ATT-36/2022, VOID CALCULATIONS

1.0 SCOPE

This method describes the procedure for determining the % Air Voids (V_a), and the % VMA (Voids in the Mineral Aggregate), of formed Marshall Specimens and Asphalt Concrete Pavement Cores using these methods:

Part 1: ***Void Calculations using the Air Void Tables***, or

Part 2: ***Void Calculations by Theoretical Maximum Specific Gravity (Gmm)*** (The Gmm of a HMA mixture is the specific gravity excluding air voids)

2.0 EQUIPMENT

Calculator
Air Voids Table (included in the Mix Design)
Data Sheets:
Mix Moisture Content and Marshall Density Data, such as MAT 6-80, and
Core Density, Extraction and Sieve Analysis, such as MAT 6-79, or
Core Density, Ignition Method and Sieve Analysis, such as MAT 6-98, or
ACP Density and Void Contents, such as MAT 6-40.
MTD Data Sheets (ASTM D2041)
Lot Paving Report – Appendix B.09a

3.0 PROCEDURE

3.1 Dry Density, Asphalt Content, and Gmm

1. Determine the ***Dry Density*** of each set of Field Formed Marshall specimens, and each Field Core, as directed in ATT-7, DENSITY, Immersion Method, Saturated Surface Dry Asphalt Concrete Specimens (or ATT-6 for Waxed Specimens).

2. Determine the ***Corrected Asphalt Content*** using;

   a) ATT-12, EXTRACTION, or

   b) ATT-74, IGNITION ASPHALT CONTENT

3. Determine the ***Theoretical Maximum Specific Gravity of the Bituminous Paving Mixtures*** for each lot, usually this is an average of 5 tests throughout the day, split from the same loose mix samples as the Marshall specimens, as directed in ATT-75.

***Part I, VOID CALCULATIONS using Air Void Tables*:**

3.2 Void Contents (QA & QC Acceptance Lots)

1. QA Acceptance Lot:

A Lot in which all acceptance testing is conducted by the Consultant using quality assurance test procedures.

a) ***FIELD CORES:***

Determine each ***Core Dry Density,*** and the ***Average Corrected Asphalt Content*** of all the cores.
These two values will be used to determine the Core % Air Voids (using the Air Void Tables from the associated Mix Design).

b) ***MARSHALL BRIQUETTES:***

Determine the ***Average Dry Density*** of each set of two Field Formed Marshall specimens, as directed in ATT-7, DENSITY, Immersion Method, Saturated Surface Dry Asphalt Concrete Specimens (or ATT-6 for Waxed Specimens), from the test series fresh mix sample.

Using the Average Corrected Asphalt Content of the cores obtained for that days' production, and the test series Marshall Densities, you will then determine the % Air Voids and % VMA of each Marshall Briquette, using the Air Void Tables from the associated Mix Design.

2. QC Acceptance Lot:

A Lot chosen by the Consultant in which acceptance testing for Asphalt Content and Gradation is based upon the Contractor's quality control tests. All other quality assurance testing will remain the responsibility of the Consultant.

a) ***FIELD CORES:***

Determine each ***Core Dry Density*** of all the cores.

The ***Contractor's Corrected Asphalt Contents***, shown on their Lot Paving Report (which can be Nuclear, Extracted or Ignition Asphalt Contents of loose mix or cores), are also reported on the Consultants Lot Paving Report.

Each Core Dry Density and the Contractors Mean Asphalt Content will be used to determine the Core % Air Voids (using the Air Void Tables from the associated Mix Design).

1. ***MARSHALL BRIQUETTES:***

Determine the ***Average Dry Density*** of each set of two Field Formed Marshall specimens, as directed in ATT-7, DENSITY, Immersion Method, Saturated Surface Dry Asphalt Concrete Specimens (or ATT-6 for Waxed Specimens), from the test series fresh mix sample.

Using the Contractors Mean Corrected Asphalt Content *of the cores obtained for that days' production,* ***and the Consultants test series Marshall Densities****, you will then* ***determine the % Air Voids and % VMA*** *of each Marshall Briquette,* ***using the Air Void Tables from the associated Mix Design.***

3.2.1 Using the Mix Design Airvoids Table

A table showing "Dry Densities vs Asphalt Content" is included with every Asphalt Mix Design.

Preparation and submission of asphalt mix designs for Consultant verification and approval are the responsibility of the Contractor. The Contractor shall use Professional Engineering services and a qualified testing laboratory licensed to practice in the Province of Alberta, to assess the aggregate materials proposed for use and to carry out the design of the asphalt mixture. The design testing laboratory shall have obtained pre-qualification status for the Department in the category of Mix Design – Marshall.

