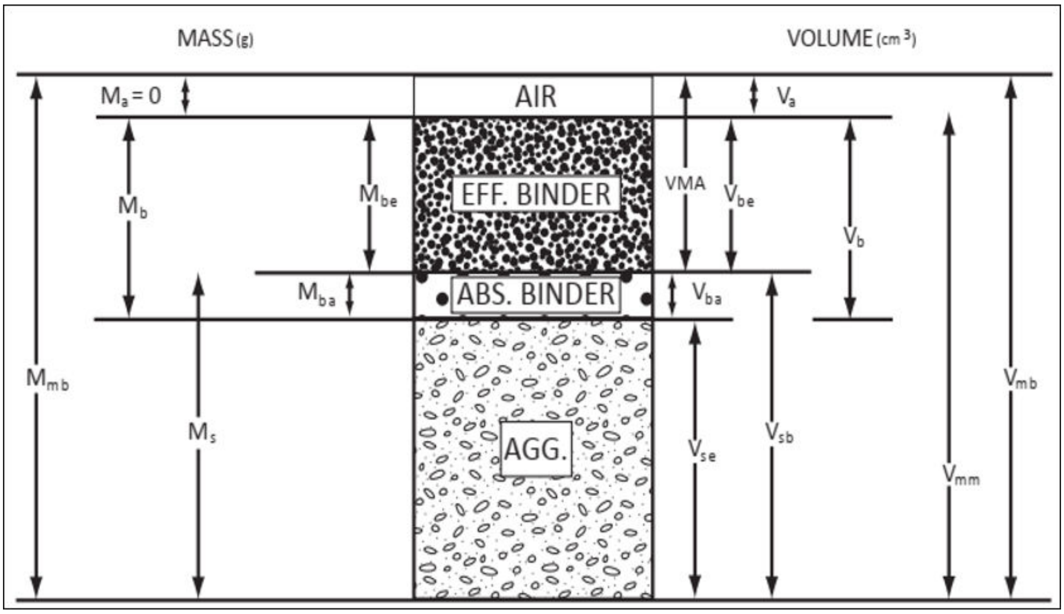
Mixture Components

Material	Specific Gravity		Mix Composition	
		Bulk	Percent by Mass of Total Mix	Percent By Mass of Total Aggregate
Asphalt Cement	1.030(G_b)		5.3 (P_b)	5.6 (P_b)
Coarse Aggregate		2.716(G_1)	47.4(P_1)	50.0(P_1)
Fine Aggregate		2.689(G_2)	47.3(P_2)	50.0(P_2)
Mineral Filler	---		---	---

Paving Mixture

Bulk specific gravity of compacted paving mixture sample, G_{mb} = 2.442

Maximum specific gravity of paving mixture sample, G_{mm} = 2.535



This table provides the basic data for a sample of paving mixture. These design data are used in the sample calculations used in the remainder of this chapter.

Basic Data for Sample of Paving Mixture

Mixture Components				
	Specific Gravity		Mix Composition	
Material		Bulk	Percent by Mass of Total Mix	Percent By Mass of Total Aggregate
Asphalt Cement	1.030(G_b)		5.3 (P_b)	5.6 (P_b)
Coarse Aggregate		2.716(G_1)	47.4(P_1)	50.0(P_1)
Fine Aggregate		2.689(G_2)	47.3(P_2)	50.0(P_2)
Mineral Filler	---		---	---
Paving Mixture				
Bulk specific gravity of compacted paving mixture sample, G_{mb} = 2.442				
Maximum specific gravity of paving mixture sample, G_{mm} = 2.535				

Bulk Specific Gravity of Aggregate

When the total aggregate consists of separate fractions of coarse aggregate, fine aggregate, and mineral filler, all having different specific gravities, the bulk specific gravity for the total aggregate is calculated using:

$$G_{sb} = \frac{P_1 + P_2 + \ldots + P_N}{\frac{P_1}{G_1} + \frac{P_1}{G_2} + \ldots + \frac{P_N}{G_N}}$$

where G_{sb} = bulk specific gravity for the total aggregate
P_1, P_2, P_N = individual percentages by mass of aggregate
G_1, G_2, G_N = individual bulk specific gravities of aggregate

The bulk specific gravity of mineral filler is difficult to determine accurately. However, if the apparent specific gravity of the filler is substituted, the error is usually negligible.

