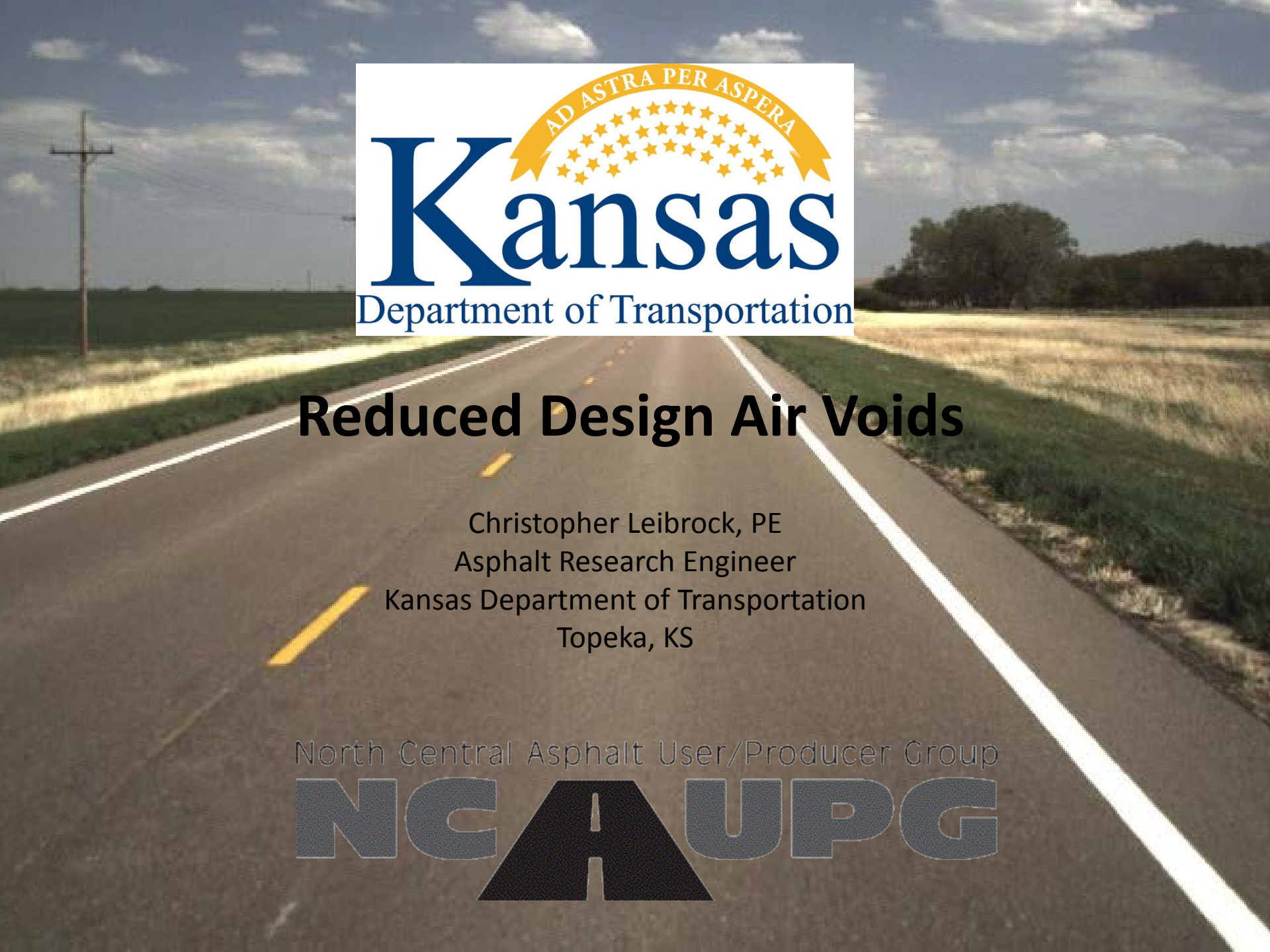


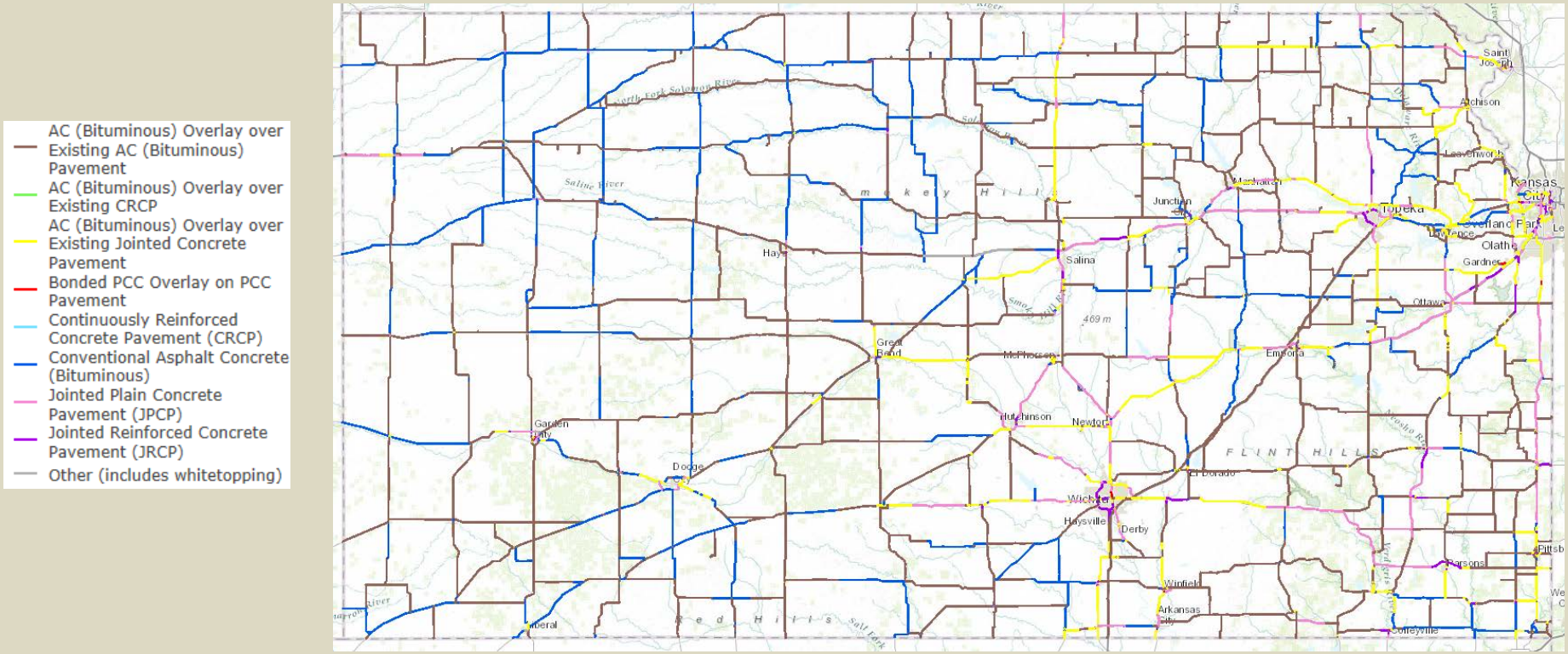
Reduced Design Air Voids

Christopher Leibrock, PE
Asphalt Research Engineer
Kansas Department of Transportation
Topeka, KS

