Understanding VMA and RAS Specific Gravity

The 5th Asphalt Shingle Recycling Forum

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Heritage Research Group

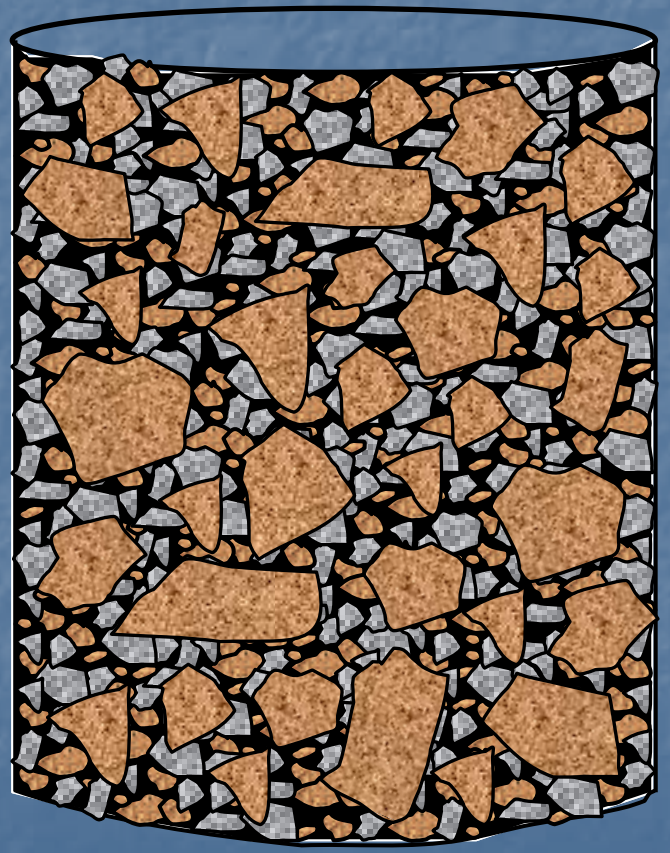
What is **VMA**?

- **V**oids in the **M**ineral **A**ggregate
  - "Mineral Aggregate" = **Non-Asphalt** Components
- **VMA** is the intergranular **space** occupied by asphalt and air in a compacted asphalt mixture.
- **Absorbed** asphalt is **not** part of VMA.

Calculating **VMA**…

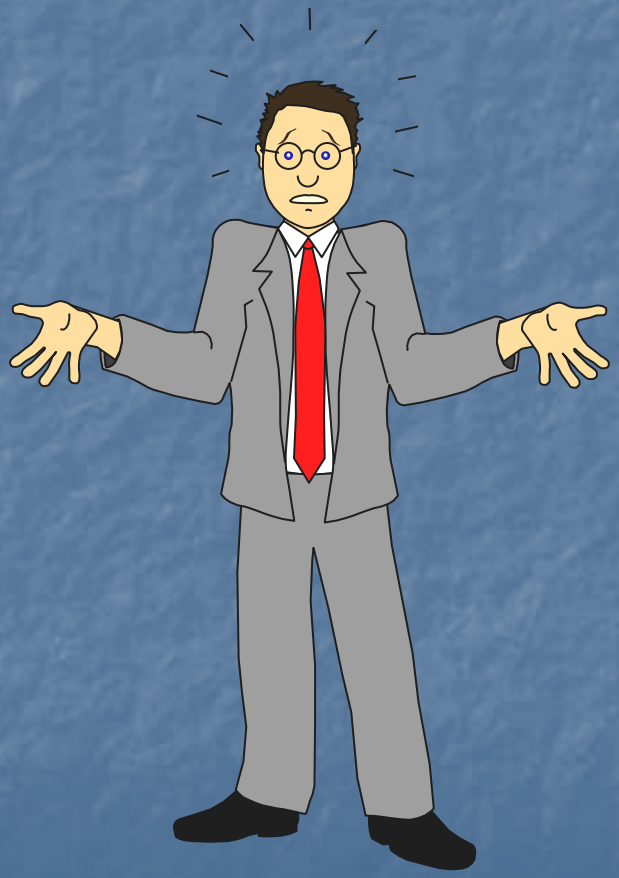
$$VMA = 100 - \left\{ \frac{(G_{mb} * P_s)}{G_{sb}} \right\}$$

- G_{mb} = Mix Bulk Specific Gravity
- P_s = Percent Stone (i.e. Non-Asphalt)
- G_{sb} = Combined Aggregate Bulk Specific Gravity (i.e. Non-Asphalt)



Why is **VMA** Important?

