research projects of this type engineers too often try to confirm certain preconceived ideas and they are quick to jump at early indications of differences in performance. The effects of weather and traffic do not become evident overnight, or even in a few years.

Specific Gravity of Aggregates in Asphaltic-Paving Mixtures

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WEIGHT-VOLUME relations are widely used as criteria for the design of bituminous paving mixtures. The determination of specific gravity of the various constituents of the paving mixture is therefore a necessary part of the design procedure. However, a uniform procedure for determining specific gravity of aggregates for use in the design of bituminous paving mixtures has not been adopted. This report compares values of specific gravity obtained by several procedures. Three procedures were studied which yield the specific gravity of the aggregate directly: bulk specific gravity, apparent specific gravity and bulk impregnated specific gravity. Two other procedures were studied which measure the specific gravity of the bituminous mixture directly: aerosol and vacuum procedure and aerosol and pycnometer procedure.

The bulk-impregnated specific-gravity procedure and the aerosol and vacuum procedure were both found to yield values of specific gravity considered to closely represent the probable weight-volume relationships in bituminous mixtures. The aerosol and vacuum procedure required less time than the bulk, apparent, and bulk-impregnated procedures.

● REQUIREMENTS for percent voids, percent of maximum density and percent voids filled with bitumen are all used for the design of plant mix bituminous mixtures. Practically all design procedures used today involve the use of one or more of these criteria for establishing the proper mixture.

The practical use of these design criteria raises two very pertinent questions in the experienced engineer's mind. The first question concerns the problem of whether or not his laboratory compacted specimen really represents the density which can be expected in the actual pavement after it has been under traffic for several years. The second question concerns the problem of how the specific gravity of the loose mixture, or the ratio of the weight of material to the space actually occupied by the constituents of the mixture, is to be determined. This report deals with the second question.

Traditionally the volume occupied by the loose mixture has been found by determining either the apparent or the bulk specific gravity of each component of the mixture and using these values together with the weight proportions of each component to find the volume occupied (solid volume) by the total mixture or in other words the weighted specific gravity of the total mixture. Assume for example that a mixture of 100 gm is composed of 60 gm of aggregate A, 35 gm of aggregate B and 5 gm of asphalt with apparent specific gravities of 2.60, 2.65 and 1.02 respectively. The solid volume of the 100 gm of mixture would then be (60/2.60) (35/2.65) (5/1.02) = 41.19 cc and the weighted specific gravity would be (100/41.19) = 2.43. If the compacted mixture in the pavement occupies a volume of 43 cc per 100 gm the volume of voids or air space is then (43 − 41.19) = 1.81 cc and the percentage voids, by volume, is (1.81/43) 100 = 4.21.

The method is specific and the procedure is exact but the specific gravity values used are subject to question. All aggregates contain voids. In siliceous gravels and igneous rocks the volume of such voids is generally quite small, in most limestones it is of appreciable magnitude and in aggregates such as slag the volume of voids becomes quite large. Specific gravity measurements are made by weighing aggregates in water so that the void spaces are more or less filled at the time of measurement. In the bituminous mixture the same volume conditions will exist only if the bitumen fills the voids to the same extent that water does. This is probably generally not true. As stated previously two procedures have been used rather generally in the past for calculating voids in bituminous mixtures. One procedure uses the bulk specific gravities of the aggregates which essentially assumes that the bitumen fills none of the aggregate voids. The other procedure uses apparent specific gravities which assumes that the bitumen fills the aggregate voids to the same extent as does water. The following example illustrates the differences in the two procedures. Suppose that 100 gm of absolutely dry aggregate is immersed 24 hours in water, then removed and all surface water eliminated to bring the aggregate to the "saturated surface dry condition." It is found to weigh 102 gm in this state. The aggregate is then weighed in water and is found to weigh 63 gm. The decrease in aggregate weight will be the weight of water displaced and since 1 gm = 1 cc (assuming average temperatures) will also be equal to the volume displaced. The bulk specific gravity (on a dry weight basis), is then $100/(102 - 63) = 100/39 = 2.56$ and the apparent specific gravity is $100/(100 - 63) = 100/37 = 2.70$. This difference between bulk and apparent specific gravity is not unusual. If a mixture containing 95 percent of this aggregate and 5 percent asphalt cement with specific gravity of 1.02 is found to have a compacted specific gravity of 2.30 the computed per cent voids would be 3.4 based on the bulk specific gravity and 7.8 based on the apparent specific gravity. The difference in percent voids becomes quite significant in view of the fact that specification requirements rarely permit more than a 4 percent range of voids for the compacted paving mixture, for example 2 to 6 percent.