Upon approval of the Asphalt Mix Design, the Air Void Table may be used.

Prior to using the table, ensure that the contract number, mix type, pit name and location are correct.

1. Locate, on the table, the specimen's Dry Density in kg/m^3, as shown in Figure 1.

2. Proceed along the Dry Density line to where it intercepts the Sample Asphalt Content and pick off the % Airvoids, the % Voids Filled with Asphalt (VFA), and the % Voids in Mineral Aggregate (VMA).

   Interpolate any intermediate values on the X & Y axis for Asphalt Content and Density.

Voids in Mineral Aggregate (VMA):

VMA is the air void spaces that exist between aggregate particles in a compacted paving mixture, including spaces filled with asphalt, expressed as a percentage of total volume of the specimen. VMA represents the space that is available to accommodate the asphalt and the volume of air voids necessary in the mixture. The more VMA in the dry aggregate, the more space is available for the film of asphalt. Based on the fact that the thicker the asphalt film on the aggregate particles the more durable the mix, minimum VMA values should be adhered to so that a durable asphalt film thickness can be achieved. 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.

When VMA is too low, there is not enough room in the mix to add sufficient asphalt binder to adequately coat the individual aggregate particles. Alternately, mixes with a low VMA are more sensitive to small changes in asphalt binder content. Excessive VMA will cause an unexpectedly low mix stability.

Contract #	12345
Mix Type	H1
Design Asphalt Content	5.40
Asphalt Relative Density	1.0250
Asphalt Ultimate Absorption	0.63
Bulk Relative Density of Aggregate	2.593