Using the sample paving mixture data:

$$G_{sb} = \frac{50.0 + 50.0}{\frac{50.0}{2.716} + \frac{50.0}{2.689}} = \frac{100}{18.41 + 18.59} = 2.703$$

Effective Specific Gravity of Aggregate

When based on the maximum specific gravity of a paving mixture, G_{mm}, the effective specific gravity of the aggregate, G_{se}, includes all void spaces in the aggregate particles except those that absorb asphalt. G_{se} is determined using:

$$G_{se} = \frac{P_{mm} - P_b}{\dfrac{P_{mm}}{G_{mm}} - \dfrac{P_b}{G_b}}$$

where G_{se} = effective specific gravity of aggregate
G_{mm} = maximum specific gravity (ASTM D 2041/AASHTO T 209) of paving mixture (no air voids)
P_{mm} = percent by mass of total loose mixture = 100
P_b = asphalt content at which ASTM D 2041/AASHTO T 209 test was performed, percent by total mass of mixture
G_b = specific gravity of asphalt

Using the sample paving mixture data:

$$G_{se} = \frac{100 - 5.3}{\dfrac{100}{2.535} - \dfrac{5.3}{1.030}} = \frac{94.7}{39.45 - 5.15} = 2.761$$

NOTE: The volume of asphalt binder absorbed by an aggregate is almost invariably less than the volume of water absorbed. Consequently, the value for the effective specific gravity of an aggregate should be between its bulk and apparent specific gravities. When the effective specific gravity falls outside these limits, its value must be assumed to be incorrect. The calculations, the maximum specific gravity of the total mix by ASTM D 2041/AASHTO T 209, and the composition of the mix in terms of aggregate and total asphalt content should then be rechecked to find the source of the error.

Maximum Specific Gravity of Mixtures with Different Asphalt Contents

In designing a paving mixture with a given aggregate, the maximum specific gravity, G_{mm}, at each asphalt content is needed to calculate the percentage of air voids for each asphalt content. While the maximum specific gravity can be determined for each asphalt content by ASTM D 2041/AASHTO T 209, the precision of the test is best when the mixture is close to the design asphalt content. Also, it is preferable to measure the maximum specific gravity in duplicate or triplicate.

After calculating the effective specific gravity of the aggregate from each measured maximum specific gravity and averaging the G_{se} results, the maximum specific gravity for any other asphalt content can be obtained using the equation shown below. The equation assumes the effective specific gravity of the aggregate is constant, and this is valid since asphalt absorption does not vary appreciably with changes in asphalt content.

$$G_{mm} = \frac{P_{mm}}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

where G_{mm} = maximum specific gravity of paving mixture (no air voids)
P_{mm} = percent by mass of total loose mixture = 100
P_s = aggregate content, percent by total mass of mixture
P_b = asphalt content, percent by total mass of mixture
G_{se} = effective specific gravity of aggregate
G_b = specific gravity of asphalt

Using the specific gravity data from the sample paving mixture data, the effective specific gravity, G_{se}, and an asphalt content, P_b, of 4.0 percent:

$$G_{mm} = \frac{100}{\frac{96.0}{2.761} + \frac{4.0}{1.030}} = \frac{100}{34.77 + 3.88} = 2.587$$

Asphalt Absorption

Absorption is expressed as a percentage by mass of aggregate rather than as a percentage by total mass of mixture. Asphalt absorption, P_{ba}, is determined using:

$$P_{ba} = 100 \times \frac{G_{se} - G_{sb}}{G_{sb} G_{se}} \times G_b$$

where P_{ba} = absorbed asphalt, percent by mass of aggregate
G_{se} = effective specific gravity of aggregate
G_{sb} = bulk specific gravity of aggregate
G_b = specific gravity of asphalt

Using the bulk and effective aggregate specific gravities determined earlier and the asphalt specific gravity from the sample paving mixture data:

$$P_{ba} = 100 \times \frac{2.761 - 2.703}{2.703 \times 2.761} \times 1.030 = 100 \times \frac{0.058}{7.463} \times 1.030 = 0.8$$

Effective Asphalt Content of a Paving Mixture

The effective asphalt content, P_{be}, of a paving mixture is the total asphalt content minus the quantity of asphalt lost by absorption into the aggregate particles. It is the portion of the total asphalt content that remains as a coating on the outside of the aggregate particles and it is the asphalt content which governs the performance of an asphalt paving mixture. The formula is:

$$P_{be} = P_b - \frac{P_{ba}}{100} \times P_s$$

where P_{be} = effective asphalt content, percent by total mass of mixture
P_b = asphalt content, percent by total mass of mixture
P_{ba} = absorbed asphalt, percent by mass of aggregate
P_s = aggregate content, percent by total mass of mixture