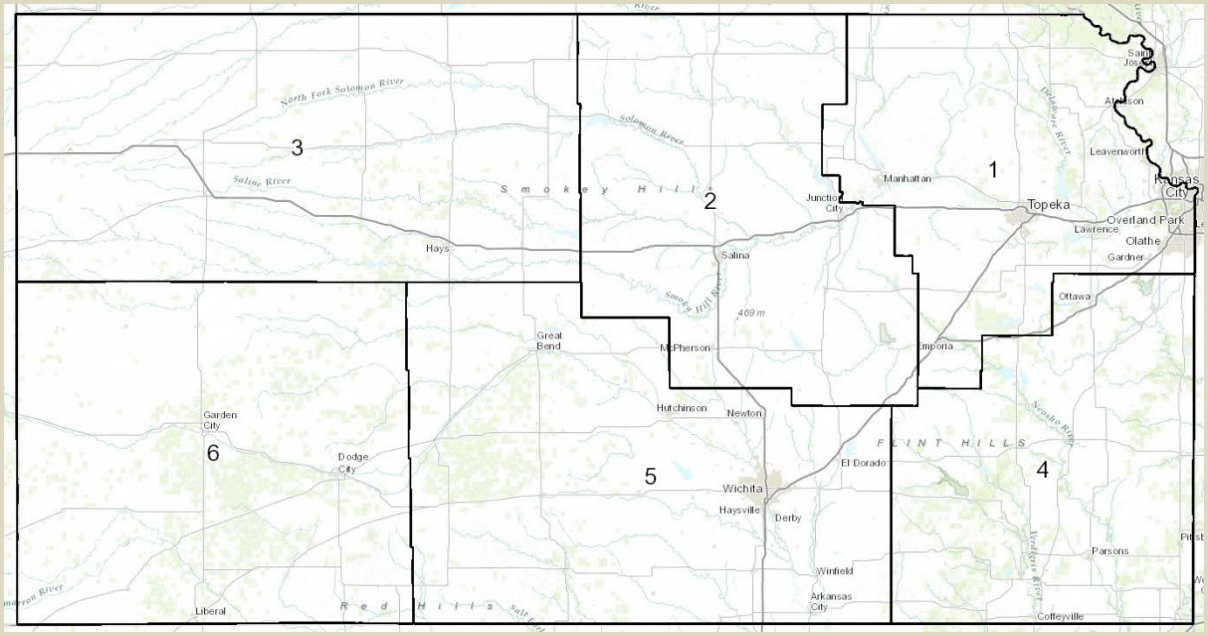
North Central Asphalt User/Producer Group
NCAUPG

Asphalt at Kansas DOT

- AC binders & Marshall prior to SHRP
- Issued Notice: Fiscal year 1997 – all mixes contain PG binders
- October 29, 1996: Technical Advisory (PG into Spec.)
- Only Virgin mixes until 2007 when RAP was reintroduced
- Now: RAP, RAS, WMA, Rejuvenators all potentially in a mix



KDOT Asphalt Specifications



- Binder is not a separate pay item, mix paid by ton
- KDOT no longer develops mix designs
- Contractors develop mix design to meet KDOT specifications
- District Engineers approve the mix design
- Mix designs are verified at District Laboratories
- Preapproval on aggregate sources, Specific Gravities published
- RAP is sourced from DOT only and processed according to spec

So, where are we now?

Change the Volumetric Properties

- Idea driven by CO DOT's work in the 1990's

Concept:

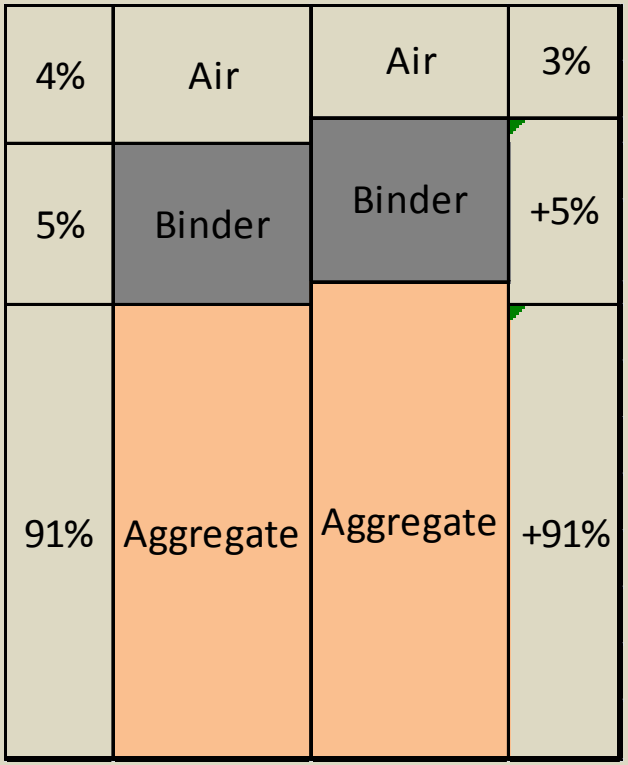
- Either Air Voids or Design Revolutions would change
- Overall goal is to get more binder in the mix

Lower Revolutions:

- Goal is to improve durability
- Reduce permeability
- D/B to limit dust
- Always on the border of spec's

Reduced Air Voids:

- Similar concept to low rev's
- Bump Nini +0.5 (≤ 91.5 at 7 gyrations)
- Increased density in field
- Hamburg requirement (10,000 @ 12.5mm)



What Kansas DOT Tried (…and is still working on)

First project in 2007, D3, not much changed

- Ndes = 75
- Nini ≤ 91.0 @ 7 gyr
- Va = 3.5%

Next project in 2009, lower Ndes, all borderline on specs.

- Ndes = 60
- Nini ≤ 91.0 @ 7 gyr
- Va = 3.5%

In 2010, the 3.0% air void projects began

KDOT has put down roughly 70 3% air void projects throughout the state, except District 2

A typical 3% mix:

- 3.0% design air voids
- Nini ≤ 91.5 @ 7 gyrations
- Ndes = 75 gyrations
- RAP limit at 25% or blending chart
- Hamburg *(10,000 @ 12.5mm)*
- *Cold mill, inlay/overlay*

- District 3 is the lead, rarely “standard” pavement
- Districts are taking to the method differently
- Some Districts have pushed ahead with more projects
- Still no project in District 2

Special Provision Issued for Project

- Av required at Ndes
- Nini, Ndes, Nmax set
- Tighten Av Single Test Value
- Adjust Av pay adjustments
- Hamburg requirement
- RAP requirements
- Otherwise, typical design sheet

Blending Chart or Given Range

Use the material milled from the project as the RAP source. Utilizing the RAP information below develop a blending chart using the KDOT supplied blending chart spreadsheet. Provide a HMA mix that results in the low side of the PG binder grading colder than -23°C. If no RAP is used then a PG64-22 binder may be used.

TABLE 2: RAP INFORMATION FOR BLENDING CHART

RAP Sample Location	RAP PG High Grade	RAP PG Low Grade	% AC
106 KA-4083-01	83°C	-7°C	6.9

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION TO THE
STANDARD SPECIFICATIONS, EDITION 2007

SECTION 602

MODIFIED REQUIREMENTS – ASPHALT MIXTURES

Project Number: 16-75 KA-3714-01

The asphalt mix listed in **TABLE 1** has the following project mix requirements. [Reference **TABLE 602-1**, COMBINED AGGREGATE REQUIREMENTS].