AIR VOIDS TABLE

Density		ASPHALT CONTENT															
		4.7	**4.8**	**4.9**	**5.0**	**5.1**	**5.2**	**5.3**	**5.4**	**5.5**	**5.6**	**5.7**	**5.8**	**5.9**	**6.0**	**6.1**	**6.2**
2303	**Airvoids**	6.4	6.3	6.2	6.1	6.0	5.8	5.7	5.6	5.5	5.3	5.2	5.1	5.0	4.8	4.7	4.6
	VFA	57.9	58.8	59.5	60.4	61.3	62.8	63.7	64.3	65.2	66.7	67.5	68.3	68.9	70.4	71.2	72.0
	VMA	15.2	15.3	15.3	15.4	15.5	15.6	15.7	15.7	15.8	15.9	16.0	16.1	16.1	16.2	16.3	16.4
2308	**Airvoids**	6.2	6.1	6.0	5.9	5.7	5.6	5.5	5.4	5.3	5.1	5.0	4.9	4.8	4.6	4.5	4.4
	VFA	58.7	59.6	60.3	61.3	62.7	63.6	64.5	65.4	66.0	67.5	68.4	69.2	70.0	71.3	72.0	72.8
	VMA	15.0	15.1	15.1	15.2	15.3	15.4	15.5	15.6	15.6	15.7	15.8	15.9	16.0	16.0	16.1	16.2
2313	**Airvoids**	6.0	5.9	5.8	5.7	5.5	5.4	5.3	5.2	5.0	4.9	4.8	4.7	4.6	4.4	4.3	4.2
	VFA	59.5	60.4	61.3	62.0	63.6	64.5	65.4	66.2	67.5	68.4	69.2	70.1	70.9	72.2	73.0	73.8
	VMA	14.8	14.9	15.0	15.0	15.1	15.2	15.3	15.4	15.4	15.5	15.6	15.7	15.8	15.8	15.9	16.0
2318	**Airvoids**	5.8	5.7	5.6	5.5	5.3	5.2	5.1	5.0	4.8	4.7	4.6	4.5	4.3	4.2	4.1	4.0
	VFA	60.3	61.2	62.2	63.1	64.4	65.3	66.2	67.1	68.6	69.3	70.1	71.0	72.4	73.2	73.9	74.7
	VMA	14.6	14.7	14.8	14.9	14.9	15.0	15.1	15.2	15.3	15.3	15.4	15.5	15.6	15.7	15.7	15.8
2323	**Airvoids**	5.6	5.5	5.4	5.3	5.1	5.0	4.9	4.8	4.6	4.5	4.4	4.3	4.1	4.0	3.9	3.8
	VFA	61.1	62.1	63.0	63.9	65.5	66.2	67.1	68.0	69.5	70.4	71.1	71.9	73.4	74.2	75.0	75.6
	VMA	14.4	14.5	14.6	14.7	14.8	14.8	14.9	15.0	15.1	15.2	15.2	15.3	15.4	15.5	15.6	15.6
2328	**Airvoids**	5.4	5.3	5.2	5.1	4.9	4.8	4.7	4.6	4.4	4.3	4.2	4.1	3.9	3.8	3.7	3.6
	VFA	62.2	62.9	63.9	64.8	66.4	67.3	68.0	68.9	70.5	71.3	72.2	72.8	74.3	75.2	76.0	76.8
	VMA	14.3	14.3	14.4	14.5	14.6	14.7	14.7	14.8	14.9	15.0	15.1	15.1	15.2	15.3	15.4	15.5
2333	**Airvoids**	5.2	5.1	5.0	4.9	4.7	4.6	4.5	4.3	4.2	4.1	4.0	3.8	3.7	3.6	3.5	3.4
	VFA	63.1	63.8	64.8	65.7	67.4	68.3	69.2	70.5	71.4	72.3	73.2	74.7	75.3	76.2	77.0	77.8
	VMA	14.1	14.1	14.2	14.3	14.4	14.5	14.6	14.6	14.7	14.8	14.9	15.0	15.0	15.1	15.2	15.3
2338	**Airvoids**	5.0	4.9	4.8	4.6	4.5	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.5	3.4	3.3	3.1
	VFA	64.0	65.0	65.7	67.4	68.3	69.2	70.1	71.7	72.4	73.3	74.1	75.7	76.5	77.2	78.0	79.5
	VMA	13.9	14.0	14.0	14.1	14.2	14.3	14.4	14.5	14.5	14.6	14.7	14.8	14.9	14.9	15.0	15.1
2343	**Airvoids**	4.8	4.7	4.6	4.4	4.3	4.2	4.1	3.9	3.8	3.7	3.6	3.4	3.3	3.2	3.1	2.9
	VFA	65.0	65.9	66.9	68.3	69.3	70.2	71.1	72.7	73.6	74.3	75.2	76.7	77.6	78.4	79.1	80.5
	VMA	13.7	13.8	13.9	13.9	14.0	14.1	14.2	14.3	14.4	14.4	14.5	14.6	14.7	14.8	14.8	14.9
2348	**Airvoids**	4.6	4.5	4.4	4.2	4.1	4.0	3.9	3.7	3.6	3.5	3.4	3.2	3.1	3.0	2.9	2.7
	VFA	65.9	66.9	67.9	69.9	70.3	71.2	72.1	73.8	74.6	75.5	76.2	77.8	78.6	79.5	80.3	81.6
	VMA	13.5	13.6	13.7	13.8	13.8	13.9	14.0	14.1	14.2	14.3	14.3	14.4	14.5	14.6	14.7	14.7
2353	**Airvoids**	4.4	4.3	4.2	4.0	3.9	3.8	3.7	3.5	3.4	3.3	3.2	3.0	2.9	2.8	2.7	2.5
	VFA	66.9	67.9	68.9	70.6	71.5	72.3	73.2	74.8	75.7	76.6	77.3	78.9	79.7	80.6	81.4	82.9
	VMA	13.3	13.4	13.5	13.6	13.7	13.7	13.8	13.9	14.0	14.1	14.1	14.2	14.3	14.4	14.5	14.6
2358	**Airvoids**	4.2	4.1	4.0	3.8	3.7	3.6	3.5	3.3	3.2	3.1	2.9	2.8	2.7	2.6	2.4	2.3
	VFA	67.9	68.9	69.9	71.6	72.6	73.5	74.3	75.9	76.8	77.7	79.3	80.0	80.9	81.7	83.2	84.0
	VMA	13.1	13.2	13.3	13.4	13.5	13.6	13.6	13.7	13.8	13.9	14.0	14.0	14.1	14.2	14.3	14.4
2363	**Airvoids**	4.0	3.9	3.8	3.6	3.5	3.4	3.2	3.1	3.0	2.9	2.7	2.6	2.5	2.4	2.2	2.1
	VFA	69.2	70.0	71.0	72.7	73.7	74.6	76.3	77.0	77.9	78.8	80.4	81.3	82.0	82.9	84.4	85.2
	VMA	13.0	13.0	13.1	13.2	13.3	13.4	13.5	13.5	13.6	13.7	13.8	13.9	13.9	14.0	14.1	14.2
2368	**Airvoids**	3.8	3.7	3.6	3.4	3.3	3.2	3.0	2.9	2.8	2.7	2.5	2.4	2.3	2.2	2.0	1.9
	VFA	70.3	71.3	72.1	73.8	74.8	75.8	77.4	78.4	79.1	80.0	81.6	82.5	83.3	84.1	85.6	86.4
	VMA	12.8	12.9	12.9	13.0	13.1	13.2	13.3	13.4	13.4	13.5	13.6	13.7	13.8	13.8	13.9	14.0

3.2.2 Manually Calculating the AV's & VMA

An alternative to using the Air void Tables, and extrapolating the numbers from the AV Table, is to manually calculate the AV's & VMA.
This is the same way all the Air void Table numbers are actually calculated.

