NCDOT Superpave Mix Design Certification Class

Day One

- 8:30 am – Introductions/Course Requirements and Overview
- 9:00 am – NCDOT Specifications, Special Mix Types, General Mix Design Steps, Equipment Calibrations/Verifications, and Mix Design Programs
- 10:00 am – Break
- 10:15 am – In Depth Mix Design Procedures/Calculations
- 12:00 pm – Lunch Break

- 1:00 pm – In Depth Mix Design Procedures/Calculations, Continued
- 2:00 pm – Break
- 2:15 pm –TSR Testing Procedures for Mix Design
- 3:15 pm – Aggregate Consensus Properties and Sand Source Changes
- 4:15 pm – Mix Design Submittal and Approval
- 4:30 pm – Questions/Comments

Day Two

- 8:30 am – Instructions for Written Test
- 8:45 am – Begin Test
- 12:00 pm – All Testing Complete

Contacts:

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NCDOT DIVISION QA SUPERVISORS

Rev. 06-2013

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1	Merry Hill	Tony Bracy	252-482-5474	252-482-1458	252-345-4611	252-338-4849	10-51-02
2	Kinston	*Donnie Best	252-527-1644	252-527-1660	None	252-268-6674	01-23-26
3	Burgaw	Fred Arendt	910-259-0286	910-259-0285	None	910-602-0584	04-68-06
4	Wilson	Gary Starling	252-296-3575	252-234-1119	None	252-245-0996	01-53-26
5	Youngsville	Jan Womble	919-562-0018	919-562-0990	None	919-524-4847	07-13-01
6	Fayetteville	Tommy Bowen	910-486-1379	910-486-1390	None	910-624-4708	14-55-24
7	Greensboro	Norm Abrams	336-621-4285	336-621-3481	None	336-382-2396	02-16-44
8	Aberdeen	Bradley Comer	910-944-7245	910-944-3157	None	910-690-5122	03-51-05
9	Lexington	Randall Ashmore	336-248-2265	336-248-2803	336-237-5120	336-399-6689	13-56-01
10	Charlotte	Steve McAllister	704-537-6892	704-537-7242	None	704-507-4235	05-13-10
11	N. Wilkesboro	Jeffrey Canter	336-667-8310	336-667-8312	None	336-957-1052	15-13-32
12	Lincolnton	Joel Hamrick	704-748-6401	704-732-0523	None	704-524-9756	09-04-01
13	Asheville	Kathy McAbee	828-298-4653	828-299-9604	None	828-273-2703	12-53-01
14	Whittier	Dale Buchanan	828-497-6128	828-497-5074	None	828-507-9883	08-23-15

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Feb. 1, 2005

NCDOT
Policy for Natural Sand Source Change
In Asphalt Mix Designs/Job Mix Formulas

Once a mix design/job mix formula using a specified natural sand source has been approved, no other sand source shall be utilized in that mix design/job mix formula, unless approved by the Department. If the Contractor desires to use a different sand source, the mix may either be redesigned using the new sand source, or if the sands are deemed reasonably similar, he may request approval to substitute the new source in accordance with these procedures. In order to determine if the sands are reasonably similar, gradation, specific gravity, and applicable consensus property tests must be performed. For purposes of this policy, a new sand source is defined as any source other than the original property source specified on the approved mix design. The DENR mining permit number will determine the original property source.

If the Contractor elects to request approval to substitute a new sand source in an existing mix design/job mix formula, gradation and specific gravity tests must be performed on the individual source. Also, consensus property tests (Fine Aggregate Angularity (FAA) and Sand Equivalent) must be performed on the fine portion of the aggregate blend using the new sand source. The Contractor shall also perform a mix verification test on mix that contains the new natural sand in accordance with Article 609-4 of the Standard Specifications. The results will be recorded on Form QA/QC-1 and submitted to the NCDOT Asphalt Mix Design Engineer at the Materials and Test Lab, with copies to the applicable QA Lab. This mix verification will suffice for the initial mix verification on the new mix design/job mix formula, if approved. In addition to these test results, the following will be submitted to the Asphalt Mix Design Engineer for review and approval:

- 25 lb. sample of the new sand source.
- QMS-1 with the Original JMF Number listed and the "New Sand Source Request" note checked.
- Copy of original mix design Form M&T 601 (SP).
- New Form M&T 601 (SP) with new sand source gradations and specific gravities and blend gradations and gravities shown.
- New 0.45 power chart showing the new mix gradation.
- DENR mining permit cover letter showing name, location, mining permit number, and the NCDOT HiCAMS FA number, if available.
- Completed M&T Form 620, Consensus Property Worksheet, showing Fine Aggregate Angularity and Sand Equivalent test results.

The new sand properties and mix verification test results will be evaluated by the Asphalt Mix Design Engineer. At his discretion, the Asphalt Mix Design Engineer may require a new set of test specimens for verifying rutting susceptibility of the proposed mix design. These specimens will be tested using the Asphalt Pavement Analyzer and shall meet the minimum depth requirements for that mix type. Based on these test results, the Asphalt Mix Design Engineer will either approve or reject the substitution of the new source in the existing mix design. If the new sand source is approved for use by the Asphalt Mix Design Engineer, a new mix design and job mix formula (JMF) indicating the new sand source will be issued by the Department.

This policy will be used only for mix designs containing less than or equal to 25% natural sand. If the percent sand is greater than 25%, the mix shall be redesigned. This policy applies only to natural sand(s) and not manufactured sand(s).

An example of the required paperwork is included with this policy.

NOTE: When a sand source change is being made in several mixes of the same type and the verification on the initial mix design sand source change does not indicate significant differences in mix properties, the Engineer may, at his discretion, waive the mix verification requirement on subsequent mix designs of the same mix type at a given plant. However, a minimum of one mix verification must be performed for each mix type at each plant. Other documentation as listed above will be required for each mix design/job mix formula change.

Quality of Fine Aggregate from Approved Sources

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Revised Date 3/2/12

No.	Div.	OWNER	LOCATION	TYPE	INSPECTOR	SAMPLE	F M	DEL SUB	SP GR	ABS	STRENGTH RATIO		YEARLY	SOUNDNESS			OTHER
327		AMERICAN MATERIALS	CLARK	2S	CHRISTIAN	4/17/2013	2.22	0.2	2.65	0.4	108.7	101.9	Apr-2014	4/17/2013	4.0	Apr-2016	
168		AGGREGATE USA	MIDWAY, MASCOT TN	2MS	RHYMER	4/9/2013	2.93		2.81	0.5	158.7	165.7	Apr-2014	4/9/2013	1.3	Apr-2016	
483		AMERICAN MATERIALS	BAILEY MINE	2S	CHRISTIAN	5/3/2013	2.62	0.2	2.65	0.3	113.1	120.3	May-2014	5/3/2013	1.2	May-2016	
478		AMERICAN MATERIALS	DUPREE MINE	2S	ROGERSON	1/9/2013	2.77	1.0	2.65	0.2	106.7	115.4	Jan-2014	1/9/2013	3.6	Jan-2016	
253		AMERICAN MATERIALS	IVANHOE	2S	JACKSON	1/30/2013	2.50	0.2	2.66	0.1	109.3	99.3	Jan-2014	1/30/2013	4.2	Jan-2016	
387		AMERICAN MATERIALS	PINNER	2S	JACKSON	8/6/2012	2.78	0.2	2.62	0.4	118.2	117.0	Aug-2013	7/28/2009	0.8	Jul-2012	
432		AMERICAN MATERIALS	RICHARDSON MINE	2S	JACKSON	2/6/2013	2.48	0.2	2.66	0.3	115.3	124.5	Feb-2014	2/6/2013	5.6	Feb-2016	
211		AMERICAN MATERIALS	WADE	2S	CHRISTIAN	11/16/2011	2.17	0.1	2.63	0.4	118.7	120.3	Nov-2012	6/17/2010	0.5	Jun-2013	
60		APAC-ATLANTIC - T-A DIVISION	CANDOR	2S	HORNE	6/8/2013	2.60	0.1	2.63	0.7	119.4	128.8	Jun-2014	6/8/2013	2.3	Jun-2016	
265		B & T SAND	EDMUNDS	2S	ADAIR	7/9/2012	2.64	0.2	2.63	0.3	125.4	125.6	Jul-2013	8/3/2010	0.8	Aug-2013	SC516
410		B & T SAND	EDMUNDS 3 - WHITE	2S	ADAIR	7/21/2009	2.46	0.2	2.63	0.5	117.2	120.9	Jul-2010	4/16/2007	1.1	Apr-2010	
460	1	BENT RIVER MATERIALS	BENT RIVER	2S	LONG	8/10/2011	2.55	0.1	2.64	0.5	112.9	126.7	Aug-2012	12/8/2010	1.5	Dec-2013	
340		BEST S & G	BROOKS	2S	RUDD	2/20/2013	2.54	0.2	2.65	0.3	118.8	110.7	Feb-2014	2/20/2013	3.1	Feb-2016	
340		BEST S & G	BROOKS	4S	RUDD	2/20/2013	1.90	0.6	2.65	0.3	106.3	105.1	Feb-2014	2/20/2013	8.0	Feb-2016	
362		BOXLEY AGGREGATES	BLUE RIDGE	2MS	LOWRANCE	11/19/2009	3.20	0.0	2.71	1.2	158.3	165.7	Nov-2010	11/12/2008	1.3	Nov-2011	VA 2004
422	10	BUCKHORN MATERIALS	BLACK CREEK SC	2MS	ADAIR	1/31/2013	1.75	0.0	2.65	0.2	110.9	108.8	Jan-2014	10/10/2012	2.8	Oct-2015	SC595
422	10	BUCKHORN MATERIALS	BLACK CREEK SC	4S	ADAIR	10/10/2012	1.90	0.2	2.63	0.5	101.0	109.1	Oct-2013	10/10/2012	5.0	Oct-2015	SC595
439	10	BURKE COUNTY SAND	KEYSVILLE GA	2S	PRESTRESS	5/5/2009	2.10	0.2	2.64	0.3	110.3	117.2	May-2010	5/5/2009	1.1	May-2012	GA 197F
462	0	BUTLER SAND	BUTLER GA	2S	PRESTRESS	4/2/2013	2.52	0.1	2.65	0.3	111.1	125.9	Apr-2014	4/11/2011	0.9	Apr-2014	GA 007F
22134	0	CARDINAL REALTY, INC	GALAX VA	2MS	WHITLEY	5/1/2012	3.21	0.0	2.74	0.8	123.6	130.8	May-2013	5/1/2012	1.5	May-2015	
192		CARDINAL REALTY, INC	SAND MOUNTAIN SAND	2S	MCLAIN	5/31/2013	2.51	1.0	2.65	0.3	134.3	137.5	May-2014	5/7/2012	2.3	May-2015	VA 1083
155		CARDINAL REALTY, INC	WYTHE	2S	MCLAIN	5/31/2013	2.67	1.0	2.65	0.4	122.8	132.9	May-2014	5/7/2012	2.0	May-2015	VA 1082
334		CAROLINA SAND	BURKE CO	2S	MCLAIN	6/21/2011	2.66	0.5	2.61	1.0	95.9	112.3	Jun-2012	3/11/2009	1.9	Mar-2012	
181		CAROLINA SAND	PEE DEE	2S	JACKSON	1/29/2013	2.39	0.0	2.65	0.2	105.4	108.7	Jan-2014	1/11/2010	0.8	Jan-2013	SC506
461		CAROLINA SAND	WALKER	2S	WALLACE	3/9/2011	2.77	0.4	2.62	1.0	104.4	107.7	Mar-2012	3/9/2011	1.1	Mar-2014	
445	9	CAROLINA STALITE	GOLD HILL	2MS	WALLACE	1/25/2010	3.30	0.2	1.93	4.7	142.9	159.9	Jan-2011	1/25/2010	2.2	Jan-2013	
171	5	CAROLINA SUNROCK CORP	BUTNER	2MS	WATKINS	8/23/2010	2.48	0.0	2.95	0.7	138.7	144.2	Aug-2011	8/19/2009	1.4	Aug-2012	
397	5	CAROLINA SUNROCK CORP	KITTRELL	2MS	WATKINS	8/18/2009	2.71	0.0	2.64	0.3	137.7	132.9	Aug-2010	8/18/2009	0.7	Aug-2012	
440	5	CAROLINA SUNROCK CORP	WOODSDALE	2MS	WATKINS	8/23/2010	2.84	0.1	2.81	0.7	137.1	142.7	Aug-2011	8/17/2009	2.5	Aug-2012	
436		CEMEX	DEERFIELD	2S	PRESTRESS	8/13/2012	2.36	1.2	2.62	0.3	110.5	119.1	Aug-2013	8/1/2011	0.8	Aug-2014	SC544
449		CHURCH SAND & STONE	MILLER PIT	2S	MCLAIN	2/12/2013	2.61	0.8	2.65	0.7	101.5	100.5	Feb-2014	2/12/2011		Feb-2014	
317		COMMERCIAL READY MIX PROD	NEWSOME #2	2S	LONG	8/22/2012	2.91	0.4	2.61	0.4	109.2	122.1	Aug-2013	1/18/2013	6.1	Jan-2016	
393	4	COOL SPRING S & G	BEACON TOWER	2S	RUDD	11/18/2010	3.11	0.3	2.62	0.8	129.1	133.2	Nov-2011	8/13/2008	1.6	Aug-2011	
393	4	COOL SPRING S & G	BEACON TOWER	4S	RUDD	11/18/2010	2.65	0.4	2.61	1.0	131.9	139.3	Nov-2011	8/12/2008	1.2	Aug-2011	
463	4	COOL SPRING S & G	DUCKWORTH	2S	RUDD	4/26/2011	2.74	0.3	2.60	0.7	142.9	146.0	Apr-2012	4/26/2011	1.9	Apr-2014	
404		FRANCIS S&G	FRANCIS	2S	LONG	8/5/2011	2.47	0.2	2.63	0.3	117.9	124.2	Aug-2012	6/4/2009	1.1	Jun-2012	
113		G. S. MATERIALS	EMERY	2S	HORNE	5/24/2013	2.61	0.2	2.63	0.8	127.7	125.7	May-2014	5/24/2013	2.8	May-2016	SC580
122		G. S. MATERIALS	HALL	2S	HORNE	7/16/2013	2.75	0.4	2.65	0.5	123.5	114.7	Jul-2014	8/18/2011	0.8	Aug-2014	
143		GLOVER MATERIALS CO.	ROGERS QUARTER	2S	LONG	5/20/2013	2.89	1.4	2.64	0.3	130.2	139.4	May-2014	8/22/2012	3.7	Aug-2015	
344		GRAND STRAND AGGREGATES	GORETOWN	2MS	ASHER	4/25/2013	2.60		2.65	0.9	136.2	136.4	Apr-2014	4/25/2013	3.6	Apr-2016	
22		HANSON, INC.	ELLIOTT	2S	HORNE	7/17/2013	2.61	0.1	2.63	0.7	129.1	113.5	Jul-2014	1/31/2013	3.4	Feb-2016	
10		HANSON, INC.	MARLBORO	2S	CHRISTIAN	7/16/2013	2.41	0.2	2.63	0.8	106.7	105.6	Jul-2014	7/16/2013	3.3	Jul-2016	SC106
64		HANSON, INC.	PAGELAND #1 (Brewer C-10)	2MS	ADAIR	10/10/2012	2.32	0.1	2.65	0.4	113.4	119.8	Oct-2013	9/12/2011	0.7	Sep-2014	SC529
464		HANSON, INC.	ROUGEMONT	2MS	WATKINS	7/15/2011	2.96	0.1	2.69	0.7	149.5	159.4	Jul-2012	7/15/2011	0.9	Jul-2014	
438	13	HANSON, INC.	SANDY FLATS	2MS	TALLENT	2/2/2012	2.60	0.0	2.65	0.4	101.9	139.2	Feb-2013	2/2/2012	0.3	Feb-2015	
400	13	HEDRICK INDUSTRIES	GROVESTONE	2MS	RHYMER	5/7/2013	2.76	0.0	2.84	0.5	146.8	125.2	May-2014	4/28/2010	0.6	Apr-2013	
226		HEDRICK INDUSTRIES	LAKE NORMAN	2MS	BULLOCK	5/7/2012	2.82	0.1	2.78	0.7	131.0	139.3	May-2013	1/21/2011	4.0	Jan-2014	
221		HEDRICK INDUSTRIES	LILESVILLE	2S	ADAIR	10/18/2012	2.84	1.3	2.64	0.4	127.0	119.1	Oct-2013	10/4/2010	0.8	Oct-2013	
111		HEDRICK INDUSTRIES	NORMAN MINE (D & J)	2S	HORNE	5/30/2013	2.83	0.3	2.64	0.7	120.5	137.8	May-2014	8/1/2011	0.5	Aug-2014	
126		HEDRICK INDUSTRIES	NORTH BUNCOMBE	2MS	RHYMER	5/7/2013	3.08	0.0	2.78	0.4	111.3	108.0	May-2014	5/18/2011	7.5	May-2014	
412	10	HEDRICK INDUSTRIES	PAGELAND 4/LAKE NORM	2MS	ADAIR	6/21/2011	2.07	0.1	2.65	0.4	126.9	123.4	Jun-2012	6/1/2010	1.3	Jun-2013	
239		HEDRICK INDUSTRIES	PAGELAND SC PIT 3	2MS	ADAIR	4/8/2013	2.44	0.0	2.78	0.4	124.4	107.4	Apr-2014	3/15/2011	1.2	Mar-2014	SC541
239		HEDRICK INDUSTRIES	PAGELAND SC PIT 3	4S	ADAIR	4/8/2013	2.14	0.2	2.65	0.5	122.8	122.7	Apr-2014	4/8/2013	3.8	Apr-2016	SC541