Page 600-6, TABLE 602-1, delete note 4 and replace with the following:
4. The target air voids (V_a) for any mix designation shall be 3.0% at N_{des} gyrations.

Page 600-6, TABLE 602-1, delete note 6 and replace with the following:
6. The level of compaction of the mix when compacted to N_{ini} gyrations shall be less than the percent of the G_{mm} shown in the Contract Special Provision, and when compacted to N_{max} gyrations shall be a maximum of 98.5% of the G_{mm}.

Page 600-14, TABLE 602-12, change the Single Test Value for Air Voids @ N_{des} gyrations to ± 1.0%.

Page 600-23, 602.9d(1), change the upper specification limit, USL, for V_a to 4.00% and the lower specification limit, LSL, for V_a to 2.00%.

Page 600-23, TABLE 602-16, change the Upper Specification Limit, USL, to 4.50% and change the Lower Specification Limit, LSL, to 1.50%

TABLE 1: PROJECT MIX REQUIREMENTS

MIX CRITERIA	SR-12.5A (PG64-22)[1]
AGGREGATE:	
Coarse Angularity (min.%)	75
Uncompacted Voids-Fine (min. %)	42
Sand Equivalent (min. %)	40
Reclaimed Asphalt Pavement (RAP) (max. %)	25
RAP Bulk Specific Gravity	2.521
COMPACTION REVOLUTIONS:	
N_{ini} (level of compaction)	7 (≤91.0)
N_{des}	75
N_{max}	115
MIX:	
VFA	65 - 82
Hamburg Wheel Test Requirements (Minimum # of Passes @ 12.5 mm Rut Depth)	10,000[2]

(1) Between 0 and 25% RAP may be used. Use the material milled from the project as the RAP source. The required binder and name shown below are based on the percent RAP used in the contract. The mix will be paid for at the bid price of SR-12.5A (PG64-22).

Percent RAP	Name
0	SM-12.5A (PG64-22)
1 - 15	SR-12.5A (PG64-22)
16 - 25	SR-12.5A (PG58-28)

(2) Include the Hamburg Wheel Test results when submitting the Job Mix Formula to the District Materials Engineer for review and approval. The Hamburg Wheel Test will be completed by Kansas State University.

For information only, the 20 year design lane traffic is 0.8 million ESALs.
11/10/14 C&M (BTH)

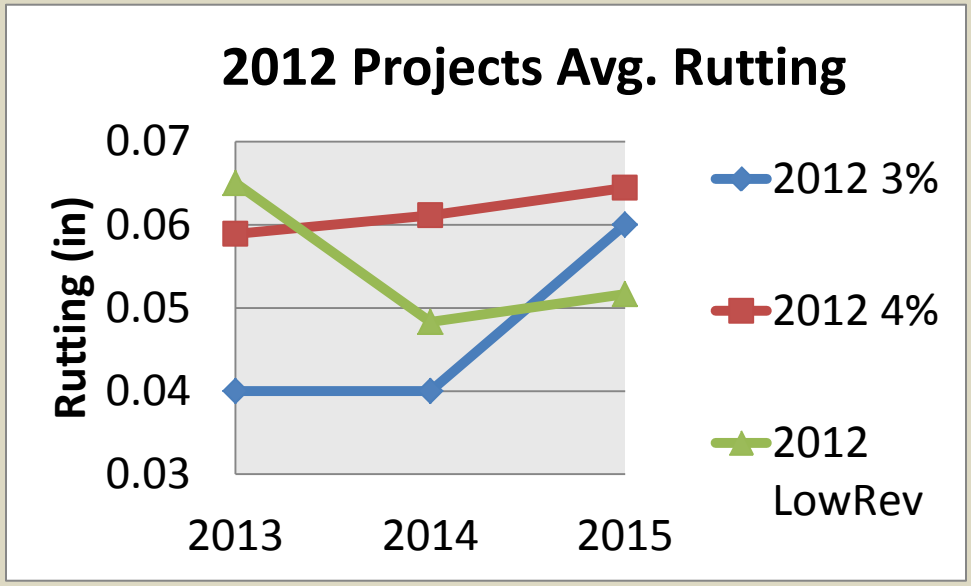
So, did we get more binder?

Yes and no.

- District Dependent on quantity increase
- Aggregate source driving contents (East vs. West)
- Limited amount of projects from Districts (other than D3)
- Need to determine RAP amounts, aggregate differences

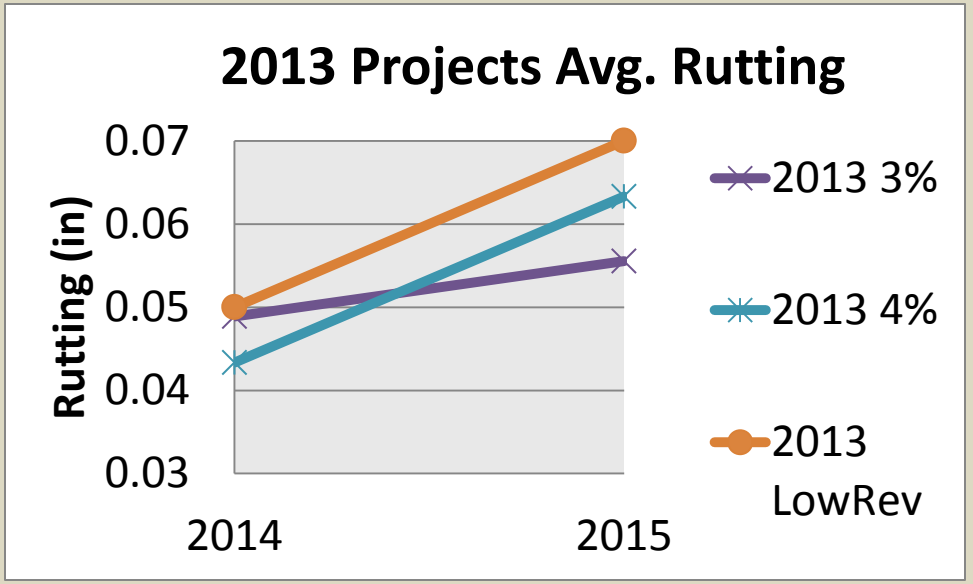
DIST	Mix	Air Voids		% Binder		No. of Prjs
		Avg	Stdev	Avg	Stdev	
1	3%	3.43	0.63	5.77	0.18	3
	4%	4.10	0.62	5.21	0.19	2
	diff	-0.67	0.01	0.56	-0.01	
2	4%	3.77	0.63	5.49	0.18	2
3	3%	3.38	0.78	5.08	0.19	25
	4%	4.34	0.69	4.79	0.25	17
	diff	-0.96	0.10	0.29	-0.06	
4	3%	3.60	0.54	6.16	0.19	4
	4%	3.43	0.68	5.42	0.52	1
	diff	0.18	-0.14	0.73	-0.33	
5	3%	3.16	0.59	5.26	0.22	1
	4%	4.21	0.66	5.29	0.29	7
	diff	-1.05	-0.08	-0.04	-0.06	
6	3%	3.14	0.59	5.16	0.18	1
	4%	3.96	0.62	5.03	0.21	4
	diff	-0.83	-0.04	0.13	-0.04	