The difficulties involved in the use of the specific gravities of the various individual aggregates can be eliminated by measuring the specific gravity of the aggregate immersed in asphalt or of the completed paving mixture directly since the aggregate will then be in the proper state as far as bitumen absorption is concerned. Several procedures have been proposed by various investigators for this direct measurement. In the following pages are presented the results of studies of several of these procedures for a number of different aggregates. Since it is essential that specific gravity determinations be regularly made in field laboratories where elaborate equipment is not available this study was primarily restricted to methods adaptable to the field laboratory. Tests were conducted at room temperature and no attempt was made to adhere to a single standard temperature, for example 77°F, since precise temperature control, particularly for temperatures requiring refrigeration, is seldom available in a field laboratory. Test temperatures were recorded.

The procedures studied were: (1) bulk-impregnated specific-gravity test of the South Atlantic District, Corps of Engineers; (2) specific gravity of bituminous mixtures using aerosol solution and vacuum; and (3) specific gravity of bituminous mixtures using aerosol solution and pycnometer. The bulk and apparent specific gravities of the aggregates used were also determined.

SPECIFIC-GRAVITY-TEST PROCEDURES

Bulk and Apparent-Specific Gravity of Course Aggregate and Fine Aggregate

The procedure used in obtaining the bulk and apparent specific gravity of individual aggregates was essentially that described in AASHO T 84–85, Specific Gravity and Absorption of Fine Aggregate. Exceptions were the use of a 1000-ml flask instead of a 500-ml flask and the use of a vacuum to remove air from the sample instead of the procedure of rolling the flask on a flat surface as recommended in the standard. The procedure consisted of the following steps:

1. The coarse and fine aggregate were immersed in water at room temperature for a period of 24 hours.

2. The soaked aggregates were removed from the water and brought to saturated surfaces dry condition as follows: (1) The soaked coarse aggregate was rolled in an absorbant clean cloth until all visible films of

water were removed from the surface of the particles. (2) The soaked fine aggregate was spread on a flat surface and exposed to gently moving air under a fan with constant stirring to secure uniform drying. This operation was continued until the sample reached a free flowing condition. (3) At intervals the sample was placed loosely in the standard conical mold and tamped lightly 25 times with the standard metal rod and the mold lifted vertically. By so doing the moisture content was obtained at which the cone of the fine aggregate just slumped upon removal of the mold. At this moisture content the fine aggregate was considered to be in its saturated surface dry condition.

3. About 500 gm of aggregate saturated surface dry and weighed to the nearest 0.1 gm was introduced into a 1000-ml volumetric flask (weight A).

4. The volumetric flask was then filled to the volume mark with distilled water and subjected to vacuum by the ordinary laboratory aspirator until the air was removed. Figure 1 shows a sample of limestone ready for testing and a sample in the volumetric flask under vacuum. The removal of air in the sample was judged by the maintenance of constant water level in the neck of the flask after applying vacuum for several minutes. The flask was then filled with distilled water exactly to the mark and the weight of flask plus water plus sample was determined to the nearest 0.1 gm (weight B).

5. The sample was then decanted into a pan, dried to constant weight at a temperature of 110°C, cooled to room temperature and weighed to the nearest 0.1 gm (weight C).

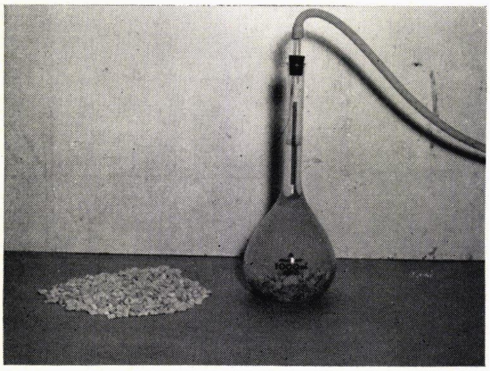

Figure 1. Sample of limestone and flask under vacuum for bulk and apparent specific gravity procedure.

