Increasing AC In Hot Mix Asphalt

Ontario Asphalt Pavement Council

Partners in Quality Road Tour

April, 2018

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Outline

- Introduction
- Benefits of Higher AC
- Mix Design Practice 101
- Is Getting Higher AC an Assurance of Better Pavements?
- Current Mix Design Practice and Short Comings for Performance
- Innovations for Better Performance
  - Performance Based Mix Design – Balanced Mix Design.
  - Is Higher AC the Only Thing Required for Better Pavements?
  - Regression Mix Design
- Summary and Closing

- Superpave Mix Design
  - Test procedure and materials change with traffic loading
    - More Robust for Higher Traffic Loading
- Overall North American experience with Superpave has seen a reduction in AC%
    - Some US States Have Adjusted Superpave Design Process for Higher Traffic Pavements
      - Reduced Gyrations = Increased AC
    - Other States – Innovative Design and Construction Process
      - Balanced Mix Design
      - HMA Regression

- Higher AC = Longer Pavement Life
  - Problems on projects regularly linked to lean mixes.
    - Early Age Fatigue Cracking
    - Overall Reduction in Expected Life
- Why Longer Pavement Life ?
  - Increased AC film thickness =
    - Slower oxidization of AC in Mix
    - Reduction in cracking potential of pavement
      - Increased Fatigue resistance
      - Increased flexibility

- Other Benefits
  - Higher in-place density during placement
    - AC acts as lubricant
    - Highly Polymerized AC’s can be difficult to compact
      - Extra AC helps offset difficulties
  - Higher Compaction = Reduction in permeability
    - Lower in-place air voids
    - Slower Oxidization of AC

- Higher AC % Encouraged by MTO
  - AC for bid purposes
    - If % AC content exceeds bid AC, Additional AC cost is paid as extra to contract
  - Recent Specification changes default to fine graded mix design

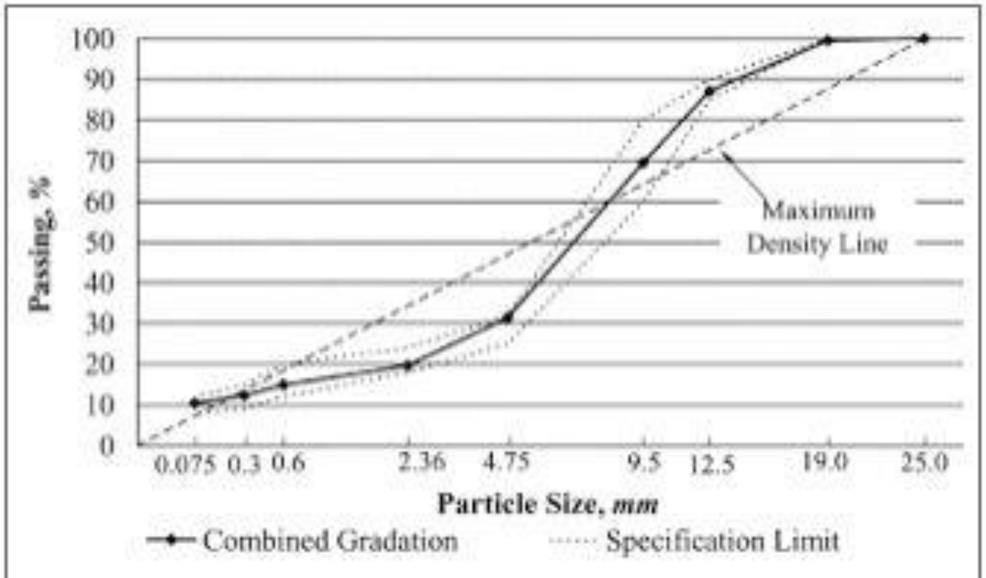
- Municipal Specifications - Higher AC contents
  - Some municipalities have resisted implementing Superpave
    - Concerns about lean Superpave Mixes
  - Minimum AC contents being specified for mix types
    - Marshall and Superpave
  - Mixes finer than 12.5 mm being specified for surface.
      - 9.5mm mixes

- Industry
  - OAPC / ORBA supports all Initiatives that will improve Pavement Quality
  - AC Suppliers Strongly Support Increased AC Content

- Everyone Wants Benefits expected from Higher AC
  - Increased AC Content alone may not provide the desired benefits
    - AC Content is only one factor in pavement performance
    - Interaction of individual materials, HMA mix design, and placement needs to be considered.
      - Changes in proportions cause reactions
    - With Current Mix Design Processes and Specifications
        - Reactions can be Positive or Negative

- Mix Design Practice – 101
  - Combine available aggregates and AC to achieve…
    - Densest possible aggregate structure within gradation specification limits, while..
    - Maintaining the Specified Volumetric Properties
      - Air Voids
      - VMA
      - VFA
      - Dust Ratio