Using the sample paving mixture data:

$$P_{be} = 5.3 - \frac{0.8}{100} \times 94.7 = 4.5$$

Percent VMA in Compacted Paving Mixture

The voids in the mineral aggregate, VMA, are defined as the intergranular void space between the aggregate particles in a compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume. The VMA is calculated on the basis of the bulk specific gravity of the aggregate and is expressed as a percentage of the bulk volume of the compacted paving mixture. Therefore, the VMA can be calculated by subtracting the volume of the aggregate determined by its bulk specific gravity from the bulk volume of the compacted paving mixture. The calculation is illustrated for each type of mixture percentage content.

If the mix composition is determined as percent by mass of total mixture:

$$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$$

where VMA = voids in mineral aggregate (percent of bulk volume)
G_{sb} = bulk specific gravity of total aggregate
G_{mb} = bulk specific gravity of compacted mixture (ASTM D 1188 or D 2726/AASHTO T 166)
P_s = aggregate content, percent by total mass of mixture

Using the sample paving mixture data:

$$VMA = 100 - \frac{2.442 \times 94.7}{2.703} = 100 - 85.6 = 14.4$$

Or, if the mix composition is determined as percent by mass of aggregate:

$$VMA = 100 - \frac{G_{mb}}{G_{sb}} \times \frac{100}{100 + P_b} \times 100$$

where P_b = asphalt content, percent by mass of aggregate.

Using the sample paving mixture data:

$$VMA = 100 - \frac{2.442}{2.703} \times \frac{100}{100 + 5.6} \times 100 = 100 - 85.6 = 14.4$$

Percent Air Voids in Compacted Mixture

The air voids, V_a, in the total compacted paving mixture consist of the small air spaces between the coated aggregate particles. The volume percentage of air voids in a compacted mixture can be determined using:

$$V_a = 100 \times \frac{G_{mm} - G_{mb}}{G_{mm}}$$

where V_a = air voids in compacted mixture, percent of total volume
G_{mm} = maximum specific gravity of paving mixture (as calculated earlier or as determined directly for a paving mixture by ASTM D 2041/AASHTO T 209)
G_{mb} = bulk specific gravity of compacted mixture

Using the sample paving mixture data:

$$V_a = 100 \times \frac{2.535 - 2.442}{2.535} = 3.7$$

Percent VFA in Compacted Mixture

The percentage of the voids in the mineral aggregate that are filled with asphalt, VFA, not including the absorbed asphalt, is determined using:

$$VFA = 100 \times \frac{VMA - V_a}{VMA}$$

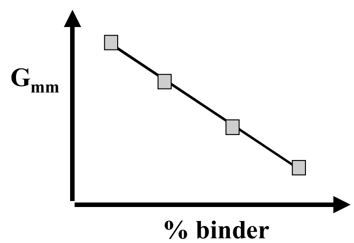
where, VFA = voids filled with asphalt, percent of VMA
VMA = voids in mineral aggregate, percent of bulk volume
V_a = air voids in compacted mixture, percent of total volume

Using the sample paving mixture data:

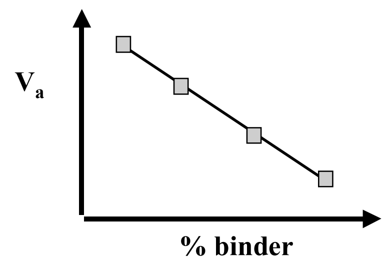
$$VFA = 100 \times \frac{14.4 - 3.7}{14.4} = 74.3$$

EFFECT OF CHANGING ASPHALT CONTENT ON VOLUMETRIC PROPERTIES

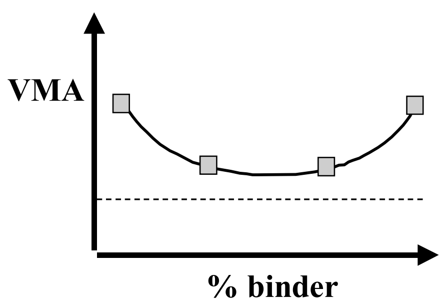
Maximum Theoretical Specific Gravity at Other Asphalt Contents



