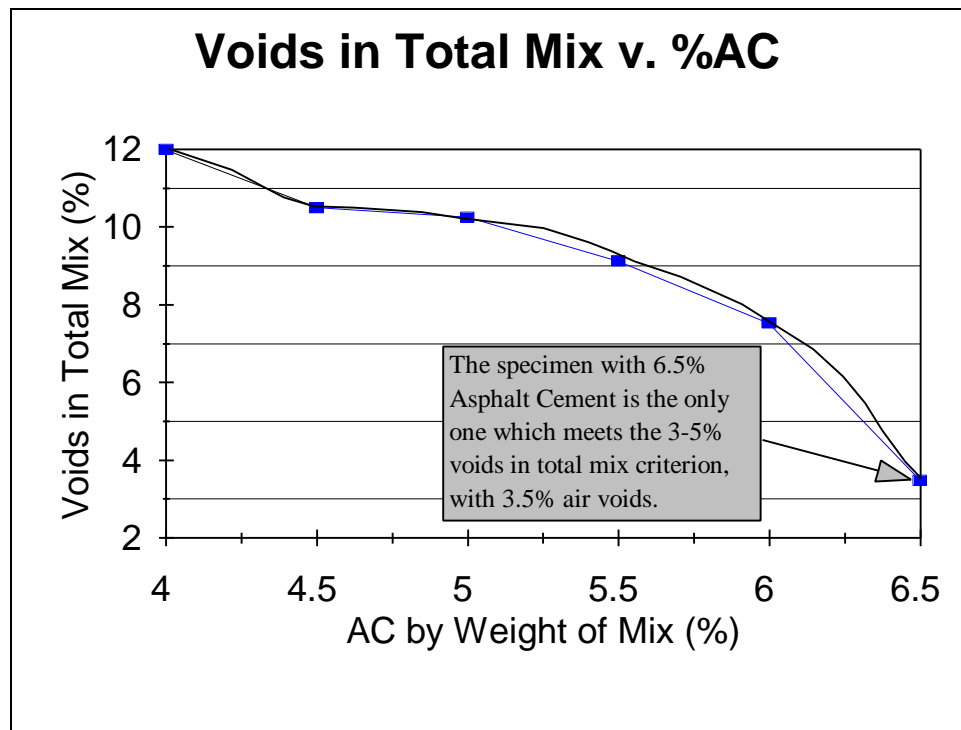


Figure 2.2: Voids in Total Mix versus Asphalt Content

III. Discussion

Procedure

Preparation of the specimen

One specimen were prepared in the same manner as the specimens in laboratory no. 8, with the exception of the compaction process. The same weights and mixture times were used to obtain a mixture containing 6.5% bituminous material. The specimen was then allowed to cool to 100 F before testing.

Testing for maximum specific gravity of the specimen

A pycnometer flask was filled completely with water and the weight of the flask and water combination was determined. The pycnometer flask was then emptied.

The specimen was then tested to determine its maximum specific gravity. After the specimen was cooled, it was placed in the empty pycnometer flask and enough water was added to thoroughly cover the sample. The specimen was then subjected to a partial vacuum for a period of 15 minutes, allowing the air bubbles to escape from the asphaltic mixture and the void spaces to be filled with water. As the vacuum was applied to the specimen in the pycnometer flask, the flask was agitated for 30 seconds of every 100 seconds to induce sufficient infiltration of water into the void spaces.

The pycnometer flask was then filled completely with water and allowed to stand at room temperature for 10 minutes. The flask containing the specimen and water was then weighed. The maximum specific gravity of the pavement mixture was determined from the weight of the dry sample in air (1229.9 grams), the weight of the pycnometer filled with water (6267.3 grams), and the weight of the pycnometer filled with the asphalt mix and water (6962.3 grams). Thus, the maximum specific gravity was $1229.9 / ((1229.9 + 6267.3) - 6962.3) = 2.3$. Sample calculations are located in the appendix.

Answers to "Observations and Discussion"

1. What precautions must be met in performing this test?

1. All weights measured must be exact.
2. When preparing the specimen, the asphalt cement should not touch the sides of the mixing container before mixing, or some cement will not mix with the aggregates.
3. The pycnometer flask must be completely filled with water and dry on the outside when determining the maximum specific gravity, or errors will result from excess or inadequate amounts of water.
4. When determining the maximum specific gravity of asphaltic specimens, the temperature must be kept constant, or an error will result in the maximum specific gravity of the specimen due to a change in density with temperature. This is especially important for the bituminous pavement mixture, which can undergo significant changes in density with temperature. The ASTM designation for the temperature at which the test should be performed is 25 C.
5. When using a partial vacuum to evacuate the air bubbles from the bituminous mixture in water, it is important that this process is done for the correct amount of time (15 min.). If it is done too quickly, all the air bubbles will not be evacuated from the mixture. If the vacuum is applied to the specimen for too long, error may be induced due to water getting under the bituminous coating. To be most accurate in evacuating the air from the bituminous mixture, an optimum time may be established by trial reduction of test time until further reduction yields lower specific gravities. (ASTM D 2041 - 78).
6. When transferring the pavement mixture between the mixing container and the pycnometer flask, care must be taken to insure that as much of the mixture as possible is transferred. If all of the mixture is not transferred, some of the mixture will remain in the mixing container or on the mixer itself and an error in the maximum specific gravity will result.

