ASPHALT

THE SMOOTH QUIET RIDE

ASPHALT 100% RECYCLABLE

Michigan Aggregates Association

MDOT HMA Mix Selection & Design Changes

February 2nd, 2022

ASPHALT PAVEMENT ASSOCIATION OF MICHIGAN

MICHIGAN RIDES ON US

Asphalt.

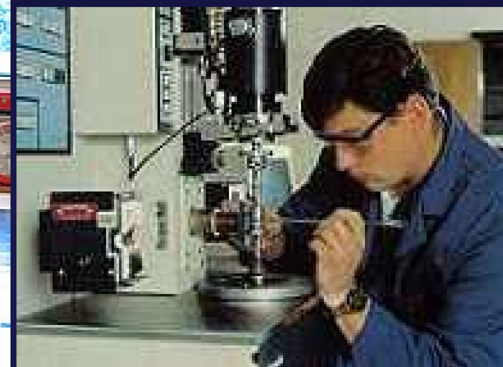
Asphalt Mix Selection

Asphalt Mix Selection

Presentation Outline

- **History**
  - **Evolution of mix design**
  - **Binders**
- What is Regression?
- RAP
- APAM Mix Recommendations
- New MDOT Mix Designations

Asphalt Mix Selection



Mix History

Asphalt Mix Selection

1970's (Marshall)

- 4.11 Bituminous Aggregate Pavement
- 4.12 Bituminous Concrete Pavement
  - 9A Binder
  - 25A Leveling/Wearing
  - 31A Wearing

Asphalt Mix Selection

Stability Mixes (Marshall)

1980's

- #500 & #700   20C Bases
- #1100 L & T   20A, 20AA
- #1300, #1500, #1800 L &T   20AA

Asphalt Mix Selection

Performance Mixes (Marshall)

1990's

- 2B, 2C	Bases
- 3B, 3C	Leveling
- 4B, 4C	Top
- 11A	Base, Leveling
- 13, 13A	Base, Leveling, Top
- 36A, 36B	Leveling, Top

Asphalt Mix Selection

SuperPave Mixes

2000's

- LVSP, E03, E1, E3, E10, E30, E50 (EL, EML, EMH & EH)
- 2E03 thru 5E50

Asphalt Mix Selection

SuperPave Mixes

5EL:

5 = Mixture Number (2 thru 5)

corresponds to aggregate gradation

2 = Base Mix

5 = Top Mix

Asphalt Mix Selection

SuperPave Mixes

5EL:

EL = Mixture Type

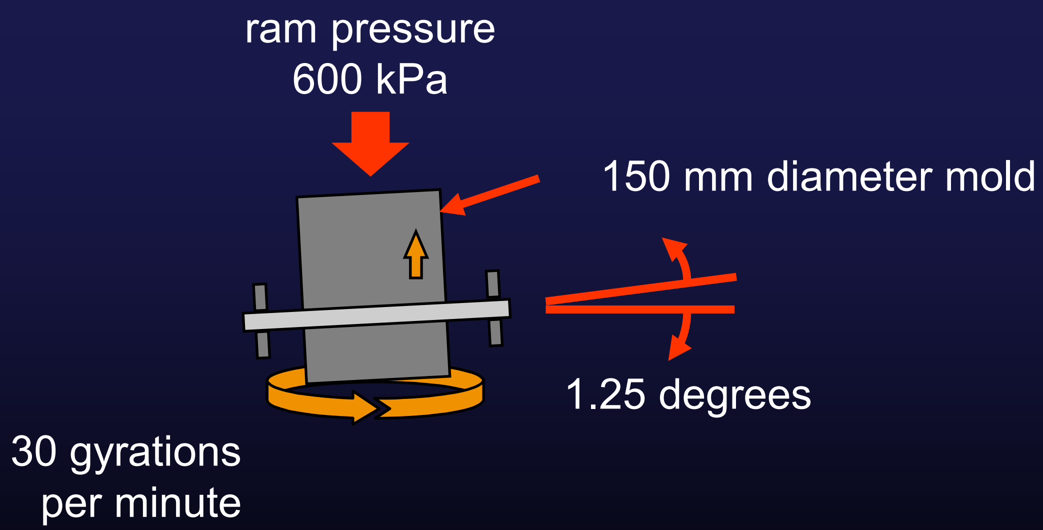
corresponds to estimated traffic

EL thru EH

Asphalt Mix Selection

Marshall vs. Superpave Mix

1. Compaction of mix design samples
   a. Marshall Hammer
   b. Gyratory Compactor
2. Aggregate Properties
3. Mix Design Air Voids