6. The weight of the volumetric flask filled to the mark with distilled water from which the air was removed by application of vacuum with the aspirator was determined to the nearest 0.1 gm (weight D).

7. The bulk specific gravity was calculated by the following formula:

$$\text{bulk specific gravity} = \frac{C}{A + D - B}$$

8. The apparent specific gravity was calculated by the following formula:

$$\text{apparent specific gravity} = \frac{C}{C + D - B}$$

Bulk-Impregnated Specific-Gravity Test

The procedure employed is essentially that recommended by the U. S. Corps of Engineers, South Atlantic District. The following procedure was used:

1. An aggregate sample of 1000 gm (weight A), oven dry, containing the various aggregates in the same proportions as proposed for the paving mixture was prepared.

2. Sufficient quantity of the same asphalt as that proposed for the paving mixture was heated to 275–300F and poured into a one gallon pail to a depth of about two inches. A sheet metal stirrer was inserted into the pail and the asphalt was allowed to cool to room temperature.

3. The pail with asphalt and stirrer was weighed in air (weight D) and in water (weight E) at room temperature. In order to equalize the temperature of asphalt and water, the pail with asphalt and stirrer was kept in the water bath for about four hours.

4. The aggregate and the pail with asphalt and stirrer were kept separately over night in an oven at 275 F. to 300 F.

5. The materials were removed from the oven and the hot aggregate was added to the hot asphalt with constant stirring. The surface of the asphalt was lightly flamed to remove air bubbles.

Figure 2 shows the equipment for the test and illustrates the introduction of the aggregate into the asphalt.

6. The aggregate asphalt mixture was allowed to cool to room temperature. The pail

with stirrer, asphalt, and aggregate, was weighed in air (weight F) and water (weight G) using the same procedure and temperature as in step three above.

7. The impregnated specific gravity was calculated as follows:

$$\text{impregnated specific gravity} = \frac{A}{F - G - D + E}$$

8. If the specific gravity of the asphalt is desired it may be obtained at the same time by making additional weighings of the pail plus stirrer in air (weight B) and in water (weight C).

$$\text{specific gravity of asphalt} = \frac{D - B}{(D - E) - (B - C)}$$

Specific Gravity of Bituminous Mixtures Using Aerosol Solution and Vacuum

The test procedure is essentially that proposed by James M. Rice in The Crushed Stone Journal, September 1953, page 10, in an article entitled "New Test Method for Direct Measurement of Maximum Density of Bituminous Mixtures." The measurements were made in a volumetric flask and a solution of 0.1 percent aerosol in distilled water was used instead of plain water. The aerosol solution was used because it wets the bitumen coated aggregate much more readily than plain water thus simplifying the removal of the air. Measurements were made both on mixtures prepared in the laboratory and on "field" mixtures obtained from actual construction projects. Samples of both the aggregates and the paving mixture were obtained from the construction projects.

Preparation of Laboratory Mixtures for Test. The procedure used in the preparation of the various laboratory mixtures tested for specific gravity was as follows:

1. The separate aggregates were dired to constant weight and the proper quantity of each for a 1500 gm batch was weighed into a tarred aluminum pan. The aggregates were thoroughly mixed with a trowel.

2. The pans were then placed in a 250°F oven and left for a minimum of four hours. The asphalt cement was heated to 250°F in a separate container just prior to the mixing operation.

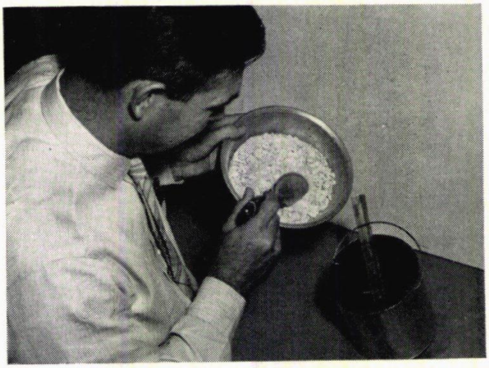

Figure 2. Introducing aggregate in bulk-impregnated specific-gravity procedure.