Performance - Rutting

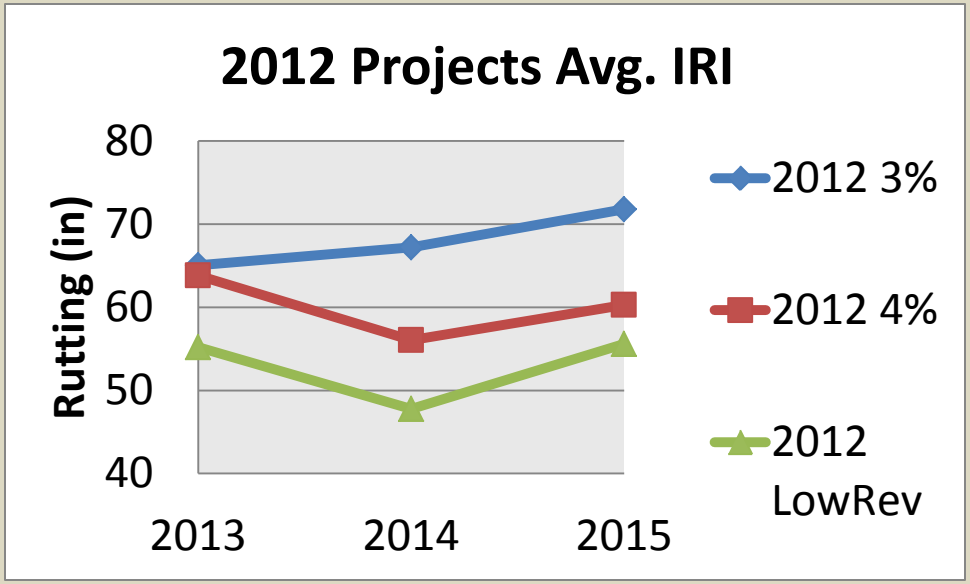


- Still a little early to really know
- At least equivalent performance
- Minimal rutting so far

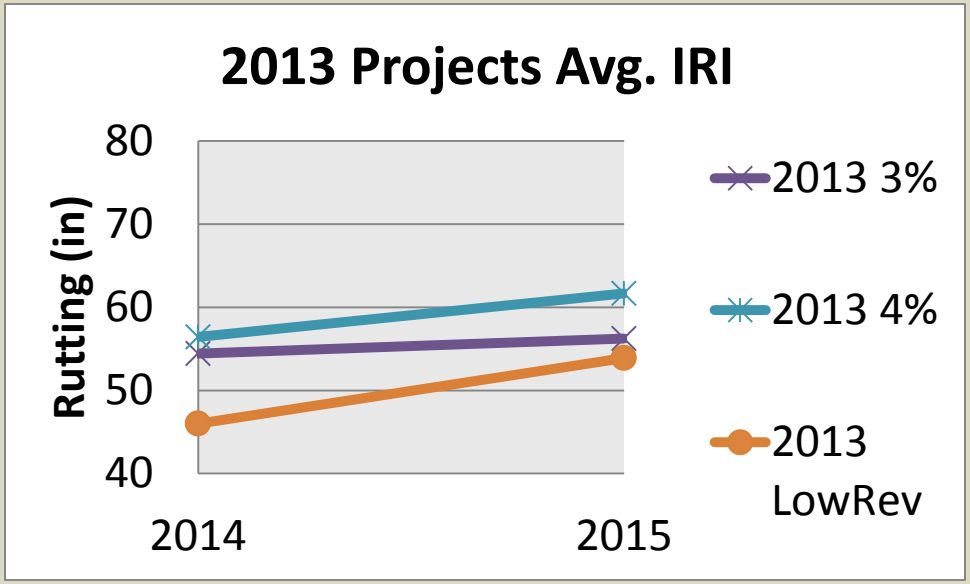
- Minimal rutting seen
- Rate not consistent, better in 2013 than 2012



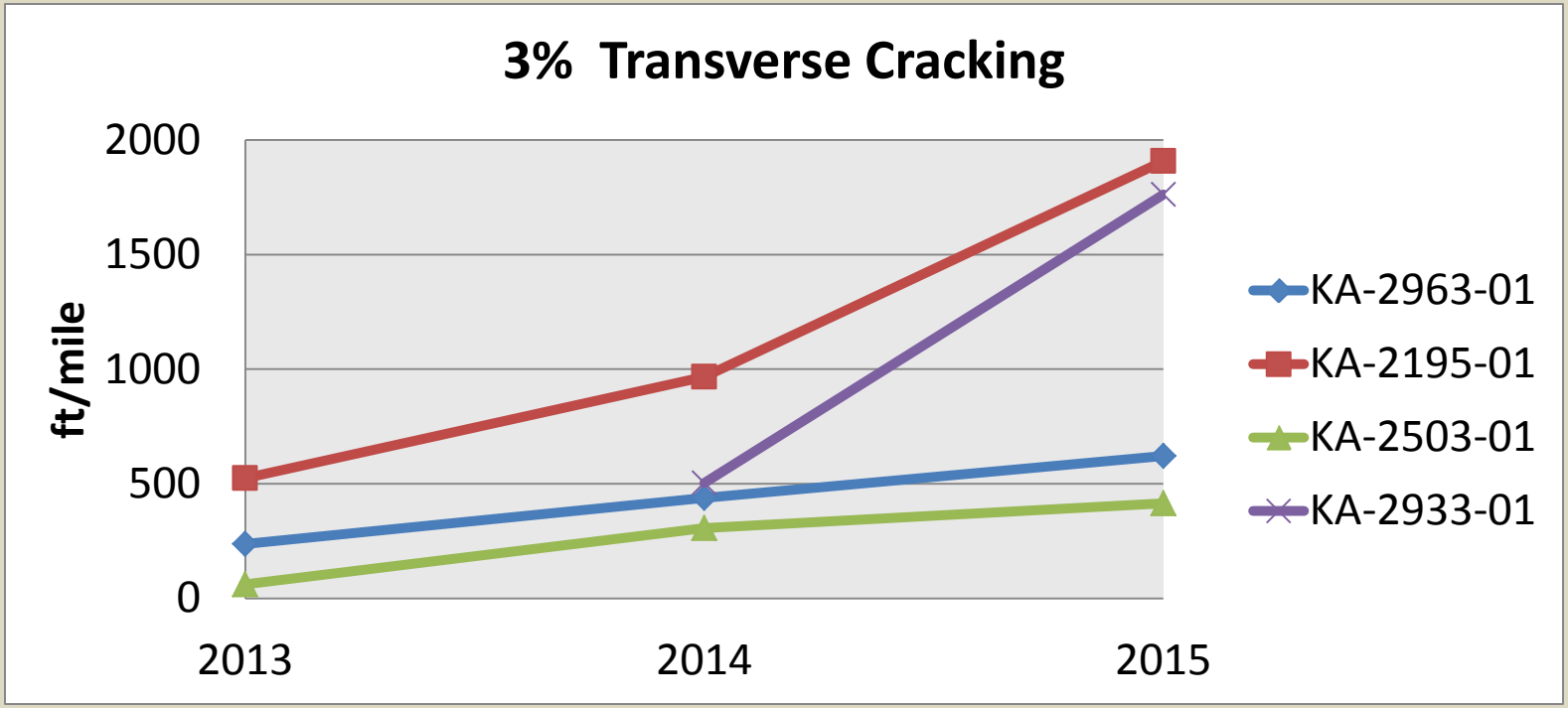
Performance – Ride Quality



- Still a little early to really know
- At least equivalent performance



Performance – Cracking



- Looking acceptable so far
- Still not solving thermal/reflective cracking
- Equivalent to standard mixes

Pay Factors for Air and Density

	3%	4%
Air Avg	0.024	0.021
Stdev	0.017	0.023
Dens Avg	0.035	0.021
Stdev	0.012	0.016