Asphalt Mix Selection

ASPHALT PAVEMENT ASSOCIATION OF MICHIGAN

Mix Gradation

	5E	4E	LVSP	13A	36A	4C
1 ½ inch	---	---	---	---	---	---
1 inch	---	---	---	---	---	---
¾ inch	---	100	100	100	---	100
½ inch	100	90-100	75-95	75-95	100	91-100
3/8 inch	90-100	≤ 90	60-90	60-90	92-100	≤ 90
No. 4	≤ 90	---	45-80	45-80	65-90	≤ 67
No. 8	47-67	39-58	30-65	30-65	55-75	15-52
No. 16	---	---	20-50	20-50	---	≤ 37
No. 30	---	---	15-40	15-40	25-45	≤ 27
No. 50	---	---	10-25	10-25	---	≤ 20
No. 100	---	---	5-15	5-15	---	≤ 15
No. 200	2 - 10	2 - 10	3 - 6	3 - 6	3 -10	3 - 6

SuperPave vs. Marshall

Asphalt Mix Selection

Asphalt Cement History

Asphalt Mix Selection

Asphalt Cement History

- Penetration Grades – 1920's
  - 85-100
  - 120-150
  - 200-300
- Viscosity Grades – 1960's
  - AC-2.5
  - AC-5
  - AC-10
- PG Binders: Mid 90's
  - PG 58-28

SUPERPAVE
Performance Grade (PG)
Binder Specification

- Fundamental properties related to pavement performance
- In-service & construction temperatures
- Short and long term aging

Superpave Asphalt Binder Specification

The grading system is based on climate

PG 58 - 28

Performance Grade

Average 7-day max pavement temperature

Min pavement temperature

Is a PG a Modified Binder ?

Effect of Loading Rate

Reliability

"Rule of 90"

Rounding

Effect of Traffic

Example: PG 70 - 28 has a temperature range of 70 to - 28 or 98 C. Therefore, this binder is probably modified !! *(Depends on Asphalt Source!)*

What Binders are Used in Michigan

- 76-28P
- 70-22P, 70-28P
- 64-28, 64-34P
- **64-22**
- **58-28**
- 58-22, 58-34

Presentation Outline

- History
  - Evolution of mix design
  - Binders
- **What is Regression?**
- RAP
- APAM Mix Recommendations
- New MDOT Mix Designations

Important Asphalt Mix Properties

We want

- Stability
- Durability
  - Fatigue resistance
  - Low temperature crack resistance
- Impermeability
- Workability

How?