Densest Structure achieved closest to 0.45 power Maximum Density Line



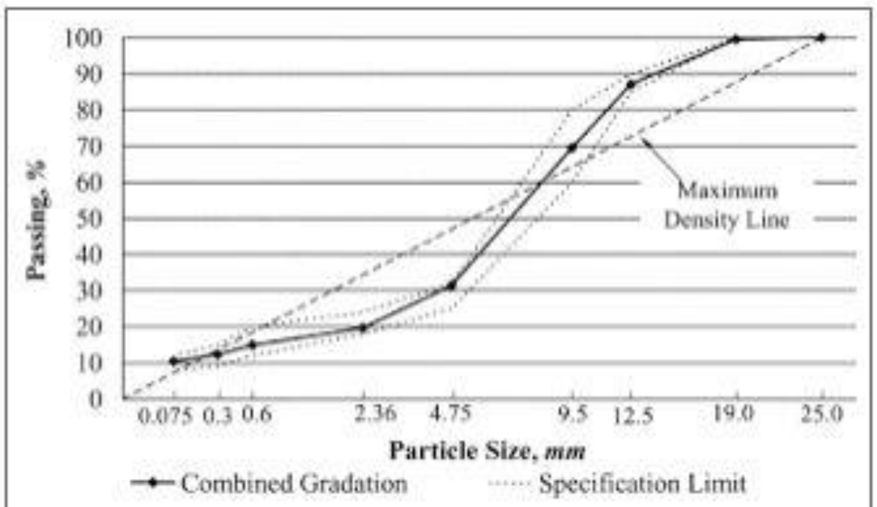
Maximum Density Line for 25mm Maximum Particle Size

- Mix Design Practice – 101

- Designer uses available aggregates.
  - Each HMA supplier uses their own suite of aggregates year after year.
  - Competition prevents implementation of material changes that could increase cost
- Designer selects optimum blend of aggregates and AC for mix JMF
- Selected JMF May Not Align With Current Owner Initiatives for Higher AC
  - MTO AC for Bid purposes
  - Municipal minimum AC contents

• Mix Design Practice – 101

- Designer can make limited adjustments to increase Voids and make room for more AC
  - Move gradation away from Zero Air Void line
    - Keep mix on fine side of envelope
      - + 1% Passing 4.75mm = +0.1% Voids
    - Reduce dust content in Mix
      - -1% Passing 75 um = +0.75% Voids
  - Use more cubical aggregates – Potential Cost Increase



Maximum Density Line for 25mm Maximum Particle Size

- Designer Can Adjust Gradation to Allow More AC
  - Finer Mixes Have Higher AC, but…
    - Higher Aggregate Surface Area
    - Higher Surface Area May Offset Benefit of Increased AC%

- Increase in AC Should Result in Increase in Film Thickness
  - Slower Oxidization
  - Increased flexibility

- Is Higher AC an Assurance of Pavement Performance?

Sieve Size	Hot Mix Type				
	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm
37.5	100				
25	95.0	100			
19	54.5	95.0	100		
16	90.5	75.8	97.5		
12.5	50.0	56.5	95.0	100	100
9.5	86.0	49.7	67.5	95.0	97.5
4.75	45.5	42.8	50.0	61.0	95.0
2.36	32.0	36.0	43.0	49.5	80.7
1.18	26.4	29.8	35.6	40.8	66.3
600	20.8	23.6	28.2	32.1	52.0
300	15.2	17.4	20.8	23.4	37.7
150	9.6	11.2	13.4	14.7	23.3
75	4.0	5.0	6.0	6.0	9.0
PB (%)	4.00	4.5	5.20	5.50	7.80

- Aggregate gradation selected at middle of specification –
- Actual mixes will vary.
- AC % based on current MTO AC for Bid Purposes for 25mm, 19mm, 12.5mm

	Hot Mix Type				
	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm
SA (Sf/lb)	25.9	29.9	35.4	38.4	59.4
PB (%)	4.00	4.5	5.20	5.50	7.80
Abs (%)	0.85	0.85	0.85	0.85	0.85
PBe (%)	3.18	3.69	4.39	4.70	7.02

	Hot Mix Type				
	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm
SA (Sf/lb)	25.9	29.9	35.4	38.4	59.4
PB (%)	4.00	4.5	5.20	5.50	7.80
Abs (%)	0.85	0.85	0.85	0.85	0.85
PBe (%)	3.18	3.69	4.39	4.70	7.02
FT (Microns)	**6.228**	**6.285**	**6.377**	**6.304**	**6.238**

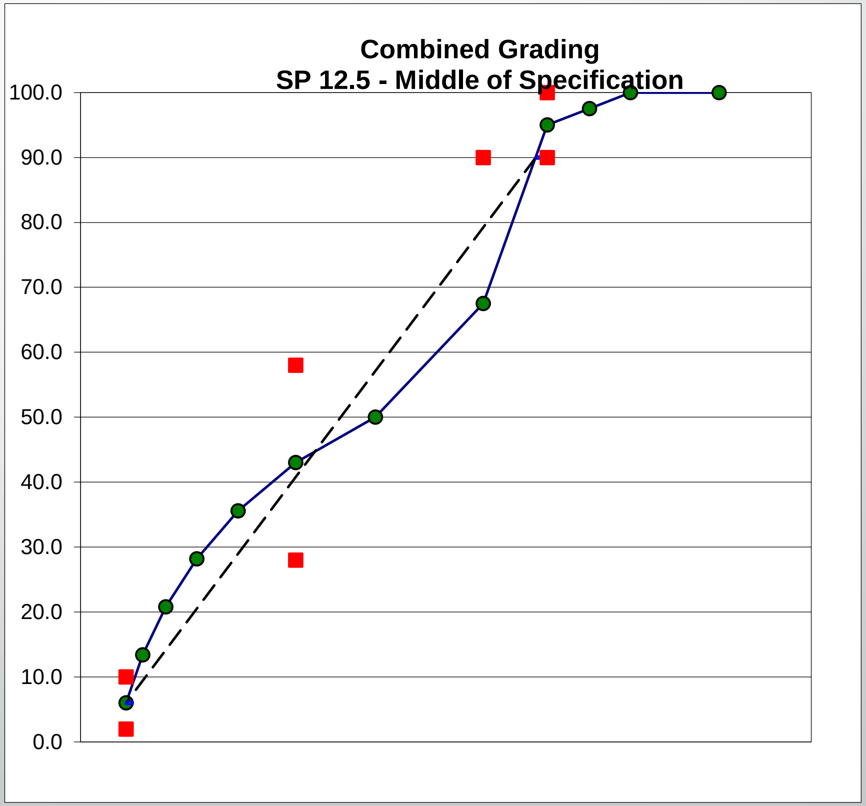
- Example Gradings show Film Thickness is effectively the same for each mix type.