- Appears air and density is being met
- Pay factors appear to be higher for the 3% jobs
- Deviation appears tighter on the 3% jobs

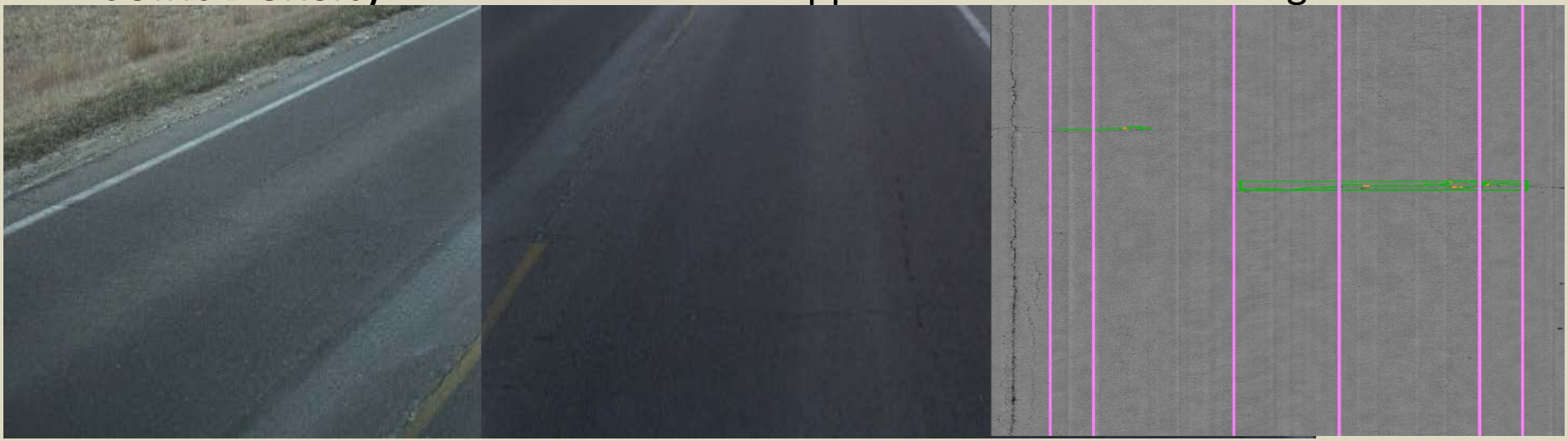
Further Analysis Needed:

Are the bids changing because of different requirements?
Are pay factors driving the bid any differently?

Other Items

Joint Density

- Doesn't appear to be common or regular

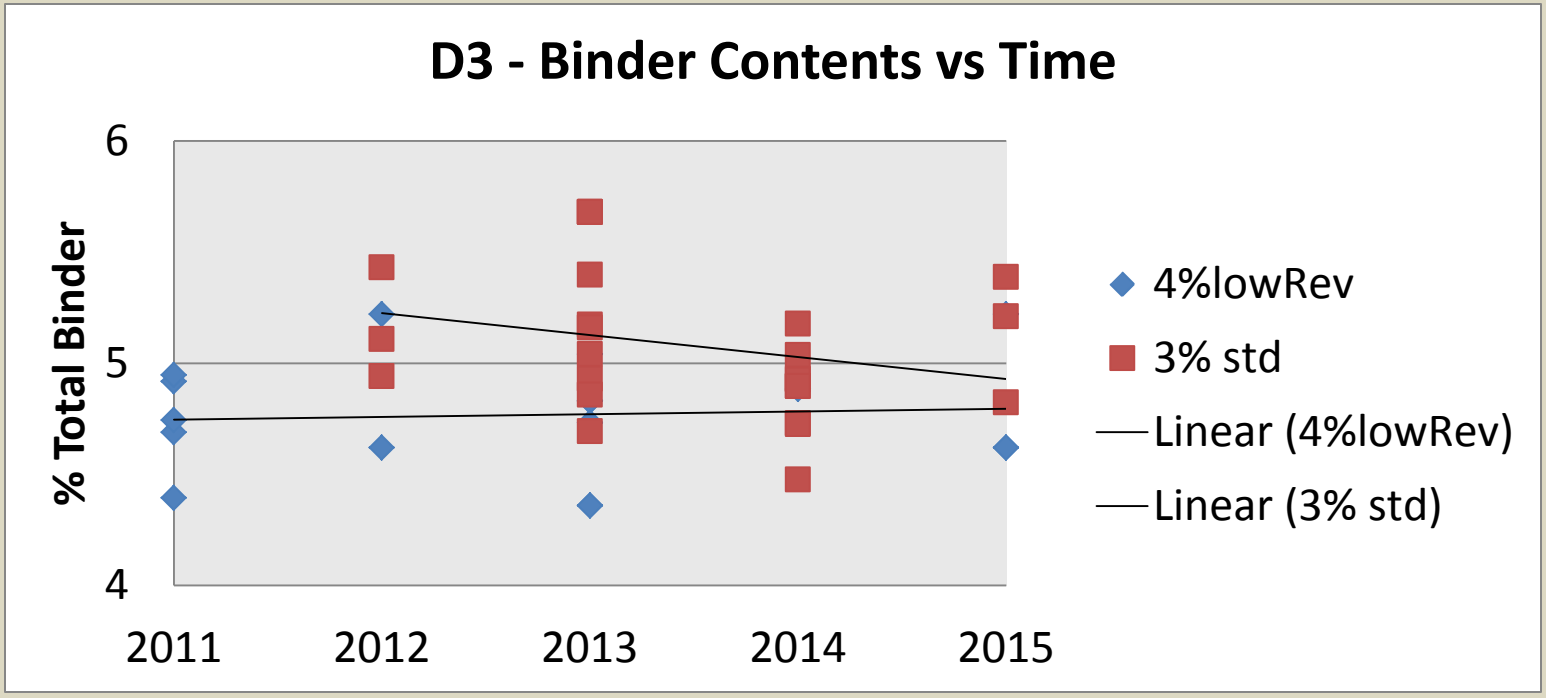


Shoulder Deterioration

- Cracking stops at mainline

Conclusions

- Increases binder content, but is it enough?
- Performance appears adequate, time will tell
- Mix can still be “tweaked” to cut binder and increase aggregate



Many people helped to bring these projects to see the light of day. As well, many people assisted in gathering the data for this presentation. The following are recognized:

- Jeff Stewart, District Engineer, District 3
- Rick Kreider, Bureau Chief, Materials & Research
- Travis Scott, Dist. Const. & Materials Eng., District 3
- Blair Heptig, Field Engineer, Const. & Mat.
- Scott Ashwill, CMS Materials Coordinator
- Alan Vitt, CMS Applications Developer
- Zandra Myrick, Management Analyst
- Rick Miller, Pavement Management Engineer
- Cliff Hobson, Adv. Technology Research Engineer

Thank you.