Materials Selection

Volumetric design

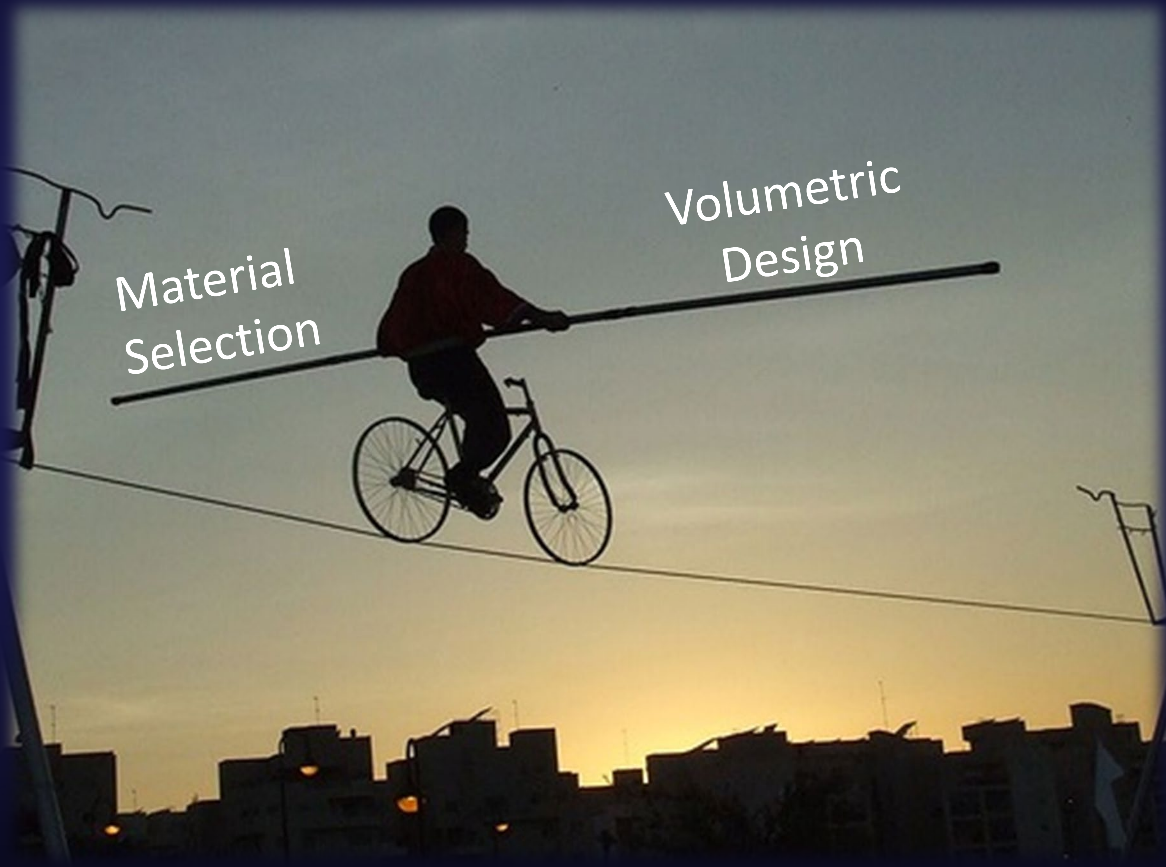
Mix Design Goals
Balancing Act

Smooth Quite Ride

Strength &
Stability

No
- Rutting
- Shoving
- Flushing

Workability



Durable

No
- Cracking
- Raveling

Skid
Resistance

Requirements for All Designs

- Sufficient asphalt binder to ensure a durable pavement
- Sufficient stability under traffic loads
- Sufficient air voids
  - Upper limit to prevent excessive environmental damage
  - Lower limit to allow room for initial densification due to traffic
- Sufficient workability

Changes made in MDOT mixture specifications to improve durability:

- 2012- Regressed air voids from 4.0% to 3.5%.
  - Resulted in about 0.2% additional asphalt cement in these mixes. (PWL spec 12SP501 (U), 09-27-11)
- October 2014 -Regressed air voids from 3.5 % to 3.0 %.
  - The first projects were let in the October 2014.
  - Apply to all mixtures starting in March 2015. (PWL spec 12SP501 (U-03), 12-08-14)
- January 2015- Eliminated the use of coarse graded Superpave mixtures for top and leveling courses. Fine graded mixtures required.

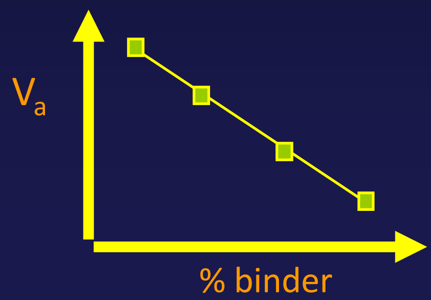
Air Void Regression

Air Void Regression Basics :

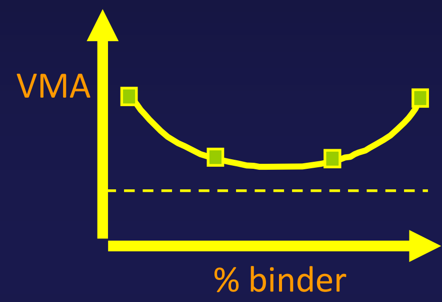
- To Improve durability of HMA
- Mix Design done at 4.0% Air Voids
  - APAM Suggests regression of all top course mixes to 3.0% Air Voids
- Looking at Mix Design, the AC needed to achieve 3.0% Air Voids is Determined.