	Hot Mix Type					
	25 mm	19 mm		12.5 mm	9.5 mm	4.75 mm
SA (Sf/lb)	25.9	29.9		35.4	38.4	59.4
PB (%)	4.00	4.5	4.80	5.20	5.50	7.80
Abs (%)	0.85	0.85	0.85	0.85	0.85	0.85
PBe (%)	3.18	3.69	3.99	4.39	4.70	7.02
FT (Microns)	**6.228**	**6.285**	**6.822**	**6.377**	**6.304**	**6.238**

- Film Thickness will increase with increased AC if gradation is not adjusted.

- **Specifying Minimum AC / Artificially Increasing AC**
  - May Not Guarantee Better Performance

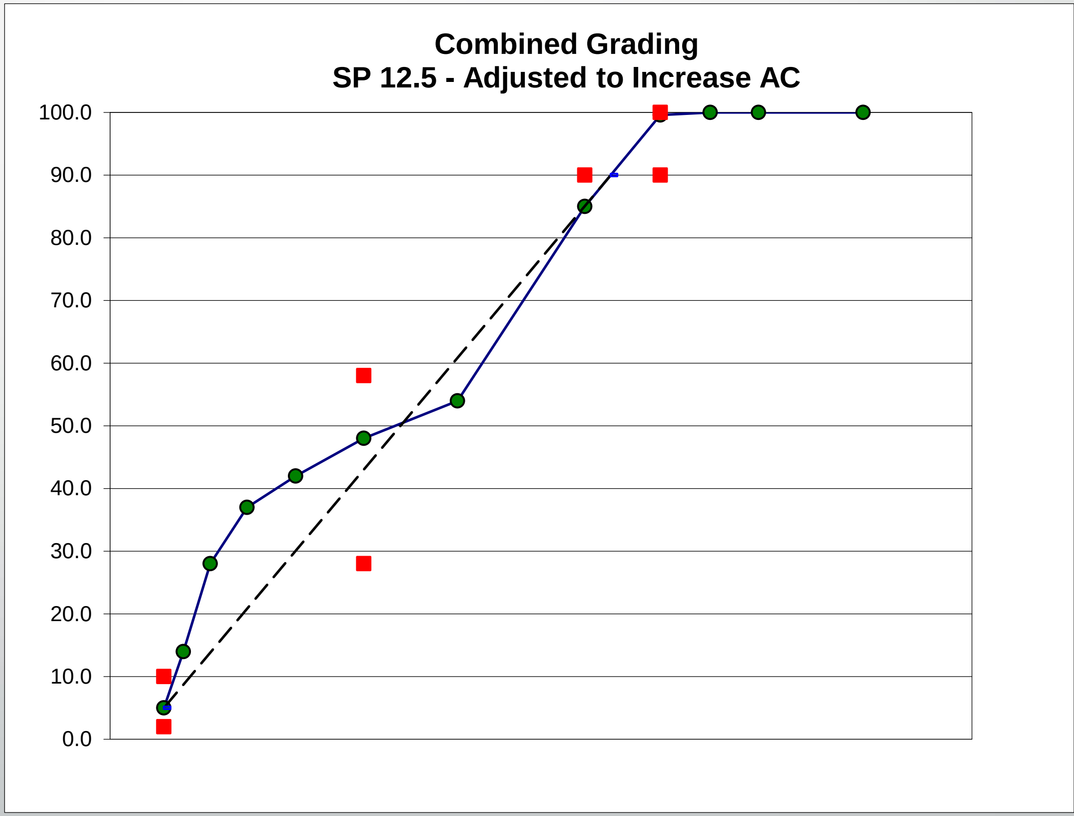
Sieve Size	% Passing
19	100.0
16	97.5
12.5	95.0
9.5	67.5
4.75	50.0
2.36	43.0
1.18	35.6
600	28.2
300	20.8
150	13.4
75	6.0
PB	5.2%



12.5mm Mix : Gradation Middle of Specification

- Gradation Adjusted to Increase AC
  - Designer adjusts proportions of available aggregates
  - Unlikely to make changes that will increase mix cost by adding or changing aggregates

Sieve Size	% Passing
19	100.0
16	100.0
12.5	99.6
9.5	85.0
4.75	54.0
2.36	48.0
1.18	42.0
600	37.0
300	28.0
150	14.0
75	5.0
PB	5.5%