2. What is the purpose of obtaining the maximum specific gravity?

In conjunction with the bulk specific gravity, determined in Experiment no. 8, the maximum specific gravity may be used to calculate the percentage of total voids in an asphaltic concrete pavement mixture (%AC). After determining the total voids, the results may be combined with results from pavement mixtures with differing, known asphalt cement contents. A graph of voids in total mix versus %AC may be constructed, as in fig. 2.2, and the asphaltic mixes falling within 2-4% or 2-5% air voids may be considered for use in pavement structures. In conjunction with graphs of Marshall stability versus %AC (Lab 10) and Unit Weight versus %AC (Lab 8), the optimum pavement mixture may be completely determined.

3. Why is it necessary to know the void content of a bituminous mix?

The void content of a bituminous mix must be known to determine whether or not the bituminous mixture meets specifications. (See experiment no. 10 for specifications).

Specifications are given for the void content in a bituminous mixture (usually between 2-5% air voids in the total mix) so for the following two reasons:

First, adequate voids must exist in the total compacted mixture (above 2%) to permit a small amount of compaction when traffic load is applied without loss of stability. At the same time, blushing and bleeding of asphalt from the pavement mixture must be prevented to prevent a slippery road surface.

Second, the void content in a bituminous mixture must be low enough (below 5%) to prevent harmful penetration of air and moisture into the compacted mixture.

4. How would increasing the asphalt cement content of the bituminous mix affect the specific gravity?

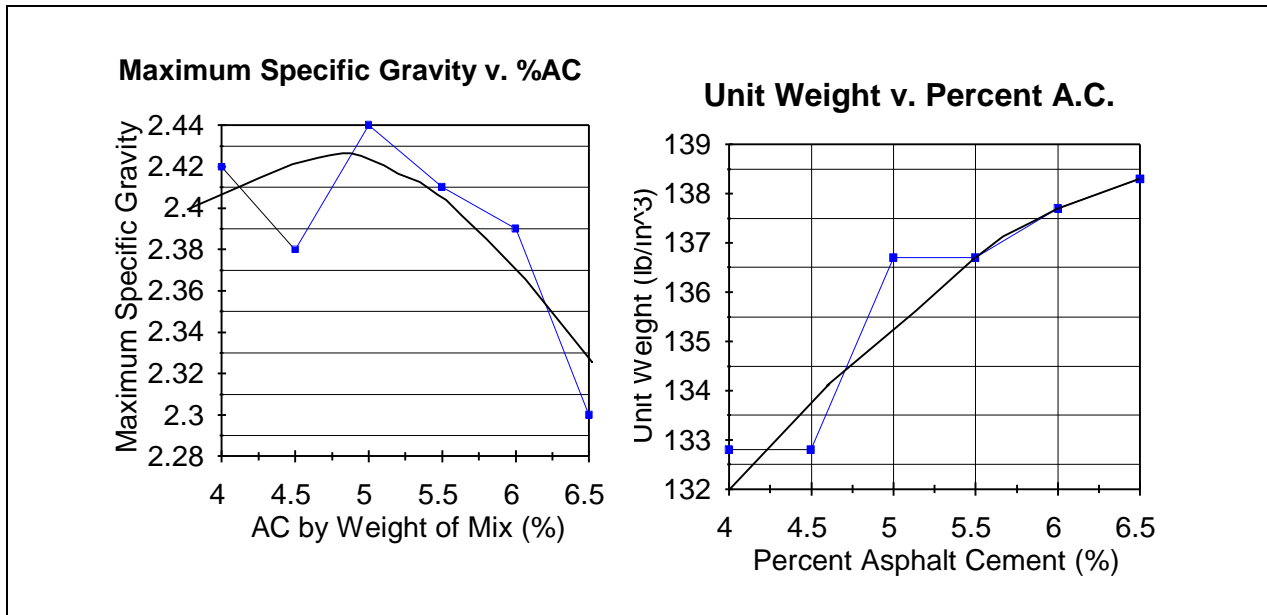


Figure 3.1: Effects of changes in asphalt cement content on maximum specific gravity and unit weight (bulk specific gravity X 62.4).

The effect of changes in asphalt cement content on the specific gravity of a bituminous mix may be observed in fig. 3.1. As more asphalt cement is added to the aggregate mixture, initially *bulk* specific gravity will increase. This is because the air voids are being filled by the asphalt cement, which has a greater density than air.

But soon, the *bulk* specific gravity will decrease. The specific gravity would begin to decrease because the asphalt cement would have filled all the possible void spaces after a certain amount. Larger spaces between the aggregates would begin to exist which are filled with the less dense asphaltic concrete. The result would be a

lower specific gravity. The decrease did not occur in this test, but it would eventually occur if the percent asphalt cement was increased.