3. The aggregates were placed in the previously heated mixing bowl of a Hobart C-10 mixer and the proper quantity of heated asphalt cement was weighed into the bowl. The materials were then thoroughly mixed with the C-10 mixer, for two minutes.

4. The sample was spread in a thin layer on a clean metal top table and separated as it cooled to room temperature as much as possible with a small trowel and spatula using care not to fracture the mineral particles. Figure 3 shows the material spread out ready for testing.

Preparation of Field Mixtures for Test. (1) The sample was removed, in chunks, from the shipping container and placed in a flat laboratory pan. It was then warmed, with constant stirring, until hot enough that it could be broken down readily. (2) The sample was then spread in a thin layer on a metal table and separated as much as possible with a small trowel and spatula using care not to fracture the mineral particles.

Preparation of Aerosol Solution. It is quite probable that any one of a number of different wetting agents will serve satisfactorily to promote wetting of bitumen coated aggregates by water. Aerosol was selected because a small supply was available in the stockroom. A solution of 0.1 percent by weight was found to give satisfactory wetting without excessive foaming. Solutions were prepared using both the solid aerosol and a 75 percent aqueous solution. The manufacturer's recommendations for use were followed carefully. When using the solid aerosol it was first necessary to prepare a 10 percent solution, allow to

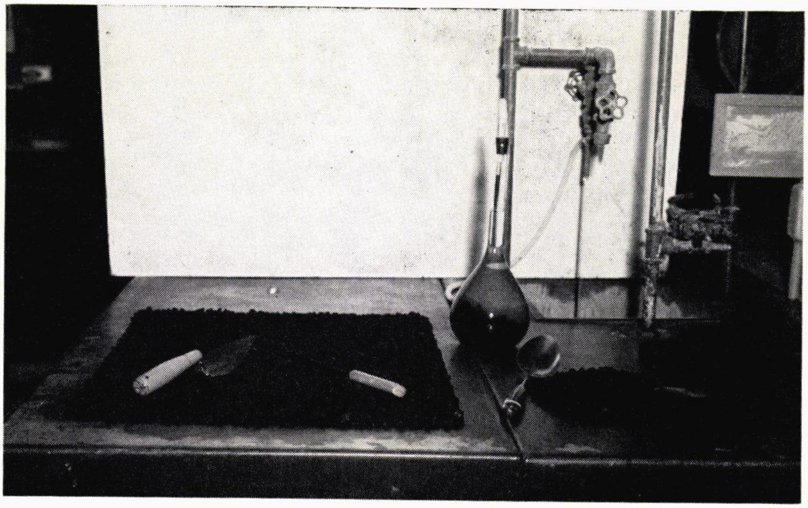

Figure 3. Sample of bituminous mixture and equipment for aerosol with vacuum procedure.

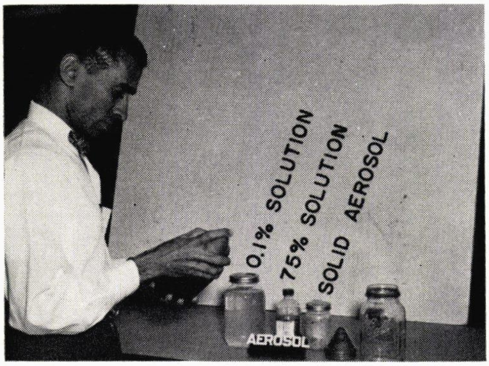

Figure 4. Aerosol and pycnometer specific gravity procedure.

stand 24 hours to form a jell and then dilute to the required 0.1 percent strength. Figure 4 shows the solid aerosol and the solutions used.

Determination of Specific Gravity. The following technique was used for the vacuum method.

1. About 500 gm of the sample was weighed to the nearest 0.1 gm (weight A) and introduced into a 1000 cc volumetric flask.

