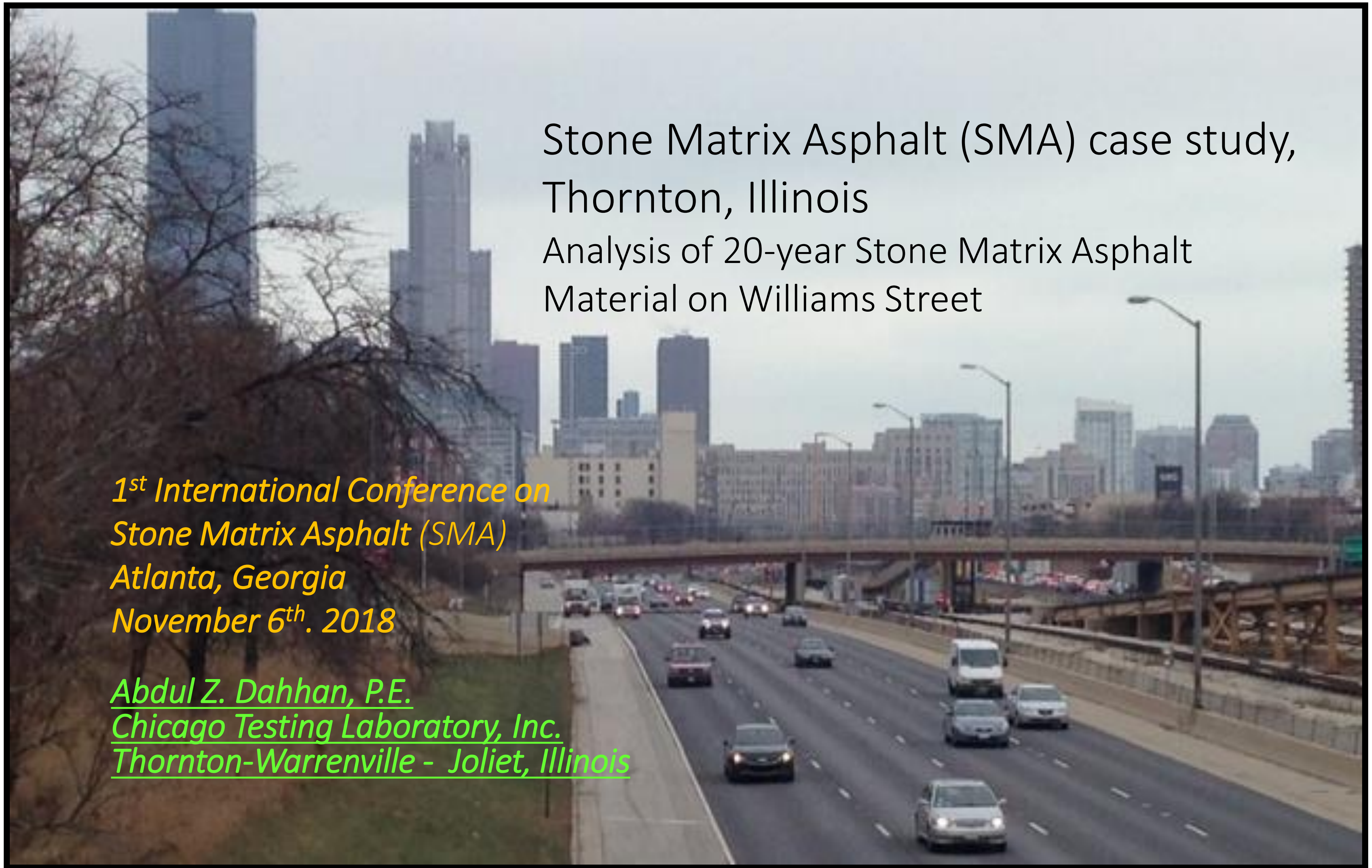

Stone Matrix Asphalt (SMA) case study, Thornton, Illinois

Analysis of 20-year Stone Matrix Asphalt Material on Williams Street

1st International Conference on Stone Matrix Asphalt (SMA)
Atlanta, Georgia
November 6th. 2018

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Acknowledgments:

Dan Gallagher, Gallagher Asphalt Corporation
George R. Houston, IDOT Region 1, District 1 Materials
Paul Yerkes, Chicago Testing Laboratory, Inc.
Ahmad El Khatib, Chicago Testing Laboratory, Inc.
Tim Murphy, Owens Corning
Jason Guerra, Owens Corning
Courtney Rice, Paving Engineer, Owens Corning
Tim Murphy, P.E. Murphy Pavement Technology
Jay Miller, formerly of Chicago Testing Laboratory, Inc.
John Yzenas, Edw. C. Levy Company
Kelly L. Cook, Supervisor, Levy Technical Laboratories

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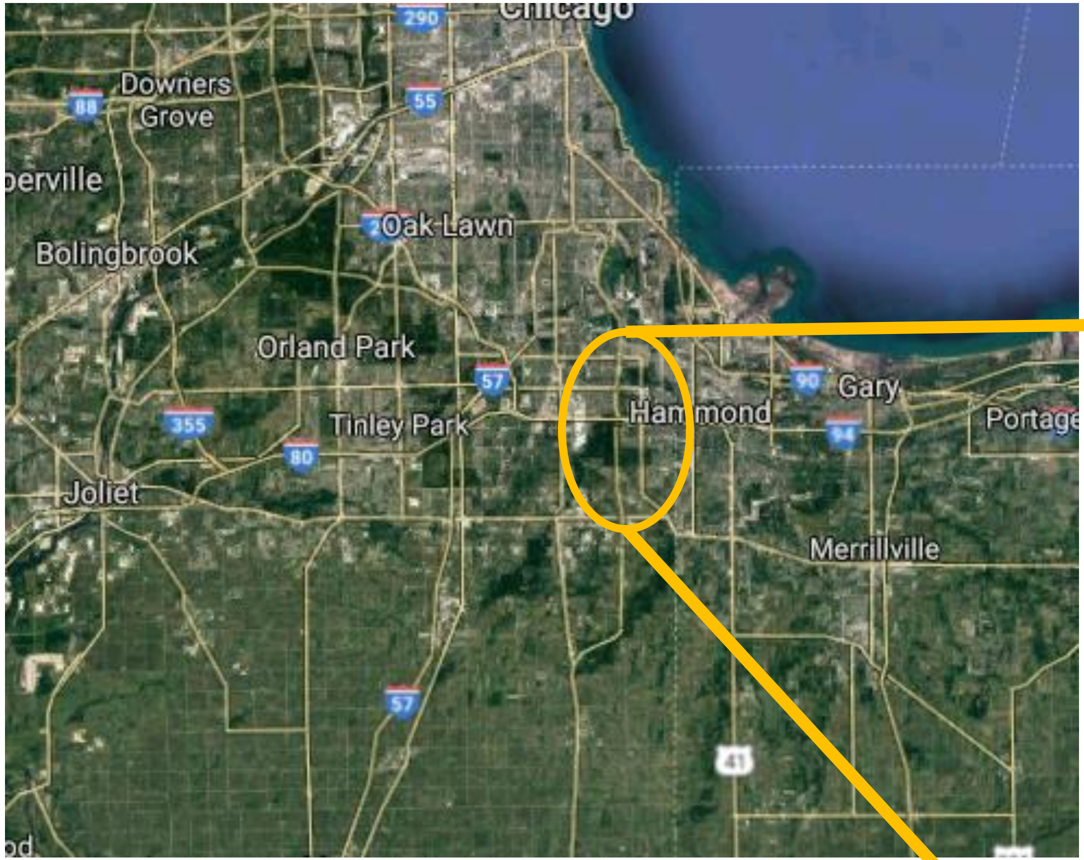

Thornton, Illinois
25 miles due south of Downtown Chicago

Located in Thornton is the "World's Toughest Intersection"
at the corner of Williams and Margaret

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Located in Thornton is the “World’s Toughest Intersection” at the corner of Williams and Margaret

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At the World's Toughest Intersection, Margaret & Williams Sts., in Thornton, Illinois,

SMA has been the mix of choice.

In 1997, the Illinois Department of Transportation scheduled this intersection and Williams St. to be resurfaced with SMA.

The original project scope called for two lifts of SMA mix.