	No.	Div.	OWNER	LOCATION	TYPE	INSPECTOR	SAMPLE	F M	DEL SUB	SP GR	ABS	STRENGTH RATIO		YEARLY	SOUNDNESS			OTHER
	327		AMERICAN MATERIALS	CLARK	2S	CHRISTIAN	4/17/2013	2.22	0.2	2.65	0.4	108.7	101.9	Apr-2014	4/17/2013	4.0	Apr-2016	
	415		HEDRICK INDUSTRIES	SOUTH MCDOWELL	2MS	RHYMER	5/7/2013	2.57	0.1	2.75	0.4	135.3	118.5	May-2014	5/7/2013	2.6	May-2016	
	177		HOFFMAN MATERIALS	HOFFMAN SAND	2S	MCLAIN	2/6/2013	2.10	0.3	2.62	1.0	106.2	104.6	Feb-2014	2/6/2013	5.0	Feb-2016	
	455		LAFARGE AGGREGATES	FRIENDSHIP	2MS	RHYMER	8/24/2010	2.63	0.1	2.66	0.3	151.6	163.0	Aug-2011	8/24/2010	1.6	Aug-2013	
	475		LANIER SAND	GASTON SC 1	2S	ADAIR	3/28/2013	2.42	0.2	2.66	0.2	114.0	132.0	Mar-2014	3/28/2013	7.9	Mar-2016	
	433	12	LAWNDALE SAND	LAWNDALE	2S	BULLOCK	12/17/2010	2.18	0.5	2.63	0.7	109.1	120.3	Dec-2011	7/15/2008	1.5	Jul-2011	
	451	14	LBM INDUSTRIES	DILLSBORO	2S	RHYMER	11/8/2012	3.10	0.5	2.95	0.1	147.4	126.4	Nov-2013	11/8/2012	2.5	Nov-2015	
	247		LBM INDUSTRIES	HEWITT	2MS	RHYMER	11/6/2012	2.87	0.0	2.75	0.1	160.2	151.5	Nov-2013	11/6/2012	1.4	Nov-2015	
	162		LBM INDUSTRIES	WHITEWATER FALLS	2MS	RHYMER	5/22/2013	2.86	0.0	2.68	0.6	128.7	134.7	May-2014	5/22/2013	1.6	May-2016	
	473		LUCK STONE	GILMERTON SALES YARD	2S	HOLLIDAY	2/27/2012	2.64		2.62	0.4	92.3	120.7	Feb-2013	2/27/2012	1.8	Feb-2015	
	336		MAR MAC	MAR MAC - GOLDSBORO	2S	RUDD	9/12/2012	2.46	0.0	2.62	0.4	120.7	108.5	Sep-2013	7/26/2013	4.6	Jul-2016	
	336		MAR MAC	MAR MAC - GOLDSBORO	4S	RUDD	6/27/2013	2.17	0.0	2.62	0.3	110.5	103.8	Jun-2014	8/2/2013	0.9	Aug-2016	
	354	4	MAR MAC	MILL CREEK - PRINCETON	2S	FERRELL	5/27/2009	2.66	0.2	2.62	0.4	112.0	125.7	May-2010	5/27/2009	0.7	May-2012	
	203		MARTIN MARIETTA	ARROWOOD	2MS	ADAIR	9/6/2012	3.11	0.0	2.98	0.3	127.1	128.3	Sep-2013	9/9/2010	0.8	Sep-2013	
	104		MARTIN MARIETTA	BELGRADE	2MS	JACKSON	2/4/2013	2.59	0.0	2.62	1.8	145.0	151.8	Feb-2014	2/4/2013	4.1	Feb-2016	
	392		MARTIN MARIETTA	BONDS	2MS	HISSOM	4/10/2013	3.01	0.2	2.73	0.5	120.4	115.4	Apr-2014	3/26/2013	1.2	Mar-2016	
	58		MARTIN MARIETTA	CASTLE HAYNE	2MS	JACKSON	2/8/2013	2.84	0.2	2.67	0.8	135.4	161.1	Feb-2014	2/8/2013	2.0	Feb-2016	
	214		MARTIN MARIETTA	CLARKS	2MS	JACKSON	7/18/2012	2.66	0.0	2.64	1.2	145.7	150.3	Jul-2013	7/18/2012	4.0	Jul-2015	
	377	9	MARTIN MARIETTA	DENVER	2MS	BULLOCK	7/5/2013	2.81	0.0	2.66	0.4	127.9	141.6	Jul-2014	7/5/2013	1.8	Jul-2016	
	382	5	MARTIN MARIETTA	GARNER	2MS	RAY	2/14/2013	2.83	0.0	2.66	0.4	124.3	115.8	Feb-2014	11/13/2012	0.8	Nov-2015	
	251		MARTIN MARIETTA	JAMESTOWN		WALLACE	2/26/2013	2.96		2.71	0.5	134.9	131.6	Feb-2014	2/26/2013	3.9	Feb-2016	
	414		MARTIN MARIETTA	KINGS MOUNTAIN	2MS	BULLOCK	7/26/2010	2.95	0.1	2.75	0.4	136.3	132.6	Jul-2011	7/26/2010	1.4	Jul-2013	
	429	10	MARTIN MARIETTA	LOAMAY, KERSHAW	2S	ADAIR	5/28/2013	2.25	0.2	2.64	0.4	130.8	136.5	May-2014	5/28/2013	4.1	May-2016	
	429	10	MARTIN MARIETTA	LOAMAY, KERSHAW	4S	ADAIR	11/8/2012	2.05	0.5	2.65	0.1	127.4	115.7	Nov-2013	11/7/2011	0.7	Nov-2014	
	423	10	MARTIN MARIETTA	MALLARD CREEK	2MS	ADAIR	12/11/2012	2.61	0.0	2.83	0.2	155.6	133.1	Dec-2013	2/3/2011	4.9	Feb-2014	
	310		MARTIN MARIETTA	ONSLOW	2MS	JACKSON	2/4/2013	3.24	0.0	2.58	3.3	154.7	132.9	Feb-2014	2/4/2013	2.0	Feb-2016	
in	163		MARTIN MARIETTA	POMONA	2MS	FOSQUE	4/9/2012	2.62	0.0	2.78	0.4	143.9	157.3	Apr-2013	4/9/2012	1.2	Apr-2015	
	411		MARTIN MARIETTA	ROCK HILL	2MS	ADAIR	10/15/2012	2.85	0.1	2.78	0.4	132.7	131.4	Oct-2013	8/23/2010	1.2	Aug-2013	SC142
	119		MARTIN MARIETTA	ROCKY POINT	2MS	PRESTRESS	9/7/2011	3.15	0.0	2.64	1.2	178.3	181.7	Sep-2012	9/7/2011	4.7	Sep-2014	
	305		MARTIN MARIETTA	SALEM	2MS	WALLACE	4/24/2012	2.47	0.0	3.25	0.6	130.5	149.7	Apr-2013	4/24/2012	1.0	Apr-2015	
	100		MARTIN MARIETTA	WOODLEAF	2MS	WALLACE	9/13/2011	2.62	0.1	2.67	0.4	132.7	137.5	Sep-2012	1/30/2009	1.5	Jan-2012	
	381	4	MATTHEWS S&G	MATTHEWS - FOUR OAKS	2S	RUDD	11/22/2010	3.17	0.2	2.62	0.6	125.3	136.2	Nov-2011	11/22/2010	1.5	Nov-2013	
	472	4	MATTHEWS S&G	MATTHEWS 3	2S	RUDD	4/11/2013	2.24	0.2	2.64	0.4	123.4	112.9	Apr-2014	2/7/2012	1.7	Feb-2015	
	472	4	MATTHEWS S&G	MATTHEWS 3	4S	RUDD	4/11/2013	2.24	0.2	2.64	0.4	123.4	112.9	Apr-2014	2/7/2012	1.7	Feb-2015	
	164		MAYMEAD LIMESTONE CO	POTTER - SHOUNS TN	2MS	LOWRANCE	10/1/2012	3.84	0.0	2.75	0.5	122.5	126.8	Oct-2013	12/1/2010	0.8	Dec-2013	
	434	10	MCINTYRE SAND	ASKEW MINE	2S	ADAIR	7/11/2012	2.76	0.3	2.59	0.9	105.1	109.3	Jul-2013	7/6/2011	1.4	Jul-2014	
	384	4	MIDEAST SERVICES	HOWELL WOODS	2S	RUDD	2/6/2013	3.29	0.4	2.61	0.5	126.9	123.4	Feb-2014	2/6/2013	1.8	Feb-2016	
	356		MORTON MINERALS	CAMERON	2S	JACKSON	5/13/2009	2.24	0.2	2.65	0.2	93.7	95.1	May-2010	5/13/2009	0.5	May-2012	
	386		NEUSE S & G	GAY	2S	JACKSON	9/21/2009	2.94	0.3	2.64	0.3	112.2	111.7	Sep-2010	8/12/2008	0.8	Aug-2011	
	402		NEUSE S & G	HUNTER OUTLAW	2S	JACKSON	7/27/2009	2.81	0.3	2.64	0.3	121.1	118.0	Jul-2010	7/27/2009	0.7	Jul-2012	
	446	2	NEUSE S & G	TILGHMAN SC	2S	WALKER	6/21/2013	2.93	0.1	2.66	0.2	116.1	124.2	Jun-2014	7/29/2013	4.2	Jul-2016	
	6		OLDCASTLE STONE	LILESVILLE (BONSAL)	2S	ADAIR	10/18/2012	2.89	1.3	2.64	0.7	134.2	122.7	Oct-2013	10/18/2012	1.7	Oct-2015	
	347		PATTON SAND CO	PATTON PIT	2S	MCLAIN	8/31/2012	2.97	0.2	2.57	0.9	100.4	101.2	Aug-2013	8/29/2012	3.8	Aug-2015	
	447	2	PEA CREEK MINE	HATCHER	2S	JACKSON	7/12/2013	2.48	0.1	2.65	0.2	134.5	130.4	Jul-2014	6/21/2012	6.0	Jun-2015	
	447	2	PEA CREEK MINE	HATCHER	4S	JACKSON	8/2/2011	2.34	0.2	2.65	0.2	115.4	121.6	Aug-2012	8/12/2011	0.3	Aug-2014	
	408		POUNDING MILL QUARRIES	BLUEFIELD	2MS	MCLAIN	5/31/2012	3.58	0.0	2.69	0.8	112.8	151.2	May-2013	5/31/2012	2.5	Jun-2015	VA 1025
	254		PRETTY GOOD SAND CO	GREAT	4S	RUDD	2/11/2013	2.48	0.6	2.63	0.5	124.3	115.5	Feb-2014	2/11/2013	3.6	Feb-2016	
	254		PRETTY GOOD SAND CO	GREAT	2S	RUDD	2/11/2013	2.96	0.4	2.63	0.5	122.1	124.7	Feb-2014	2/11/2013	3.8	Feb-2016	
	88	12	RINKER MATERIALS	ABINGDON VA	2MS	CHURCH	1/2/2013	3.98	0.1	2.85	0.3	130.5	136.8	Jan-2014	1/2/2013	0.6	Jan-2016	VA 1058
	168		RINKER MATERIALS	MIDWAY, MASCOT TN	2MS	PRESTRESS	1/18/2013	2.85	0.1	2.82	1.1	168.4	159.3	Jan-2014	1/18/2013	2.9	Jan-2016	
	78	12	RINKER MATERIALS	WATAUGA TN	2MS	CHURCH	1/2/2013	3.23	0.0	2.78	0.3	155.4	158.2	Jan-2014	1/2/2013	1.9	Jan-2016	
	399	3	RIVERFRONT COMPANY	OAK RIDGE #2	2S	JACKSON	2/4/2013	2.37	1.0	2.66	0.1	124.9	131.7	Feb-2014	2/4/2013	4.0	Feb-2016	
	399	3	RIVERFRONT COMPANY	OAK RIDGE #2	4S	JACKSON	2/4/2013	2.72	1.0	2.66	0.1	106.0	130.6	Feb-2014	2/4/2013	3.8	Feb-2016	
	407	3	RJ BUSHHOGGING	WILLIS NECK 1	2S	JACKSON	7/18/2012	2.73	0.2	2.63	0.2	149.4	156.3	Jul-2013	7/18/2012	5.9	Jul-2015	

No.	Div.	OWNER	LOCATION	TYPE	INSPECTOR	SAMPLE	F M	DEL SUB	SP GR	ABS	STRENGTH RATIO		YEARLY	SOUNDNESS			OTHER
327		AMERICAN MATERIALS	CLARK	2S	CHRISTIAN	4/17/2013	2.22	0.2	2.65	0.4	108.7	101.9	Apr-2014	4/17/2013	4.0	Apr-2016	
407	3	RJ BUSHHOGGING	WILLIS NECK 1	4S	JACKSON	8/19/2011	1.98	0.2	2.64	0.3	106.9	121.9	Aug-2012	7/28/2009	1.2	Jul-2012	
482		RJ BUSHHOGGING	WILLIS NECK 2	2S	ROGERSON	5/30/2013	2.58	0.0	2.65	0.2	106.5	115.2	May-2014	5/30/2013	3.1	May-2016	
453		SAVANNAH SAND	SAVANNAH MINE	2S	TALLENT	1/31/2013	2.49	0.1	2.65	0.3	113.2	117.8	Jan-2014	1/31/2013	2.0	Feb-2016	
448	2	SHELTON CREEK LLC	SHELTON CREEK	2MS	JACKSON	3/3/2010	3.16	0.0	2.62	1.6	166.8	165.6	Mar-2011	3/3/2010	4.5	Mar-2013	
231		SOLITE CORP	RAPPAHANNOCK FARM	2S	PRESTRESS	9/9/2009	2.85	0.4	2.64	0.8	134.6	135.0	Sep-2010	9/9/2009	2.1	Sep-2012	VA 6033
419		SOUTH CAROLINA MINERALS	BEECH ISLAND	2S	ADAIR	6/26/2013	2.69	0.0	2.65	0.4	120.7	121.1	Jun-2014	6/26/2013	2.4	Jun-2016	
430		SOUTH CAROLINA MINERALS	GASTON SC 1	2S	ADAIR	8/18/2009	2.40	0.2	2.64	0.4	121.9	125.1	Aug-2010	11/6/2007	1.2	Nov-2010	
405	6	SOUTHEASTERN MINERALS	ALAMAC	2S	CHRISTIAN	6/18/2010	2.53	0.3	2.64	0.4	114.3	124.2	Jun-2011	6/29/2009	0.8	Jun-2012	
210		SOUTHEASTERN MINERALS	MUSSELWHITE	2S	CHRISTIAN	5/19/2009	2.72	0.2	2.63	0.6	99.7	107.4	May-2010	7/31/2007	1.6	Jul-2010	
444		STANDARD SAND & SILICA	IVEY MINE GA	2S	TALLENT	2/20/2013	2.49	0.2	2.66	0.4	112.4	130.6	Feb-2014	2/20/2013	3.3	Feb-2016	
129		SUMTER CO SAND	GLASSCOCK	2S	PRESTRESS	1/3/2013	2.69	0.2	2.66	0.4	180.1	118.9	Jan-2014	1/3/2013	1.6	Jan-2016	SC545
241		SUPERIOR SAND LLC	BLACK CREEK	2S	JACKSON	2/1/2013	1.46	0.3	2.67	0.1	107.3	126.1	Feb-2014	11/17/2011	0.6	Nov-2014	
456	10	THOMAS CONCRETE	SIMPSON MINE	2S	ADAIR	8/16/2012	2.69	0.4	2.59	1.0	121.9	114.7	Aug-2013	8/12/2010	0.7	Aug-2013	
236		VULCAN MATERIALS	BOONE	2MS	LOWRANCE	10/1/2012	3.83	0.0	2.73	0.8	130.7	119.4	Oct-2013	10/1/2012	2.0	Oct-2015	
66	13	VULCAN MATERIALS	BRISTOL TN	2MS	BULLOCK	3/25/2013	3.17	0.0	2.66	0.3	134.9	129.1	Mar-2014	2/17/2012	0.3	Feb-2015	
339		VULCAN MATERIALS	CABARRUS	2MS	ADAIR	1/19/2012	2.90	0.2	2.75	0.5	132.6	142.3	Jan-2013	1/25/2011	4.7	Jan-2014	
158		VULCAN MATERIALS	EAST FORSYTH	2MS	WALLACE	4/24/2012	2.72	0.0	2.71	0.5	126.9	148.6	Apr-2013	10/19/2011	2.2	Oct-2014	
458		VULCAN MATERIALS	ENKA	2MS	RHYMER	11/10/2010	2.68	0.0	2.72	0.3	108.2	105.9	Nov-2011	11/10/2010	1.1	Nov-2013	
183		VULCAN MATERIALS	GREYSTONE	2MS	WATKINS	1/11/2012	2.77	0.1	2.66	0.4	121.2	116.2	Jan-2013	1/11/2012	0.4	Jan-2015	
361	13	VULCAN MATERIALS	GREYSTONE GREENE TN	2MS	RHYMER	1/24/2012	3.12	0.1	2.62	1.3	124.0	151.8	Jan-2013	1/24/2012	4.0	Jan-2015	
416		VULCAN MATERIALS	GREYSTONE GREENVILLE	2S	TALLENT	3/8/2010	2.88	0.4	2.60	1.2	138.2	150.6	Mar-2011	3/8/2010	5.8	Mar-2013	
372		VULCAN MATERIALS	LIBERTY	2MS	ADAIR	10/12/2011	2.83	0.0	2.69	0.2	120.9	115.7	Oct-2012	10/12/2011	0.7	Oct-2014	SC158
435		VULCAN MATERIALS	LITHIA SPRINGS	2MS	PRESTRESS	1/16/2013	2.55	0.0	2.65	0.1	152.5	138.9	Jan-2014	1/16/2013	2.6	Jan-2016	GA 168F
466	9	VULCAN MATERIALS	NORTH	2MS	WAGONER	4/24/2012	2.73	0.0	2.92	0.5	151.4	168.6	Apr-2013	10/19/2011	0.9	Oct-2014	
212		VULCAN MATERIALS	PACOLET	2MS	MCLAIN	7/19/2011	2.97	0.0	2.65	0.4	104.7	105.7	Jul-2012	11/20/2007	1.4	Nov-2010	SC163
266		VULCAN MATERIALS	PINEVILLE	2MS	ADAIR	8/23/2012	3.08		2.89	0.8	127.3	152.0	Aug-2013	8/23/2012	3.3	Aug-2015	
172		VULCAN MATERIALS	PUDDLEDOCK	2S	PRESTRESS	12/20/2012	2.34	0.2	2.63	0.3	136.4	117.1	Dec-2013	12/20/2011	0.6	Dec-2014	VA 4018
374		VULCAN MATERIALS	ROCKINGHAM	2MS	CHAVIS	10/25/2012	3.05		2.67	0.8	93.8	116.3	Oct-2013	10/25/2012	2.2	Oct-2015	
457		VULCAN MATERIALS	SEVIERVILLE	2MS	RHYMER	11/10/2010	2.91	0.1	2.72	1.0	134.1	163.5	Nov-2011	11/10/2010	1.3	Nov-2013	
76		VULCAN MATERIALS	SMITH GROVE	2MS	WALLACE	4/24/2012	3.19	0.1	2.79	0.4	144.1	153.5	Apr-2013	4/24/2012	0.7	Apr-2015	VA 3010
197		VULCAN MATERIALS	SOUTH BOSTON	2MS	WATKINS	11/18/2009	2.91	0.0	2.75	0.8	153.8	157.5	Nov-2010	11/18/2009	1.9	Nov-2012	
165		WADE MOORE EQUIPMENT CO	FLEMING SAND	2S	WATKINS	4/19/2013	2.90	1.0	2.63	0.5	108.7	101.9	Apr-2014	7/26/2013	3.4	Jul-2016	
480		WAKE STONE CORP	NASH	2MS	SKINNER	4/29/2013	2.52		2.68	0.4	134.7	134.7	Apr-2014	4/29/2013	1.6	Apr-2016	
481		WAKE STONE CORP	KNIGHTDALE	2MS	SKINNER	5/3/2013	2.85		2.66	0.4	137.8	123.6	May-2014	5/3/2013	1.7	May-2016	
368		WEEKS SAND	CAMERON	2S	HORNE	7/20/2011	2.48	0.2	2.63	0.5	108.8	130.6	Jul-2012	4/8/2009	1.2	Apr-2012	
403		WESTSIDE MINERALS LLC	LAGRANGE	2S	JACKSON	7/12/2013	2.27	0.7	2.65	0.4	115.8	121.1	Jul-2014	7/18/2012	4.7	Jul-2015	
403		WESTSIDE MINERALS LLC	LAGRANGE	4S	JACKSON	7/27/2009	2.10	0.1	2.63	0.4	120.3	135.2	Jul-2010	7/27/2009	0.9	Jul-2012	
330		WILLIAMS S & G	SMITH	2S	JACKSON	1/12/2009	2.50	0.2	2.64	0.4	106.1	106.5	Jan-2010	1/12/2009	3.0	Jan-2012	
						DATE				%	3 DAY	7 DAY	CK DUE	DATE	LOSS	DUE	STATE ID

ANY SOURCE IN ITALIC DID NOT MEET STRENGTH RATIO REQUIREMENTS AND SHOULD NOT BE USED IN STATE PROJECTS.