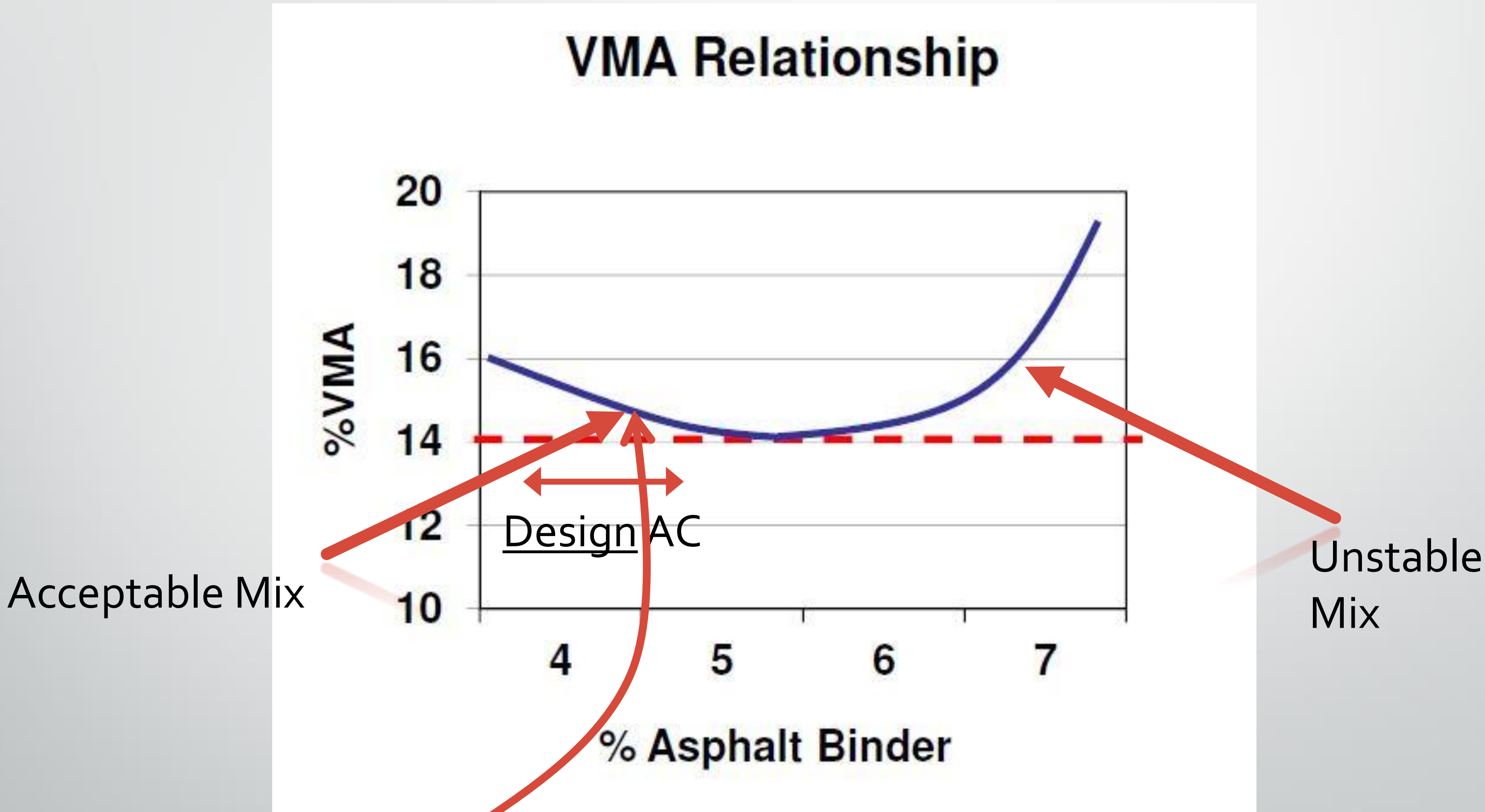
`	12.5mm Middle of Specification	12.5mm Finer Gradation
SA (Sf/lb)	35.396	38.340
PB	5.2	5.5
Abs	0.85	0.85
PBe	4.3942	4.6968

`	12.5mm Middle of Specification	12.5mm Finer Gradation
SA (Sf/lb)	35.396	38.340
PB	5.2	5.5
Abs	0.85	0.85
PBe	4.3942	4.6968
Ft (Microns)	6.377	6.313

Has the 0.3% Extra AC Added provided a benefit?

- Mix Design Practice
- Performance Prediction Shortcomings
  - Focus on Developing Optimum Design Blend using....
    - Available Aggregates
    - Available AC
  - Do Not focus on Predicting Performance of HMA
  - Do Not Incorporate Measures to Predict Pavement Life

- Minimal guidance to identify poor performing mixes
    - VMA Curve – Identify potential instability / Rut prone mix
    - Unstable mix if AC Content set beyond bottom of curve (AI-MS2)