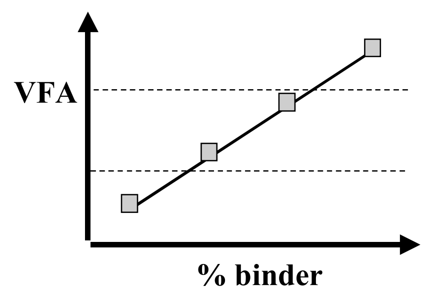
Air Void Content



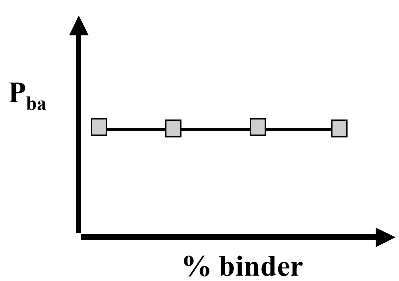
Voids in the Mineral Aggregate



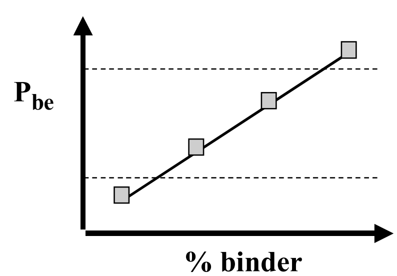
Voids Filled With Asphalt



Absorbed Asphalt Content



Effective Asphalt Content



* Given

$G_b = 1.03$
$G_1 = 2.716$
$G_2 = 2.689$

$G_{mb} = 2.442$
$G_{mm} = 2.535$

by Mass of total Mix
$P_b = 5.3$
$P_1 = 47.4$
$P_2 = 47.3$

by Mass of total Aggregate.
$P_b = 5.6$
$P_1 = 50$
$P_2 = 50$

solution

① $V_{mb} = \boxed{1}$ $\rightarrow$

[2] $G_{mb} = \frac{M_{mb}}{V_{mb}} \Rightarrow 2.442 = \frac{M_{mb}}{V_{mb} \rightarrow 1} \Rightarrow \boxed{M_{mb} = 2.442}$

[3] $G_{mm} = \frac{M_{mb}}{V_{mm}} \Rightarrow 2.535 = \frac{2.442}{V_{mm}} \Rightarrow \boxed{V_{mm} = 0.9633}$

[4] $P_b = \frac{M_b}{M_{mb}} \Rightarrow 5.3\% = \frac{M_b}{\underset{2.442}{M_{mb}}} \rightarrow \boxed{M_b = 0.1269}$

[5] $M_s + M_b = M_{mb} \rightarrow M_s = 2.442 - 0.1269 \boxed{= 2.3151}$

[6] $V_a = V_{mb} - V_{mm} \Rightarrow \boxed{V_a = 0.0367}$

⑦ $G_b = \frac{M_b}{V_b} \Rightarrow 1.03 = \frac{0.1269}{V_b}$ $\boxed{V_b = 0.1232}$

[8] $G_{sb} = \frac{P_1 + P_2}{\frac{P_1}{G_1} + \frac{P_2}{G_2}} = \frac{50 + 50}{\frac{50}{2.716} + \frac{50}{2.689}} = \boxed{2.7024}$

⑨ $G_{sb} = \frac{M_s}{V_{sb}} \Rightarrow V_{sb} = \frac{M_s}{G_{sb}} = \frac{2.3151}{2.7024} \boxed{= 0.8566} = V_{sb}$

⑩ $G_{se} = \frac{M_s}{V_{se}} = V_{se} = \frac{2.3151}{2.7607} = \boxed{0.8386 = V_{se}}$

$G_{se} = \frac{P_s}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}} = \frac{94.7}{\frac{100}{2.535} - \frac{5.3}{1.03}} = 2.7607$