TO BE USED IN ASPHALT

No.	Div.	OWNER	LOCATION	TYPE	INSPECTOR
378	9	AARON SAND	AARON PIT - TANGLEWOOD	1S	CARRIKER
421	9	AARON SAND	BOONEVILLE (#61)	RS	CARRIKER
395	9	AARON SAND	FARMINGTON ROAD	1S	CARRIKER
395	9	AARON SAND	FARMINGTON ROAD	RS	CARRIKER
418	9	AARON SAND	IDOLS DAM	RS	CARRIKER
409	7	AARON SAND	MINE #52	1S	WALLACE
385	9	AARON SAND	YADKIN RIVER	1S	MYERS
417	10	B & T SAND	LEXINGTON 3	1S	ADAIR
341		BLUE RIDGE SAND	FRIES	1S	WAGONER
413		CAROLINA MATERIAL SALES	LAKE LURE	AS	TALLENT
428	12	CAROLINA SAND	DELIGHT	2S	BULLOCK
442	9	CAROLINA SAND	MCMAHAN	RS	POTTS
461		CAROLINA SAND	WALKER	AS	WALLACE
465		CAROLINA SAND	GRANTS CREEK PIT	AS	WALLACE
449		CHURCH SAND & STONE	MILLER PIT	AS	MCLAIN
450	10	CLARK BROTHERS FARM LLC	CLARK-ENOREE	RS	ADAIR
422	10	BUCKHORN MATERIALS	BLACK CREEK	AS	ADAIR
479		HEDRICK INDUSTRIES	AQUADALE	2MS	THOMAS
239		HEDRICK INDUSTRIES	PAGELAND	AS	ADAIR
396	14	LBM INDUSTRIES	WHITEWATER FALLS	2MS	RHYMER
429	10	LOAMAY LLC	KERSHAW	AS	ADAIR
454	10	PAGELAND SAND	MOUNT CROGHAN	AS	ADAIR
347	11	PATTON SAND	PATTON	1S	MCLAIN
447		PEA CREEK MINES	HATCHER	1S	JACKSON
443	3	RIVERSIDE SAND	RIVERSIDE #3 (Wallace)	AS	JACKSON
159	1	RPC CONTRACTING	FORBES	P	LONG
380	9	SLATE SAND	SHOALS	P	CARRIKER
85		VULCAN MATERIALS	MORGANTON	2MS	TALLENT
477		GLOVER MATERIALS	MEHERRINE MINE	1S	LONG

SAMPLE DATE	F M	DEL SUB	SP GR	ABS %	STRENGTH RATIO 3 DAY	7 DAY	YEARLY CK DUE	Re S DATE
4/19/2004								4/19/2004
1/15/2008								1/15/2008
7/25/2005								
5/26/2009								5/26/2009
11/30/2007								11/30/2007
3/27/2007								3/27/2007
1/20/2004	3.38		2.64	0.7	100	108.9		1/20/2004
9/7/2010		0.0						9/7/2010
7/2/2003	3.11		2.62	0.9	106.6	115.7		8/2/2006
7/17/2007	1.73							7/17/2007
5/12/2008	2.79	0.3	2.64	0.7	113.7	120.7		
10/26/2009		0.5	2.63	0.7				10/26/2009
3/9/2011		0.5						3/9/2011
11/26/2012	2.16	1.0	2.65	0.5	114.4	129.3		11/26/2012
7/20/2012	2.08	0.3	2.62	1.0	99.5	111.0		7/20/2012
4/10/2013	3.00	0.9						4/10/2013
9/12/2011	1.83	0.2	2.62	1.0	113.2	123.4		9/12/2011
4/1/2013							Apr-2014	4/1/2013
6/21/2011		0.2						6/1/2010
9/23/2013	1.96	0.3						11/15/2010
9/10/2013	1.85	0.2						9/10/2013
8/29/2011	3.86	0.3	2.62	0.4	106.6	111.3		8/29/2011
8/2/2011	2.85	0.2						8/2/2011
7/19/2012	1.46	0.3						7/19/2012
11/1/2011		0.2						11/1/2011
7/30/2009								7/30/2009
2/3/2012	2.41							2/3/2012
2/21/2013	2.65	0.6						2/21/2013

evised Date 10/11/11

OUNDNESS LOSS	DUE	OTHER STATE ID
2.9	Apr-07	
3.7	Jan-11	
2.1	May-12	
2.7	Nov-10	
2.4	Mar-10	
1.8	Jan-07	
0.5	Sep-13	
4.5	Aug-09	
2.0	Jul-10	
1.1	Oct-12	
2.1	Mar-14	
4.5	Nov-15	
5.1	Jul-15	
4.1	Apr-16	
1.4	Sep-14	
2.0	Apr-2016	
1.3	Jun-13	
1.3	Nov-13	
3.0	Sep-16	
3.8	Aug-14	
0.4	Aug-14	
6.6	Jul-15	
0.8	Nov-14	
1.6	Jul-12	
0.8	Feb-2015	
3.8	Feb-16	

303 — Revised Date 3/22/2012

	NUMBER	DIV.	OWNER	LOCATION	P/Q	MONTH DUE	INSPECTOR	SAMPLE DATE	LA A	LA B	LA C	SP. GR A	SP. GR B	SP. GR C	ABS %	DEL SUB	LA DUE	SOUNDNESS DATE	SOUNDNESS 3/4	SOUNDNESS 3/8	SOUNDNESS #4	SOUNDNESS DUE	SCREENINGS SOUNDNESS DATE	SCREENINGS SOUNDNESS % LOSS	SCREENINGS SOUNDNESS DUE	UNIT WEIGHT DATE	UNIT WEIGHT SIZE	UNIT WEIGHT LBS/CU FT	OTHER STATE ID
	347	11	AGGREGATES USA	MACON GA	Q	SEPT	TALLENT	1/28/2013	21	22	23	2.71	2.71	2.70	0.5		Jan-14	1/28/2013	0.2	0.3	0.9	Jan-2016							GA 028C
	183		AGGREGATES USA	MIDWAY (Mascot TN)	Q	APR	RHYMER	4/9/2013	20	19	19	2.80	2.80	2.80	0.4		Apr-14	4/9/2013	0.2	0.3	0.7	Apr-2016							
	133	11	AGGREGATES USA	WATAUGA TN	Q	JUL	CHURCH	1/2/2013	22	19	20	2.77	2.77	2.78	0.3		Jan-14	7/22/2008	0.9	0.2	0.4	Jul-2011	8/9/2005	1.2	Aug-2008				
	351	11	ALLEGHANY STONE	GLADE VALLEY	Q	NOV	MCLAIN	7/30/2013	40	37	36	2.73	2.73	2.70	0.7		Jul-14	7/3/2012	0.3	0.3	1.1	Jul-2015							
	287	8	AMERICAN MATERIALS	CLARK	P	APR	CHRISTIAN	4/20/2010	40	38	39	2.64	2.64	2.63	0.4		Apr-11	4/20/2010	0.2	0.9	1.9	Apr-2013							
	3	11	ARARAT ROCK PROD.	MT. AIRY	Q	MAY	MCLAIN	3/27/2013	36	39	39	2.77	2.77	2.75	0.6	0.06	Mar-14	8/4/2011	0.1	0.2	0.8	Aug-2014	3/17/2004	3.9	Mar-2007	7/9/2009	57	100.1	
	341	4	BEST S&G	GOLDSBORO	C	APR	RUDD	8/1/2012	28	28	31	2.50	2.50	2.46	3.1		Aug-13												
	312	10	BOGGS MATERIALS	BOGGS 601 YARD	Y	APR	HISSOM	2/8/2013	37	35	36	2.45	2.52	2.47	4.4		Feb-14												
	334	11	BOXLEY AGGREGATES	BLUE RIDGE	Q	NOV	LOWRANCE	11/19/2009	18	17	18	2.78	2.78	2.78	0.3		Nov-10	11/12/2008	3.5	0.7	0.7	Nov-2011							VA 2004
	142	7	BOXLEY AGGREGATES	FIELDALE	Q	APR	FOSQUE	3/1/2013	28	27	29	2.88	2.88	2.88	0.6	0.07	Mar-14	3/16/2011	0.2	0.2	0.7	Mar-2014	10/28/1998	2.7	Oct-2001				
	325	10	BUCKHORN MATERIALS	LYNCHES RIVER	Q	JUN	ADAIR	6/17/2013	36	34	40	2.65	2.64	2.64	0.5		Jun-14	8/2/2013	0.1	0.2	0.5	Aug-2016	1/6/2011	1.1	Jan-2014				
	11	11	CARDINAL STONE CO.	GALAX (Grayson, VA)	Q	APR	MCLAIN	5/22/2013	21	20	22	2.74	2.74	2.75	0.7	0.03	May-14	5/22/2013	0.2	0.3	0.9	May-2016	5/22/2013	3.1	May-2016	6/1/2010	57	102.3	VA 1009
**	123	11	CARDINAL STONE CO.	SMETHPORT	Q	JUL	MCLAIN	5/29/2013	46	42	39	3.09	3.07	3.06	0.7		May-14	5/24/2011	0.1	0.2	0.5	May-2014	6/21/2005	3.6	Jun-2008				
	78	5	CARDINAL STONE CO.	SOUTH BOSTON	Q	APR	WATKINS	4/12/2013	26	24	27	2.73	2.75	2.74	0.8	0.07	Apr-14	4/13/2012	0.1	0.6	1.0	Apr-2015	12/5/2007	1.6	Dec-2010				VA 3010
	26	9	CAROLINA STALITE	AQUADALE - lightweight	Q	MAR	THOMAS	2/16/2011	27	16	11	1.49	1.51	1.57	3.6		Feb-12	2/18/2010	0.0	0.0	0.5	Feb-2013	10/14/1999	1.0	Oct-2002	1/20/1998	67	49.7	
	226	9	CAROLINA STALITE	GOLD HILL	Q	JAN	WALLACE	5/2/2012	31	30	26	1.42	1.44	1.52	3.5	0.11	May-13	5/2/2012				May-2015				3/12/2003	67	53.5	
	178	5	CAROLINA SUNROCK	BUTNER	Q	JAN	WATKINS	4/2/2013	24	23	25	2.98	2.98	2.98	0.4	0.11	Apr-14	9/14/2011	0.2	0.4	1.2	Sep-2014	8/19/2009	2.6	Aug-2012				
	304	5	CAROLINA SUNROCK	KITTRELL	Q	JUN	WATKINS	1/8/2013	37	38	39	2.64	2.63	2.63	0.3		Jan-14	12/14/2011	0.1	0.2	1.0	Dec-2014	9/25/2012	3.6	Sep-2015				
	332	5	CAROLINA SUNROCK	NORTH RALIEGH	Y	JUN	WATKINS	6/19/2012	42	38	40	2.49	2.51	2.47	4.7		Jun-13												
	303		CAROLINA SUNROCK	RDU DISTRIBUTION CENTER		SEPT	SKINNER	8/28/2013	36	33	37	2.52	2.52	2.51	3.6		Aug-14												
	329	5	CAROLINA SUNROCK	WOODSDALE	Q	FEB	WATKINS	2/6/2012	18	18	19	2.79	2.82	2.81	0.5		Feb-13	2/6/2012	2.9	0.4	1.1	Feb-2015	8/17/2009	7.5	Aug-2012				
	374	7	CEMEX, INC.	EDEN	Q	MAR	WESTMOREI	2/12/2013	18	17	16	2.73	2.73	2.72	0.5	0.07	Feb-14	3/28/2011	0.1	0.3	0.3	Mar-2014				1/19/2011	57	96.2	
	352	10	DH GRIFFIN CRUSHING	CHARLOTTE	C	OCT	ADAIR	10/30/2012	33	34	35	2.56	2.53	2.47	3.7		Oct-13												
	190	13	EXPLOSIVE SUPPLY CO.	WOODLAWN	Q	APR	RHYMER	10/2/2012	48	44	43	2.83	2.83	2.82	0.5		Oct-13	10/27/2011	0.4	1.1	3.3	Oct-2014	1/25/2010	14.0	Jan-2013				
	343	10	FEREBEE	PINEVILLE	Q	APR	ADAIR	4/23/2013	32	30	30	2.53	2.53	2.52	1.4		Apr-14												
**	272	3	GRAND STRAND AGG'S	GORETOWN MINE	Q	MAR	JACKSON	2/1/2013	44	43	45	2.44	2.47	2.48	2.9		Feb-14	8/15/2011	1.4	0.8	2.1	Jun-2014	2/21/2007	1.9	Feb-2010				
**	316	13	HANSON, INC.	ANDERSON	Q	JUL	TALLENT	8/2/2011	52	51	48	2.75	2.72	2.70	0.6		Aug-12	8/2/2011	0.1	0.2	0.7	Aug-2014							SC105
**	285		HANSON, INC.	ATHENS GA	Q	JUN	TALLENT	6/25/2012	46	48	49	2.70	2.69	2.69	0.6		Jun-13	6/25/2012	0.2	0.3	0.9	Jun-2015							GA 023C
	61	5	HANSON, INC.	CRABTREE	Q	MAR	RAY	9/7/2012	22	20	24	2.64	2.64	2.63	0.5	0.03	Sep-13	9/7/2012	0.1	0.2	0.7	Sep-2015	9/7/2012	1.6	Sep-2015	5/15/2001	67	96.9	
	63	8	HANSON, INC.	ELLIOTT	P	AUG	HORNE	11/16/2011	40	38	36	2.63	2.63	2.62	0.5	0.02	Nov-12	10/1/2010	0.4	1.5	4.5	Oct-2013							
	295	0	HANSON, INC.	GAINESVILLE GA	Q	FEB	RHYMER	2/14/2012	36	35	38	2.63	2.63	2.61	0.6		Feb-13	1/13/2011	0.1	0.3	1.0	Jan-2014							GA 024C
	367		HANSON, INC.	HABERSHAM	Q	OCT	RHYMER	11/6/2012	32	31	34	2.70	2.68	2.68	0.5		Nov-13	10/27/2010	0.1	0.2	0.6	Oct-2013							
	282	5	HANSON, INC.	HOLLY SPRINGS	Q	FEB	SHEARER	2/21/2013	27	26	28	2.66	2.66	2.64	0.6	0.08	Feb-14	2/21/2013	1.5	1.3	4.3	Feb-2016	7/27/2009	0.7	Jul-2012				
	120	10	HANSON, INC.	JEFFERSON SC	Q	AUG	ADAIR	8/16/2012	40	40	44	2.63	2.63	2.62	0.5	0.15	Aug-13	8/4/2010	0.2	0.3	0.8	Aug-2013	5/13/2010	0.9	May-2013				SC111
	138	6	HANSON, INC.	LEON GARDNER	Q	AUG	HORNE	1/31/2013	32	33	34	2.61	2.62	2.61	0.5	0.10	Jan-14	1/31/2013	0.1	0.2	0.5	Feb-2016	11/16/2011	1.2	Nov-2014				
	222	10	HANSON, INC.	LOWERY SC	Q	DEC	ADAIR	12/17/2012	35	34	37	2.64	2.64	2.62	0.4		Dec-13	12/17/2012	0.1	0.2	0.8	Dec-2015	8/3/2009	1.2	Aug-2012				SC112
**	34	8	HANSON, INC.	MARLBORO	P	SEPT	CHRISTIAN	7/17/2013	54	55	52	2.63	2.63	2.63	0.4		Jul-14	7/17/2013	0.2	0.3	0.8	Jul-2016							SC106
	66	4	HANSON, INC.	NEVERSON	Q	MAY	RAY	5/21/2013	36	37	38	2.64	2.64	2.62	0.6		May-14	5/9/2011	0.0	0.1	0.5	May-14	2/12/2013	2.0	Feb-16				
	67	5	HANSON, INC.	NORTH RALIEGH (WF)	Q	SEPT	WATKINS	12/3/2012	37	38	39	2.77	2.77	2.77	0.5	0.10	Dec-13	9/7/2010	0.1	0.3	1.2	Sep-2013	12/3/2013	1.9	Dec-2016				
ASR	64	4	HANSON, INC.	PRINCETON	Q	MAY	RUDD	3/13/2013	21	19	22	2.73	2.72	2.70	0.5		Mar-14	3/2/2012	0.2	0.2	0.5	Mar-2015	3/2/2012	3.6	Mar-2015				
	65	4	HANSON, INC.	ROCKY MOUNT	Q	AUG	RUDD	4/8/2013	30	28	30	2.67	2.66	2.66	0.5		Apr-14	4/8/2013	0.1	0.5	1.6	Apr-2016	9/20/2012	4.6	Sep-2015				
	371	4	HANSON, INC.	ROCKY MOUNT #2	Q	APR	RUDD	7/19/2013	32	33	36	2.69	2.68	2.67	0.5		Jul-14	4/15/2011	0.4	0.7	0.8	Apr-2014	8/23/2012	14.5	Aug-2015				
	217	5	HANSON, INC.	ROUGEMONT	Q	APR	WATKINS	4/2/2013	14	14	16	2.70	2.70	2.68	0.5	0.08	Apr-14	8/19/2011	0.1	0.2	0.9	Aug-2014	9/2/2009	1.4	Sep-2012				
	298		HANSON, INC.	SANDY FLATS	Q	NOV	RHYMER	12/11/2013	48	50	52	2.68	2.67	2.66	0.4		Dec-14	11/22/2011	0.1	0.2	0.6	Nov-2014							SC113
	368	14	HANSON, INC.	TOCCOA GA	Q	OCT	RHYMER	11/6/2012	40	41	44	2.64	2.64	2.62	0.4		Nov-13	10/27/2010	0.4	0.4	0.8	Oct-2013							GA 034C
	328	13	HANSON, INC.	WALTON CO GA	Q	JUN	RHYMER	6/21/2011	38	39	41	2.67	2.66	2.65	0.5		Jun-12	6/14/2010	1.1	0.3	0.9	Jun-2013							
	115	14	HARRISON, INC.	CHEROKEE (MURPHY)	Q	SEPT	RHYMER	9/10/2012	27	25	30	2.73	2.73	2.73	0.5		Sep-13	9/20/2011	0.2	0.8	1.0	Sep-2014	2/20/2012	3.4	Feb-2015				
	15	14	HARRISON, INC.	DILLSBORO	Q	AUG	RHYMER	2/28/2013	46	48	49	2.94	2.93	2.92	0.5		Feb-14	2/28/2013	0.2	0.4	1.3	Feb-2016	7/30/2009	2.8	Jul-2012				
	16	14	HARRISON, INC.	FRANKLIN	Q	JAN	RHYMER	1/7/2013	42	43	44	2.73	2.73	2.73	0.5		Jan-14	1/9/2012	0.2	0.3	1.8	Jan-2015	2/20/2012	1.7	Feb-2015				
	195	14	HARRISON, INC.	HAYESVILLE	Q	JUL	RHYMER	6/28/2012	36	36	40	2.73	2.73	2.72	0.5		Jun-13	6/28/2012	0.2	0.3	0.4	Jun-2015	2/20/2012	3.2	Feb-2015				
	193	14	HARRISON, INC.	MASSEY BRANCH	Q	OCT	RHYMER	9/23/2011	44	47	49	2.73	2.72	2.70	0.7		Sep-12	9/30/2009	1.5	1.4		Sep-2012							
	116	14	HARRISON, INC.	MISSION DAM	Q	JUL	RHYMER	7/29/2013	29	29	28	2.74	2.74	2.73	0.5		Jul-14	6/28/2012	0.2	0.4	1.2	Jun-2015	11/17/2003	2.8	Nov-2006	5/10/2005	57	96.6	
	1	14	HARRISON, INC.	WAYNESVILLE	Q	MAY	RHYMER	5/20/2013	32	32	33	2.81	2.79	2.77	0.8		May-14	5/20/2013	0.5	0.6	2.1	May-2016	7/30/2009	6.7	Jul-2012				
	386		HARSCO CORP.	PLANT 62		JUL	LONG	7/2/2013	17	16		3.38	3.39		1.6		Jul-14	7/2/2013	5.0	1.7		Jul-2016							
	274	9	HEDRICK INDUSTRIES	AQUADALE - normal	Q	JAN	THOMAS	1/23/2013	13	12	13	2.77	2.77	2.77	0.1		Jan-14	2/16/2011	0.1	0.2	0.6	Feb-2014	9/24/1999	1.3	Sep-2002				
**	280	13	HEDRICK INDUSTRIES	GREEN RIVERQ		AUG	RHYMER	11/30/2012	45	47	50	2.68	2.68	2.67	0.6		Nov-13	6/26/2012	1.9	0.3	1.1	Jun-2015	5/24/2011	2.8	May-2014				
	146	13	HEDRICK INDUSTRIES	GROVESTONE	Q	APR	RHYMER	4/22/2013	34	34	38	2.76	2.78	2.74	0.6		Apr-14	3/10/2011	0.3	0.5	1.5	Mar-2014	7/30/2009	0.8	Jul-2012				
	168	12	HEDRICK INDUSTRIES	LAKE NORMAN	Q	JUL	BULLOCK	5/31/2013	28	30	33	2.73	2.72	2.71	0.7	0.06	May-14	5/7/2012	0.3	0.3	1.0	May-2015	4/12/1989	4.6	Apr-1992	6/22/2004	67	104.0	
	379		HEDRICK INDUSTRIES	LILESVILLE	Q	JUN	ADAIR	6/11/2012	41	41	41	2.68	2.66	2.63	0.7		Jun-13	6/11/2012	0.2	0.2	1.3	Jun-2015							
	131	13	HEDRICK INDUSTRIES	N. BUNCOMBE	Q	NOV	TALLENT	4/8/2013	30	28	32	2.77	2.76	2.74	0.6		Apr-14	3/17/2011	0.1	0.3	0.5	Mar-2014	7/30/2009	6.8	Jul-2012				
	283	13	HEDRICK INDUSTRIES	SOUTH MCDOWELL	Q	JAN	RHYMER	1/7/2013	40	41	42	2.64	2.64	2.61	0.5		Jan-14	1/7/2013	0.1	0.3	0.7	Jan-2016	7/30/2009	1.2	Jul-2012	5/2/2008	57	99.5	
	163	13	JOHNSON PAVING CO.	TOM'S CREEK	Q	APR	TALLENT	8/20/2010	33	32	34	2.65	2.65	2.64	0.4		Aug-11	8/21/2008	0.5	0.5	1.0	Aug-2011	8/3/2006	1.0	Aug-2009				
	383		JT RUSSELL & SONS INC	RILEY QUARRY		FEB	THOMAS	2/27/2013	18	17	19	2.74	2.73	2.71	0.6		Feb-14	2/27/2011				Feb-2014							
	365	14	LAFARGE AGGREGATES	FRIENDSHIP	Q	AUG	TALLENT	8/24/2010	38	38	43	2.65	2.65	2.64	0.4		Aug-11	8/24/2010	0.1	0.2	0.9	Aug-2013							GA 102C
	318	9	LARCO CONSTRUCTION	WINSTON SALEM GLENN	C	DEC	WAGONER	1/20/2010	40	39	40	2.47	2.50	2.47	4.1		Jan-11												
	23	14	LBM INDUSTRIES	HEWITT	Q	SEPT	RHYMER	10/3/2012	35	31	36	2.76	2.75	2.75	0.3		Oct-13	10/3/2012	0.2	0.4	1.5	Oct-2015	8/31/2000	4.0	Sep-2003				
	119	14	LBM INDUSTRIES	WHITEWATER FALLS	Q	MAY	RHYMER	5/22/2013	40	39	41	2.68	2.68	2.66	0.5		May-14	5/29/2012	0.1	0.2	0.5	May-2015	9/8/2000	1.9	Sep-2003				
	292	7	LUCK STONE CO	PITTSBORO	Q	APR	HORNE	4/27/2012	16	13	14	2.84	2.85	2.84	0.4		Apr-13	4/27/2012	0.2	0.9	1.2	Apr-2015	8/7/2013	2.5	Jun-2016				
	335		LUCK STONE CO	ROCKVILLE	Q	JUL	PRESTRESS	5/20/2013	19		18	2.72		2.67	0.3		May-14	7/7/2011		0.1	0.9	Jul-14							VA 4011
	105		MARTIN MARIETTA	AUGUSTA (DAN QUARRY	Q	AUG	MEDFORD	8/5/2013		18			2.65		0.6		Aug-14												
	31	10	MARTIN MARIETTA	ARROWOOD	Q	DEC	ADAIR	12/6/2012	31	30	34	2.93	2.92	2.95	0.4		Dec-13	12/14/2010	0.1	0.1	0.3	Dec-2013	9/9/2010	1.2	Sep-2013				