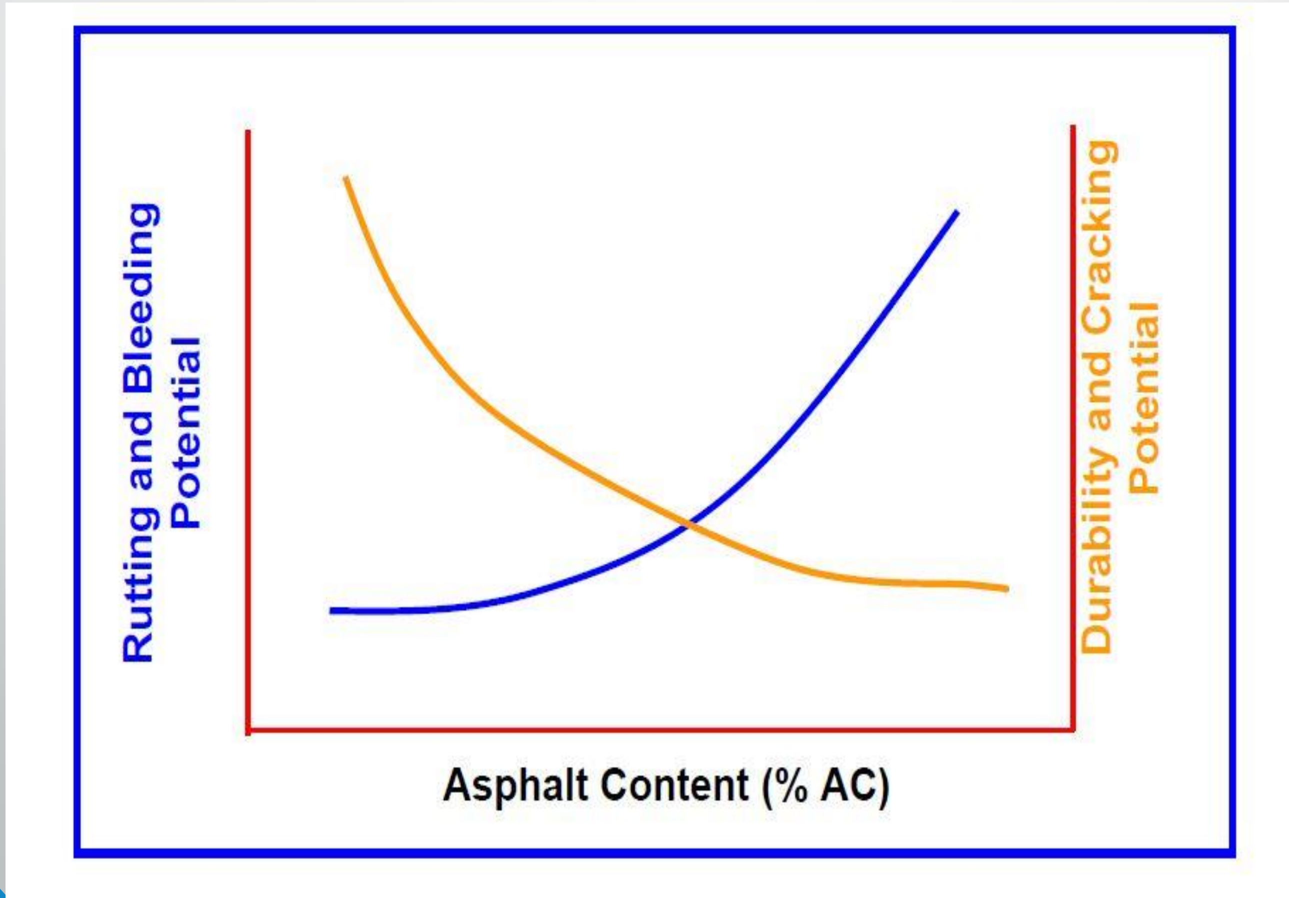
- JMF AC must be established before bottom of curve
- No guidance for mixes with Poor Fatigue resistance

Innovations for Better Performance

- Performance Based Mix Design
  - Superpave intended to have a level 2 and 3 Design Procedures
    - Laboratory Performance Testing of Mix designs based on Traffic Level
    - Not yet implemented and branded specifically as a part of Superpave Design.
      - Many test procedure options
      - No Consensus on the "Best Test"
  - Some agencies have developed performance test requirements.
    - Have data from previous testing

- Texas DOT - Balanced Mix Design
  - Performance Based Design

- Considers Impacts of AC Content on Mix
  - Increased AC results in Higher Tendency for Deformation
  - Reduced AC Results in Higher Cracking Potential



- Performance Tests
  - **Deformation**
    - Hamburg Wheel Tracking Test (WHTT) AASHTO T 324

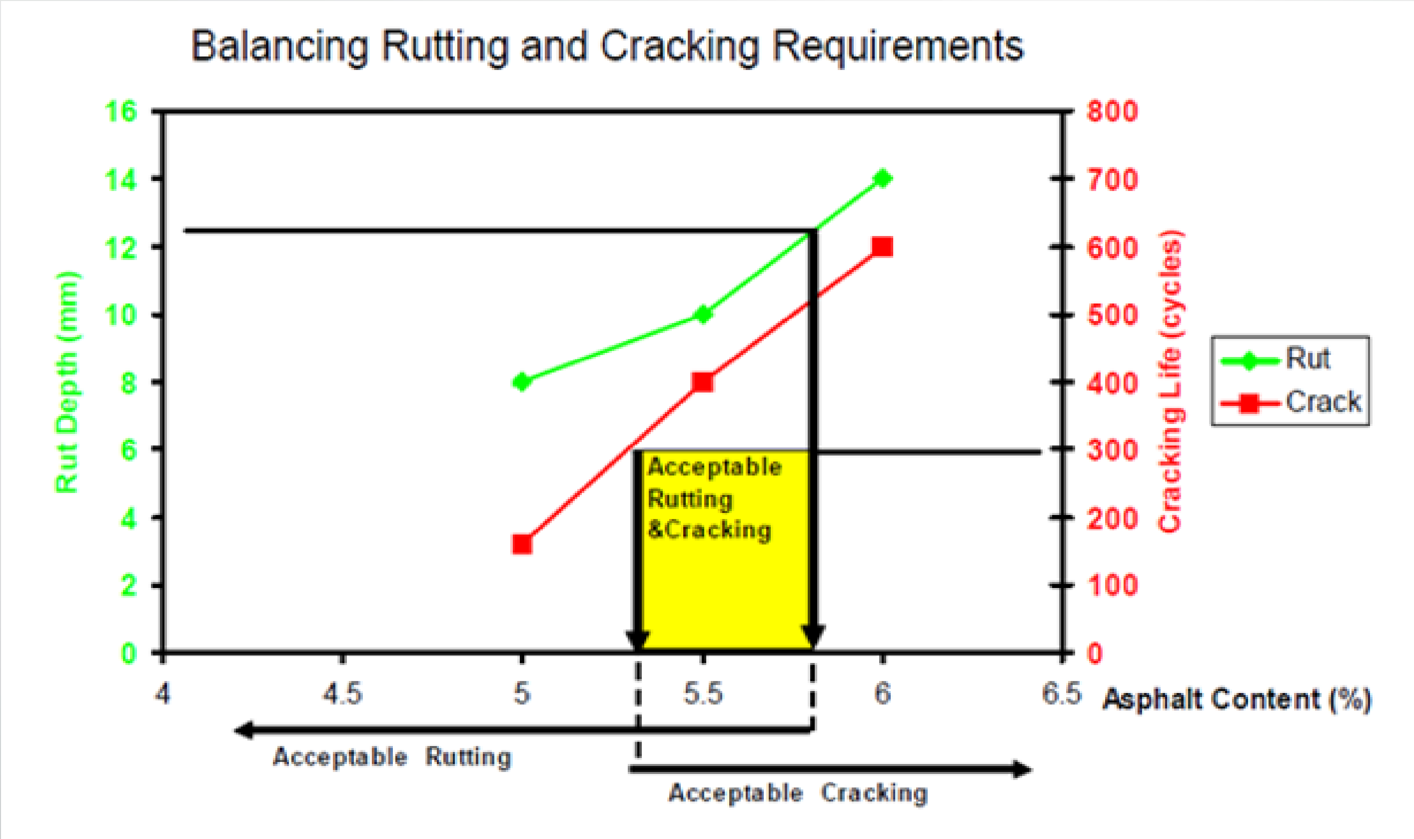
  - Provides Expected depth of rutting expected with traffic
  - **Fatigue**
    - Texas Overlay Tester (OT) Tex-248-F
    - Provides Expected Cracking of mix based on repeated loading

