產業技術硏究(江原大學校 產業技術硏究所 論文集) 第7輯(1987)
Research Report, The Institute of Industrial Technology, Kangweon Nat'l Univ., Korea, Vol.7, 1987.

아스팔트 콘크리트의 最大密度 算定

李 奉 鶴* 金 光 宇**

Estimation of the Maximum Density for Asphaltic Concrete

Bong Hak Lee* Kwang Woo Kim**

Abstract

The maximum specific gravity of asphaltic concrete can be calculated based on the effective specific gravity of aggregates and the specific gravity of asphalt cement. The maximum specific gravity is sometimes obtained based on the apparent specific gravity of aggregates and specific gravity of asphalt concrete. However, the apparent specific gravity is in general greater than the effective specific gravity for most aggregates. This study showed, by comparing the results obtained based on two specific gravities, that application of the apparent specific gravity instead of the effective specific gravity resulted in discrepancies in the calculated values of effective asphalt content, air void and maximum density.

1. Introduction

In determining the maximum density or maximum specific gravity (G_{mm}) of asphaltic concrete, the maximum theoretical density is sometimes used or, as is the case of several state's department of transportation(DOT) in the U.S., maximum density is calculated based on the specific gravity of asphalt cement (G_b) and the apparent specific gravity of the aggregates (G_{sa}) (2). Generally accepted methods of the determining maximum specific gravity of asphalt mixture are described in ASTM D2041 and AASHTO T209. According to the MS-2, a hand book of the Asphalt Institute, calculation of maximum specific gravity of asphaltic concrete should

* Assist. Prof., Civil Eng., Kangweon National Univ., and Visiting Prof., Clemson University, Clemson, SC 29631, U.S.A.
** Graduate Assist, Civil Eng., Clemson Univ., Clemson, SC, U.S.A.

be based on the effective specific gravity of aggregates (G_{se}) and the specific gravity of asphalt (G_b) (4).

In general, aggregates have some volume of permeable (to water) and impermeable voids. When aggregates are used in the asphalt mixture, some portions of the permeable voids are filled in with the asphalt cement and the rest of the permeable voids are remained without being filled in. That is, the volume of asphalt absorption in the permeable voids is usually smaller than total permeable volume of water absorption. Consequently the effective volume, as shown in Figure 1, lies between bulk and apparent volumes (3). Therefore, the apparent specific gravity of aggregates is larger than effective specific gravity.

According to this reasoning, the value of maximum specific gravity obtained by state DOT method will be larger than the value calculated based on the effective specific gravity. This paper will examine the differences in magnitudes of air voids and effective asphalt content when different bases of specific gravity are used.

2. Characterization of aggregate voids

As mentioned in introduction, aggregates permeable and impermeable voids, and some portions of the permeable voids are filled in with asphalt cement. Because of the permeable voids in aggregate, three types of aggregate volumes are defined. These three types of volumes will be the bases for calculation of three types of specific gravities, bulk, effective, and apparent specific gravities, respectively.

The difference between apparent volume and effective volume is based on the magnitude of asphalt absorbed in permeable voids. The difference between apparent and effective specific gravity caused by the absorbed asphalt volume lead to a difference in the maximum specific gravities calculated. This difference consequently affects the value of air void in asphalt mixture.

To show the volume concept in the asphalt mixture, the following table and figure illustrate the volumes of aggregates used in determining specific gravity.

3. Comparison of Differences

Bulk and apparent specific gravities of aggregates are determined by use of standard test methods — ASTM C128(1). The effective specific gravity of aggregates in asphaltic concrete may be calculated by the maximum specific gravity of asphaltic mixture which is determined by using ASTM D2041. Reversing this calculation, it is possible to acquire the maximum specific gravity of mixture on the basis of the effective specific gravity (4).