	NUMBER	DIV.	OWNER	LOCATION	P/Q	MONTH DUE	INSPECTOR	SAMPLE DATE	LA A	LA B	LA C	SP. GR A	SP. GR B	SP. GR C	ABS %	DEL SUB	LA DUE	SOUNDNESS DATE	SOUNDNESS 3/4	SOUNDNESS 3/8	SOUNDNESS #4	SOUNDNESS DUE	SCREENINGS SOUNDNESS DATE	SCREENINGS % LOSS	SCREENINGS SOUNDNESS DUE	UNIT WEIGHT DATE	UNIT WEIGHT SIZE	UNIT WEIGHT LBS/CU FT	OTHER STATE ID
ASR	30	7	MARTIN MARIETTA	ASHEBORO	Q	OCT	HORNE	7/29/2013	23	23	25	2.77	2.77	2.77	0.5	0.15	Jul-14	2/25/2011	0.1	0.4	0.6	Feb-2014	3/1/2012	2.2	Mar-2015				
ASR	32	10	MARTIN MARIETTA	BAKERS	Q	NOV	THOMAS	6/25/2012	17	16	14	2.77	2.77	2.76	0.3		Jun-13	7/6/2010	0.4	1.4	1.8	Jul-2013	5/5/2010	0.8	May-2013				
	38	2	MARTIN MARIETTA	BELGRADE	Q	SEPT	JACKSON	2/4/2013	51	49	47	2.41	2.41	2.42	3.9		Feb-14	2/4/2013	1.5	2.2	3.9	Feb-2016	3/16/1995	0.5	Mar-1998				
	176	4	MARTIN MARIETTA	BENSON	Q	JAN	RAY	1/15/2013	21	19	20	2.73	2.73	2.73	0.6		Jan-14	2/8/2011	0.2	0.2	0.8	Feb-2014	11/8/2011	0.6	Nov-2014				
	276	10	MARTIN MARIETTA	BONDS	Q	JAN	ADAIR	4/10/2013	27	27	28	2.73	2.73	2.73	0.4		Apr-14	2/1/2011	0.1	0.3	1.3	Feb-2014	5/4/2010	1.3	May-2013				
	39	7	MARTIN MARIETTA	BURLINGTON	Q	NOV	FOSQUE	2/28/2013	21	22	24	2.87	2.87	2.87	0.5	0.09	Feb-14	2/28/2013	0.2	0.2	0.6	Feb-2016	3/10/2005	4.2	Mar-2008				
**	5	11	MARTIN MARIETTA	CALDWELL (Hudson)	Q	MAY	MCLAIN	6/11/2013	48	52	44	2.72	2.72	2.75	0.5	0.19	Jun-14	5/18/2011	0.1	0.2	0.7	May-2014	5/21/2001	1.2	May-2004	7/14/2008	57	97.8	
	330	0	MARTIN MARIETTA	CAMAK GA	Q	DEC	PRESTRESS	8/13/2012		30			2.66		0.4		Aug-13	8/1/2011		0.3		Aug-2014							GA 052C
	40	3	MARTIN MARIETTA	CASTLE HAYNE	Q	AUG	JACKSON	1/30/2013	42	43	44	2.46	2.47	2.50	2.8		Jan-14	1/30/2013	5.7	3.3	6.7	Jan-2016	10/18/1991		Oct-1994				
	221	10	MARTIN MARIETTA	CAYCE	Q	AUG	ADAIR	1/3/2013	25	24	29	2.64	2.63	2.60	0.4		Jan-14	8/20/2012	0.1	0.2	1.1	Aug-2015							SC122
	28	7	MARTIN MARIETTA	CENTRAL ROCK	Q	FEB	FOSQUE	8/12/2013	30	31	33	2.64	2.60	2.59	3.5	0.08	Aug-14	2/25/2013	0.2	1.3	2.6	Feb-2016	4/1/2004	2.4	Apr-2007				
	2	7	MARTIN MARIETTA	CHAPEL HILL (American)	Q	OCT	HORNE	2/19/2013	17	16	19	2.85	2.84	2.86	0.4	0.11	Feb-14	11/29/2012	0.1	0.4	0.7	Nov-2015	11/3/2010	3.3	Nov-2013				
	41	10	MARTIN MARIETTA	CHARLOTTE	Q	MAY	ADAIR	12/11/2012	16	15	17	2.84	2.84	2.82	0.3		Dec-13	12/11/2012	0.1	0.1	0.5	Dec-2015	5/4/2010	1.0	May-2013				
	267		MARTIN MARIETTA	CHESTERFIELD	Q	MAR	ADAIR	2/27/2012	37	37	40	2.61	2.61	2.60	0.7		Feb-13	1/20/2010	0.5	0.6	3.5	Jan-2013	5/13/2010	0.8	May-2013				
	189	2	MARTIN MARIETTA	CLARKS	Q	SEPT	STRICKLAND	5/2/2013	51	50	46	2.29	2.30	2.33	4.2		May-14	3/12/2012	1.9	1.1	2.7	Mar-2015							
	339	6	MARTIN MARIETTA	CUMBERLAND	Q	FEB	CHRISTIAN	3/18/2012	33	33	28	2.73	2.72	2.71	1.4		Mar-13	3/18/2012	1.4	3.1	5.6	Mar-2015							
	169	12	MARTIN MARIETTA	DENVER	Q	JUL	BULLOCK	7/5/2013	29	28	32	2.70	2.70	2.68	0.7	0.07	Jul-14	7/5/2013	0.1	0.3	0.6	Jul-2018				3/3/2004	67	96.3	
	201	7	MARTIN MARIETTA	EAST ALAMANCE	Q	APR	FOSQUE	6/20/2013	24	20	21	2.83	2.83	2.83	0.4	0.06	Jun-14	8/20/2013	0.1	0.1	0.6	Jun-2016	5/5/2004	1.3	May-2007				
	42	1	MARTIN MARIETTA	FOUNTAIN	Q	SEPT	STRICKLAND	8/9/2012	24	22	23	2.68	2.68	2.67	0.4		Aug-13	1/1/2012	0.1	0.6		Jan-2015	8/9/2012	4.1	Aug-2015				
**	270	5	*MARTIN MARIETTA*	*FRANKLIN*	*Q*	*MAR*	*RAY*	*4/16/2013*	*48*	*51*	*56*	*2.65*	*2.64*	*2.63*	*0.5*	*0.10*	*Apr-14*	*4/16/2013*	*0.2*	*0.2*	*1.0*	*Apr-2016*	*7/5/2006*	*1.7*	*Jul-09*				
	220	5	MARTIN MARIETTA	FUQUAY	Q	DEC	SHEARER	2/21/2013	30	31	32	2.68	2.68	2.67	0.4	0.06	Feb-14	2/16/2012	0.1	0.2	0.5	Feb-2015	7/27/2009	1.3	Jul-2012				
	57	5	MARTIN MARIETTA	GARNER	Q	JUN	RAY	2/14/2013	44	42	45	2.84	2.63	2.63	0.4	0.02	Feb-14	3/21/2012	0.2	1.3	6.5	Mar-2015	11/8/2011	1.7	Nov-2014				
	43	12	MARTIN MARIETTA	HICKORY	Q	AUG	BULLOCK	10/1/2012	38	37	39	2.74	2.74	2.74	0.5	0.09	Oct-13	7/13/2010	0.3	0.2	0.7	Jul-2013	9/20/2000	7.7	Sep-2003	6/22/2004	67	97.1	
	46	7	MARTIN MARIETTA	JAMESTOWN	Q	OCT	FOSQUE	1/14/2013	33	34	35	2.71	2.70	2.68	0.5	0.11	Jan-14	1/14/2013	0.3	0.1	0.4	Jan-2016	2/19/2004	0.9	Feb-2007				
	47	9	MARTIN MARIETTA	KANNAPOLIS	Q	FEB	WALLACE	12/9/2011	34	35	36	2.61	2.63	2.82	0.7	0.08	Dec-12	12/9/2011	0.1	0.3	1.3	Dec-2014	3/22/2001	2.1	Mar-2004	3/22/2001	67	96.3	
	48	12	MARTIN MARIETTA	KINGS MOUNTAIN	Q	AUG	BULLOCK	10/3/2012	24	22	26	2.74	2.74	2.74	0.4	0.15	Oct-13	8/3/2011	0.1	0.3	0.5	Aug-2014	6/14/1990	1.4	Jun-1993	7/22/2003	67	101.8	
	97	8	MARTIN MARIETTA	LEMON SPRINGS	Q	MAR	HORNE	1/30/2013	18	17	19	2.67	2.67	2.67	0.4	0.12	Jan-14	1/30/2013	0.1	0.5	2.0	Jan-2016	6/4/2013	2.2	Jun-2016				
	268	12	MARTIN MARIETTA	MAIDEN	Q	OCT	MCLAIN	10/15/2012	33	36		2.74	2.75		0.7		Oct-13	10/12/2011	0.7	1.5		Oct-14							
	188	10	MARTIN MARIETTA	MALLARD CREEK	Q	NOV	ADAIR	11/29/2012	18	18	21	2.84	2.83	2.83	0.4		Nov-13	12/13/2011	2.2	1.5	3.3	Dec-2014	5/11/2010	0.6	May-2013				
	37	10	MARTIN MARIETTA	MATTHEWS	Q	NOV	ADAIR	8/12/2013	13	12	13	2.79	2.78	2.78	0.4		Aug-14	7/30/2012	0.1	0.2	0.9	Jul-2015	8/26/2009	1.3	Aug-2012	9/24/2001	67	99.2	
	259	2	MARTIN MARIETTA	ONSLOW	Q	DEC	JACKSON	2/4/2013	40	40	42	2.41	2.41	2.41	4.7		Feb-14	7/18/2011	15.0	8.5	6.4	Jul-2014							
ASR	51	7	MARTIN MARIETTA	POMONA	Q	FEB	FOSQUE	1/29/2013	18	18	20	2.84	2.83	2.81	0.4	0.80	Jan-14	1/29/2013	0.1	0.2	0.6	Jan-2016	2/19/2004	1.1	Feb-2007				
	376	7	MARTIN MARIETTA	POMONA - recycled conc		FEB	FOSQUE	2/20/2012	34	33	38	2.70	2.69	2.64	1.4		Feb-13												
	156	5	MARTIN MARIETTA	RALIEGH-DURHAM	Q	OCT	WATKINS	10/8/2012	23	23	24	2.82	2.82	2.80	0.3	0.03	Oct-13	10/15/2010	0.1	0.1	0.5	Oct-2013	10/8/2012	4.1	Oct-2015				
	52	7	MARTIN MARIETTA	REIDSVILLE	Q	FEB	FOSQUE	2/1/2013	23	22	24	2.76	2.75	2.75	0.4	0.07	Feb-14	2/1/2013	0.1	0.2	0.5	Feb-2016	2/10/2005	5.5	Feb-2008				
	271	10	MARTIN MARIETTA	ROCK HILL	Q	APR	ADAIR	4/11/2013	20	19	24	2.81	2.80	2.80	0.3		Apr-14	4/11/2013	0.1	0.3	0.4	Apr-2016	8/23/2010	1.2	Aug-2013				SC142
	161	3	MARTIN MARIETTA	ROCKY POINT	Q	AUG	JACKSON	1/12/2012	43	42	41	2.51	2.51	2.53	2.9		Jan-13	1/12/2012	6.8	5.0	15.6	Jan-2015	9/30/1992	5.0	Oct-1995				
	207	10	MARTIN MARIETTA	ROCKY RIVERQ		JUL	THOMAS	8/24/2011	13	15	23	2.82	2.80	2.79	0.3		Aug-12	8/24/2011	0.3	0.8	1.6	Aug-2014							
	209	9	MARTIN MARIETTA	SALEM	Q	JAN	WALLACE	4/29/2013	44	42	45	2.41	2.40	2.39	6.5	0.11	Apr-14	4/29/2013	0.1	0.2	0.8	Apr-2016	1/16/2002	3.2	Jan-2005	2/5/2003	67	98.0	
	54	12	MARTIN MARIETTA	STATESVILLE	Q	JUL	MCLAIN	7/10/2013	42	40	41	2.87	2.86	2.81	0.7	0.17	Jul-14	2/28/2012	0.2	0.4	0.8	Feb-2015				8/30/2011	78m	101.8	
ASR	102	9	MARTIN MARIETTA	THOMASVILLE	Q	JAN	WALLACE	3/5/1901	17	16	20	2.79	2.78	2.76	0.4	0.10	Mar-02	3/22/2012	0.2	1.3	0.9	Mar-2015	2/28/2005	2.9	Feb-2008	2/28/2005	87	99.2	
	56	9	MARTIN MARIETTA	WOODLEAF	Q	JUL	WALLACE	12/20/2011	33	36	40	2.76	2.74	2.74	0.6	0.07	Dec-12	1/30/2009	0.1	0.2	0.6	Jan-2012	7/26/2000	2.1	Jul-2003	10/19/2001	67	97.1	
	359	11	MATHIS QUARRIES	MATHIS	Q	MAR	CHURCH	7/18/2013	30	33	36	2.72	2.72	2.71	0.8		Jul-14	7/18/2013	0.1	0.7	1.3	Jul-2016	7/18/2013	3.0	Jul-2016				
	153	11	MAYMEAD LIMESTONE CO.	POTTER	Q	JUN	LOWRANCE	10/1/2012	22	19	22	2.75	2.74	2.73	0.5		Oct-13	10/1/2012	0.3	0.8	1.3	Oct-2015	6/13/2001	1.0	Jun-2004				
	370	12	MAYMEAD MATERIALS	STATESVILLE	C	DEC	MCLAIN	12/13/2010	33	34		2.46	2.48		4.5		Dec-11												
	113	13	MCCRARY STONE SERVICE	MARSHALL	Q	NOV	RHYMER	12/4/2012	28	26	28	2.93	2.95	2.95	0.7		Dec-13	12/4/2012	0.5	0.8	3.9	Dec-2015	7/29/2009	2.7	Jul-2012				
	180	11	MOUNTAIN MATERIALS	MOUTH OF WILSON	Q	JUL	MCLAIN	10/2/2012	28	26	29	2.74	2.72	2.74	0.5		Oct-13	10/2/2012	0.4	0.8	1.4	Oct-2015	12/18/2000	11.6	Dec-2003				VA 1080
	311	12	NA EMERALD MINES	ALEXANDER-HIDDENITE	Q	JUL	MCLAIN	10/19/2012	46	46		2.74	2.75		0.6		Oct-13	5/11/2010	0.1	0.2		May-2013							
**	24	11	NC GRANITE CORP	MOUNT AIRY	Q	MAY	MCLAIN	3/26/2013	50	51	52	2.64	2.63	2.61	0.7		Mar-14	8/10/2011	0.1	0.2	0.8	Aug-2014				7/9/2009	57	94.1	
**	273	11	NORTH 321 STONE INC.	NORTH 321	Q	APR	MCLAIN	11/23/2011	47	48	49	2.65	2.64	2.65	0.6		Nov-12	8/16/2010	0.1	1.1	4.5	Jun-2013							
	307	13	POUNDING MILL QUARRIES	BLUEFIELD	Q	MAR	MCLAIN	6/4/2013	25	22	20	2.71	2.71	2.70	0.4	0.01	Jun-14	5/31/2012	0.1	0.3	0.4	Jun-2015				3/30/2011	57	95.0	WV P020A
	313	11	RADFORD Q OF BOONE	DOE CREEK	Q	SEPT	CHURCH	12/8/2011	30	32	37	2.56	2.55	2.55	1.5		Dec-12	11/24/2010	0.3	0.8	3.7	Nov-2013							
	229	11	RADFORD Q OF BOONE	GLENDALE SPRINGS	Q	MAY	MCLAIN	8/3/2011	41	40	39	2.75	2.74	2.73	0.6		Aug-12	8/3/2011	0.1	0.3	1.2	Aug-2014							
	122	11	RADFORD Q OF BOONE	RADFORD (Bamboo)	Q	SEPT	CHURCH	10/2/2012	32	29	34	2.84	2.85	2.87	0.6		Oct-13	11/28/2011	0.1	0.2	1.2	Nov-2014	11/28/2011	8.5	Nov-2014				
	302	10	RED CLAY INDUSTRIES	CHARLOTTE	C	MAR	TUCKER	1/22/2010	35	33	37	2.51	2.54	2.51	4.8		Jan-11												
	251	11	RINKER MATERIALS	ABINGDON	Q	JUL	CHURCH	1/2/2013	21	17	16	2.85	2.83	2.85	0.2		Jan-14	7/23/2008	0.2	0.4	0.5	Jul-2011	7/13/2005	1.2	Jul-2008				
	158	11	RINKER MATERIALS	UNICOI	Q	JUL	CHURCH	1/2/2013	18	17	16	2.81	2.82	2.82	0.3		Jan-14	7/22/2008	0.1	0.4	0.4	Jul-2011	8/9/2005	1.4	Aug-2008				
**	369	12	*ROGERS GROUP*	*HENRIETTA*	*Q*	*FEB*	*BULLOCK*	*6/4/2013*	*52*	*55*	*55*	*2.66*	*2.66*	*2.64*	*0.4*		*Jun-14*	*2/22/2011*	*0.1*	*0.2*	*0.6*	*Feb-2014*							
	355	11	SALEM STONE	ENGLISH CONST		JAN	MCLAIN	1/20/2010	44	47		2.64	2.65		0.5		Jan-11	1/20/2010	0.3	1.1		Jan-2013							
	346	11	SALEM STONE	SYLVATUS VA	Q	SEPT	MCLAIN	6/28/2013	14	15	16	2.69	2.67	2.68	0.7		Jun-14	5/7/2012	1.0	3.4	2.3	May-2015							VA 1062
	340	3	SHELTER CREEK LLC	SHELTER CREEK	Q	SEPT	JACKSON	11/28/2011	31	33	34	2.51	2.50	2.54	3.5		Nov-12	11/28/2011	1.5	3.6	7.7	Nov-2014							
	75	7	SOUTHSIDE MATERIALS	SHELTON	Q	JUL	FOSQUE	1/16/2013	30	28	30	2.82	2.62	2.81	0.4	0.11	Jan-14	1/16/2013	0.3	0.3	0.9	Jan-2016	12/8/1997	1.4	Dec-2000				
	360	13	TAYLOR AND MURPHY	MARS HILL (C202107) #2	C	MAR	TALLENT	3/22/2010	29	27		2.76	2.79		0.5		Mar-11	3/22/2010	0.4	0.5		Mar-2013							
	364	13	TAYLOR AND MURPHY	MARS HILL (C202107) #3	C	JUL	TALLENT	7/22/2010	28	28	32	2.79	2.80	2.78	0.5		Jul-11	7/22/2010	0.1	0.5	1.2	Jul-2013							
	366	13	TAYLOR AND MURPHY	MARS HILL (C202107) #4	C	OCT	TALLENT	9/7/2010	24	23	26	2.77	2.79	2.77	0.5		Sep-11	9/7/2010	0.1	0.4	0.9	Sep-2013							
**	60	13	THOMPSON CONTRACTORS	MILL SPRINGS	Q	MAR	RHYMER	3/18/2013	40	41		2.80	2.79		0.4		Mar-14	3/8/2011	0.1	0.2		Mar-2014							
	59	13	THOMPSON CONTRACTORS	MILLER CREEK	Q	OCT	RHYMER	10/5/2012	42	42	43	2.83	2.82	2.82	0.4		Oct-13	10/5/2012	0.1	0.2	0.6	Oct-2015	2/28/2012	0.8	Feb-2015				
	79	11	VULCAN MATERIALS	115 QUARRY	Q	MAY	LOWRANCE	10/3/2012	36	34	38	2.75	2.75	2.75	0.4		Oct-13	7/15/2010	0.1	0.3	0.7	Jul-2013	10/20/2011	1.2	Oct-2014				
	82	12	VULCAN MATERIALS	BLACKSBURG SC	Q	JUN	BULLOCK	7/31/2013	38	36	37	2.82	2.81	2.81	0.4	0.08	Jul-14	8/24/2011	1.6	0.8	3.2	Aug-2014				6/29/2004	67	103.2	SC148
	114	14	VULCAN MATERIALS	BLAIRSVILLE	Q	AUG	RHYMER	8/1/2012	27	26	29	2.74	2.71	2.72	0.4		Aug-13	8/2/2011	0.1	0.2	0.6	Aug-2014	8/1/2006	1.8	Aug-2009				GA 090C
	21	11	VULCAN MATERIALS	BOONE	Q	JUN	LOWRANCE	10/1/2012	25	25	24	2.75	2.71	2.69	0.4		Oct-13	11/9/2010	0.1	0.5	1.0	Nov-2013	6/17/2005	2.1	Jun-2008				
	104	11	VULCAN MATERIALS	BRISTOL TN	Q	JUL	CHURCH	7/30/2013	23	22	18	2.71	2.71	2.81	0.4		Jul-14	3/25/2013	0.2	0.3	0.5	Mar-2018	7/12/2005	1.8	Jul-2008				