- Used in Texas for many years to monitor performance
  - Good understanding of relationship with local materials
  - Acceptance Limits Based on Performance Experience

Balanced Mix Design

- Mix Design Completed as Typical
  - Gyratory Samples fabricated at incremental AC contents
  - Optimum AC Selected at 4% Air Voids
- Gyratory Samples at each AC content tested for
  - Rutting Performance
  - Fatigue Resistance / Cracking Prediction
- Results Plotted Against Acceptance Limits

- Balancing the Mix Against Acceptance Limits



6. If JMF AC at 4% Voids in Initial Design Falls in Acceptable Ranges

- Mix Accepted
- If Not
  - Mix Reformulated

- AC Content of Mix can be adjusted within established AC Range
  - To provide best overall performance
  - To address specific performance concerns
    - Soft AC
    - Historical performance
    - Traffic Loading
- Change of Mindset Required
  - Air voids established for balanced design not necessarily 4%
  - Could be higher or lower than established in initial Design
  - Acceptance during production
    - Air Void range adjusted to fit new target AC percent

- Advantages of Performance Based Mix Design
  - Identify high AC limit for mix that will allow acceptable rutting depth
  - Identify low AC limit for mix to prevent early age cracking.
    - Benefit for RAP Mixes
  - Mix AC content can be set to provide best performance for expected conditions.

- Restrictions to Implementation in Ontario
  - Specialized equipment required.
    - High cost
    - Unproven in Ontario
  - Unfamiliar test procedures
  - Will take a few years before industry gears up
- MTO Currently Conducting Research
  - Developing Understanding of Test Methods Most Appropriate for Ontario Conditions
  - Potential Development of Performance Based Mix Design in Future

- Is AC Content the only thing that influences Pavement Performance?
  - Compaction
  - MTO recognizes benefit

    Recent Increase in LL% for Compaction – 92%

    Consistent with Majority of US States

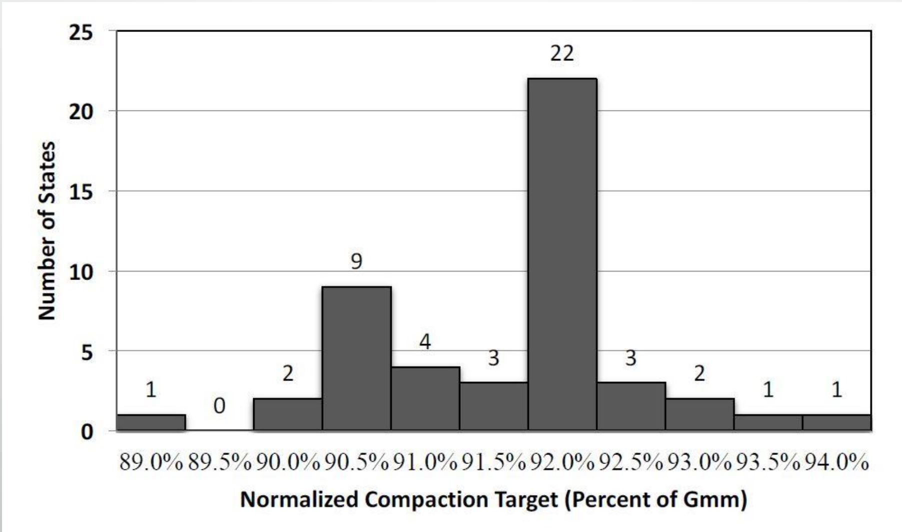


Figure 1. Normalized Compaction Targets by State (Source: AASHTO 2007 SOM Survey)

- 1.5% increase in density leads to 10% increase in fatigue life. (UK-AI Study)
- Reduced Air Voids = Increase in Fatigue Life