- It ensures a minimum **EFFECTIVE** AC **VOLUME**
- The **EFFECTIVE** volume drives mix **durability** – resistance to aging from the climatic and traffic conditions



Specific Gravity

$$= \frac{\text{Mass}}{\text{Volume}}$$

RAS Specific Gravity - G_{se}

- G_{sb} – Not practical for RAS
- G_{se} – Commonly used (**AASHTO PP 53**)

Heritage Research Group RAS Investigation

- Max specific gravity ($\mathbf{G_{mm}}$ includes AC)
  - Vacuum Pyc
  - CORE**LOK**
  - Virgin AC added – Vacuum Pyc
- Extracted gradation and % AC
- $\mathbf{G_{se}}$ determined for each:
  - Source
  - Using each of the max specific gravity tests

Calculating G_{se}…

$$G_{se} = \frac{(100 - P_b)}{\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)}$$

Sampling, Blending & Splitting

- Nine Sources:
  - Ft. Wayne, IN
  - **Chicago, IL (MW)**
  - Chicago, IL (TOS)
  - Nashville, TN
  - Denver, CO
  - Cincinnati, OH
  - Kansas City, MO
  - Indianapolis, IN
  - Stockton, CA


Individual Samples

Standard Rice Test


Standard Rice Test
72° F Water Temp


Add Hot Water and Stir!
Cool to room temp BEFORE vacuuming


Much Fewer Floaters!

72° F Water

170° F Water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PROGRAM
YES
MENU
NO
POWER
OFF
ON


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Mixing RAS + Virgin AC

- RAS pre-heated (230° F) for 1 hr
- PG 64-22 added (300° F) at 15% by total weight of RAS sample


Standard Rice Test

HRG Data

Source	G_{se} (Std Rice)	G_{se} (CoreLok)	G_{se} (Added AC)	Average RAS AC
Ft. Wayne, IN TOS				
Chicago, IL MW				
Chicago, IL TOS				
Nashville, TN TOS				
Denver, CO TOS				
Cincinnati, OH TOS				
Kansas City, MO TOS				
Indianapolis, IN TOS				
Stockton, CA TOS				
AVERAGE				

$$G_{se} = \frac{(100 - P_b)}{\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)}$$

HRG Data

Source	G_{se} (Std Rice)	G_{se} (CoreLok)	G_{se} (Added AC)	Average RAS AC
Ft. Wayne, IN TOS	2.577	2.474	2.443	26.2
Chicago, IL MW	2.615	2.562	2.518	19.0
Chicago, IL TOS	2.518	2.536	2.490	24.0
Nashville, TN TOS	2.601	2.640	2.592	21.5
Denver, CO TOS	2.544	2.526	2.484	23.5
Cincinnati, OH TOS	2.512	2.512	2.489	23.9
Kansas City, MO TOS	2.581	2.532	2.423	26.0
Indianapolis, IN TOS	2.573	2.605	2.537	23.2
Stockton, CA TOS	2.619	2.659	2.591	30.6
AVERAGE	**2.571**	**2.561**	**2.507**	**24.2**

Understanding VMA…

An accurate specific gravity of each Non-Asphalt component is a must in order to **calculate** the correct VMA value!

$$G_{sb} = \frac{100}{\frac{P_1}{G_{sb(1)}} + \frac{P_2}{G_{sb(2)}} + \ldots + \frac{P_n}{G_{sb(n)}}}$$

- G_{sb} = Combined **bulk** specific gravity
- $P_{1\ldots}$ = Individual **aggregate %**
- $G_{sb(1\ldots)}$ = Individual aggregate **bulk** specific gravity

RAS Specific Gravity – Does it matter?

	CA1	CA2	FA1	FA2	MF	RAS			Comb G_{sb}	VMA	Pba
G_{sb}	2.63	2.64	2.65	2.67	2.70						

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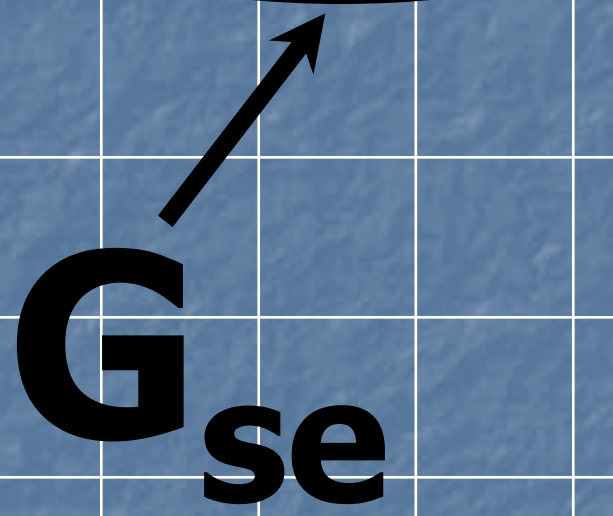