	NUMBER	DIV.	OWNER	LOCATION	P/Q	MONTH DUE	INSPECTOR	SAMPLE DATE	LA A	LA B	LA C	SP. GR A	SP. GR B	SP. GR C	ABS %	DEL SUB	LA DUE	SOUNDNESS DATE	SOUNDNESS 3/4	SOUNDNESS 3/8	SOUNDNESS #4	SOUNDNESS DUE	SCREENINGS SOUNDNESS DATE	SCREENINGS SOUNDNESS % LOSS	SCREENINGS SOUNDNESS DUE	UNIT WEIGHT DATE	UNIT WEIGHT SIZE	UNIT WEIGHT LBS/CU FT	OTHER STATE ID
	186	9	VULCAN MATERIALS	CABARRUS	Q	AUG	ADAIR	5/28/2013	30	22	32	2.75	2.82	2.74	0.4		May-14	9/19/2011	0.1	0.2	1.1	Sep-2014	4/29/2010	1.3	Apr-2013				
	249	10	VULCAN MATERIALS	CLEAR CREEK	Q	FEB	ADAIR	3/5/2013	12	12	13	2.83	2.81	2.80	0.2		Mar-14	2/27/2012	1.1	0.3	0.5	Feb-2015	5/5/2010	1.2	May-2013				
	210	10	VULCAN MATERIALS	COLUMBIA SCQ		NOV	ADAIR	10/25/2012	23	24	27	2.63	2.63	2.63	0.3		Oct-13	11/22/2011	0.1	0.4	0.8	Nov-2014	11/3/1997	3.2	Nov-2000				SC151
	205	1	VULCAN MATERIALS	DALE CHESTER VA	Q	JUN	RUDD	5/12/2011	41	43	48	2.64	2.63	2.82	0.4	0.10	May-12	5/2/2010	1.0	1.3	0.9	May-2013	6/2/2010	1.6	Jun-2013				VA 4015
	139	9	VULCAN MATERIALS	EAST FORSYTH	Q	FEB	WALLACE	4/24/2012	32	32	35	2.76	2.80	2.77	0.4	0.05	Apr-13	3/22/2011	0.8	0.4	0.4	Mar-2014	2/21/2000	5.0	Feb-2003				
	88	11	VULCAN MATERIALS	ELKIN	Q	FEB	MCLAIN	3/1/2013	23	22	23	2.68	2.67	2.64	0.4		Mar-14	3/1/2013	0.4	0.5	0.9	Mar-2016	3/5/2004	1.5	Mar-2007	7/6/2009	57	95.7	
	69	13	VULCAN MATERIALS	ENKA	Q	OCT	TALLENT	10/16/2012	31	30	34	2.71	2.72	2.73	0.5	0.07	Oct-13	8/15/2011	0.1	0.3	0.9	Aug-2014	8/10/2009	1.4	Aug-2012				
	372	0	VULCAN MATERIALS	FOREST PARK GA	Q	APR	PRESTRESS	4/7/2013		49			2.67		0.6		Apr-14	4/11/2011		0.0		Apr-2014							GA 015C
	214	0	VULCAN MATERIALS	GARRISONVILLE VA	Q	OCT	PRESTRESS	9/9/2009		17			2.96		0.2		Sep-10	9/9/2009		0.7		Sep-2012							VA 6012
ASR	85	9	VULCAN MATERIALS	GOLD HILL	Q	JAN	WALLACE	5/25/2012	13	11	12	2.76	2.76	2.76	0.3	0.06	May-13	5/16/2011	0.1	0.4	0.7	May-2014	2/27/2001	2.1	Feb-2004				
	70	5	VULCAN MATERIALS	GREYSTONE	Q	DEC	WATKINS	2/22/2013	39	41	43	2.62	2.64	2.64	0.4	0.07	Feb-14	2/22/2013	0.2	0.2	0.6	Feb-2016	5/26/2010	1.3	May-2013	4/8/2002	67	97.2	
	236	13	VULCAN MATERIALS	GREYSTONE-NOLICH	P	MAR	RHYMER	3/13/2013		42	46		2.58	2.57	1.4		Mar-14	3/22/2012		1.1	4.9	Mar-2015							
ASR	345		VULCAN MATERIALS	HAVRE DE GRACE MD	Q	FEB	RUDD	2/14/2012	17	16	19	2.80	2.81	2.81	0.4		Feb-13	2/14/2012	0.2	0.6	0.6	Feb-2015							
	81	14	VULCAN MATERIALS	HENDERSONVILLE	Q	JUL	RHYMER	7/12/2012	34	34	33	2.67	2.66	2.66	0.4		Jul-13	7/12/2012	0.1	0.2	0.4	Jul-2015	7/29/2009	0.9	Jul-2012				
	137	1	VULCAN MATERIALS	JACK VA	Q	JUN	RUDD	12/20/2013	24	22	27	2.64	2.66	2.68	1.0		Dec-14	6/2/2010	0.1	0.4	0.7	Jun-2013	5/21/2011	0.9	May-2014				VA 4016
	356		VULCAN MATERIALS	KODAK	Q	FEB	RHYMER	12/12/2011	22	20	22	2.71	2.71	2.71	0.2		Dec-12	2/19/2010	0.1	0.2	0.5	Feb-2013	2/19/2010	0.6	Feb-2013				
	71	5	VULCAN MATERIALS	LAWRENCVILLE	Q	MAR	RAY	8/8/2010	32	34	36	2.72	2.72	2.70	0.4	0.07	Jun-11	8/8/2010	0.2	0.3	0.6	Jun-2013	2/5/2004	1.6	Feb-2007				VA 4022
**	91	11	VULCAN MATERIALS	LENIOR	Q	JUN	MCLAIN	6/24/2013	47	49	49	2.76	2.74	2.72	0.7	0.49	Jun-14	11/30/2011	0.1	0.3	0.8	Nov-2014	5/15/2001	1.1	May-2004	6/12/2009	67	102.3	
**	278	10	VULCAN MATERIALS	LIBERTY	Q	APR	ADAIR	2/6/2013	46	48	50	2.67	2.65	2.64	0.7		Feb-14	2/6/2013	0.2	0.5	1.2	Feb-2016	4/13/2000	2.6	Apr-2003				SC158
	333	0	VULCAN MATERIALS	LITHIA SPRINGS	Q	NOV	PRESTRESS	1/16/2013		39			2.61		0.4	0.01	Jan-14	7/12/2011		0.2		Jul-2014							GA 047C
	358		VULCAN MATERIALS	MARYVILLE TN	Q	FEB	TALLENT	2/18/2010	18	16	20	2.82	2.82	2.82	0.2		Feb-11	2/18/2010	0.1	0.2	0.8	Feb-2013							
	7	13	VULCAN MATERIALS	MORGANTON	Q	APR	TALLENT	4/11/2013	42	40	43	2.83	2.83	2.83	0.4		Apr-14	4/11/2012	0.2	0.2	0.9	Apr-2015	2/2/2012	0.8	Feb-2015				
	72	9	VULCAN MATERIALS	NORTH	Q	FEB	WAGONER	4/24/2012	23	21	25	2.84	2.84	2.83	0.4	0.13	Apr-13	6/11/2010	0.1	0.3	0.8	Jun-2013	2/13/1998	2.6	Feb-2001	4/17/2003	67	104.0	
**	83	12	VULCAN MATERIALS	PACOLET	Q	JUN	BULLOCK	10/2/2012	46	47	45	2.66	2.65	2.64	0.5	0.11	Oct-13	10/2/2012	0.1	0.2	0.4	Oct-2015				6/19/2004	67	91.8	SC163
	12	14	VULCAN MATERIALS	PENROSE	Q	FEB	RHYMER	1/30/2013	28	27	14	2.71	2.71	2.70	0.4		Jan-14	1/30/2013	0.1	0.4	0.7	Jan-2016	8/10/2009	1.0	Aug-2012				
	101	10	VULCAN MATERIALS	PINEVILLE	Q	JUL	ADAIR	8/13/2012	24	23	27	2.99	2.99	2.97	0.4		Aug-13	7/18/2011	0.6	0.4	0.7	Jul-2014	12/22/1997	3.7	Dec-2000				
**	25	14	VULCAN MATERIALS	RABUN GAP GA	Q	MAY	RHYMER	5/22/2013	46	47	48	2.67	2.66	2.64	0.6		May-14	8/2/2013	0.1	0.4	0.9	Aug-2016	11/15/2004	1.0	Nov-2007				GA 036C
	218	1	VULCAN MATERIALS	RICHMOND	Q	JUN	LONG	6/29/2011	38	35	38	2.67	2.70	2.71	0.6		Jun-12	8/29/2011	5.1	0.8	3.0	Jun-14	3/29/2007	3.1	Mar-10				VA 4044
	94	8	VULCAN MATERIALS	ROCKINGHAMQ		MAR	CHRISTIAN	1/30/2013	33	34	35	2.70	2.70	2.69	0.5		Jan-14	1/30/2013	0.2	0.5	0.8	Jan-2016	9/29/2009	1.8	Sep-2012				
	357		VULCAN MATERIALS	SEVIERVILLE	Q	FEB	RHYMER	12/12/2011	21	19	20	2.75	2.76	2.74	0.3		Dec-12	2/19/2010	0.1	0.2	0.4	Feb-2013	2/19/2010	1.4	Feb-2013				
	55	1	VULCAN MATERIALS	SKIPPERS	Q	JAN	LONG	6/18/2013	18	17	28	2.64	2.63	2.65	0.7		Jun-14	1/24/2013	0.2	0.3	0.7	Jan-2016	1/24/2013	1.6	Jan-2016				VA 5004
	80	9	VULCAN MATERIALS	SMITH GROVE	Q	FEB	WAGONER	6/17/2013	27	24	32	2.96	2.96	2.96	0.5	0.07	Jun-14	8/2/2013	0.1	0.5	2.1	Aug-2016	2/2/1998	3.2	Feb-2001	4/19/2002	67	109.0	
**	111	13	VULCAN MATERIALS	SPRUCE PINE	Q	OCT	RHYMER	10/23/2012	48	46	51	2.96	2.96	2.94	0.5		Oct-13	10/12/2011	0.1	0.2	1.0	Oct-2014	2/2/2012	1.7	Feb-2015				
	76	9	VULCAN MATERIALS	STOKESDALE	Q	MAY	FOSQUE	2/26/2013	38	37	36	2.70	2.69	2.67	0.5	0.09	Feb-14	3/16/2011	0.2	0.3	0.9	Mar-2014	4/18/2005	1.9	Apr-2008				
	98	5	WAKE STONE CORP.	KNIGHTDALE	Q	JUN	RAY	1/29/2013	37	38	42	2.63	2.61	2.63	0.5	0.06	Jan-14	12/1/2011	0.1	0.4	1.6	Dec-2014	12/1/2011	1.1	Dec-2014				
	100	8	WAKE STONE CORP.	MONCURE	Q	OCT	HORNE	10/5/2012	14	12	16	2.83	2.85	2.84	0.4	0.02	Oct-13	10/5/2012	0.5	0.4	0.7	Oct-2015	7/30/2009	1.8	Jul-2012				
**	289		WAKE STONE CORP.	MYRTLE BEACH	Q	APR	JACKSON	2/1/2013	42	41	39	2.46	2.45	2.48	2.7		Feb-14	5/2/2011	0.4	0.9	2.3	May-14							SC170
	223	4	WAKE STONE CORP.	NASH COUNTY	Q	JUN	RUDD	9/6/2012	23	22	28	2.72	2.71	2.67	0.5		Sep-13	10/6/2010	0.1	0.3	1.2	Oct-2013	10/6/2010	1.0	Oct-2013				
	157	5	WAKE STONE CORP.	TRIANGLE	Q	SEPT	RAY	4/16/2013	46	44	44	2.65	2.64	2.64	0.5	0.08	Apr-14	4/16/2013	0.3	0.3	1.8	Apr-2016	7/30/2009	7.6	Jul-2012				
	361		WYTHE STONE	WYTHEVILLE	Q	MAR	PRESTRESS	3/31/2010		24			2.72		0.1		Mar-11	3/31/2010		0.1		Mar-2013							VA 1082
	244	13	YANCEY STONE	LOW GAP	Q	JAN	RHYMER	1/14/2013	33	32	34	2.75	2.75	2.74	0.5		Jan-14	1/14/2013	0.2	0.5	0.9	Jan-2016	7/29/2009	2.5	Jul-2012				
	378	13	YOUNG & MCQUEEN	DELLINGER WASTE	C	JAN	RHYMER	1/23/2012	36	35	40	2.90	2.88	2.88	0.5		Jan-13	1/23/2012	2.2	1.2	2.4	Jan-2015							
	362	13	YOUNG & MCQUEEN	SWISS LOOP CUT	C	MAR	TALLENT	3/23/2010	29	26	31	2.78	2.77	2.76	0.4		Mar-11	3/23/2010	0.4	0.4	1.3	Mar-2013							

ASR = Alkali-Silica Reactivity

** = twice a year needed to be run.

Any source in Italic did not pass LA abrasion tests and should not be used in state projects.