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Analysis of lifted slabs indicated significant deformation extending to approx. 9 inches deep into the pavement.

Full Depth HMA Pavement: 1997

How the Pavement in the North Bound Lanes looked back then!

The decision was to remove the inferior plastic and deformed mix at the intersection and replace it to a depth of 11” of SMA.

Three lifts were of dolomitic aggregate SMA, and the additional top lift was 2” comprised of a steel slag aggregate as the wearing surface.

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Summary of the project QC test results in 1997:

	Target	Binder SMA	Target	Surface SMA
Gmm	2.480	2.506	2.875	2.865
Gmb	2.381	2.365	2.760	2.792
Voids (%)	4.0	5.4	4.0	2.5
Density (%)	94.0	94.3	94.0	96.2
AC (%)	5.8	5.7	5.8	5.7

Gradation (%)	Formula	Binder	Formula	Surface
12.5 mm	76	70	86	86
4.75 mm	21	19	29	31
236 mm	17	15	17	18
750 mm	7.5	7.1	7.0	6.5

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In late 2017, IDOT decided on another overlay at the intersection of William and Margaret Sts.

This offered a unique opportunity to examine the long-term health of this 20-year-old pavement. The evaluation included:

- Removal of full-depth slab of the SMA Pavement
- Coring of the full depth SMA Pavement
- AASHTO 164-14, Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)
- ASTM D7643-16, Standard Practice for Determining the Continuous Grading Temperatures and Continuous Grades for PG Graded Asphalt Binders
- AASHTO T166-16, Bulk Specific Gravity (Gmb) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
- AASHTO T209-12, Theoretical Maximum Specific Gravity (Gmm) and Density of Hot Mix Asphalt (HMA)
- AASHTO T245-15, Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus
- AASHTO T283-14, Resistance of Compacted Bituminous Mixture to Moisture-Induced Damage.
- AASHTO T324-17, Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)
- Determining the Fracture Potential of Asphalt Mixtures Using the Illinois Flexibility Index Test (I-FIT)

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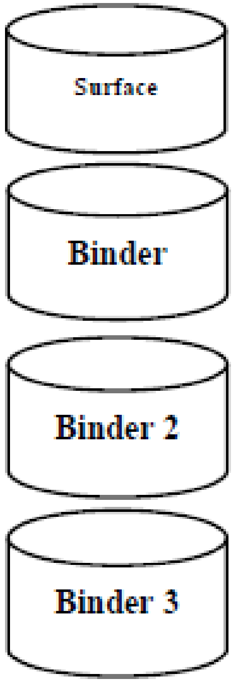
Location of coring areas in the Fall of 2017

CTL ID	Location Details
A	6-inch cores 100 feet from Williams St. and Margaret St. stop line. No significant visual rutting.
B	6-inch cores 50 feet from Williams St. and Margaret St. stop line. Some visual rutting identified.
S-1	Surface lift of 4-inch cores taken from Williams St.
B-1	Binder lift of 4-inch cores taken from Williams St.



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Summary of gradation test results indicates performance typical to that of a 12.5 mm SMA mixture.

Sieve Size		S-1 Surface Lift		B-1 Binder Lift	
		Percent Passing			
19 mm	3/4"	100	100	100	100
12.5 mm	1/2"	85	87	77	76
9.5 mm	3/8"	69	70	51	49
4.75 mm	No.4	37	36	26	26
2.36 mm	No.8	25	25	24	24
1.18 mm	No.16	20	20	20	20
0.6 mm	No.30	16	16	17	17
0.3 mm	No.50	14	13	14	14
0.15 mm	No.100	11	11	13	12
0.075 mm	No.200	8.3	8.1	9.7	9.8

Mix Lift	AC Content
A Surface Lift	5.8
A Binder Lift	5.7

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Summary of volumetric test results

CTL ID	G_{mb}	G_{mm}	Density
A Surface Lift	2.824	2.956	96%
A Binder Lift	2.421	2.533	96%
B Surface Lift	2.850	2.937	97%
B Binder Lift	2.484	2.530	98%

CTL ID	Average Unconditioned Strength	Average Conditioned Strength	Tensile Strength Ratio
S-1 Surface Lift	194.9	149.0	0.76
B-1 Binder Lift	184.5	122.6	0.66