In applying this calculation, South Carolina Department of Highways and Public Transportations (SCDHPT) uses an apparent specific gravity in

Table 1. Identification of Volumes by Voids in Asphaltic Concrete

Volume	Voids in Mixture			
Bulk Volume	V aggregate solids	+ V voids permeable to water	+ voids permeable to asphalt	+ impermeable voids
Effective Volume	V aggregate solids	+ V voids permeable to water	+ impermeable voids	
Apparent Volume	V aggregate solids	+ V impermeable voids	+	

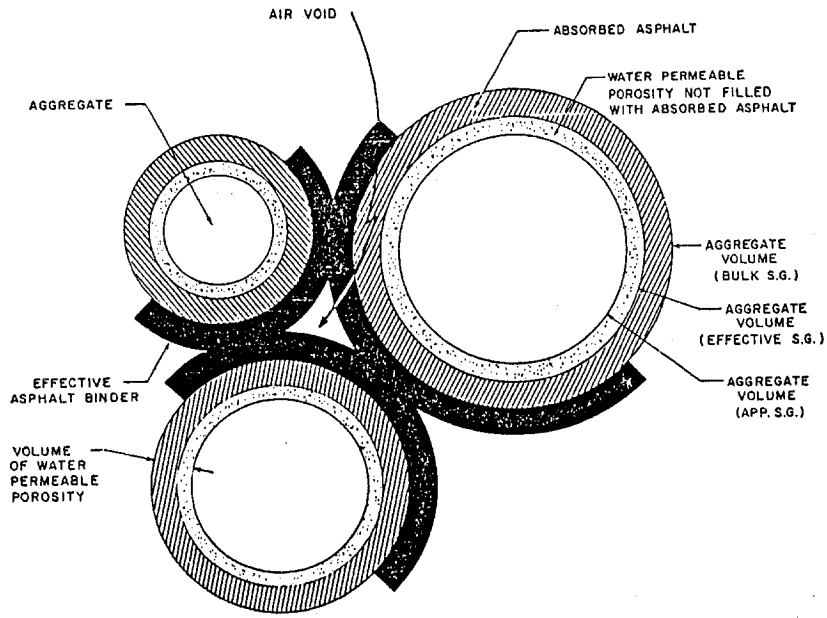
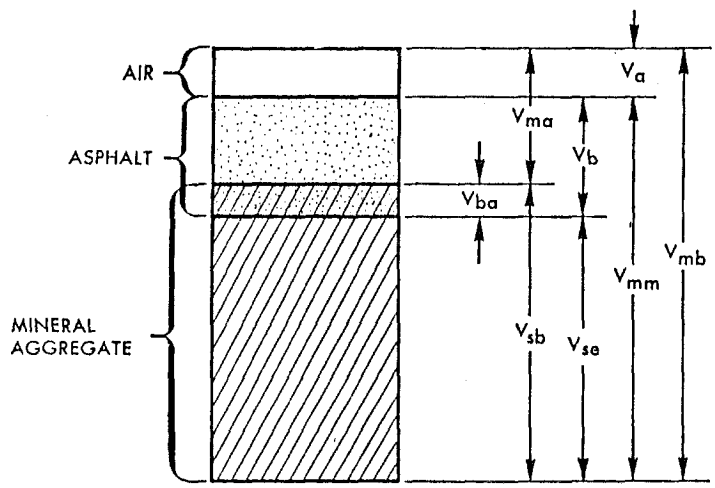


Figure 1. Description of Asphalt Paving Mixture & Volume Difference

place of an effective specific gravity(2). It may be allowable to use apparent specific gravity in place of effective specific gravity as long as the aggregates have negligibly small absorption rate of asphalt. As a matter of record, however, many types of South Carolina aggregates are permeable to some extent(5). Therefore, the effective and apparent specific gravities will be different.

Application of an apparent specific gravity in place of an effective specific gravity in calculation of asphalt absorption by aggregates gives a different result. This difference results in a serious discrepancies in values of the effective asphalt content(P_{be}) and the air void(P_a) Here, the summation of effective asphalt content% by volume of the total mixture plus air void% is defined as Void in Mineral Aggregates (VMA).

The value of effective asphalt content based on the apparent specific gravity is smaller than the values based on effective specific gravity. On the other hand, the air void based on the apparent specific gravity will be larger than that based on the effective specific gravity. The effective asphalt contents decreases and air void increases as the increases as the specific gravity is increased. The VMA, however, stays in the same level since the increasing air void value compensates the value of decreased effective asphalt content. The volumes in a compacted asphalt specimen show as a block diagram in Figure 2.