Design Binder Content

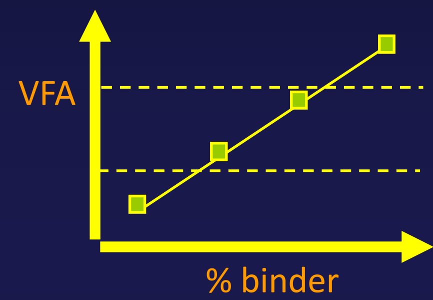
Air Voids



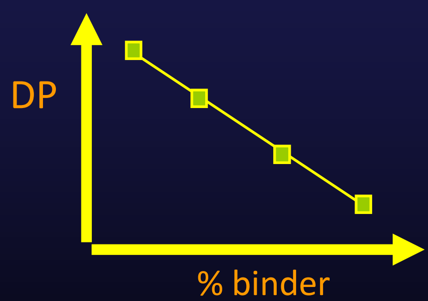
VMA



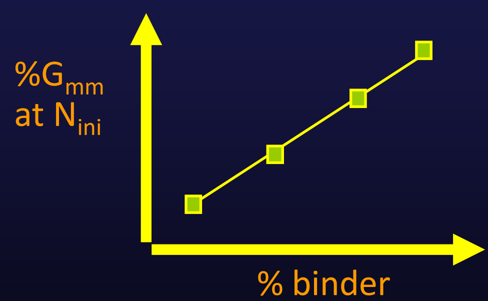
VFA



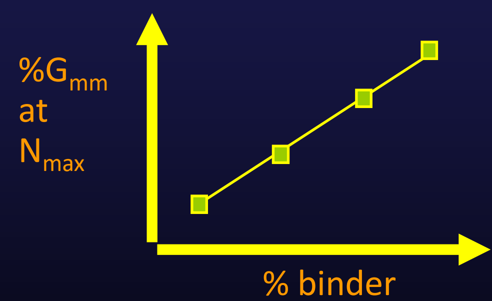
Dust/Asphalt



$\%G_{mm}$ @ N_{ini}



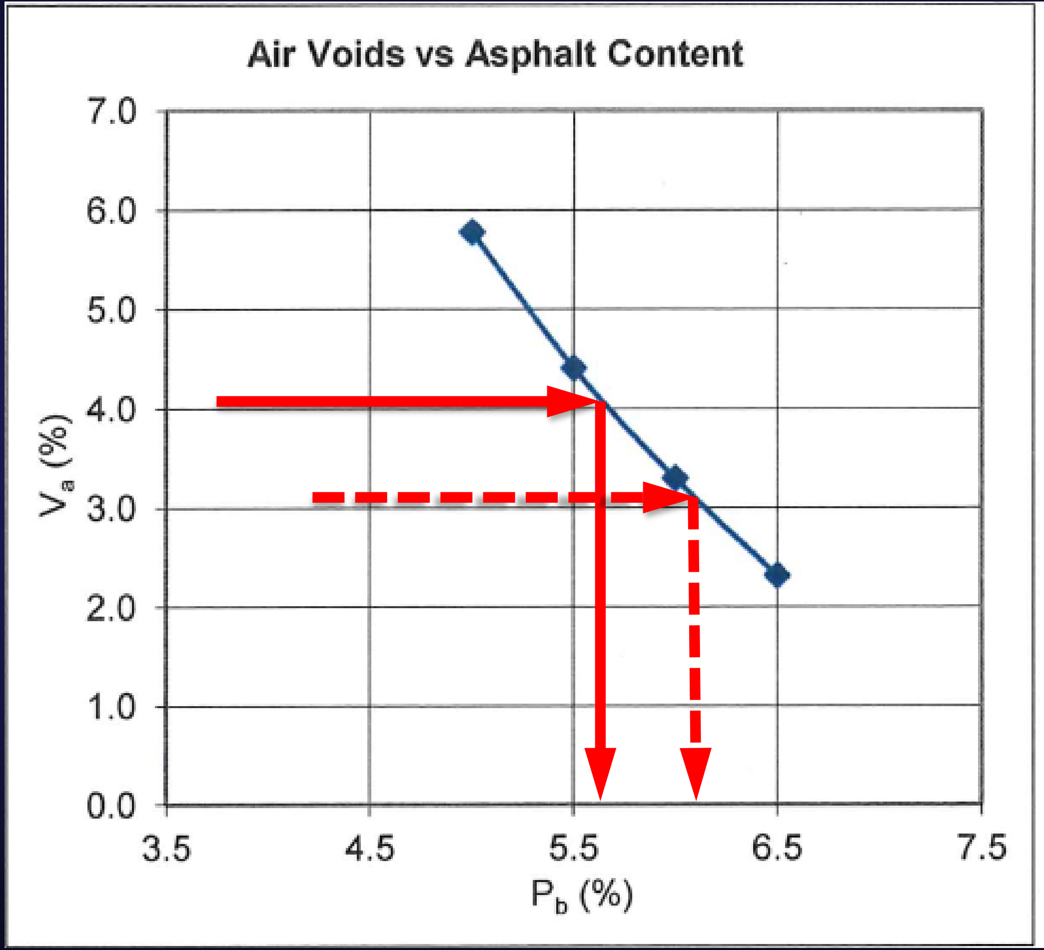
$\%G_{mm}$ @ N_{max}



Air Void Regression

Original Optimum %AC = ~ 5.7

Regressed Optimum %AC = ~ 6.1



Presentation Outline

- History
  - Evolution of mix design
  - Binders
- What is Regression?
- **RAP**
- APAM Mix Recommendations
- New MDOT Mix Designations

Why Recycle RAP into HMA?

- Best and Highest use
- Same or better performance as virgin mix
- Reduces demand for new materials
- Reduces carbon footprint
- Contains valuable materials
- Save $

Why Recycle RAP into HMA?