2. The volumetric flask was then filled to the volume mark with the 0.1 percent aerosol solution.

3. The entrapped air in the sample was removed by applying vacuum to the volumetric flask with an aspirator. The application of vacuum was continued until no further change in the level of the aerosol solution occurred on prolonged application of vacuum. Figure 3 shows a sample in the flask under vacuum.

4. The volumetric flask was filled exactly to the mark with the aerosol solution and was weighed to the nearest 0.1 gm (weight B).

5. The volumetric flask was filled to the mark with aerosol solution alone and subjected to vacuum in order to take out the entrapped air. The flask was again filled with aerosol solution to the mark and weighed to the nearest 0.1 gm (weight C).

6. The specific gravity of the mixture was calculated by the formula

$$\text{specific gravity} = \frac{A}{A + C - B}$$

Specific Gravity of Bituminous Mixtures Using Aerosol Solution and Pycnometer

The vacuum procedure is limited in field application because vacuum will not be available in many field laboratories. Because of the extremely good wetting of the bitumen-aggregate mixture by the aerosol solution it seemed feasible to use a simple method not involving vacuum. The Texas Highway Department uses a field pycnometer which consists of an ordinary narrow mouth fruit jar fitted with a conical pycnometer cap as shown in Figure 4. A match mark on the jar and cap is used to insure seating of the pycnometer cap at the same elevation. This piece of equipment was selected for use.

The following technique was used in finding the specific gravity of the bitumen-aggregate mixtures with the pycnometer.

1. About 500 gm of the sample was weighed to the nearest 0.1 gm (weight A), and introduced slowly into the pycnomter which was partly filled with 0.1 percent aerosol solution. The mixture was agitated by means of a spatula at intervals in order to drive out as many air bubbles as possible.

2. After the entire sample was introduced, the pycnometer was filled with the aerosol solution. In order to remove the entrapped air the pycnometer was then shaken vigorously in both hands while holding the finger of one hand over the pycnometer opening. The process was continued till no visible air bubbles came out. Figure 4 illustrates the shaking process. The pycnometer with sample and aerosol solution was weighed to the nearest 0.1 gm (weight B).

3. The pycnometer was completely filled with aerosol solution entrapped air removed as described in step 2, and weighed to the nearest 0.1 gm (weight C).

4. The specific gravity of the mixture was calculated by the formula:

$$\text{specific gravity} = \frac{A}{A + C - B}$$

Difficulty was encountered in removing entrapped air in this procedure, particularly for the sheet asphalt mixtures. A limited number of determinations were made in which the solution was raised to temperatures at or near boiling for periods of 30 minutes to 1 hour. The results obtained were rather erratic and not easily reproducible. The values so obtained are shown for the sheet asphalt mixture only.

TABLE 1
PROPERTIES OF COARSE AGGREGATES

	Crushed Limestone†		River Gravel‡		Crushed Slag§	
	Coarse, percent	Fine, percent	Coarse, percent	Fine, percent	Coarse, percent	Fine, percent
Gradation						
Pass 5/8"*—ret'd 1/2"	8	0	0	0	0	0
Pass 1/2"*—ret'd 1/4"	90	9	100	0	100	0
Pass 1/4"*—ret'd no. 10	2	79	0	100	0	100
Pass no. 10—ret'd no. 40	0	7	0	0	0	0
Pass no. 40	0	5	0	0	0	0
Specific Gravity and Absorption						
Bulk specific gravity	2.53	2.52	2.62	2.62	2.53	2.58
Apparent specific gravity	2.71	2.72	2.68	2.68	2.88	2.92
Water absorption, percent	2.4	3.3	1.7	1.7	4.8	4.5

* Round openings.
† Servex Materials Company, New Braunfels, Texas.
‡ Gifford-Hill Company, Hearne, Texas.
§ Lone Star Steel Company, Daingerfield, Texas.