When determining the *maximum* specific gravity, it is assumed that no voids exist in the specimen. As the asphalt content in the specimen is increased, the *maximum* specific gravity would behave the same as the *bulk* specific gravity, except it would reach its peak at a lower asphalt content. This is because after all the asphalt is absorbed by the aggregate, no air voids exist for the asphalt cement to go to. The specific gravity then begins to decrease since more space is taken up by the asphalt cement.

Uses of the test

The standard test method for theoretical maximum specific gravity of bituminous paving mixtures is used to determine the maximum specific gravity of asphaltic pavement specimens. The maximum specific gravity and bulk specific gravity of a specimen may be used to calculate the percent air voids in a pavement mixture. For a pavement mixture, it is desirable if the percent air voids is between 2 and 5%. The percent asphalt cement containing between 2 and 5% air voids is then used in conjunction with the percent asphalt cement at the maximum stability and the maximum unit weight to determine the optimum paving mixture.

Advantages/Disadvantages

Advantages:

If the maximum specific gravity test is performed properly, it can be an accurate method of determining the specific gravity of asphaltic mixtures. In addition, the maximum specific gravity of a specimen is required to determine the percent air voids in the compacted mixture and the voids in the mineral aggregate of the bituminous mixture. So the maximum specific gravity test is a test which determines useful engineering properties of a bituminous mixture.

Disadvantages:

A good, accurate maximum specific gravity determination is hard to obtain because of the many variables involved in determining a specific gravity. Some of these variables which must be kept constant throughout the test include temperature and the amount of water in the pycnometer flask.

In addition, when transferring the pavement mixture between the mixing container and the pycnometer flask, it is extremely difficult to assure all the mixture is transferred. This results in a lower specific gravity reading than what might otherwise be obtained.

Finally, the use of laboratory specimens in determining the maximum specific gravity of asphaltic pavement mixtures may not always be representative of field conditions. But the maximum specific gravity determined in the laboratory may nevertheless be useful for engineering purposes. Nuclear methods may be used for determining the properties of in-place field specimens.

Possible Errors

The possible errors include the following:

1. The scale appeared to be somewhat off when weights were measured. The fluctuations were small compared to the weights measured, however. Fluctuations of the scale were in the range of +/- 1 gram.
2. Some of the paving mixture was left in the mixing container after pouring all that could be poured into the pycnometer flask. The unweighed paving mixture resulted in a lower-than-maximum specific gravity.
3. Either bubbles remaining in the paving mixture (from applying vacuum for too short a time) or water infiltrating under the bituminous coating of the mineral aggregates (from applying vacuum for too long a time) would have resulted in a suspect specific gravity reading.
4. The asphaltic mixture was not cooled completely to room temperature before it was added to the water and weighed. Many temperature variations occurred in the lab, which had a likely effect on the specific gravity of the water and the final specific gravity of the paving mixture.

Limitations of this Lab

The lab was limited because the variations in temperature were ignored in the testing of the specimen. In addition, only one specimen containing 6.5% asphalt concrete was tested. The temperature variations may be ignored when dealing with general engineering applications of pavements. But the ASTM guide suggests that the standard deviation of the specific gravities of the test results should be 0.004 and that the maximum difference between 2 results should be 0.011. One cannot tell whether this degree of accuracy was obtained, however, since only one specimen was tested. Three specimens would need to be tested to determine the degree of accuracy obtained in the maximum specific gravity of the asphaltic specimens.

IV. Conclusions

Properties of the paving material

The 6.5% asphalt paving mixture was determined to have a maximum specific gravity of 2.30. From the maximum specific gravity of the paving mixture, the percent air voids was calculated to be 3.48%. The %VMA was calculated to be 17.5%, and the asphalt cement filled 80.1% of this void space. The specimen tested was found to have the lowest amount of voids in the total mix and the lowest VMA of all tested specimens. The 6.5% asphalt paving mixture tested also was the only paving mixture to fall within the 2-5% total air voids specification. Finally, it was discovered that as the asphalt cement added to the aggregate mixture increases, the percent voids in the mixture will decrease and the bulk and maximum specific gravities will follow a parabolic curve, first rising, reaching an optimum, then falling after a maximum saturation is obtained. The maximum specific gravity reaches an optimum before the bulk specific gravity.

Engineering Significance of this lab

From the maximum and bulk specific gravities of laboratory specimens, the percent voids in the total mixture may be obtained. For the 6.5% asphalt concrete specimen, the 3.48% air voids in the specimen means that it should be considered for use in pavement structures. From the Marshall stability test and the unit weight of the asphalt specimen, one can see that the 6.5% asphalt concrete specimen would perform well in a pavement structure. For specifications and properties of the 6.5% asphalt mixture, see the conclusion of the next experiment. So the 6.5% asphalt mixture should be the mixture used in the design and construction of flexible pavements. The maximum specific gravity test was essential in determining the air voids and which pavement to use.

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.