KDOT Specifications

TABLE 602-1: COMBINED AGGREGATE REQUIREMENTS

Nom. Max. Size Mix Designation	Percent Retained – Square Mesh Sieves									Min. VMA (%)	D/B Ratio
	1½"	1"	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 200		
SM-4.75A				0	0-5	0-10		40-70	88.0-94.0	16.0	0.9 – 2.0
SR-4.75A			0	0-2	0-5	0-10		40-70	88.0-94.0	16.0	0.9 – 2.0
SM-9.5A				0	0-10	10 min.	33-53		90.0-98.0	15.0	0.6 – 1.2
SR-9.5A			0	0-2	0-10	10 min.	33-53		90.0-98.0	15.0	0.6 – 1.2
SM-9.5B				0	0-10	10 min.	53-68		90.0-98.0	15.0	0.8 – 1.6
SR-9.5B			0	0-2	0-10	10 min.	53-68		90.0-98.0	15.0	0.8 – 1.6
SM-9.5T				0	0-10	10 min.	53-68		90.0-98.0	15.0	0.8 – 1.6
SR-9.5T			0	0-2	0-10	10 min.	53-68		90.0-98.0	15.0	0.8 – 1.6
SM-12.5A			0	0-10	10 min.		42-61		90.0-98.0	14.0	0.6 – 1.2
SR-12.5A		0	0-2	0-10	10 min.		42-61		90.0-98.0	14.0	0.6 – 1.2
SM-12.5B			0	0-10	10 min.		61-72		90.0-98.0	14.0	0.8 – 1.6
SR-12.5B		0	0-2	0-10	10 min.		61-72		90.0-98.0	14.0	0.8 – 1.6
SM-19A		0	0-10	10 min.			51-65		92.0-98.0	13.0	0.6 – 1.2
SR-19A	0	0-2	0-10	10 min.			51-65		92.0-98.0	13.0	0.6 – 1.2
SM-19B		0	0-10	10 min.			65-77		92.0-98.0	13.0	0.8 – 1.6
SR-19B	0	0-2	0-10	10 min.			65-77		92.0-98.0	13.0	0.8 – 1.6

1. The requirements for Coarse Aggregate Angularity (CAA); Fine Aggregate Angularity (FAA); Sand Equivalent (SE); Gyratory compaction revolutions N_{ini}, N_{des}, N_{max}, N_{ini} level of compaction and VFA shall be as shown in the Contract Special Provisions for each mix designation.
2. The flat and elongated particles in the combined coarse aggregate shall not exceed 10% for the total sample.
3. The maximum percent moisture in the final mixture shall not exceed 0.5 for any mix designation.
4. The target air voids (V_a) for any mix designation shall be 4.0% at N_{des} gyrations.
5. The minimum tensile strength ratio (%TSR) shall be 80% for any mix designation.
6. The level of compaction of the mix when compacted to N_{ini} gyrations shall be less than the percent of the G_{mm} shown in the Contract Special Provision, and when compacted to N_{max} gyrations shall be a maximum of 98.0% of the G_{mm}.

Typical Project:

Target: 4% design air voids

SUPERPAVE GYRATORY COMPACTION EFFORTS

DESIGN ESALs (millions)	TRAVELWAY		
	N_{ini}	N_{des}	N_{max}
<0.3	6	50	75
0.3 to <3	7	75	115
3 to <30	8	100	160
≥30	9	125	205
	SHOULDER		
A*	6	50	75
B*	**	**	**

*At the contractor's option A or B may be used.
**Use traveled way design traffic properties for B.

Air Voids = Calculate from Gmm and Gmb, Run at the Pbr

TABLE 602-2: MIX PROPERTIES

Property	Abbreviation	Test Method	Additional Information
Air Voids	V_a	KT-15 & KT-58	Calculated from G_{mm} and G_{mb}. Run at the P_{br}.
Recommended Percent Asphalt	P_{br}		Produce a mix with a V_a of 3.5% to 4.5%.
Theoretical Maximum Specific Gravity	G_{mm}	KT-39	Rice Test.
Percent Tensile Strength Ratio	%TSR	KT-56	Run test at P_{br} or at 0.3% to 0.5% less than P_{br}
Sand Equivalent	SE	KT-55	
Bulk Specific Gravity of HMA	G_{mb}	KT-15	Compacted Mix Property.
Percent G_{mm} at N_{ini} and N_{des} and N_{max}	$\%G_{mm}$ @ N_{ini} $\%G_{mm}$ @ N_{des} $\%G_{mm}$ @ N_{max}	KT-15	Use G_{mm} value from KT-39. Calculated from Gyratory Compaction height data, G_{mm}, and G_{mb}.
Voids in Mineral Aggregate	VMA	KT-15 & KT-6	Calculated from G_{mb}, G_{sb}, P_b.
Voids Filled with Asphalt	VFA		Calculated from VMA and V_a @ N_{des}.
Coarse Aggregate Angularity	CAA	KT-31	
Fine Aggregate Angularity	FAA	KT-50	

Formulas for calculations are in the Superpave Volumetric Mixture Design and Analysis Handbook.

Required Submittals

TABLE 602-3: MATERIAL SUBMITTALS

Submittal	Quantity	Description	Additional Information
Aggregate for KT-15	2 Samples	Sized for 6 inch Plugs	Comply with Job Mix Gradation
Aggregate			
Binder for			
Binder for			
Each Aggr			
Uncompac			
Gyratory F			