TABLE 2
PROPERTIES OF FINE AGGREGATES

	Limestone† Screenings, Percent	Concrete‡ Sand, Percent	Field¶ Sand, Percent
Gradation			
Pass 1/4"*—ret'd no. 10	12	0	0
Pass no. 10—ret'd no. 40	46	51	2
Pass no. 40—ret'd no. 80	15	43	38
Pass no. 80—ret'd no. 200	10	6	57
Pass no. 200	17	0	3
Specific Gravity and Absorption			
Bulk specific gravity	2.57	2.62	2.62
Apparent specific gravity	2.71	2.66	2.66
Water absorption percent	2.6	0.7	0.7

* Round openings.
† Servex Materials Company, New Braunfels, Texas.
‡ Gifford-Hill Company, Hearne, Texas.
¶ Farm near Hearne, Texas.

MATERIALS AND MIXTURES

Laboratory Mixtures

The laboratory mixtures were prepared using for coarse aggregates two sizes of crushed limestone, two sizes of washed river gravel and two sizes of crushed slag. The fine aggregates consisted of limestone screenings, a washed field sand, and concrete sand. The asphalt cement used was 85–100 penetration grade meeting the requirements of the Texas Highway Department Specifications. The gradation and physical characteristics of the aggregates are shown in Tables 1 and 2. The river gravel and slag aggregates were specially prepared in order to secure a uniform mixture gradation independent of aggregate type.

The specific gravity of the asphalt cement used was obtained in accordance with AASHO

T 43-35, "Standard Method of Test for Specific Gravity of Bituminous Materials." The specific gravity of the asphalt cement was found to be 1.014. The specific gravity of the Portland Cement used in the sheet asphalt mixture was found to be 3.08 when tested in accordance with AASHO T-133-45 "Specific Gravity of Hydraulic Cement."

TABLE 3
COMPOSITIONS OF LABORATORY MIXTURES

	Type D Limestone Coarse Aggregate, Percent	Type D River Gravel Coarse Aggregate, Percent	Type D Slag Coarse Aggregate, Pecrent	Type E Sheet Asphalt, Percent
Coarse crushed limestone	30	—	—	—
Fine crushed limestone	20	—	—	—
Coarse river gravel	—	32	—	—
Fine river gravel	—	18	—	—
Coarse crushed slag	—	—	32	—
Fine crushed slag	—	—	18	—
Concrete sand	—	—	—	44
Limestone screenings	25	25	25	—
Field sand	25	25	25	44
Portland cement	—	—	—	12
Gradation				
Pass ⅝″—ret'd ½″	2	0	0	0
Pass ½″—ret'd ¼″	29	32	32	0
Pass ¼″—ret'd no. 10	19	21	21	0
Pass no. 10—ret'd no. 40	14	12	12	23
Pass no. 40—ret'd no. 80	14	13	13	36
Pass no. 80—ret'd no. 200	17	17	17	28
Pass no. 200	5	5	5	13
Asphalt cement contents used, percent	4.0, 5.0, 6.0	4.0, 5.0, 6.0	5.0, 6.5, 8.0	8.0, 10.0

TABLE 4
DESIGN MIXTURES AND SPECIFIC GRAVITY OF AGGREGATES FOR FIELD SAMPLES

Description	Percent by Weight	Apparent Specific Gravity	Bulk Specific Gravity
Field Sample No. 1			
Washed river gravel	38.3	2.69	2.60
Concrete sand	24.9	2.68	2.64
Field sand	32.6	2.65	2.57
Asphalt OA-90	4.2		
Total	100.0		
Field Sample No. 2			
Bin 1, gravel ½″ to ¼″ size	28.1	2.67	2.59
Bin 2, gravel ¼″ to no. 10	25.0	2.68	2.57
Bin 3, sand	41.9	2.68	2.43
Asphalt OA-90	5.0		
Total	100.0		

The aggregates were combined to meet the requirements of Texas Highway Department Item 317, Hot Mix Asphaltic Concrete Pavement Type D, "Fine Graded Surface Course," and Type E, "Sheet Asphalt Surface Course." The various aggregate combinations used for the laboratory mixtures and the gradations of the mixtures are shown in Table 3.

Field Mixtures

During the course of the studies of the laboratory mixtures, two hot mix asphaltic concrete resurfacing jobs were accomplished near the College. In order to provide an additional check on the test procedures samples of aggregates, and of the completed mixtures were obtained from each of the jobs. Both of the mixtures conformed to Texas Highway Department Item 317, Type D, Hot Mix Asphaltic Concrete Pavement. The compositions of the two mixtures and the bulk and apparent specific gravities of the various aggregates are shown in Table 4.