Summary of tensile strength ratio results

Rut Depths as measured In-Place

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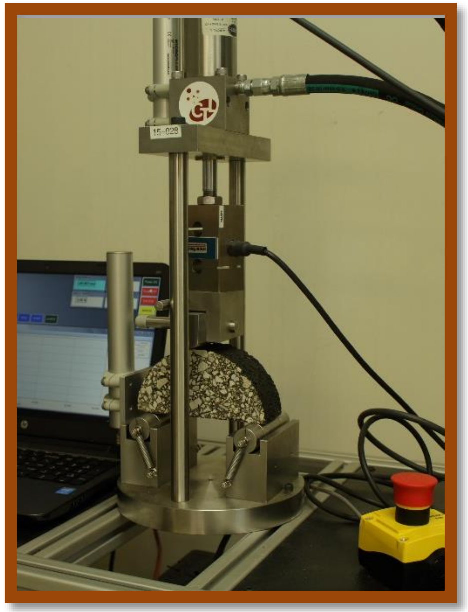
Summary of performance test results

CTL ID	Flexibility Index	Rut Depth at 10,000 Cycles	Rut Depth at 20,000 Cycles
A Surface Lift	4.4	1.76 mm	1.98 mm
A Binder Lift	12.1	1.45 mm	1.83 mm
B Surface Lift	4.6	2.50 mm	2.85 mm
B Binder Lift	18.5	1.95 mm	3.13 mm



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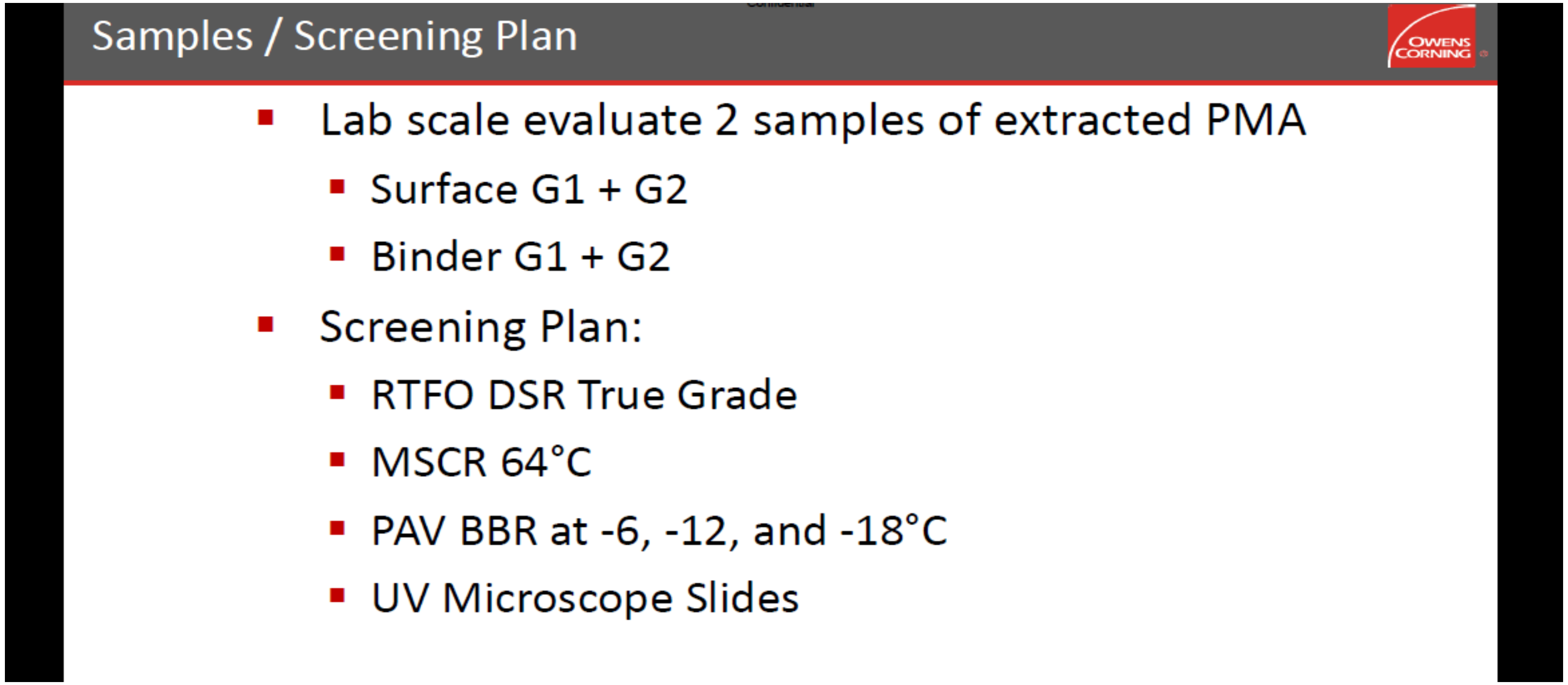
Summary of Mixtures AC content, Pen Values and AC Grading:

Mix Lift	AC Content
A Surface Lift	5.8
A Binder Lift	5.7



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Data:

Sample:	Surface G1 + G2	Binder G1 + G2		
Sample Size:	2 3-oz samples	3-oz sample		
Test:			Test:	Range:
Penetration 77°F (dmm):	28	41	ASTM D 5-13	Report
True Grade:	76.2 - 23.0	70.5 - 26.2	ASTM D 7643-16	Report
RTFO DSR 70°C (kPa, °):	4.17, 70.7	2.34, 69.5	ASTM D 7175-15	Min 2.20 kPa, Report
RTFO DSR 76°C (kPa, °):	2.21, 72.2	1.33, 70.6	ASTM D 7175-15	Min 2.20 kPa, Report
RTFO DSR 82°C (kPa, °):	1.21, 74.0	0.80, 72.0	ASTM D 7175-15	Min 2.20 kPa, Report
RTFO True Grade (°C):	76.2	70.5	ASTM D 7643-16	Report
MSCR 64°C, $R_{0.1}$ - Average % Recovery at 0.1 kPa:	58.36	69.55	ASTM D 7405-15	Report
MSCR 64°C, $R_{3.2}$ - Average % Recovery at 3.2 kPa:	45.89	56.86	ASTM D 7405-15	Report
MSCR 64°C, R_{diff} - % difference recovery 0.1 and 3.2:	21.37	18.24	ASTM D 7405-15	Report
MSCR 64°C, $J_{nr\,0.1}$ - Non-recoverable creep 0.1:	0.326	0.390	ASTM D 7405-15	Report
MSCR 64°C, $J_{nr\,3.2}$ - Non-recoverable creep 3.2:	0.442	0.576	ASTM D 7405-15	Report
MSCR 64°C, Jnr diff - % difference non-recoverable 0.1 and 3.2:	35.57	47.82	ASTM D 7405-15	Report
PAV BBR -6°C .m slope:	0.354	0.390	ASTM D 6648-08	Min 0.300
PAV BBR -6°C 'MPa Stiffness :	82	63	ASTM D 6648-08	Max 300
PAV BBR -12°C .m slope:	0.310	0.335	ASTM D 6648-08	Min 0.300
PAV BBR -12°C 'MPa Stiffness :	177	142	ASTM D 6648-08	Max 300
PAV BBR -18°C .m slope:	0.262	0.284	ASTM D 6648-08	Min 0.300
PAV BBR -18°C 'MPa Stiffness :	333	289	ASTM D 6648-08	Max 300
PAV BBR True Grade .m slope:	-23.0	-26.2	ASTM 7643-16	Report
PAV BBR True Grade 'MPa Stiffness :	-27.1	-28.3	ASTM 7643-16	Report
ΔT_c:	-4.1	-2.1		Report