REVISED April 2003

DO NOT DESIGN (OR ADJUST EXISTING MIXES) TO BE TENDER

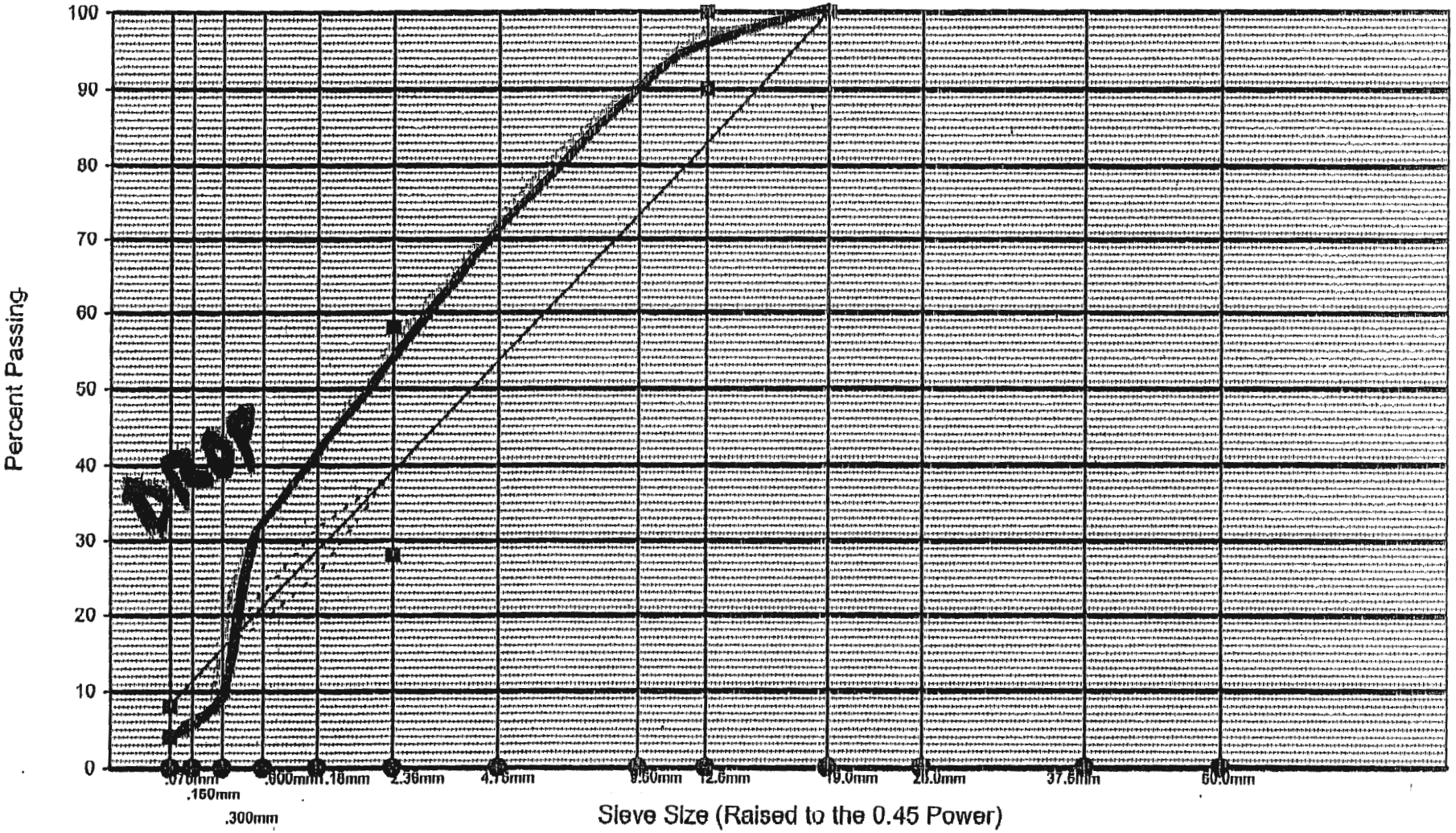
THEY CAN BE SEEN AT OR NEAR THE RESTRICTED ZONE AS:

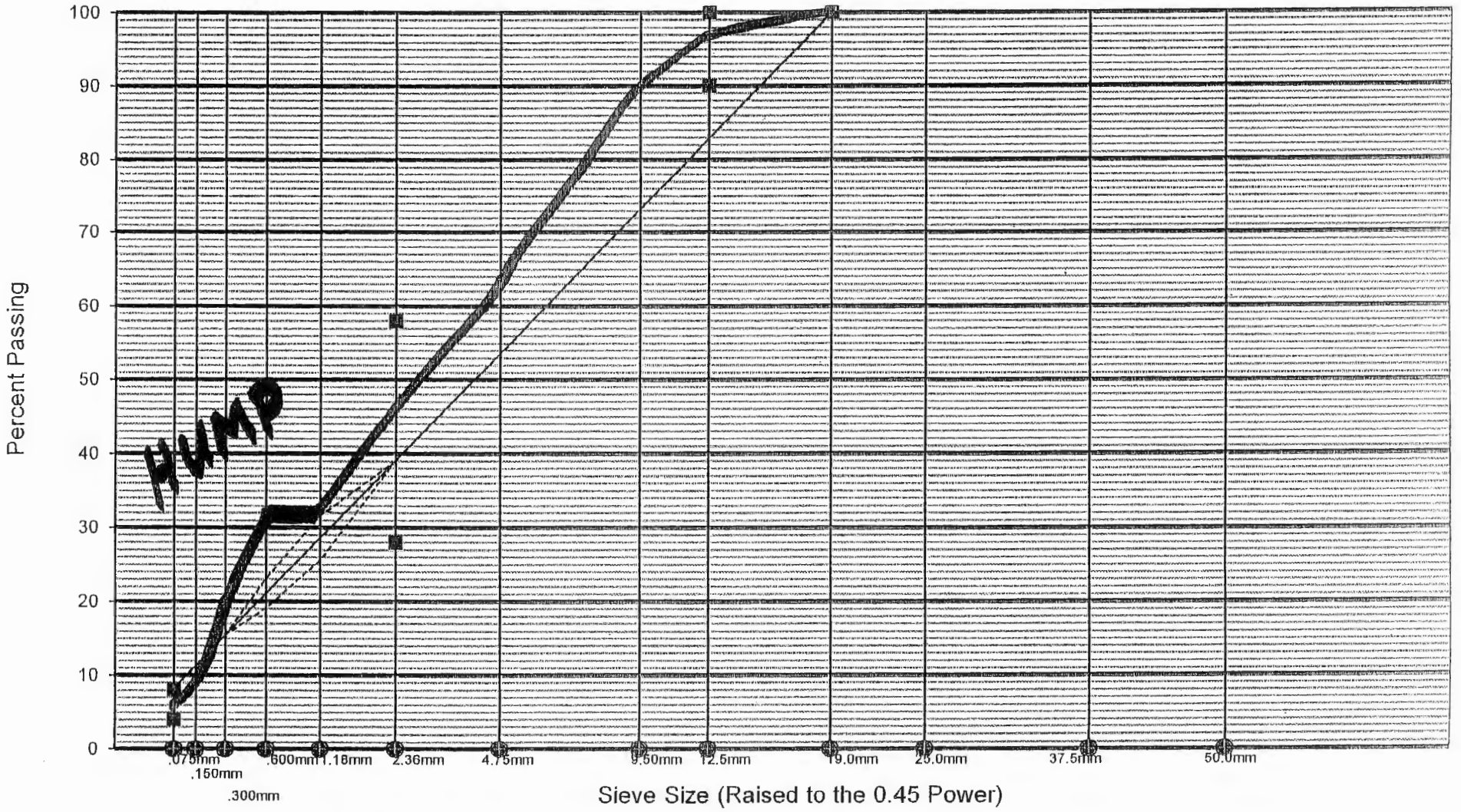
A SHARP DROP OR A HUMP IN THE PERCENTS PASSING

Mix Type S 12.5 C

Mix Design # _____

FHWA 0.45 Power Chart




100
90
80
70
60
50
40
30
20
10
0
Percent Passing
PUMP
.075mm
.150mm
.300mm
.600mm
1.18mm
2.36mm
4.75mm
9.50mm
12.5mm
19.0mm
25.0mm
37.5mm
50.0mm
Sieve Size (Raised to the 0.45 Power)