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G_{sb}	2.63	2.64	2.65	2.67	2.70	**2.00**	**2.30**	**2.60**			
BL1A	48.2	11.5	18.9	14.9	1.5	**5.0**	→		2.601	**13.6**	1.44

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BL1B	48.2	11.5	18.9	14.9	1.5		**5.0**	→	2.623	**14.3**	1.10

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BL1B	48.2	11.5	18.9	14.9	1.5		**5.0**	→	2.623	**14.3**	1.10
BL1C	48.2	11.5	18.9	14.9	1.5			**5.0**	2.640	**14.9**	0.85

RAS Specific Gravity – Does it matter? – **YES!**

	CA1	CA2	FA1	FA2	MF	RAS			Comb G_{sb}	VMA	Pba
G_{sb}	2.63	2.64	2.65	2.67	2.70	**2.00**	**2.30**	**2.60**			
Blend 1	48.2	11.5	18.9	14.9	1.5	**5.0**	→	→	2.601	**13.6**	1.44
							5.0	→	2.623	**14.3**	1.10
								5.0	2.640	**14.9**	0.85

RAS Aggregate % – Does it matter?

	CA1	CA2	FA1	FA2	MF	RAS			Comb G_{sb}	VMA	Pba
G_{sb}	2.63	2.64	2.65	2.67	2.70	**2.00**	**2.30**	**2.60**			
Blend 2	48.8	11.6	19.1	15.1	1.5	**3.9**	→		2.610	**13.9**	1.30
							3.9	→	2.627	**14.5**	1.04
								3.9	2.641	**14.9**	0.84

RAS Gravity **AND** RAS Aggregate % **Matters**!

	CA1	CA2	FA1	FA2	MF	RAS			Comb G_{sb}	VMA	Pba
G_{sb}	2.63	2.64	2.65	2.67	2.70	**2.00**	**2.30**	**2.60**			
Blend 1	48.2	11.5	18.9	14.9	1.5	**5.0**			2.601	**13.6**	1.44
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							3.9		2.627	**14.5**	1.04
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Understanding VMA…

- **RAS** typically **INCREASES** VMA
  - Angularity of the granules?
  - Influence of the fibers?
  - Dust – Angularity and/or amount?
- Do **RAS** mixes require more **Total AC**?

Scenario #1…

- Design 1
- Voids = 4.0%
- Total AC = 5.2%
- P_{ba} = 0.4%

- Design 2
- Voids = 4.0%
- **Total AC = 5.6%**
- **P_{ba} = 0.8%**

- **The Total AC difference is…P_{ba} (asphalt absorption)**

Scenario #2…

- Design **without RAS**
- Voids = 4.0%
- Total AC = 5.2%
- P_{ba} = 0.4%
- VMA = 14.8%

- Design **with RAS**
- Voids = 4.0%
- **Total AC = 5.6%**
- P_{ba} = 0.4%
- **VMA = 15.8%**

- **The Total AC difference is…VMA**

RAS changes aggregate packing!

Scenario #2 is a **Problem**!

- RAS Design requires 0.4% **MORE** AC – **WHY?**
- ***Assumption*** - Portion of RAS AC **NOT** effective
  - RAS AC contribution = 1.2%
  - Increase in Total AC = 0.4%
  - Effective RAS AC = ((1.2-0.4)/1.2) * 100 = 67%
- **Faulty assumption!**
  - 0.4% **MORE** Total AC **due to** 1.0% higher **VMA**!

Scenario #2…Revised!

- Design **without RAS**
- Air Voids = 4.0%
- Pba = 0.4%
- VMA = 14.8%
- Total AC = 5.2%

- Design **with RAS**
- Air Voids = 4.0%
- Pba = 0.4%
- **VMA = 14.8%**
- **Total AC = 5.2%**

- **Adjust aggregate packing (e.g. gradation) to offset RAS effect**

Take Away

- RAS Specific Gravity matters!
  - Determine **G_{se}** accurately
  - **G_{se}** rule-of-thumb value?
    - Fiberglass RAS – **2.500 to 2.600**?
    - Cellulose RAS – Lower Value?
- Non-RAS vs. RAS Mixes
  - Compare **VMA** and asphalt absorption values!
    - RAS specific gravity (**G_{se}**)
    - RAS **aggregate** %
  - Equal VMA results in Equal **Total** AC with constant P_{ba}

Thank You!

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