MARSHALL AIR VOIDS & VMA:

Use the CORE Lot Mean Corrected Asphalt Content, and the
Mix Design MTD's, to calculate the Marshall Air Voids and VMA.

Marshall Air Voids:

Eg. Mean AC = 5.18% Sample #1 Marshall Density = 2367
Using the MTD's shown in the Asphalt Mix Design:
@ AC 4.9% MTD = 2.456
@ AC 5.4% MTD = 2.439
@ AC 5.9% MTD = 2.424
Extrapolate the MTD @ AC 5.18% = 2.446

Marshall Air voids (%) = (1-((Density/1000)/(MTD@AC) x 100

Marshall Air voids = (1 - ((2367/1000) / (2.446))) x 100
= (1 – (2.367 / 2.446)) x 100
= (1 – 0.9677) x 100
= 3.2%

Marshall Voids in the Mineral Aggregate (VMA):

Eg. ***Mean AC = 5.18%*** Sample #1 ***Marshall Density = 2367***
Bulk Specific Gravity of Aggregate = 2.593

VMA = (1 – (((100 x Density)/(100 + AC))/(1000 x Agg BSG))) x 100

VMA = (1 – (((100 x 2367)/(100 + 5.18))/(1000 x 2.593))) x 100
= (1 – (((236700)/(105.18))/(2593))) x 100
= (1 – (2250.4278 / 2593) x 100
= (1 – 0.8679) x 100
= 0.132 x 100
= 13.2% (this should be the same value as in the AV Table)

The Marshall Air voids and VMA can also be calculated, and reported on the Lot Paving Report, to show the Air voids and VMA using the Target AC, so both AV's by Calculated AC & Target AC are shown. (see Figure 2)

CORE AIR VOIDS:

Eg. ***Mean AC = 5.18%*** Sample #1 ***Core Dry Density = 2338***
Using the MTD's shown in the Asphalt Mix Design:
@ AC 4.9% = 2.456 ; 5.4% = 2.439 ; 5.9% = 2.424
Extrapolate MTD @ AC 5.18% = 2.446

Core Air voids (%) = (1-((Density/1000)/(MTD@AC) x 100

Core Air voids = (1 - ((2338/1000) / (2.446))) x 100 **= 4.4%**

The Core Air voids can also be calculated, and reported on the Lot Paving Report, to show the Air voids using the Target AC, so both AV's by Calculated AC & Target AC are shown.

Part II, VOID CALCULATIONS by Gmm:

Using the Mean Maximum Specific Gravity (Gmm) of the uncompacted asphalt paving mixtures as tested by the Consultant, and shown on the Lot Paving Report.

3.3 Void Contents (QA & QC Acceptance Lots)

a) ***FIELD CORES:***
Calculate the Core Air Voids (by Gmm) of each core in a lot, using the average Gmm of the lot loose mix, as follows:

$$\textit{Core Air Voids (by Gmm)} = (1 - (\textit{Core Density} / \textit{Gmm})) \times 100$$

b) ***MARSHALL BRIQUETTES:***
Calculate the average Dry Density of each set of two Marshall specimens compacted from the test series of fresh loose mix samples for each Lot.

c) ***Calculate the Marshall Air Voids (by Gmm)***, using the average Marshall briquette density for each segment number in the lot, using the Gmm of that particular loose mix, as follows:

$$\textit{\% Marshall Air Voids (by Gmm)} = (1 - (\textit{Marshall Density} / \textit{Gmm})) \times 100$$

For each Marshall briquette in a lot, calculate the VMA as follows:

$$VMA\ (\%) = \left(1 - \frac{\dfrac{100 \times \text{Marshall Density}}{100 + \%AC}}{1000 \times \text{Agg BSG}}\right) \times 100$$

LOT PAVING REPORT EXAMPLE:

Formed Marshall Specimens: Marshall Densities, Loose Mix Max Specific Gravities (Gmm), AV's & VMA by Gmm, AV's & VMA using AV Tables.