NCDOT

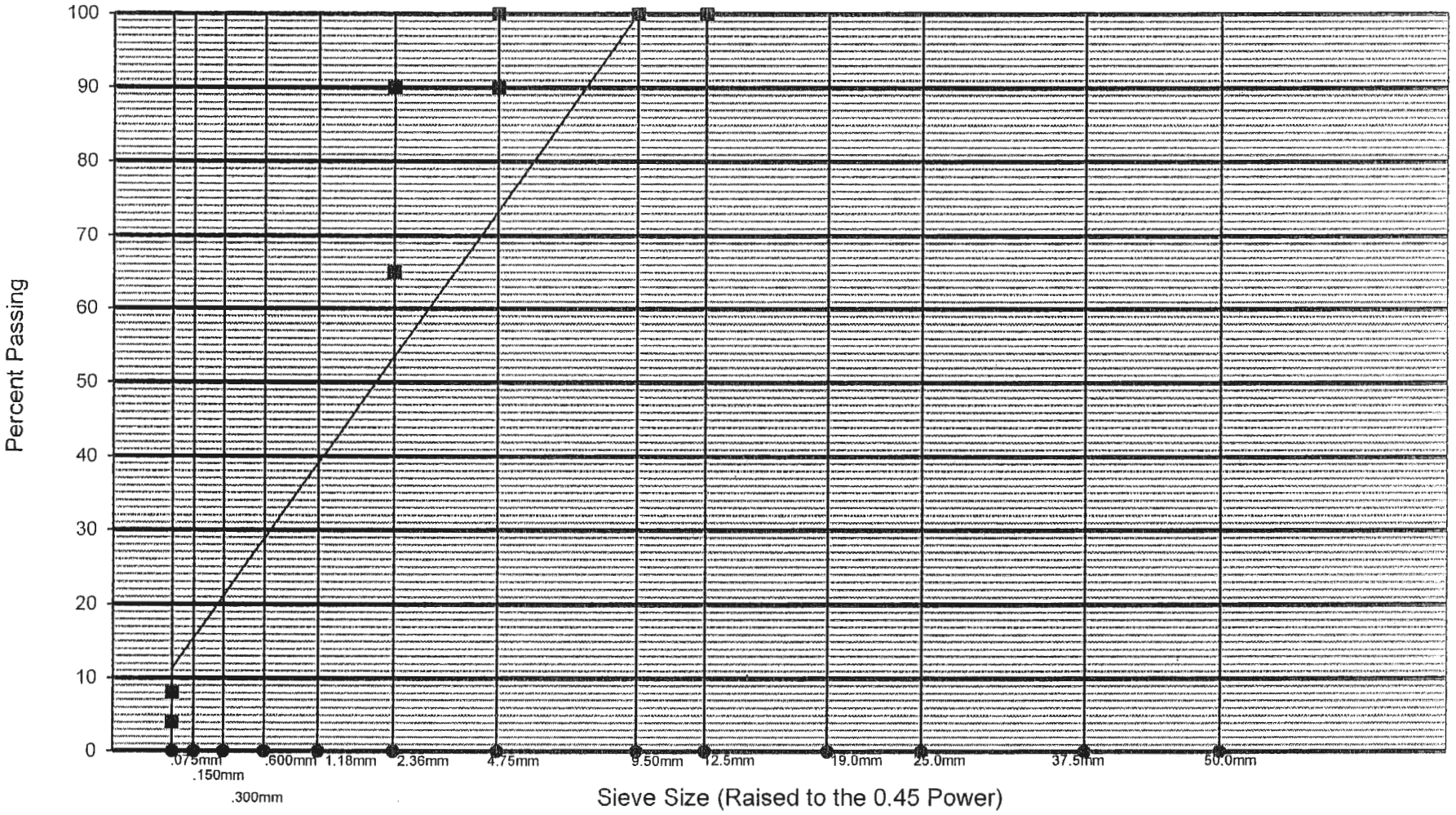
Blue Ridge Rd

Raleigh, NC

Mix Type SA1

Mix Design # _____

FHWA 0.45 Power Chart



NCDOT

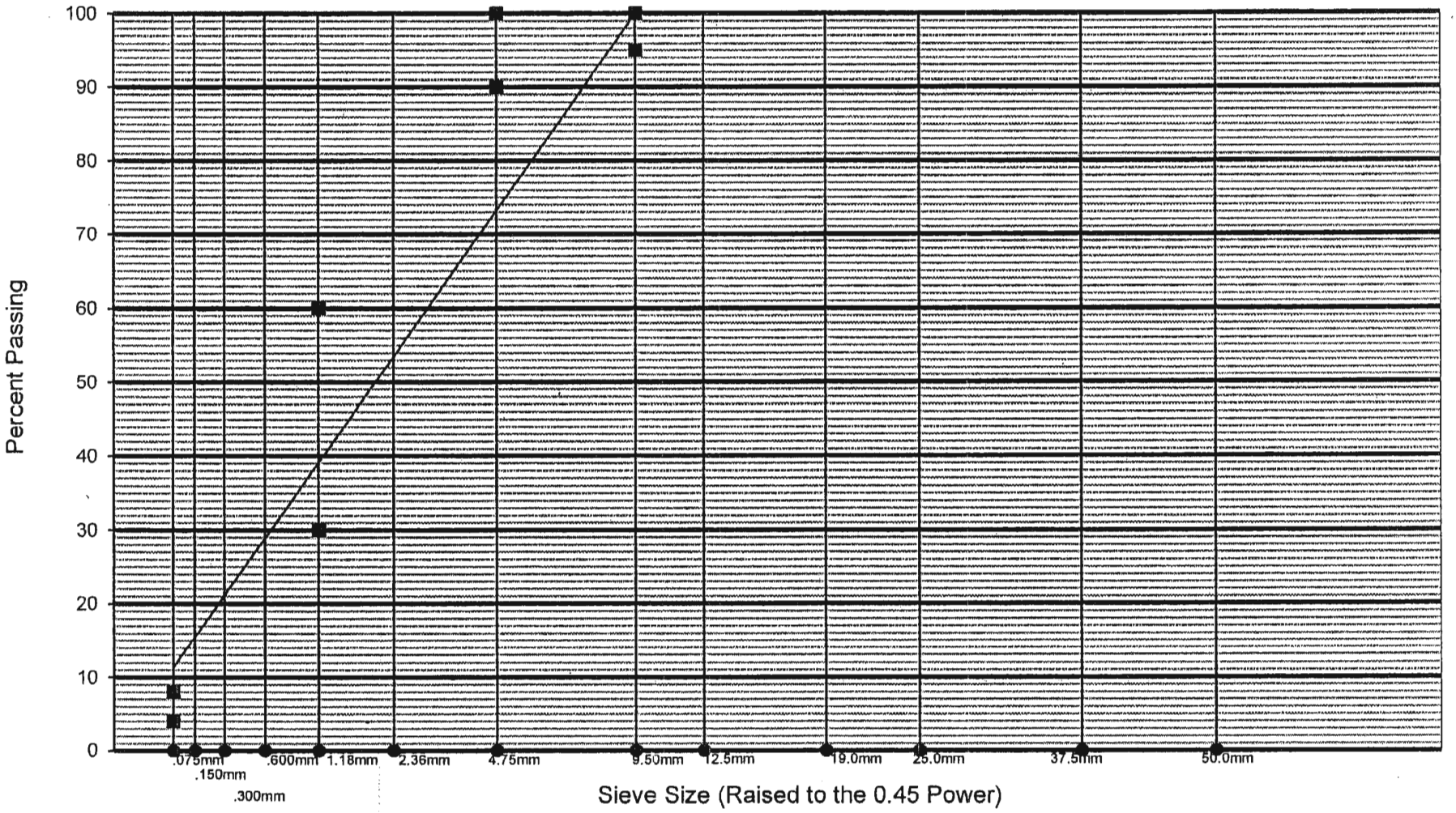
Blue Ridge Rd

Raleigh, NC

Mix Type S 4.75 A

Mix Design # _____

FHWA 0.45 Power Chart



NCDOT

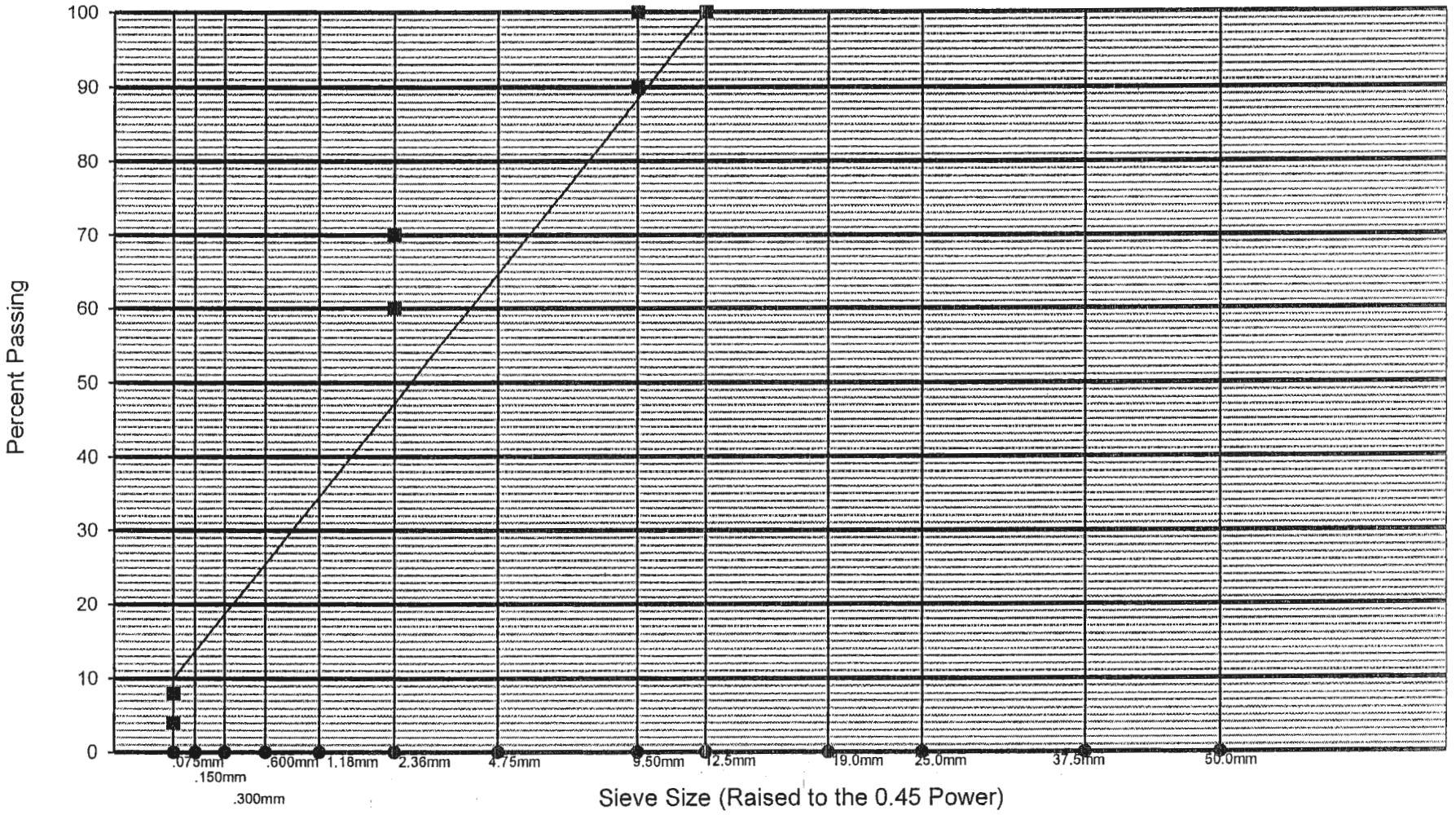
Blue Ridge Rd

Raleigh, NC

Mix Type SF 9.5 A

Mix Design # _____

FHWA 0.45 Power Chart



NCDOT

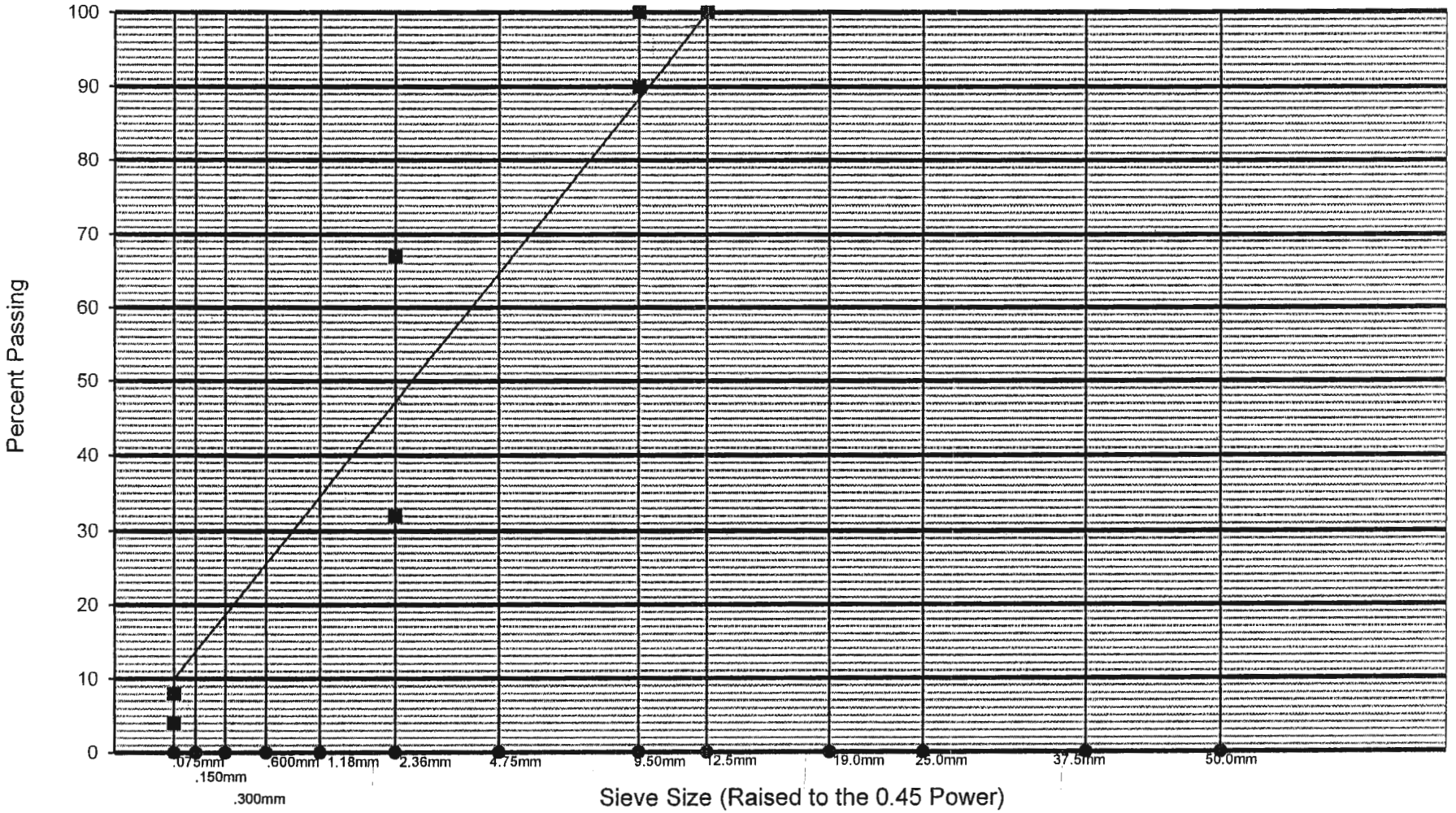
Blue Ridge Rd

Raleigh, NC

Mix Type S 9.5

Mix Design # _____

FHWA 0.45 Power Chart



NCDOT

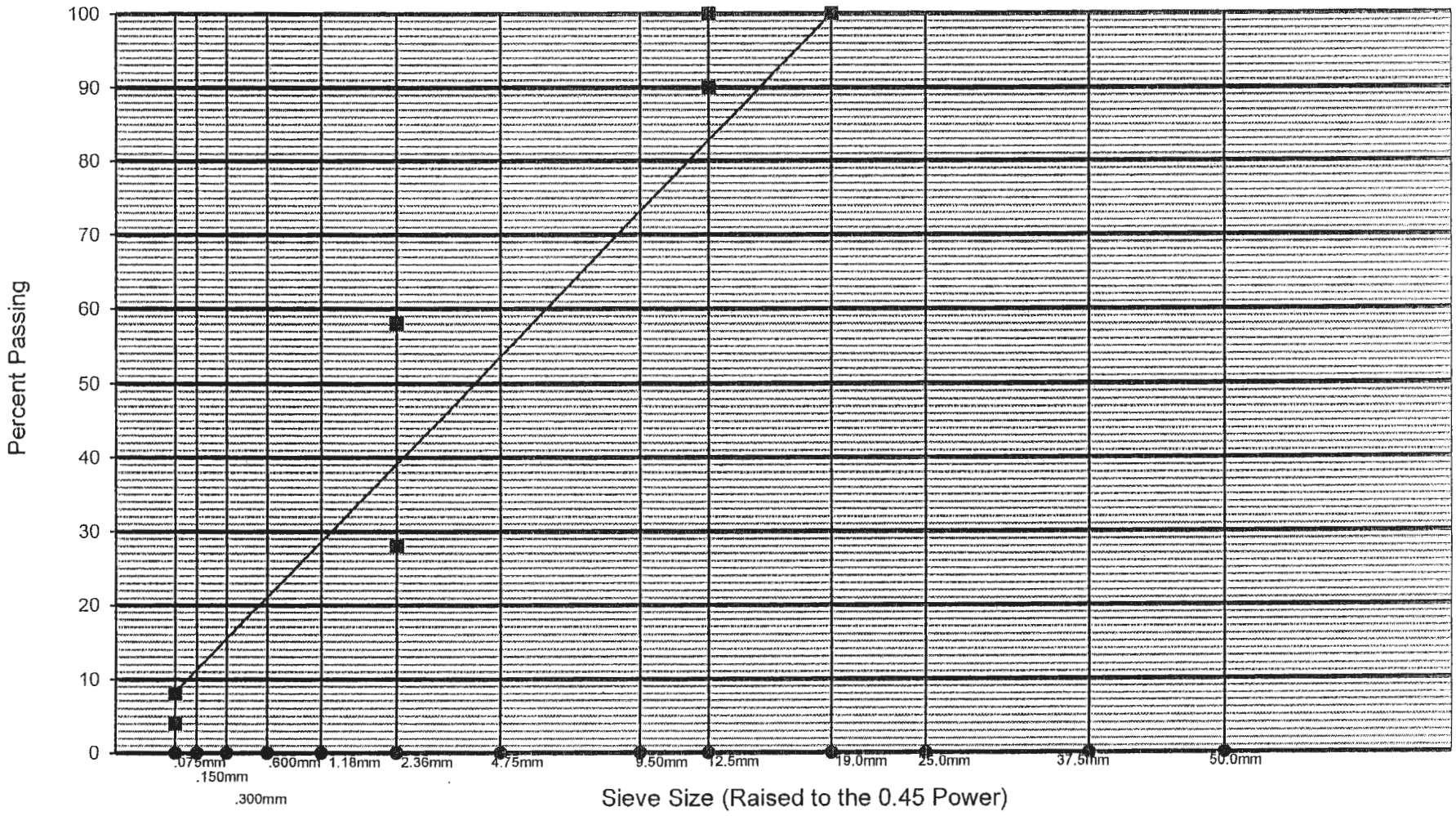
Blue Ridge Rd

Raleigh, NC

Mix Type S 12.5

Mix Design # _____

FHWA 0.45 Power Chart



NCDOT

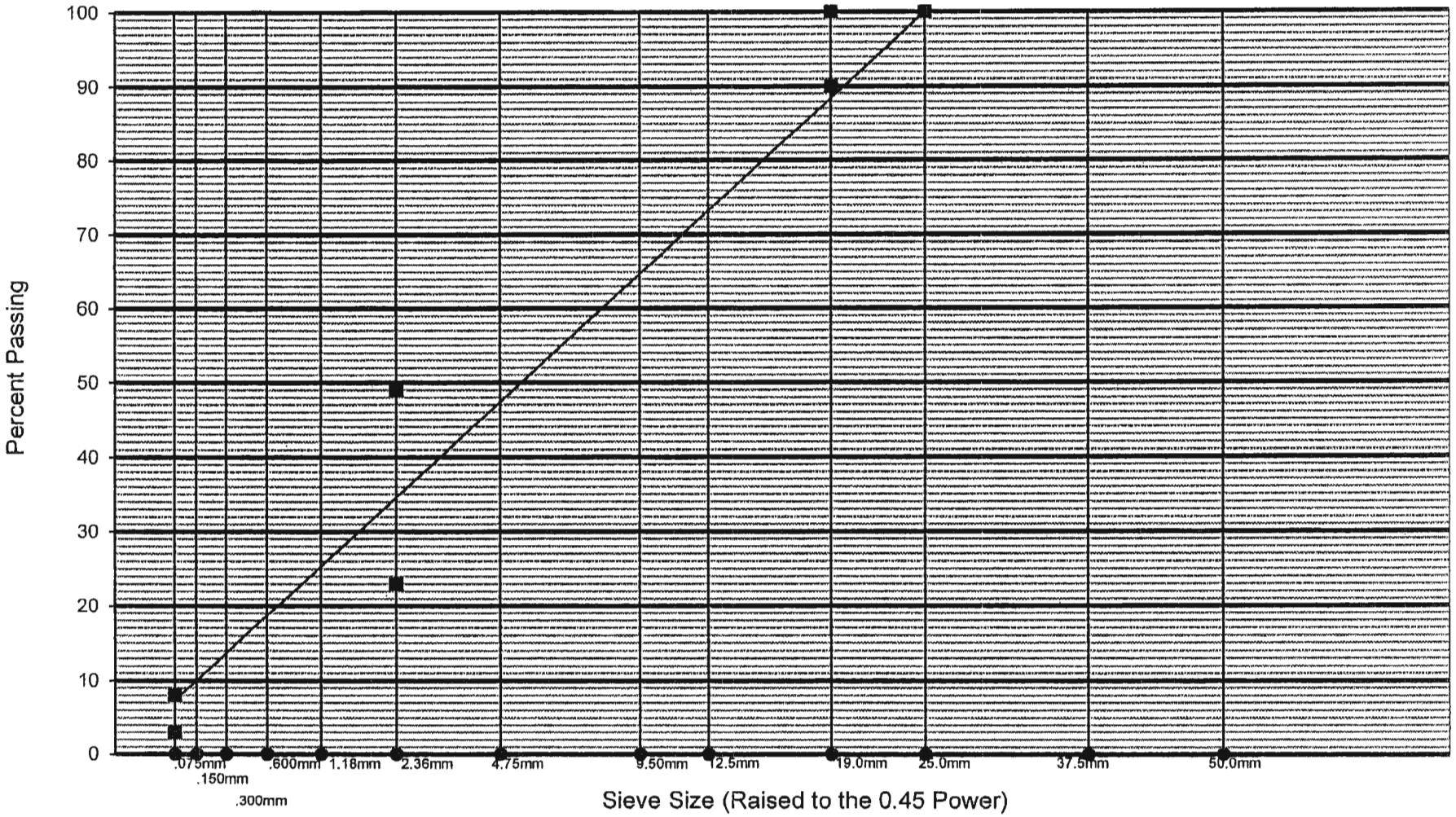
Blue Ridge Rd

Raleigh, NC

Mix Type I 19.0

Mix Design # _____

FHWA 0.45 Power Chart



NCDOT

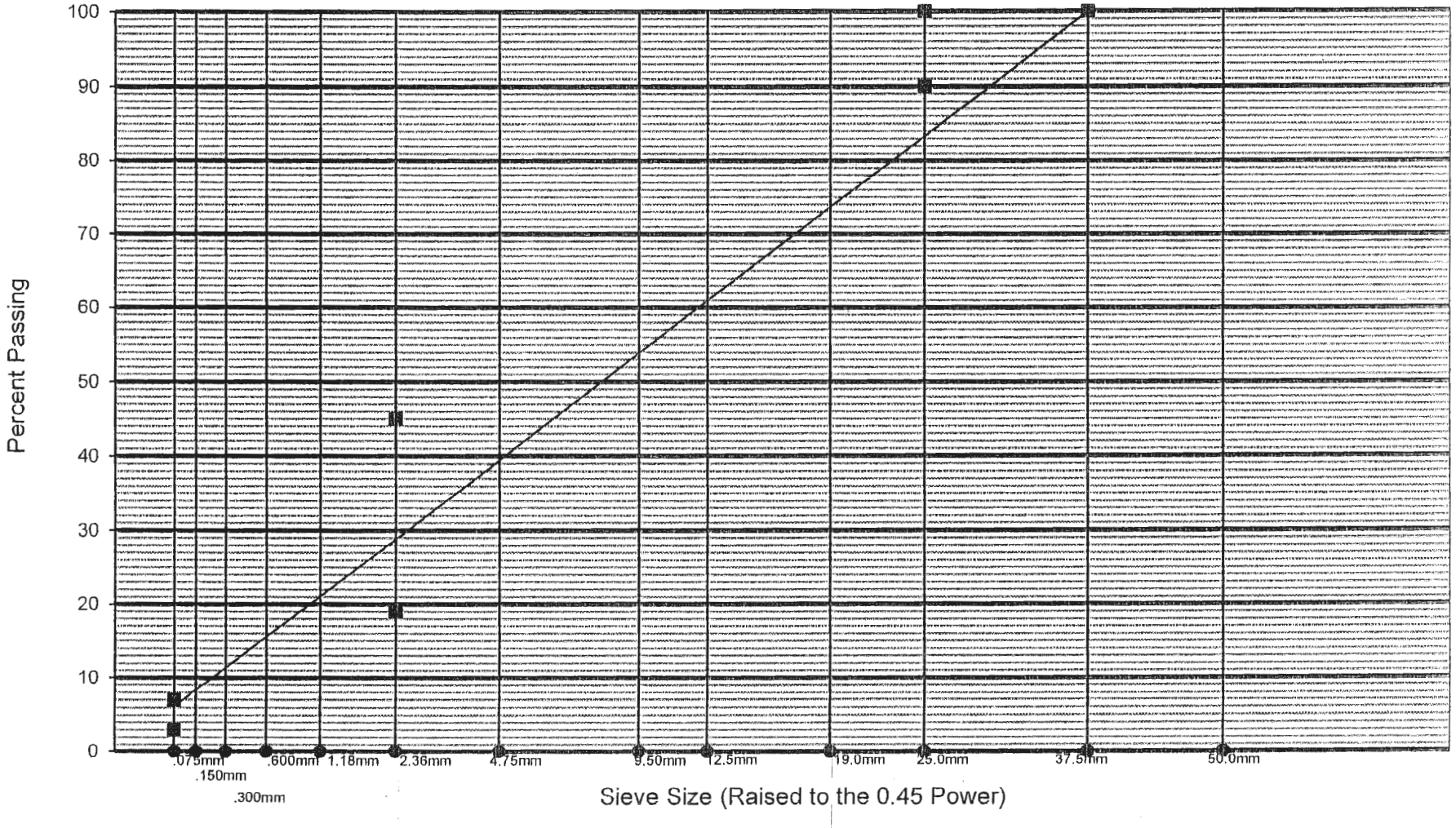
Blue Ridge Rd

Raleigh, NC

Mix Type B 25.0

Mix Design # _____

FHWA 0.45 Power Chart



Ref. A.I. MS-2 | Sixth Ed. pg. 74

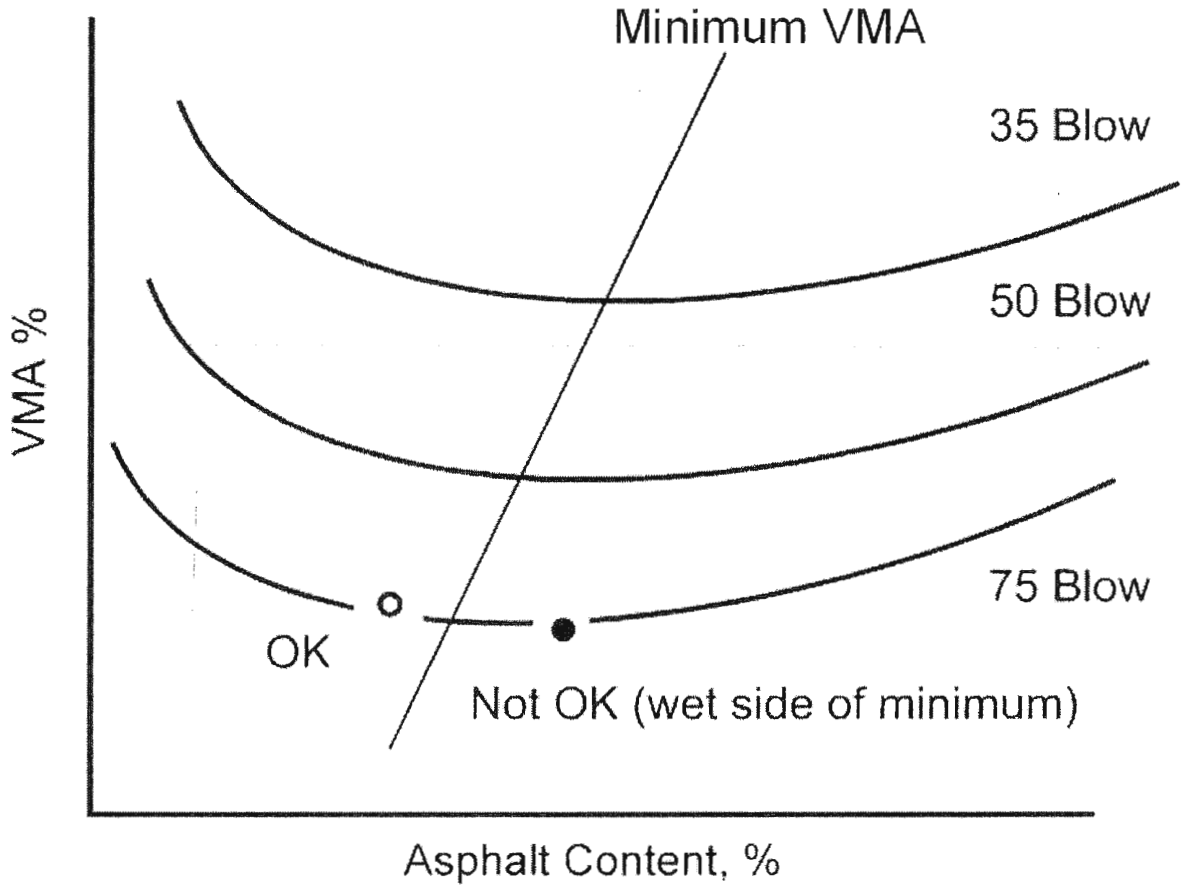


Figure 5.8 – Effect of Marshall Compactive Effort on VMA and Air Voids

Ref. A.I. MS-2 | Sixth Ed. pg. 74

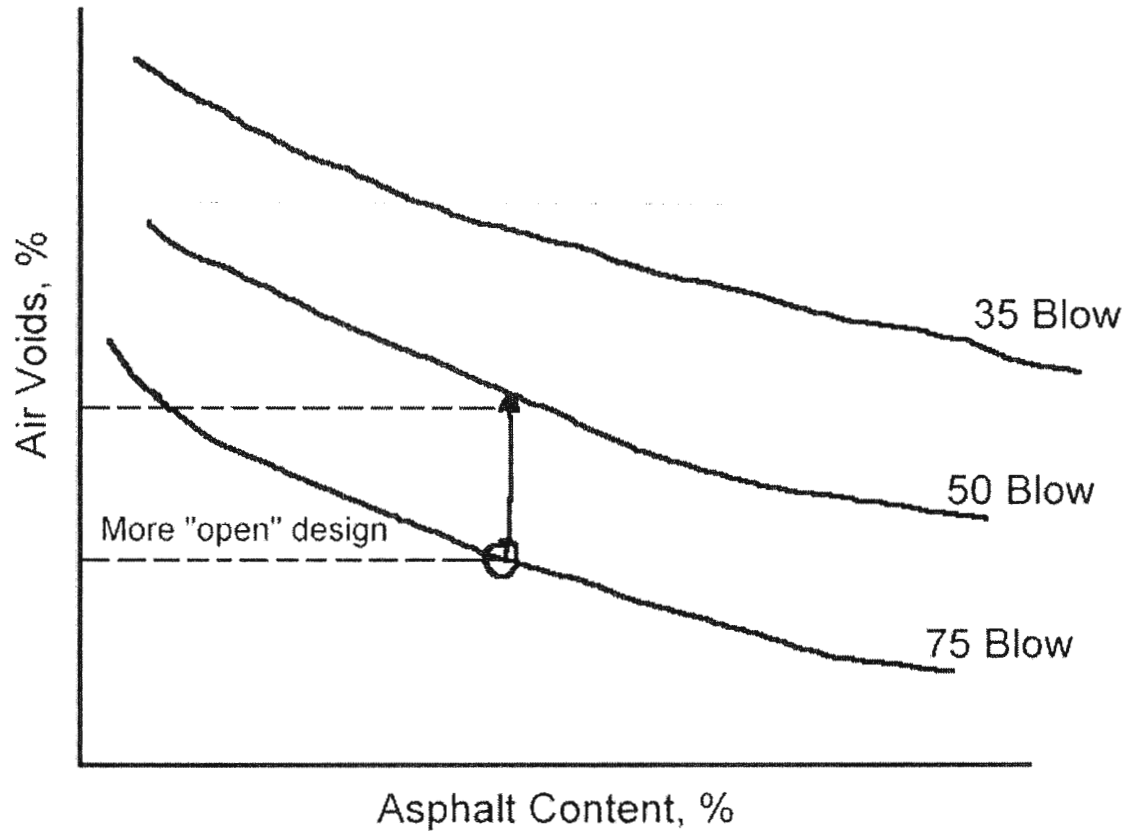


Figure 5.8 – Effect of Marshall Compactive Effort on VMA and Air Voids

Table 1012-1
Aggregate Consensus Properties [A]

Mix Type	Coarse Aggregate Angularity CAA[B]	Fine Aggregate Angularity FAA % Min.	Sand Equivalent SE % Min.	Flat & Elongated 5:1 % Ratio F&E Max.
	ASTM D5821	AASHTO T304 Method A	AASHTO T 176	ASTM D4791 Section 8.4
S 4.75A	75/-	40	40	-
SF 9.5A	75/-	40	40	-
S 9.5B	75/-	40	40	-
S 12.5B	75/-	40	40	10
I 19.0B	75/-	40	40	10
B 25.0B	75/-	40	40	10
S 9.5C	95/90	45	45	10
S 12.5C	95/90	45	45	10
I 19.0C	95/90	45	45	10
B 25.0C	95/90	45	45	10
S 12.5D	100/100	45	50	10
I 19.0D	100/100	45	50	10
S 9.5D	100/100	45	50	10
OGFC	100/100	45	45	10
UBWC	100/85	45	45	10

A. Requirements apply to the design aggregate blend
B. 95/90 denotes that 95% of the coarse aggregate has one fractured face and 90% has two or more fractured faces

TABLE 610-2
SUPERPAVE AGGREGATE GRADATION CRITERIA
(Percent Passing Control Points)

Standard Sieves (mm)	Mix Type (Nominal Max. Aggregate Size)							
	9.5 mm[A]		12.5 mm[A]		19.0 mm		25.0 mm	
	Min	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
50.0	-	-	-	-	-	-	-	-
37.5	-	-	-	-	-	-	100	-
25.0	-	-	-	-	100	-	90.0	100
19.0	-	-	100	-	90.0	100	-	90.0
12.5	100	-	90.0	100	-	90.0	-	-
9.50	90.0	100	-	90.0	-	-	-	-
4.75	-	90.0	-	-	-	-	-	-
2.36	32.0[B]	67.0[B]	28.0	58.0	23.0	49.0	19.0	45.0
1.18	-	-	-	-	-	-	-	-
0.075	4.0	8.0	4.0	8.0	3.0	8.0	3.0	7.0

A. For the final surface layer of the specified mix type, use a mix design with an aggregate blend gradation above the maximum density line on the 2.36 mm and larger sieves.

B. For Type SF9.5A, the percent passing the 2.36 mm sieve shall be a minimum of 60% and a maximum of 70%.

Figure 4.2

TABLE 610-3
SUPERPAVE MIX DESIGN CRITERIA

Mix Type	Design ESALs[A] millions	Binder PG Grade[B]	Compaction Levels G_{mm} @		Max. Rut Depth (mm)	Volumetric Properties			
			N_{ini}	N_{des}		VMA % Min.	VTM %	VFA Min.-Max.	$\%G_{mm}$ @ N_{ini}
SF9.5A	< 0.3	64 - 22	6	50	11.5	16.0	3.0 - 5.0	70 - 80	≤ 91.5
S9.5B	0.3 - 3	64 - 22	7	65	9.5	15.5	3.0 - 5.0	65 - 80	≤ 90.5
S9.5C	3 - 30	70 - 22	7	75	6.5	15.5	3.0 - 5.0	65 - 78	≤ 90.5
S9.5D	> 30	76 - 22	8	100	4.5	15.5	3.0 - 5.0	65 - 78	≤ 90.0
S12.5C	3 - 30	70 - 22	7	75	6.5	14.5	3.0 - 5.0	65 - 78	≤ 90.5
S12.5D	> 30	76 - 22	8	100	4.5	14.5	3.0 - 5.0	65 - 78	≤ 90.0
I19.0B	< 3	64 - 22	7	65	-	13.5	3.0 - 5.0	65 - 78	≤ 90.5
I19.0C	3 - 30	64 - 22	7	75	-	13.5	3.0 - 5.0	65 - 78	≤ 90.0
I19.0D	> 30	70 - 22	8	100	-	13.5	3.0 - 5.0	65 - 78	≤ 90.0
B25.0B	< 3	64 - 22	7	65	-	12.5	3.0 - 5.0	65 - 78	≤ 90.5
B25.0C	> 3	64 - 22	7	75	-	12.5	3.0 - 5.0	65 - 78	≤ 90.0
	Design Parameter						**Design Criteria**		
All Mix Types	Dust to Binder Ratio ($P_{0.075}$ / P_{be})						0.6 - 1.4		
	Tensile Strength Ratio (TSR)						85% Min.[C,D]		

A. Based on 20 year design traffic.

B. Volumetric Properties based on specimens compacted to Ndes as modified by the Department.

C. TSR for Type B 25.0 and Type B 25.0C mixes is 80% minimum.

D. AASHTO T 283 Modified (No Freeze-Thaw cycle required).

Figure 4.3

TABLE 610-4
SUPERPAVE APPLICABLE VIRGIN ASPHALT GRADES

Mix Type	Percentage of RAP in Mix		
	Category 1[A] *% RAP ≤ 20%*	**Category 2[B]** *21% ≤ % RAP ≤ 30%*	**Category 3[C]** *% RAP > 30%*
All A and B Level Mixes, I19.0C, B25.0C	PG 64-22	PG 64-22	Established by Engineer
S9.5C, S12.5C, I19.0D	PG 70-22	PG 64-22	Established by Engineer
S9.5D and S12.5D	PG 76-22	-	-

A. Category 1 RAP has been processed to a maximum size of 2".

B. Category 2 RAP has been processed to a maximum size of 1" by either crushing and or screening to reduce variability in the gradations.

C. Category 3 RAP has been processed to a maximum size of 1", fractionating the RAP into 2 or more sized stockpiles.

Figure 4.4

2013 Rules for Asphalt Mix Design Composition
Reclaimed Materials

From 610-3 (A) Mix Design General

1. Reclaimed asphalt pavement (RAP) may constitute up to 50 percent of the total material used in recycled mixtures, except for mix types RS 12.5D and RS 9.5D, and mixtures containing reclaimed asphalt shingle material (RAS).
2. Reclaimed asphalt shingle (RAS) material may constitute up to six (6) percent by weight of total mixture for any mix.
3. When both RAP and RAS are used, do not use a combined percentage of RAS and RAP greater than 20% by weight of total mixture, unless otherwise approved.
4. When the percent of binder contributed from RAS or a combination of RAS and RAP exceeds 20% but not more than 30% of the total binder in the completed mix, the virgin binder PG grade shall be one grade below (both the high and low temperature grade) the binder grade specified in Table 610-3 for the mix type, unless otherwise approved.
5. When the percent of binder contributed from RAS or a combination of RAS and RAP exceeds 30% of the total binder in the mix, the Engineer will establish and approve the virgin binder grade
6. Use approved methods to determine if any binder grade adjustments are necessary to achieve the performance grade for the specified mix type
7. For Type RS 12.5D and RS 9.5D mixes, the maximum percentage of reclaimed asphalt material is limited to 20% and must be produced using virgin asphalt binder grade PG 76-22.
8. For all other recycled mix types the virgin binder PG grade shall be as specified in Table 610-4 for the specified mix type.
9. When the percentage of RAP is greater than 20% but not more than 30% of the total mixture, use RAP meeting the requirements for processed or fractionated RAP in accordance with section 1012-1
10. When the percentage of RAP is greater than 30% of the total mixture, use an approved stockpile of RAP in accordance with subarticle 1012-1(C). Use approved test methods to determine if any binder grade adjustments are necessary to achieve the performance grades for the specified mix type. The Engineer will establish and approve the virgin asphalt binder grade to be used.