EXPERIMENTAL RESULTS

Bulk-Impregnated Specific Gravity Compared with Apparent and Bulk Specific Gravity

The values for bulk specific gravity and apparent specific gravity shown in Table 1, Table 2, and Table 4 were used to compute the weighted specific gravities of the aggregate combinations shown in Table 3. The specific gravity values obtained for the same aggregate combinations by the bulk impregnated specific gravity procedure should lie between the bulk and apparent specific gravity values. Table 5 shows the results obtained. Values shown are based on a minimum of three determinations for each value tabulated.

Specific Gravity with Aerosol and Vacuum and Specific Gravity with Aerosol and Pycnometer Compared to Bulk and Apparent Specific Gravity

The specific gravity of the asphaltic concrete mixtures found by the use of aerosol and vacuum and by the use of aerosol and the pycnometer are shown in Tables 6 and 7. For comparison purposes the computed apparent specific gravity and the computed bulk specific gravity of each mixture are also shown. The specific gravity values for the laboratory mixtures are also plotted in Figure 5. Values shown are based on a minimum

TABLE 5
APPARENT, BULK AND BULK IMPREGNATED SPECIFIC GRAVITY VALUES FOR VARIOUS AGGREGATE COMBINATIONS
Laboratory and Field Mixtures

Combination	Computed with Apparent Specific Gravity*	Bulk Impregnated Specific Gravity*	Computed with Bulk Specific Gravity*
Asphaltic concrete; limestone coarse aggregate	2.70	2.58	2.55
Asphaltic concrete; gravel coarse aggregate	2.68	2.64	2.61
Asphaltic concrete; slag coarse aggregate	2.79	2.68	2.57
Sheet asphalt	2.70	2.68	2.57
Asphaltic concrete; field sample no. 2	2.68	2.63	2.51

* Values shown are specific gravity of aggregate alone.

TABLE 6
SPECIFIC GRAVITY VALUES FOR LABORATORY ASPHALTIC CONCRETE AND SHEET ASPHALT MIXTURES

Percent Asphalt	Computed with Bulk Specific Gravity	Specific Gravity with Aerosol and Vacuum	Specific Gravity with Aerosol and Pycnometer	Computed with Apparent Specific Gravity
Crushed Limestone Coarse Aggregate				
4	2.41	2.46	2.44	2.53
5	2.38	2.42	2.42	2.49
6	2.34	2.38	2.38	2.45
Gravel Coarse Aggregate				
4	2.46	2.48	2.45	2.52
5	2.43	2.44	2.43	2.48
6	2.39	2.40	2.38	2.44
Slag Coarse Aggregate				
5	2.38	2.45	2.42	2.53
6½	2.34	2.40	2.38	2.50
8	2.28	2.32	2.29	2.44
Sheet Asphalt				
8	2.36	2.38	2.33 (2.39)*	2.39
10	2.30	2.32	2.24 (2.31)*	2.32

* Values in parentheses obtained by heating 30 minutes at 210° F.

TABLE 7
SPECIFIC GRAVITY VALUES FOR FIELD ASPHALTIC CONCRETE MIXTURES

	Computed with Bulk Specific Gravity	Specific Gravity with Aerosol and Vacuum	Specific Gravity with Aerosol and Pycnometer	Computed with Apparent Specific Gravity
Field sample 1, 4.2 percent asphalt	2.45	2.48	2.43	2.50
Field sample 2, 5.0 percent asphalt	2.34	2.46	2.43	2.47