Lot Pavement & Compaction Data: Field Core Densities, Core AV's by Gmm & AV Tables, Core Compaction by Gmm & Marshall Density

FIGURE 2

LOT PAVING REPORT - QA Testing using Maximum Specific Gravities

Alberta Transportation

MAT 6-78/19

CONTRACT NO.	12345	PROJECT NO.		PROJECT FROM		LOT NO.	1
WEEK ENDING (YY / MM / DD)		CL	HW	PROJECT TO		MIX TYPE	H2
		NO.	222	PAVING CONTRACTOR	Black Ops	MST DESIGN NO.	
		A		QA CONSULTANT		PIT NAME	
		CS	10				
DESIGN DENSITY (kg/m³)	2344	DESIGN AIR VOIDS (%)	3.7	BSG of AGGREGATE	2.587		
DESIGN AC (%)	5.5	DESIGN VMA (%)	14.1	Gmm at Design AC	2.435		
TARGET AC (%)	5.5	DESIGN LIFT THICKNESS (mm)	50				

DATE LAID (dd-mm-yyyy)	LOT AGGREGATE PROPORTIONS: COARSE AGGREGATE %	MF %	BS %	RAP %		FORMED MARSHALL SPECIMENS: DENSITY (kg/m³)	Max Spec Gravity (G_{mm}) (kg/m³)	* AIR VOIDS by Gmm (% by G_{mm})	* AIR VOIDS by Gmm VMA	* AIR VOIDS using Airvoid Table AV	* AIR VOIDS using Airvoid Table VMA (%)	ASPHALT CONTENT: SAMPLE SOURCE	SEGMENT CORRECTED ASPHALT CONTENT (%)	TEST METHOD	LOT PAVEMENT AND COMPACTION DATA: SEGMENT #	STATION (00+000)	+ OR -	LOCATION	LANE	LIFT	CORE THICKNESS (mm)	CORE DENSITY (kg/m³)	AIR VOIDS (% by G_{mm})	AIR VOIDS using AV Table	** COMPACTION % by G_{mm}	** COMPACTION by Marshall Density	CORE MOISTURE (%)
1-May-2018	27	28	8	30		2384	2435	2.1	10.9	1.8	12.8	CO	5.56	IG	1					B	60	2201	9.8	9.4	90.2	93.7	
LOT PAVING LIMITS (km)						2364	2417	2.2	11.6	2.7	13.5	CO	5.63	IG	2					B	61	2278	6.7	6.2	93.3	97.0	
FROM	TO		LANE		MAT	2304	2462	6.4	9.9	5.1	15.7	CO	5.53	IG	3					B	63	2302	5.7	5.2	94.3	98.0	
						2339	2451	4.6	10.3	3.7	14.4	CO	5.79	IG	4					B	60	2305	5.6	5.1	94.4	98.2	
						2350	2440	3.7	10.8	3.2	14.0	CO	5.88	IG	5					B	62	2294	6.0	5.6	94.0	97.7	
						2348	2441	3.8	10.7	3.3	14.1		5.68		LOT MEAN						61	2276	6.8	6.3	93.2	96.9	
ADDITIVE RA		MAT R				For QC Lots: Calculate air voids using Target AC				3.6	14.0	* Use Lot Mean Corrected asphalt content to calculate Marshall Air Voids & V.M.A. Marshall AV by Gmm = ((Gmm-Marshall Density)/ Gmm)) x 100												6.5			

4.0 HINTS AND PRECAUTIONS

1. Make sure the Air Voids Table is the correct one. Each different Mix Design has its own Air Void Table. Never use a table from another pit, or a table for the same pit from an earlier design.

2. ***At the start of the job, manually calculate the % air voids of the first few specimens and compare the data sheet results to the values obtained using the Table. If the difference between the two is greater than 0.1% further review of the design is necessary.***

3. Whenever the asphalt cement type, or grade, changes from the one reported on the mix design, compare the relative densities of the two asphalt cements. If they vary by more than 0.010, new air void tables are required.

4. The durability of an asphalt pavement is a function of the air-void content. This is because the lower the air-voids, the less permeable the mixture becomes. Air voids that are either too high or too low can cause a significant reduction in pavement life.

   Too high an air-void content provides passageways through the mix enabling the entrance of damaging air and water.

   A too low air-void content, on the other hand, **can lead to flushing**, a condition in which excess asphalt squeezes out of the mix to the surface. Density and void content are directly related. **The higher the density, the lower the percentage of voids in the mix**, and vice versa.

5. Accepted knowledge says that ***for every 1% increase in air voids from the mix design, approximately 10% of the pavement life may be lost***. That's because the more air voids a pavement has, the more that pavement is compromised in terms of pavement strength, fatigue life, durability, ravelling, rutting and susceptibility to moisture design.

6. When calculating the %AV's & %Compaction by Gmm, for each Marshall specimen and each Core specimen, use the Lot Mean Gmm for each of the calculations, ***not each individual Gmm.***

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