- RAP contains valuable materials :
  - ♦ Aggregate ~ 94% @ $17/ton
  - ♦ Asphalt ~ 6% @ $350/ton
  - ♦ Value = $36.98 /ton (minus processing)

Economic Savings Example

- Aggregate: $17.00/ton
- Asphalt: $350.00/ton
- RAP: $9.00
- Mix Design AC Content: 6.0%

Material	0% RAP	17% RAP	27% RAP
Aggregate	$15.98	$13.09	$11.39
Asphalt	$21.00	$17.43	$15.33
RAP		$1.53	$2.43
Total	$36.98	$32.05	$29.15
$ Savings		**$4.94**	**$7.83**
% Savings		**13.4%**	**21.2%**

Recommended Practices for Use of RAP

Follow best practices for the processing and management of RAP

- Contractor to sample and test RAP during processing

RAP usage specification

- RAP mixes should meet same specs as virgin mixes
- Adjust binder grade appropriately

Approved mix design including RAP

Recommended Practices for Use of RAP

Approved mix design including RAP

Know the properties of the RAP

- **Gradation , binder content , theoretical maximum specific gravity**

Mix design must be done incorporating RAP and taking into account the RAP characteristics

Mix Design Example

ASPHALT PAVEMENT ASSOCIATION OF MICHIGAN

Michigan Department of Transportation form 1931

File 300 ______

Report of Test
SUPERPAVE ™ HMA Design Mix Formula

ACCEPTED

Distribution: Project Engineer (1) -- TMI (1) -- Mix Design (1) -- Contractor (1) -- Bit File (1)

Control Section: B806 54038	Job Number: 54321A	Project Engineer: R. Steel P.E.	Engineering Firm: MDOT	Date: 8/9/0X	
Contractor: General Pavement		Plant Location: BIG RAPIDS		Plant No.: 701-01	
Mix Type: 5E3	Mix Design Number: 06MD540	Project Location:		Specification: 03SP501(F)	
% Air Voids: 4.0	VMA: 15.9	VFA: 74.8	$P200/P_{be}$: 1.1	AWI: 288	AI: 40.9
Gmm: 2.457	Gmb: 2.359	Gb: 1.029	Gsb: 2.644	Gse: 2.682	Film Thickness: 7.21

	A	B	C	D	E	F	G	H	I	J	
Pit Number	54-101	54-101	95-76	95-76						Plant	% AC
Aggregate Type	Sand FSU	Slag Sand	5/16 FSU	Sand	BHF					Rap	5.7
										Rap/Ac	9.48%
Blend %	10.0%	15.0%	26.0%	33.0%	1.0%					15.0%	Combined
Sieve Size	GRADATION							% Binder of RAP		3.60	Gradation
1 1/2" - (37.5mm)											0.0%
1" - (25.0mm)											0.0%
3/4" - (19mm)											0.0%
1/2" - (12.5mm)	100.0%	100.0%	100.0%	100.0%	100.0%					100.0%	100.0%
3/8" - (9.5mm)	100.0%	100.0%	100.0%	100.0%	100.0%					87.5%	98.1%
#4 - (4.75mm)	91.3%	91.7%	65.0%	99.9%	100.0%					67.9%	83.9%
#8 - (2.36mm)	69.9%	59.6%	39.7%	79.9%	100.0%					50.2%	61.1%
#16 - (1.18mm)	52.4%	38.7%	29.2%	66.2%	100.0%					40.8%	47.6%
#30 - (0.60mm)	36.8%	26.3%	23.8%	54.9%	100.0%					33.6%	38.0%
#50 - (0.30mm)	11.8%	18.0%	17.2%	24.9%	100.0%					20.8%	20.7%
#100 - (0.1mm)	3.6%	11.7%	11.7%	2.8%	100.0%					10.6%	8.6%
#200 - (0.075mm)	2.5%	7.7%	9.0%	0.4%	85.0%					7.4%	5.8%
1 FACE CRUSH %	30.0%	100.0%	100.0%	30.0%						75.0%	88.6%
2 FACE CRUSH %											-
L.A. ABRASION & YEAR	22-03	25-02	22-03								
Angularity Index	37.8	48.8	43	38							40.90
AWI FACTOR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
AWI VALUE #16	225	401	300	240						240	288
COMBINED Calc. Gsb	2.601	2.720	2.610	2.648						2.675	2.648
#4+ COARSE BULK S.G.			2.621								
#8 COARSE BULK S.G.		2.702	2.582								
FINE BULK S.G.	2.601	2.73	2.619	2.648						2.678	
FLAT & ELONGATED %											
SOFT PARTICLES %	0.1		0.5	0.5						0.5	

Asphalt Binder	Grade: PG 64-28	A.C. Supplier I.D. #: ABS 1005	% New AC Added: 5.16

REMARKS:

Bituminous Engineer

Recommended Practices for Use of RAP

Test the produced Mix:

- (Binder, Gradation)
- Contractor Quality Control Tests
- Owner Quality Assurance / Acceptance tests

If you have performance concerns:

- Consider testing/monitoring other properties
- Mix volumetrics (Air Voids, VMA)
- Fines to Effective Binder Ratio

Presentation Outline

- History
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Asphalt Mix Selection