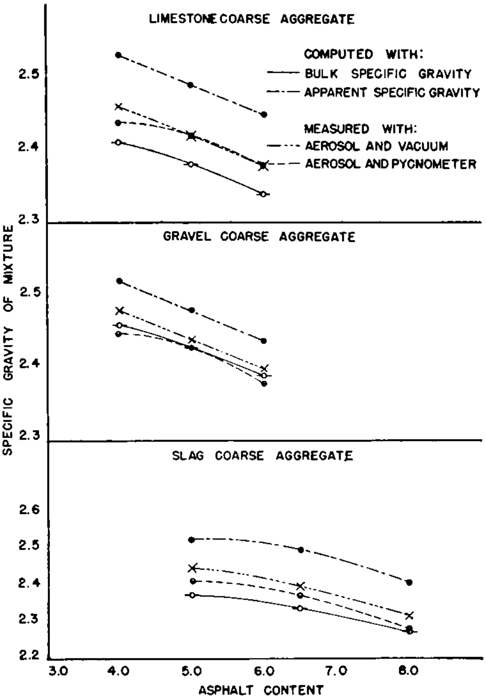

Figure 5. Specific gravity of asphaltic concrete mixtures by various procedures.

TABLE 8
COMPARISON OF AGGREGATE SPECIFIC GRAVITY FOR LABORATORY MIXTURES AND VARIOUS METHODS

Mixture	Bulk Impregnated Specific Gravity	Aggregate Alone Aerosol and Vacuum	Aggregate Alone Aerosol and Pycnometer
Asphaltic concrete; limestone coarse aggregate	2.58	2.60	2.60
Asphaltic concrete; gravel coarse aggregate	2.64	2.63	2.61
Asphaltic concrete; slag coarse aggregate	2.68	2.64	2.61
Sheet asphalt	2.68	2.70	2.61 (2.70)*

* Value in parentheses obtained by heating 30 minutes at 210° F.

of three determinations for each value tabulated.

It will be noted that the specific gravity as determined by both the bulk impregnated procedure and the aerosol with vacuum procedure falls between the values obtained using the bulk and apparent specific gravities of the aggregate in all cases. This is at least tentative evidence that both procedures are yielding values which are reasonably representative of the actual volume conditions in the mixture. The aerosol and pycnometer method generally gives lower values for specific gravity, in some cases lower than computed with the bulk specific gravity. It seems evident then that the aerosol and pycnometer procedure is not effective in completely removing the entrapped air.

When the specific gravity of the aggregates alone is computed for the aerosol with vacuum and aerosol with pycnometer procedures no trend of change with asphalt content is found. If the values are averaged, independent of asphalt content, for the laboratory mixtures the results are as shown in Table 8.

The values for the bulk impregnated method and the aerosol with vacuum method are in reasonably good agreement. Considerable difference occurs only in the case of the slag aggregate, the most porous of those tested. The values for the aerosol and pycnometer method on the other hand are lower than for both other procedures except for one case. While not tabulated it is interesting to note that the values for the bulk impregnated and aerosol with vacuum methods do not differ materially from the average of the values computed with bulk and apparent specific gravities which are shown in Table 5. For example consider the laboratory mixture with slag coarse aggregate. The average of the specific gravity value computed with bulk and apparent specific gravities for this slag mixture is 2.68 as compared to a specific gravity of 2.68 by the bulk impregnated method and 2.64 for the aerosol and vacuum method.

CONCLUSIONS

The amount of experimental work covered by this report does not support firm conclusions but on the basis of the data available the following conclusions are indicated.

1. Both the bulk impregnated specific gravity procedure and the aerosol with vacuum specific gravity procedure yield values for specific gravity which appear to closely approximate the probable weight-volume conditions in bituminous mixtures.

2. If vacuum is available both the bulk impregnated and the aerosol with vacuum procedures can be used in field laboratories.

3. For the asphaltic concrete mixtures tested the aerosol with pycnometer method gives specific gravity values equal to or slightly greater than those calculated from bulk specific gravities. The procedure is simpler than the use of bulk specific gravities since the specific gravity of the mixture is determined directly.

4. Specific gravity values for aggregates obtained by averaging the bulk and apparent specific gravities probably more closely represent the weight-to-volume relationship in bituminous mixtures than does either the bulk or the apparent specific gravity value alone.

ACKNOWLEDGMENT

The major portion of the experimental work upon which this paper is based was conducted by Bh. Subbaraju assisted by Tom Irby and Charles Southerland. Some data were also obtained in graduate classes of A. &. M. College of Texas.