Table 1. Effect of Air Voids on Fatigue Performance

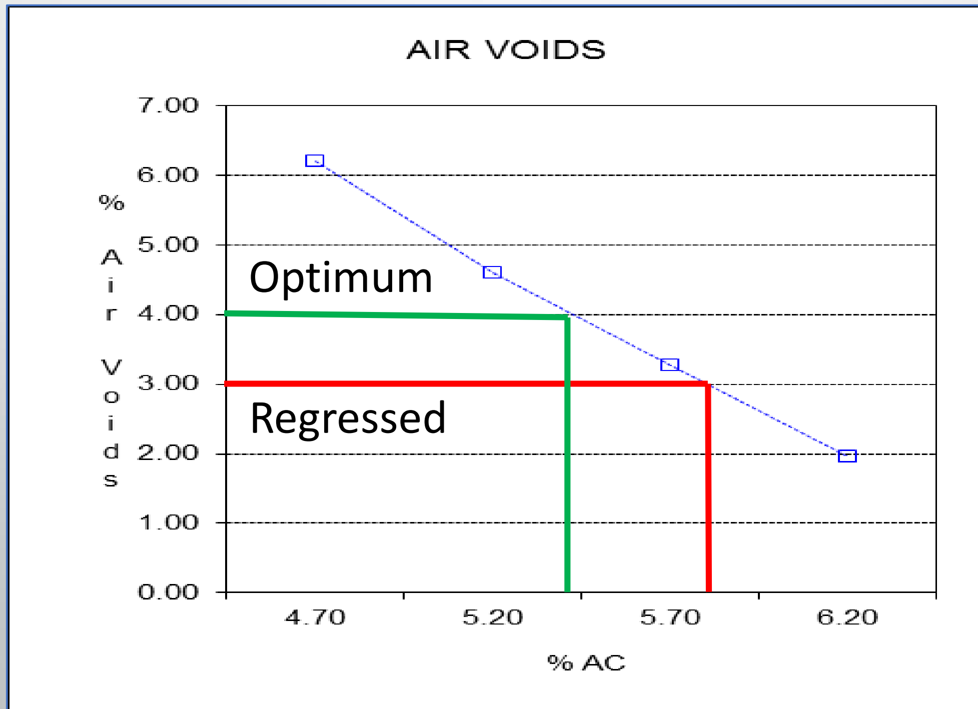
Study	Lab/Field Experiment	Mix Type	Air Voids Evaluated	Increase in Fatigue Life for 1% Decrease in Air Voids
UCB (Epps and Monismish 1969)	Lab	British Standard	4 - 14%	20.6%[1]
		California Fine	5 - 8%	43.8%[1]
		California Coarse	2.5 – 7%	33.8%[1]
UCB (Harvey and Tsai 1996)	Lab	California Dense-Graded	1 - 3% 4 - 6% 7 - 9%	15.1%[1]
WesTrack (Epps et al. 2002)	Lab	Fine	4, 8, 12%	13.5%[1]
		Fine-Plus	4, 8, 12%	13.3%[1]
		Coarse	4, 8, 12%	9.0%[1]
	Field	Fine/Fine-Plus	4, 8, 12%	21.3%[1]
		Coarse	4, 8, 12%	8.2%[1]
AI (Fisher et al. 2010)	Lab	9.5 mm Dense-Graded	4 – 11.5%	9.2%

[1] (Seeds et al. 2002)

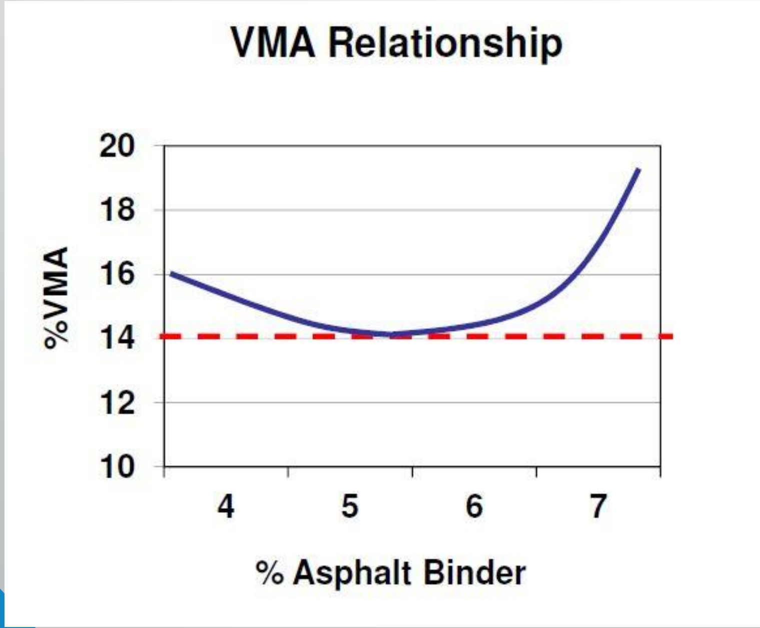
- Research Data Suggests - Best Expected Performance With
  - Higher AC
  - Lower Air Voids
  - Higher Compaction