APAM Mix Recommendations

APAM suggests avoiding the use of 13A/LVSP Mixes

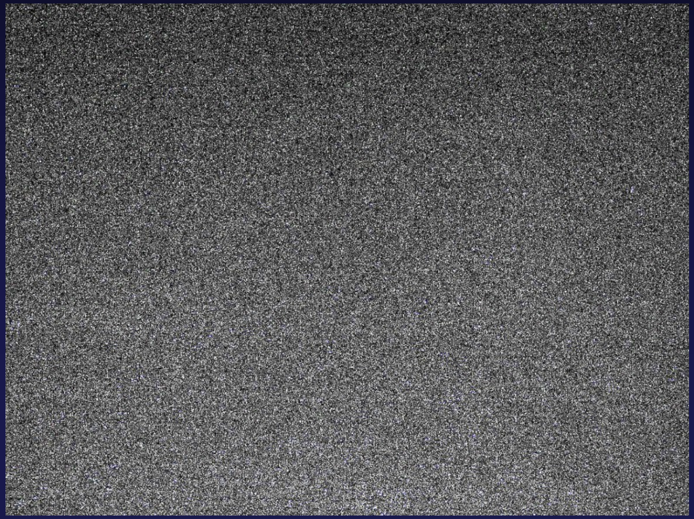
a. Coarse graded 13A (LVSP) mixes don't look good

   i. Appearance is not a "specified" item, but it can become a problem when the mix "looks" bad.

   ii. They are more susceptible to segregation, which can lead to performance issues.

Asphalt Mix Selection

Mix Recommendations



APAM Suggested Top Course Mixes

Use 5E (SuperPave) Mix

The traveling public will appreciate the nice appearance and good performance.

Asphalt Mix Selection

5E Superpave Mixture

- Regress mix to 3% air voids.
- Appropriate for traffic level
- Layer thickness between 1 ½" to 2"

Asphalt Mix Selection

Consistency is Important

In order to have better quality, more cost-effective mixes:

a. Fewer mix designs in a plant's operating area is desirable.
   - It is not efficient for one plant to make 10 different 5E1 mixes.

b. Avoid small quantities of a single mix.

c. Avoid small quantities of special binders.

Asphalt Mix Selection

Less is More

- Less mix designs.
- Less yard space.
- Less variability.

- Less cost.

- More streamlined.
- More efficient.
- More consistent.

- More lane miles paved.

LESS

MORE

Presentation Outline

- History
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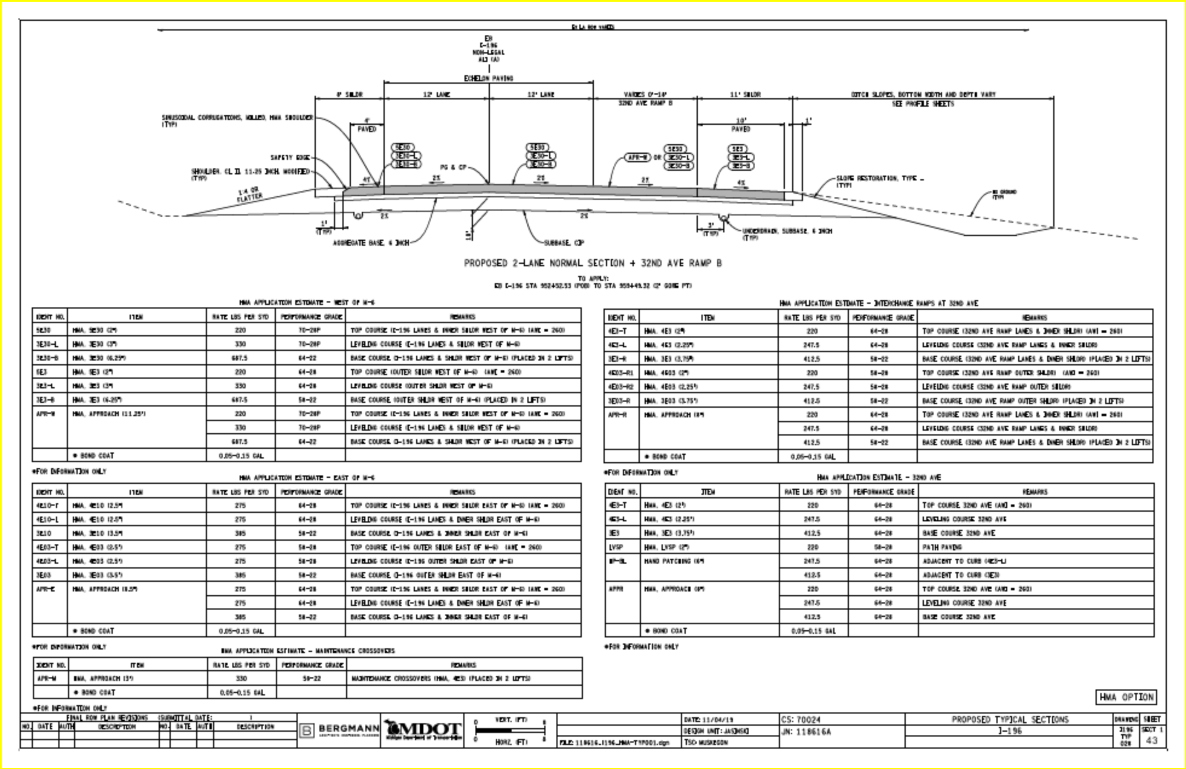
- **New MDOT Mix Designations**