$G_b = \frac{0.1269}{0.1232} = \boxed{1.030}$

⑪ $V_{ba} = V_{sb} - V_{se} = 0.8566 - 0.8386 = \boxed{0.018}$

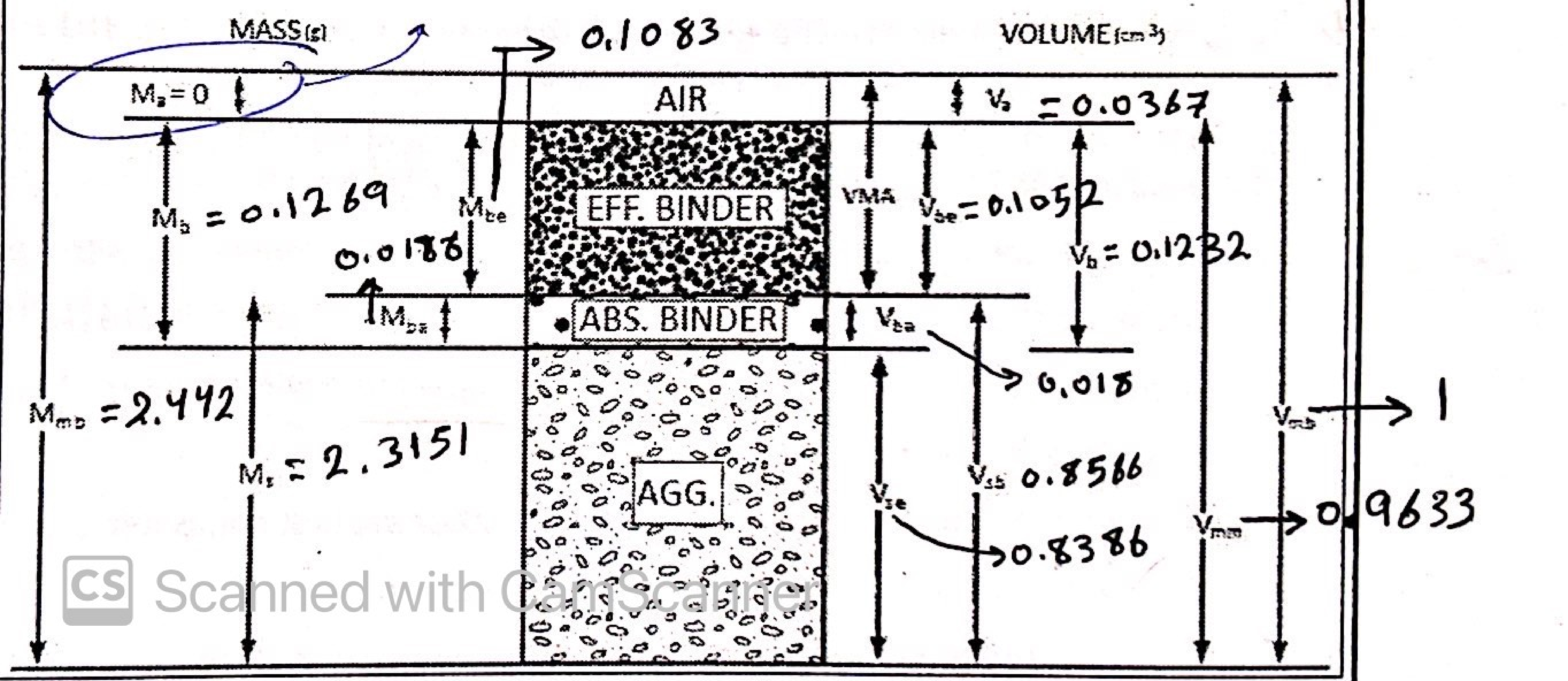
⑫ $V_{be} = V_b - V_{ba} = 0.1232 - 0.018 = \boxed{0.1052}$

$\boxed{13}$ $G_b = \dfrac{M_{be}}{V_{be}} \Rightarrow \boxed{M_{be}} = 1.03 * 0.1052 = \boxed{0.1083}$

$\boxed{14}$ $M_{ba} = M_b - M_{be} = 0.1269 - 0.1083 = \boxed{0.0186}$

$\boxed{15}$ $VMA = V_{be} + V_a = 0.1052 + 0.0367 = \boxed{0.1419}$

$\boxed{16}$ $VFA = \dfrac{V_{be}}{VMA} = \dfrac{0.1052}{0.1419} = \boxed{0.7413}$


MASS(g)
VOLUME(cm³)
0.1083
M_a = 0
AIR
V_a = 0.0367
M_b = 0.1269
M_be
EFF. BINDER
VMA
V_be = 0.1052
V_b = 0.1232
0.0188
M_ba
ABS. BINDER
V_ba
0.018
M_mb = 2.442
M_s = 2.3151
AGG.
V_mb
1
V_sb 0.8566
V_se
0.8386
V_mm
0.9633