April 2016 LETTING

PROCEDURE I SPECIFIC GRAVITIES

Producer	CMS ID Producer	Legal Description	Location	Products	Bulk Dry (Gsb)	Saturated Surf Dry	Apparent	Percent Absorp	Date Modified or Verified	Chat or SSG	Latitude	Longitude
Allied Inc	811604	S25 T15S R19W	Ellis Co		2.579	2.609	2.658	1.2	November 1, 2015	s		
Alsop	811105	S27 T05S R03W	Cloud Co.		2.538	2.563	2.603	1.0	July 1, 2015	s		
Alsop	811107	S27 T13S R01E	Dickinson Co.		2.556	2.611	2.705	2.2	December 1, 2013	s		
Alsop	811114	S05 T04S R04W	Republic Co.		2.518	2.559	2.627	1.7	November 1, 2015	s	39.73909	97.78814
Anchor Stone (WRSW)	836402	S34 T28N R32W	Jasper Co. MO	3/4"	2.532	2.584	2.672	2.1	February 1, 2016		37.10327	94.40710
APAC (FRLYARG)	804008	S07 T16S R25E	Miami Co	-1/2, -3/4	2.471	2.552	2.688	3.3	January 1, 2015			
APAC (FRLYARG)	804008	S07 T16S R25E	Miami Co	-5/16	2.402	2.515	2.709	4.7	January 1, 2015			
APAC Central (DEWY)	809101	S25 T27N R13E	Washington Co. OK	-3/4"	2.644	2.680	2.710	1.3	September 1, 2014		36.80405	95.86936
APAC Kansas	810903	S05 T27S R24W	Ford Co.		2.578	2.602	2.641	0.9	September 1, 2013	s		
APAC Kansas	826003	S14 T12S R08W	Lincoln Co.	CS-1	2.604	2.630	2.674	1.0	March 1, 2016			
APAC Kansas (CPCK)	803705	S10 T14S R23E	Johnson Co.	-3/4", -5/15"	2.532	2.599	2.716	2.7	July 1, 2015		38.85231	94.84701
APAC Kansas (CPCK)	803903	S16 T14S R23E	Johnson Co.		2.575	2.627	2.717	2.0	October 1, 2014		38.83518	94.86701
APAC Kansas (STNR Ledge)	803705	S10 T14S R23E	Johnson Co.	-3/4"	2.574	2.626	2.715	2.0	October 1, 2014		38.85297	94.84856
APAC Kansas (STNR)	803903	S16 T14S R23E	Johnson Co.		2.570	2.621	2.704	2.0	October 1, 2015		38.83191	94.86777
APAC-Shears	801934	S21 T23S R05W	Reno Co.		2.560	2.583	2.633	0.9	August 1, 2015	s		
APAC-Shears (HRFD)	801935	S02 T21S R13E	Coffey Co.	-3/4"	2.566	2.621	2.713	2.1	May 1, 2015			
Associated	819904	S12 T30S R01E	Sumner County		2.557	2.581	2.621	0.9	September 1, 2013	s		
Associated	819905	S14 T26S R01W	Sedgwick County		2.554	2.578	2.618	1.0	January 1, 2016	s		
Bayer Const Co.	801830	S08 T13S R05E	Geary Co.		2.546	2.611	2.715	2.4	November 1, 2015			
Bayer Const. Co. (TRKO)	802449	S03 T11S R09E	Riley Co.		2.515	2.584	2.703	2.8	November 1, 2015			
Beyer Crushed Rock Co (BFLS)	806901	S26 T45N R33W	Cass Co. MO		2.573	2.619	2.697	1.8	June 1, 2015		38.69476	94.55173
Bingham (Sooner Pile)	821812	S16 T29N R23E	Ottawa Co. OK		2.525	2.572	2.648	1.8	November 1, 2014	c	36.99744	94.82679
Bladen Sand	823802	S014 T02N R16W	Franklin Co. NE		2.581	2.597	2.619	0.6	February 1, 2015	s		
Blue River Sand	805404	S25 T04S R06E	Marshall Co.		2.559	2.584	2.624	1.0	November 1, 2014	s		
Carder	823503	S30 T22S R44W	Prowers Co. CO	SSG, CG	2.585	2.610	2.651	1.0	June 1, 2015	s		
Carder	823513	S19 T24S R39W	Hamilton CO		2.553	2.587	2.643	1.3	June 1, 2011	s	38.03351	102.03022
Carthage Crushed	848001	S29 T29N R31W	Jasper Co. MO		2.636	2.660	2.699	0.9	October 1, 2015		37.20735	94.32763
Concrete Enterprise	813403	S04 T28S R13W	Pratt Co.		2.559	2.590	2.641	1.2	May 1, 2013	s		
Cornejo & Sons	819304	S02 T27S R01W	Sedgewick Co.		2.533	2.561	2.605	1.1	June 1, 2015	s		
Cornejo & Sons	838202	S06 T32S R03E	Cowley Co.		2.562	2.586	2.625	0.9	April 1, 2012	s		
Cornejo Mtls	820103	S23 T26S R01W	Sedgewick Co.	SSG	2.545	2.572	2.617	1.1	May 1, 2015	s		
Cornejo Mtls	820104	S34 T28S R01E	Sedgewick Co.	SSG	2.551	2.580	2.626	1.1	October 1, 2012	s		
Cornejo Mtls	820105	S14 T31S R10E	Elk Co.	CS1A, CS1	2.482	2.563	2.700	3.2	November 1, 2015			
Crossfire Aggregates	847901	S28 T22S R46W	Prowers Co. CO		2.569	2.596	2.641	1.1	November 1, 2014	s	38.10196	102.58315
Dartmouth Sand	810401	S33 T19S R12W	Barton Co.		2.564	2.589	2.628	0.9	August 1, 2012	s		
Deweese	825001	S17 T01N R07W	Nuckolls Co. NE	SSG	2.576	2.594	2.623	0.7	November 1, 2015	s		
Dodge City Sand	813102	S32 T26S R25W	Ford Co.		2.550	2.580	2.630	1.0	April 1, 2016	s		
Dolese	809001	S36 T04N R12W	Comanche Co. OK		2.665	2.685	2.718	0.8	February 1, 2016		34.77073	98.40528
Dolese	809002	S08 T01S R01E	Davis Co, OK		2.664	2.683	2.716	0.7	February 1, 2016		34.48068	97.21703
Dolese	809402	S32 T06N R15W	Kiowa Co. OK		2.706	2.723	2.753	0.6	February 1, 2016		34.94803	98.81396
Eastern Colorado Agg	833301	S18 T23S R42W	Holly, Prowers Co, CO		2.578	2.607	2.654	1.1	August 1, 2015	s		
Flint Rock Products Pile # 2	822503	SW 1/4 S29 T29N R23E	Ottawa County, OK		2.553	2.589	2.650	1.4	June 1, 2015	c		
Granite Mountain	838701	S26 T01N R12W	Sweet Home, AR		2.600	2.615	2.641	0.6	November 1, 2014			
Gravel and Concrete	832701	S15 T22S R07W	Reno Co.		2.551	2.580	2.620	1.1	April 1, 2014	s		
Hamm	800976	S15 T14S R04E	Dickinson Co.		2.453	2.533	2.665	3.3	January 1, 2016			
Hamm (EVCK)	800977	S09 T11S R17E	Jefferson Co.		2.540	2.604	2.714	2.5	January 1, 2016			
Hamm (NEVA)	800950	S03 T07S R10E	Pottawatomie Co.		2.437	2.515	2.644	3.2	July 1, 2015			
Hamm (OZWK)	800977	S09 T11S R17E	Jefferson Co.		2.618	2.672	2.766	2.0	February 1, 2016			

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DIVISION 600							
HMA (Plant Mix) Sec. 602, 603, 611 & 1103							
Individual Aggregates	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 [75 µm]	KT-2	c	1 per 1000 TONS (1000 Mg) for each individual aggregate.		1 during the first 5000 TONS (5000 Mg) of HMA	
	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-7	c			As required	
	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)						
	Sticks in Aggregate (0.01% of mass)						
	Uncompacted Void Content of Fine Aggregate (0.1%)						

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)
DIVISION 600 (continued)	
HMA (Plant Mix) continued Sec. 602, 603, 611 & 1103	
Individual Aggregates (continued)	Uncompacted Void Content of Coarse Aggregate (0.01%)
Mineral Filler Supplement	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 [75 µm] sieve, of mass)
	Plasticity Tests (0.01 g or 0.1% of mass)
Combined Aggregate	Coarse Aggregate Angularity (Determination of Crushed Particles in Crushed Gravel) (0.1% of mass)
	Uncompacted Void Content of Fine Aggregate (0.1%)
	Sand Equivalent Test (1%)
	Flat or Elongated Particles (1%)
	Moisture Tests (0.1 g or 0.01% of mass)
Asphalt Material	Sampling
HMA Mixtures	Percent Moisture in Mixture (0.1 g or 0.01% of mass)

HMA (Plant Mix continued) Sec. 602, 603, 611 & 1103						
HMA Mixtures (continued)	Air Voids (V_a = 0.01%; G_{mm} & G_{mb} = 0.001)	KT-15, KT-39, KT-58, & SF Manual		1 per sublot. (See code n for G_{mm})	j	1 per lot. [Compact split sample on KDOT Gyratory – 1 per week or every 15,000 TONS (15,000 Mg)]
	Binder Content (by ignition) (0.1 g or 0.01% of mass)	KT-57		1 per sublot.	j	1 per lot.
	Mix Gradation (after ignition) (0.1 g or 0.01% of mass)	KT-34		1 per sublot.		1 per lot.
	Moisture Damage to Mix (Modified Lottman)	KT-56	d	1 on first lot then 1 per week or every 10,000 TONS		1 during the first 5000 TONS (5000 Mg) of HMA
Reclaimed Asphalt Pavement (RAP)	Binder Content in RAP (by ignition) (0.1 g or 0.01% of mass)	KT-57		1 during the first lot then 1 per 1000 TONS (1000 Mg) of RAP.	j	1 during the first lot then 1 per 4000 TONS (4000 Mg) of RAP.
	RAP Gradation (after ignition) (0.1 g or 0.01% of mass)	KT-34		1 per 1000 TONS (1000 Mg) of RAP.		1 during the first 5000 TONS (5000 Mg) of HMA
	Percent Moisture in RAP (0.1 g or 0.01% of mass)	KT-11		1 per lot.		
Recycled Asphalt Shingles (RAS)	Binder Content in RAS (by ignition) (0.1 g or 0.01% of mass)	KT-57		1 during the first lot then 1 per 1000 TONS (1000 Mg) of RAP + RAS.	j	1 during the first lot then 1 per 4000 TONS (4000 Mg) of RAP + RAS.
	RAS Gradation (after ignition) (0.1 g or 0.01% of mass)	KT-34		1 per 1000 TONS (1000 Mg) of RAP + RAS.		1 during the first 5000 TONS (5000 Mg) of HMA
	Percent Moisture in RAS (0.1 g or 0.01% of mass)	KT-11		1 per lot.		