New MDOT Mix Designations

- LVSP and E03 combined into EL
- E1 and E3 combined into EML
- E10 and E30 combined into EMH
- E50 eliminated and replaced with EH
- Gap Graded Superpave (GGSP) renamed to Stone Matrix Asphalt (SMA) to be consistent with national standards



New MDOT Mix Designations

- Major changes made to Tables 501-3 and 902-6
  - New Mix Design Designations
  - Changes mostly relevant to Mix Designers
- Minor changes to Tables 501-1, 501-2, 501-4 and 902-5

New MDOT Mix Designations

MICHIGAN DESIGN MANUAL
ROAD DESIGN

6.03.09A1d (continued)

Hot Mix Asphalt (HMA) Mixture Selection Guidelines

North, Grand, Bay, Southwest and University Region

Mixture Type	HMA Mainline and Ramps		High Stress HMA	
EH, SMA	PG 70-28P PG 64-22	Top & Leveling Course Base Course	PG 76-28P PG 64-22	Top & Leveling Course Base Course
EML, EMH	PG 64-28 PG 58-22	Top & Leveling Course Base Course	PG 70-28P PG 58-22	Top & Leveling Course Base Course
EL	PG 58-28 PG 58-22	Top & Leveling Course Base Course	PG 64-28 PG 58-22	Top & Leveling Course Base Course

Superior Region

Mixture Type	HMA Mainline and Ramps		High Stress HMA	
EL, EML, EMH	PG 58-34 PG 58-28	Top & Leveling Course Base Course	PG 64-34P PG 58-28	Top & Leveling Course Base Course

Metro Region

Mixture Type	HMA Mainline and Ramps		High Stress HMA	
EH, SMA	PG 70-22P PG 64-22	Top & Leveling Course Base Course	PG 76-22P PG 64-22	Top & Leveling Course Base Course
EML, EMH	PG 64-22 PG 58-22	Top & Leveling Course Base Course	PG 70-22P PG 58-22	Top & Leveling Course Base Course
EL	PG 58-22	Top, Leveling & Base Course	PG 64-22 PG 58-22	Top & Leveling Course Base Course

NOTES:

1. For shoulders paved greater than or equal to 8 feet or in a separate operation, use PG 58-28 for top and leveling course and PG 58-22 for base course for all Regions
2. For Temporary Roads, commercial and private Approaches, Wedging, and Hand Patching, use PG 64-22 for all Regions except Superior and North, use PG 58-28.

Table 501-3

ASPHALT PAVEMENT ASSOCIATION OF MICHIGAN

Existing Criteria

Superpave Gyratory Compactor (SGC) Compaction Criteria

		Number of Gyrations			
Estimated Traffic (million ESAL)	Mix Type	%Gmm at (Ni)	Ni	Nd	Nm
< 0.3	LVSP	91.50%	6	45	70
< 0.3	E03	91.50%	7	50	75
< 1.0	E1	90.50%	7	76	117
< 3.0	E3	90.50%	7	86	134
< 10	E10	89.00%	8	96	152
< 30	E30	89.00%	8	109	174
<100	E50	89.00%	9	126	204

Proposed Criteria

Superpave Gyratory Compactor (SGC) Compaction Criteria

		Number of Gyrations			
Estimated Traffic (million ESAL)	Mix Type	%Gmm at (Ni)	Ni	Nd	Nm
≤ 0.3	EL	≤91.5%	7	50	75
>0.3 - ≤3.0	EML	≤90.5%	7	75	115
>3.0 - ≤30.0	EMH	≤89.0%	8	100	160
>30.0 - ≤100	EH	≤89.0%	9	125	205

Table 902-6

ASPHALT PAVEMENT ASSOCIATION OF MICHIGAN

Existing Criteria

Superpave Aggregate Requirements

		Percent Crushed Minimum Criteria		Fine Aggregate Angularity Minimum Criteria		% Sand Equivalent Minimum Criteria		Los Angeles Abraision % Loss Maximum Criteria		% Soft Particles Maximum Criteria (a)		% Flat and Elongated Particles Maximum Criteria (b)	
Estimated Traffic (million ESAL)	Mix Type	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base
< 0.3	LVSP	55/-	-	-	-	40	40	45	45	10	10	-	-
< 0.3	E03	55/-	-	-	-	40	40	45	45	10	10	-	-
< 1.0	E1	65/-	-	40	-	40	40	40	45	10	10	-	-
< 3.0	E3	75/-	50/-	43	40	40	40	35	40	5	5	10	10
< 10	E10	85/80	60/-	45	40	45	45	35	40	5	5	10	10
< 30	E30	95/90	85/75	45	40	45	45	35	35	3	4.5	10	10
<100	E50	100/100	95/90	45	45	50	50	35	35	3	4.5	10	10