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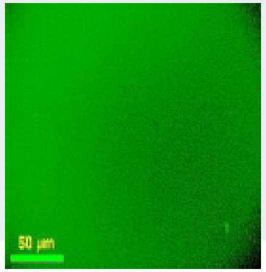
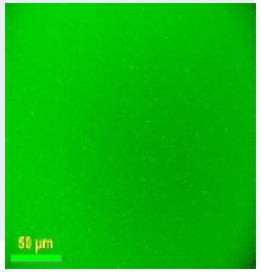
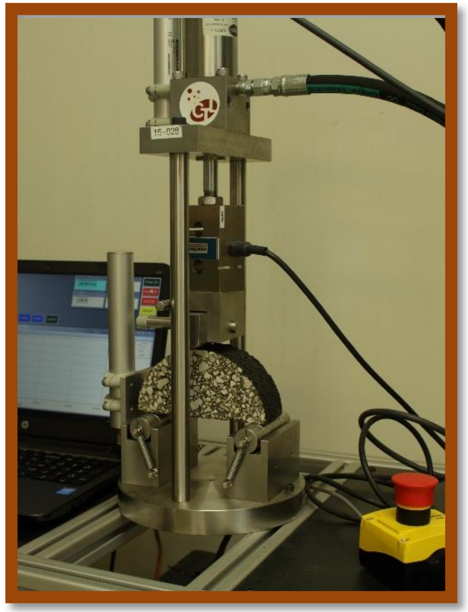
Key Findings:

- Surface sample was significantly harder and less elastic than the binder sample
- Both samples show evidence of PMA structure based on DSR phase angle, MSCR % recovery, and UV microscope

	Surface G1 + G2	Binder G1 + G2
Penetration 77°F (dmm):	28	41
True Grade:	76.2 - 23.0	70.5 - 26.2
RTFO DSR 70°C (kPa, °):	4.17, 70.7	2.34, 69.5
RTFO DSR 76°C (kPa, °):	2.21, 72.2	1.33, 70.6
MSCR 64°C, Jnr diff - % difference non-recoverable 0.1 and 3.2:	35.57	47.82
PAV BBR -12°C .m slope:	0.310	0.335
PAV BBR -12°C 'MPa Stiffness :	177	142
ΔT_c:	-4.1	-2.1
UV Microscope:		

Observations



The Flexibility Index showed that the SMA Binder course provided a better flexibility index than the SMA Surface course.

Rut Depth String Line, Williams St. Intersection

Additional rutting during the Hamburg wheel analysis showed that the in-place mixture was not expected to have significant additional deformation.

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Observations, cont.

Surface SMA asphalt binder was oxidized more than the binder lift of SMA as shown by the lower penetration values and higher Performance Grade(s).

The Polymer modification remained effective, and the PG grade was consistent with a 70-28 polymer modified material and showed marginal degradation of the low temperature grade after 20 years of pavement service life.

Degradation of the aggregate structure was observed, likely from the compaction/loading that occurred during production and/or from the loading over the 20 year period, albeit a minimal amount.

The steel slag in the surface SMA did not degrade over time and was still consistent with the steel slag aggregate material specified as measured chemically. The steel slag material was as 84% metallic and 27% ferrous oxide (FeO).

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CONCLUSIONS

Several factors contributed to the ultimate success of this SMA pavement:

- Density during production was above 94%. Little to no additional compaction was possible even with the degree of heavy loading throughout the lifecycle of the SMA.
- The stone matrix design, with stone on stone contact, also resulted in a high stability pavement which resists rutting of the mixture after initial compaction, as proven by the low Hamburg results of 2.5 (Surface SMA) an 2.5 (binder SMA) shown after 20 years.
- The stone matrix design remained durable due to high film thickness and high polymer content that remained effective over the pavement life. These properties allowed for a high durability pavement, as validated by the I-FIT results of 4.5 (Surface SMA) and 15.3 (Binder SMA) in the 20-year-old pavement cores.
- Selection of proper ingredient materials, including slag aggregate for friction wearing course; sound, clean dolomitic stone for the binder course; and polymer modified asphalt cement contributed, alongside proper mixture design, production controls and sound paving practices, all contributed to the success of the SMA.

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Summary:

Use of SMA, including full-depth perpetual SMA, is recommended in any high loading condition pavement where long term rut resistance and durability are desired.

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Summary:

IDOT's decision to use full-depth SMA at the intersection has proven successful. The original SMA binder lifts, will remain in place as a perpetual pavement intersection, now with a new polymer 4.75 mm leveling course and two inches of new surface SMA.

Material selection, mix design, construction techniques, and the extra effort put forth by Gallagher Asphalt played a significant role in the success of this Stone Matrix Asphalt Pavement.

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Thank you! Questions?

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