HMA (Plant Mix continued) Sec. 602, 603, 611 & 1103						
Completed Road Work Field Density Tests (Use Cores or Nuclear Density Gauge on all HMA roadway or shoulder construction greater than or equal to 1.5 inches)	Field Density - Cores or Nuclear Density Gauge (Gmb = 0.001; 0.1 lb/ft^3 [1 kg/m^3] or 0.01% of G_{mm})	KT-15 or KT-32	i	10 tests per lot.	i	5 companion tests per lot.
(Use approved rolling procedure and Nuclear Density Gauge on all HMA roadway or shoulder construction less than 1.5 inches)	Field Density -Nuclear Density Gauge (G_{mb} = 0.001; 0.1 lb/ft^3 [1 kg/m^3] or 0.01% of G_{mm})	KT-32	i	10 Nuclear Gauge readings per lot Verify Approved Rolling Procedure every 2 hours		
	Profilograph	KT-46		2 tracks per 12 ft (3.7 m) of width for the full length of the project.		At the Engineer's discretion.

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TABLE 602-9: NOMINAL COMPACTED THICKNESS	
Lift	Maximum Nominal Compacted Thickness
Surface	2 inches
Base	4 inches

TABLE 602-8: JOINT DENSITY REQUIREMENTS	
Nuclear Gauge Readings	Requirement
Interior Density minus Joint Density	≤ 3.0 lbs./cu. ft.
OR	
Joint Density	≥ 90.00% of G_{mm}

TABLE 602-7: SEGREGATION AND UNIFORMITY OF DENSITY CHECK		
Mix Designation	Maximum Density Range (highest minus lowest)	Maximum Density Drop (average minus lowest)
All	4.4 lbs./cu. ft.	2.2 lbs./cu. ft.

TABLE 602-12: SPECIFICATION WORKING RANGES (QC/QA)				
Mix Characteristic	Tolerance from JMF			
	Single Test Value	Plot	4 Point Moving Average Value	Plot
Binder Content	±0.6%	*	±0.3%	*
Mix Characteristic	Tolerance for Specification Limits			
	Single Test Value	Plot	4 Point Moving Average Value	Plot
Gradation (applicable sieves in TABLE 602-1)	N/A	*	zero tolerance	*
Air Voids @ N_{des} gyrations	±2.0%	*	N/A	
Voids in Mineral Aggregate (VMA)	1.0% below min.	*	zero tolerance	*
Voids Filled with Asphalt (VFA)	N/A		zero tolerance	*
Course Aggregate Angularity (CAA)	zero tolerance		N/A	
Sand Equivalent (SE)	zero tolerance		N/A	
Fine Aggregate Uncompacted Voids (FAA)	zero tolerance		N/A	
%Tensile Strength Ratio (%TSR)	zero tolerance	*	N/A	
Density @ N_{ini} and N_{max}	N/A		zero tolerance	
Dust to Effective Binder (D/B) Ratio	zero tolerance	*	zero tolerance	*

* Plot data according to subsection 106.4.
For gradations, as a minimum, plot the No. 4, 8, 30 and 200 sieves.
Plot G_{mm} to third decimal point.
Indicate Job Mix Formula (JMF) and specification working range limits for single test results on the control charts using a green ink dotted line.
Indicate the specification working range limits for the 4-point moving average results with a green ink solid line.

TABLE 602-10: DAILY PRODUCTION VS NUMBER OF SUBLOTS AND TEST REQUIREMENTS			
Daily Production (tons)	Number of Sublots	No. of Cores or Nuclear Density Tests**	No. of Verification Cores or Nuclear Density Tests**
0-599	3*	6*	3*
600-999	4*	8*	4*
1000 or more	5	10	5

*Minimum number for mixes with a specified thickness of 1½ inches or greater: The Contractor may choose to obtain the number required for 1000 or more tons. If the Contractor chooses to test 5 sublots (10 tests), KDOT will obtain 5 verification tests.
**For mixes with a specified thickness less than 1½ inch: Verification testing may be performed, but is not required. Additional testing may be performed by the Contractor. A minimum of 10 tests are required.

TABLE 602-11: MAXIMUM VARIATION OF THE SURFACE	
Length (feet)	Maximum Variation of the Surface (inches)
10	3/16
25	5/16

TABLE 602-15: DENSITY PAY FACTORS FOR SPECIFIED THICKNESS[4]			
Specified Thickness →	≥ 2"	≥ 1½"	
	All	Continuous Action[5]	No Continuous Action[6]
% of G_{mm} Average of 10 Density Tests[1]	Pay Factor[2]		Pay Factor[2]
93.0% or greater	1.040		1.040
92.0 to 92.9%	A1		A1
91.0 to 91.9%	1.000		1.000
90.0 to 90.9%	A2		1.000
89.0 to 89.9%	0.840 or Remove[3]		A3
less than 89.0%	0.840 or Remove[3]		0.840 or Remove[3]

[1]For low daily production rates less than 1000 tons, or when the Engineer's verification tests are to be used for asphalt density pay determination, the lot sample size is as determined in TABLE 602-11.

Based only on density average of lot

TABLE 602-13: MINIMUM HMA PLACEMENT TEMPERATURES							
Paving Course	Thickness (inches)	Air Temperature (°F)			Surface Temperature (°F)		
		HMA	WMA Foam	WMA Chem	HMA	WMA Foam	WMA Chem
Surface	All	50	45	40	55	50	45
Subsurface	<1.5	50	45	40	55	50	45
Subsurface	≥1.5 and < 3	40	35	30	45	40	35
Subsurface	≥ 3	30	30	30	35	32	32

TABLE 602-14: SEGREGATION PROFILE CHECKS FOR INCREASED SUBLOT SIZE		
Mix Designation	Maximum Density Range (highest minus lowest)	Maximum Density Drop (average minus lowest)
All	3.1 lbs./cu. ft.	1.9 lbs./cu. ft.

Equation 1: $Q_{LD} = \frac{\overline{X} - LSL}{S}$

$\overline{X}$ is the average measured percent of G_{mm} of all samples within a lot rounded to hundredths.
LSL is the lower specification limit for density and is defined as 91.00% of G_{mm} for traveled way plan thickness 2 inches and less and 92.00% of G_{mm} for traveled way plan thickness greater than 2 inches.

PWL for density also

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S is the standard deviation of the measured density of all samples within a lot and is calculated using equation (4) in Section 5.17.09, Part V, rounded to hundredths.