Proposed Criteria

Superpave Aggregate Requirements

		Minimum Criteria		Angularity Minimum		Minimum Criteria		Abraision % Loss		Maximum Criteria (a)		Particles Maximum	
Estimated Traffic (million ESAL)	Mix Type	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base
≤ 0.3	EL	55/-	-	-	-	40	40	45	45	10	10	-	-
		55/-	-	-	-	40	40	45	45	10	10	-	-
>0.3 - ≤3.0	EML	75/-	50/-	43	40	40	40	35	40	5	5	10	10
		75/-	50/-	43	40	40	40	35	40	5	5	10	10
>3.0 - ≤30.0	EMH	90/85	80/75	45	40	45	45	35	35	3	4.5	10	10
		90/85	80/75	45	40	45	45	35	35	3	4.5	10	10
>30.0 - ≤100	EH	100/100	95/90	45	45	50	50	35	35	3	4.5	10	10

(a) Soft particles maximum is the sum of the shale, siltstone, ochre, coal, clay-ironstone and particles that are structurally week or are non-durable in service.

(b) Maximum by weight with a 1 to 5 aspect ratio.

Note: "85/80" denotes that 85 percent of the coarse aggregate has one fractured face and 80 percent has at least two fractured faces.

Table 902-6

Table 902-6:
Superpave Final Aggregate Blend Physical Requirements

Est. Traffic (million ESAL)	Mix Type	Minimum Criteria						Maximum Criteria					
		% Crushed[a]		Fine Aggregate Angularity		% Sand Equivalent		LA Abrasion % Loss[b]		% Soft Particles[cb]		% Flat and Elongated Particles[dc]	
		Course(s)						Course(s)					
		Top and Leveling	Base	Top and Leveling	Base	Top and Leveling	Base	Top and Leveling	Base	Top and Leveling	Base	Top and Leveling	Base
<0.3	EL	55 / —	—	—	—	40	40	45	45	10	10	—	—
≥0.3 – <3	EML	75 / —	50 / —	43	40	40	40	35	40	5	5	10	10
≥3 – <30	EMH	90 / 85	80 / 75	45	40	45	45	35	35	3	4.5	10	10
≥30 – <100	EH	100 / 100	95 / 90	45	45	50	50	35	35	3	4.5	10	10

ESAL = equivalent single-axle load
(a) XX / YY denotes that XX% of the coarse aggregate has one fractured face and YY% has at least two fractured faces.
~~(b) If a blend of different aggregate sources, the abrasion value applies to each source.~~
(cb) Soft particles maximum is the sum of the shale, siltstone, ochre, coal, clay-ironstone, and particles that are structurally weak or non-durable in service.
(dc) Maximum by mass with a 1:5 aspect ratio.

Clarifies abrasion maximums are based on the combined blend

Local Roads

Existing Criteria

Superpave Aggregate Requirements

Estimated Traffic (million ESAL)	Mix Type	Percent Crushed Minimum Criteria		Fine Aggregate Angularity Minimum Criteria		% Sand Equivalent Minimum Criteria		Los Angeles Abraision % Loss Maximum Criteria		% Soft Particles Maximum Criteria (a)		% Flat and Elongated Particles Maximum Criteria (b)	
		Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base
< 0.3	LVSP	55/-	-	-	-	40	40	45	45	10	10	-	-
< 0.3	E03	55/-	-	-	-	40	40	45	45	10	10	-	-
< 1.0	E1	65/-	-	40	-	40	40	40	45	10	10	-	-
< 3.0	E3	75/-	50/-	43	40	40	40	35	40	5	5	10	10

Proposed Criteria

Superpave Aggregate Requirements

Estimated Traffic (million ESAL)	Mix Type	Minimum Criteria		Angularity Minimum		Minimum Criteria		Abraision % Loss		Maximum Criteria (a)		Particles Maximum	
		Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base	Top & Leveling	Base
≤ 0.3	EL	55/-	-	-	-	40	40	45	45	10	10	-	-
		55/-	-	-	-	40	40	45	45	10	10	-	-
>0.3 - ≤3.0	EML	75/-	50/-	43	40	40	40	35	40	5	5	10	10
		75/-	50/-	43	40	40	40	35	40	5	5	10	10

Concern over E1 moving to EML

Asphalt Mix Selection

Questions?

Thank You!

ASPHALT PAVEMENT ASSOCIATION OF MICHIGAN

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