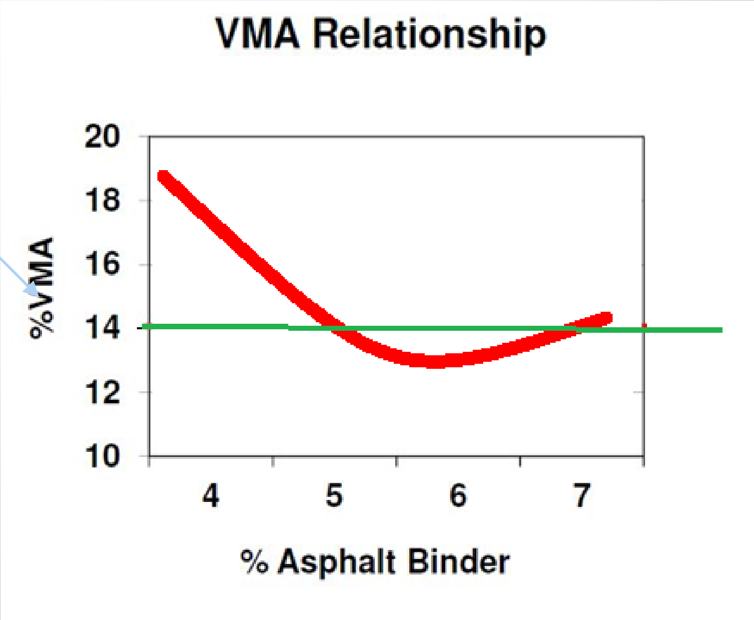
HMA Regression Mix Design - Michigan

- Established Mix design air voids reduced from 4% to 3% in ***production*** by addition of approximately 0.3-0.5% asphalt binder from optimum
- Similar process to rich bottom mixtures used in perpetual pavements.
- Difference..
  - AC % increase is limited to achieve 3% air voids (1% AV Reduction)



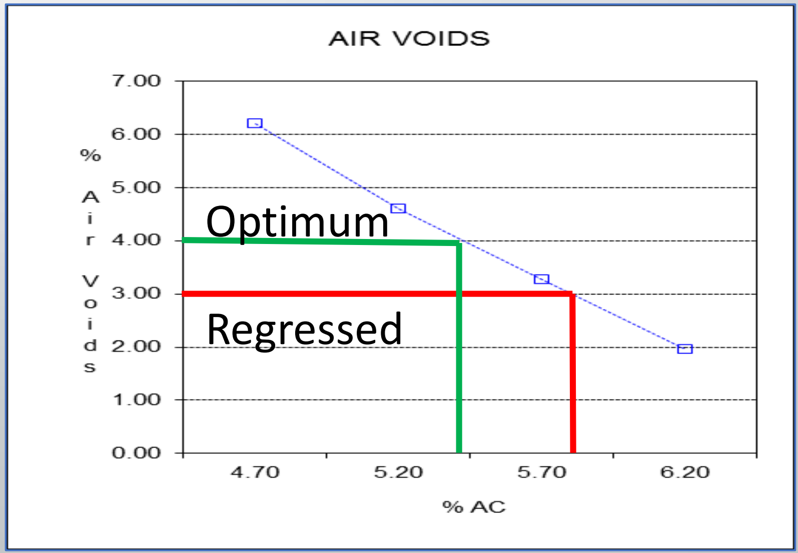
- Regression Mix Design
  - Mix Design JMF Established at N Des = 96% (4% Air Voids)
    - “Regressed” ***Production*** AC Content = AC Content at 3% Air voids
      - Typical 0.3% to 0.5% Increase in AC
      - Original VMA requirements must be met
        - Encourages Consideration of VMA in Lab design
        - Restricts Selection of Mixes with Marginal VMA





JMF AC Must Allow for VMA change with Regressed AC Content

- Production Acceptance
  - Regressed AC %
    - Example from Chart below
      - Voids regressed from 4% to 3%
      - JMF = 5.4%, Regressed AC = 5.8%
  - Regressed AC % Production limit +/- 0.35%
  - Air Voids @ N Des = 97% (3%): +/- 0.9%
  - VMA Limits – No Change
  - Compaction Lower Limit 92.5%



- Advantages
  - Controlled AC Increase
    - 0.3 to 0.5% increase – Mix Specific Adjustment
      - Film Thickness Increased – Increase in Fatigue Life
  - Controlled 1% Reduction for In Place Air voids
      - Increase in Fatigue Life
  - Higher Pavement Compaction
      - Increased AC promotes higher density across mat
      - Reduced Oxidization
      - Increased Fatigue Life
  - Optimum Aggregate Structure
      - Optimum HMA Design selected at @ N Des = 96%
      - Structure Selected Must Allow for Regressed AC and VMA

Summary

- Initiative for Higher AC and Better Performance is Supported by All
  - Owners current options are limited without changes.
    - Specify higher AC %
    - Hope to get more better performing mixes
      - Success Rate??????

- Changes in Gradation to meet minimum AC%,

or,

- Specifying Smaller Nominal Size Mixes with Higher AC%,
  - Higher Surface Areas
  - Do Not necessarily get higher film thickness to promote performance

- AC % in a mix is only one part of the performance equation.
  - Compaction and Air Voids need to be considered as well

Summary

- Performance Based Mix Design Is Ideal Solution
  - Specific Blend of Aggregates and AC can be verified.
  - Mix Design AC % can be adjusted for specific concerns
    - Premature Cracking
    - Instability problems
      - Rutting, shoving etc.
- But….
  - Test procedures accepted across Ontario are not yet available
  - May take a number of years before industry is up to speed
  - Balanced Mix design will require change in mindset for Air Voids.

Summary

- Regression May Provide An Easily Implemented Option
  - Benefits
    - AC content increased with an increase in film thickness
    - Higher Field Density
    - Reduced Air Voids
    - Design incorporates optimum aggregate structure

- All benefits point to increased fatigue resistance
  - Reduced cracking and longer lasting pavements.

- Can easily fit into current specifications with minor changes to limits
  - Aligns Well With Current Acceptance Processes

Thank You

- Questions??