V_{ma} = Volume of voids in mineral aggregate
V_{mb} = Bulk volume of compacted mix
V_{mm} = Voidless volume of paving mix
V_a = Volume of air voids
V_b = Volume of asphalt
V_{ba} = Volume of absorbed asphalt
V_{sb} = Volume of mineral aggregate (by bulk specific gravity)
V_{se} = Volume of mineral aggregate (by effective specific gravity)

Figure 2. Representation of Volumes in a Compacted Aspaltic Specimen

The following table shows typical differences in results when apparent specific gravity is used in calculation of the maximum specific gravity.

Table 2. Comparison of the Results by the Calculations Based on Different G_{mm} Values

Maximum S.G (G_{mm})	2.438 by ASTM D2041	2.478 based on apparent S.G.
Effective S.G.	2.645	using apparent S.G. (G_{sa})=2.695
Asphalt absorption(P_{ba})	0.928 %	1.658 %
Effective asphalt content(P_{be})		
by weight of mixture	4.628 %	3.993 %
by volume of mixture	10.180 %	8.660 %
Air void(P_a)	6.11 %	7.63 %
VMA=$P_{be}+P_a$	16.29 %	16.29 %
Bulk density of mixture	142.83 lb/cu ft	142.83 lb/cu ft
Max. density of mixture	152.13 lb/cu ft	154.63 lb/cu ft

Given data ; Asphalt content (P_b)= 5.5 %, Asphalt S.G. (G_b)= 1.04
Aggregate apparent S.G. (G_{sa})= 2.695, Mixture bulk S.G. (G_{mb})= 2.289
Aggregate bulk S.G. (G_{sb})= 2.584

As shown in Table 2, only a small difference (1.64 %) in maximum specific gravity (G_{mm}) of asphalt mixture causes a significant difference (24.79%) in estimated air void values. Therefore, use of apparent specific gravity instead of effective specific gravity in calculating maximum specific gravity of asphalt should be reconsidered seriously. While VMA stays in the same value ($P_{be}+P_a$= 10.18 + 6.11 =8.66 +7.63 = 16.29), the values of each effective asphalt content (P_{be}) and air void (P_a) are different. This discrepancy results in a difference in maximum density of mixture even though bulk densities of each calculation is the same.

4. Conclusion and Recommendation

In general, highly permeable aggregates have larger differences between apparent and effective specific gravities due to the larger differences in its bulk and apparent volumes(3). In practice, the effective specific gravity cannot be obtained until the maximum specific gravity of the asphaltic concrete mixture is obtained by laboratory testing. In effective specific gravity, asphalt absorption by aggregate is estimated. The calculation of asphalt absorption by aggregate and the effective asphalt content are de-

pendent upon the effective specific gravity. Therefore, how the maximum specific gravity of asphaltic concrete mixture is obtained is important in determinations of effective specific gravity, percent air voids and VMA.

Percent air void in paving mixture is one of the major factor affecting the performance (life time) of paving structure. Therefore, correct estimate of air void value will be more important than any thing else in paving mixture design. Therefore, use of apparent specific gravity in place of effective specific gravity should be reviewed again. Although some coarse aggregates contain low percentage of absorption, the value of maximum specific gravity based on apparent specific gravity will be different from the value obtained by ASTM D2041. It is desirable to use ASTM D2041 to determine the maximum specific gravity of asphaltic concrete mixture because most of aggregates are permeable to some degree.

References

1. "Annual book of ASTM standards", section 4, vol. 04.03, American Society for Testing and Meterials, 1985.
2. Chu, T.Y., "A study for improving the durability of plant-mix asphalt surfaces in South Carolina", final report to the South Carolina Department of Highway and Public Transportation and the United States Department of Transportation Federal Highway Administration, Feb. 1979.
3. Epps, J.A., and Finn, Fred N., "Asphalt concrete methods specifying in place density", proceedings, Taxas Hot Mix Asphalt pavement Association Annual Meeting, Oct. 1982.
4. "Mix design methods for asphalt concrete and other hot-mix types", Manual Series No.2 (MS-2), the Asphalt Institute, 1979.
5. "Standard Specifications for Highway Construction", South Carolina State Highway Department, 1973.