11. If a change in the source of RAP or RAS is made, a new mix design and JMF may be required in accordance with article 1012-1. Samples of the completed recycled mixture may be taken by the Department on a random basis to determine the PG grading on the recovered asphalt binder in accordance with AASHTO M 320. If the grading is determined to be a value other than required for the specified mix type, the Engineer may require the Contractor to adjust any combination of the grade, the percentage of the additional asphalt binder or the blend of reclaimed material to bring the grade to the specified value.

2013 Rules for Asphalt Mix Design Composition
Reclaimed Materials

For RAS Mixes

1. RAS material may constitute up to 6% by weight of the total mixture for any mix
2. When the percent of binder contributed from RAS exceeds 20% but not more than 30% of the total binder in the completed mix, the virgin binder PG grade shall be one grade below both the high and low temperature grade (one grade bump) of the binder grade specified in Table 610-3 for the mix type unless otherwise approved. (Mixing and compaction temperatures are determined by the specified mix type and not by the virgin binder that is used in the mix).
3. When the percent of binder contributed from RAS exceeds 30% of the total binder in the completed mix, the Engineer will establish and approve the virgin binder PG grade based on additional mix evaluation testing like blending charts, dynamic modulus, etc. (Mixing and compaction temperatures are determined by the specified mix type and not by the virgin binder that is used in the mix).
4. Use approved methods to determine if any binder grade adjustments are necessary to achieve the performance grade for the specified mix type.
5. Limit the amount of recycled binder contributed to 30% of total binder by lowering the amount of RAS by total weight of the mix if necessary

For Mixes Using Both RAS and RAP

1. When both RAP and RAS are used, do not use a combined percentage of RAS and RAP greater than 20% by weight of total mixture, unless otherwise approved Aside: the amount of RAS is limited to 6% by total weight in any mix so the amount of RAP by total weight is limited to 14% (20 – 6) when 6% RAS by total weight of the mix is used
2. For mixes using both RAS and RAP consider the amount of recycled binder contributed to the mix.
    a. For less than 20% combined recycled binder contributed, use the PG binder grade specified in Table 610-3
    b. When the percent of binder contributed from a combination of RAS and RAP exceeds 20% of the total binder in the completed mix but not more than 30%, the virgin binder PG grade shall be one grade below both the high and low temperature grade (one grade bump) of the binder grade specified in Table 610-3 for the mix type unless otherwise approved. (Mixing and compaction temperatures are determined by the specified mix type and not by the virgin binder that is used in the mix).
    c. When the percent of binder contributed from a combination of RAS and RAP exceeds 30% of the total binder in the completed mix, the Engineer will establish and approve the virgin binder PG grade based on additional mix evaluation testing like blending charts, dynamic modulus, etc. (Mixing and compaction temperatures are determined by the specified mix type and not by the virgin binder that is used in the mix).

For RAP Mixes

1. RAP may constitute up to 50% of the total material used in recycled mixes, except for mix types S12.5D, S9.5D and mixes containing RAS.
2. For RAP mixes from Category 1 in Table 610-4 below, the mixing and compaction temperatures will be as specified by the binder producer/supplier based on the virgin binder used in the mix
3. For RAP mixes from Category 2 in Table 610-4 below, the mixing and compaction temperatures are determined by the specified mix type and not by the virgin binder that is used in the mix.
4. For RAP mixes from Category 3 in Table 610-4 below, the mixing and compaction temperature will be as specified by the Engineer
5. Also for Category 1, the amount of RAP binder contributed is limited to 20% of the total binder
6. Also for Category 2, the amount of RAP binder contributed is limited to 30% of the total binder

Higher use of RAP

TABLE 610-4
SUPERPAVE MIX DESIGN CRITERIA

	Percentage of RAP in Mix		
	Category 1	Category 2	Category 3
Mix Type	% RAP ≤20%	20.1% ≤ %RAP ≤ 30.0%	%RAP > 30.0%
All A and B Level Mixes, I19.0C, B25.0C	PG 64 -22	PG 64 -22	Established by the Engineer
S9.5C, S12.5C, I19.0D	PG 70 -22	PG 64-22	Established by the Engineer
S 9.5D and S12.5D	PG 76-22	N/A	N/A

Note: (1) Category 1 RAP has been processed to a maximum size of 2 inches.
(2) Category 2 RAP has been processed to a maximum size of 1 inch by either crushing and or screening to reduce variability in the gradations.
(3) Category 3 RAP has been processed to a maximum size of 1 inch, fractionating the RAP into 2 or more sized stockpiles.

Benefits:

- No change in specification requirements for Category 1
- Anticipated lower costs of production for Categories 2 and 3
- Uses Standard Asphalt Grade as the additional virgin binder
  - Reduces the demand for PG 70-22 binder (more expensive binder)
- Anticipated increase of recycled product

Process Controls Implemented:

- Better RAP processing required for Category 2 range
- Testing of Stockpiles every 1000 tons for Category 3

More consistent gradation and asphalt contents in the RAP stockpiles

2013 Rules for Asphalt Mix Design Composition
Reclaimed Materials

For RS 12.5D and RS 9.5D Mixes

- For Type RS 12.5D and RS 9.5D mixes, the maximum percentage of reclaimed asphalt material is limited to 20% and shall be produced using virgin asphalt binder grade PG 76-22. The mixing and compaction temperatures will be as specified by the binder producer/supplier for PG 76 -22 asphalt. Also, the amount of recycled binder contributed from RAS only, RAP only, or a combination of RAS and RAP, is limited to 20% of the total binder in the mix.

For Hot-In-Place Recycled (HIP)

- These mixes are generally composed of about 80% RAP and 20% virgin materials. (Mixing and compaction temperatures are determined by the specified mix type and not by the virgin binder that is used in the mix).

For WMA

- Currently approved HMA virgin, RAP, RAS, and RAP combined with RAS mixes may be converted to warm mixes by requesting a new mix design based on an existing JMF using QMS Form 6A.
- There are no special limits on the amount of RAP allowed in the total weight of the mix. Any existing RAP design may be converted to a warm mix if approved by the Engineer.
- Warm mixes containing RAS are allowed. JMF production temperatures will be set at the WMA high limit of 275 °F (135 °C) to allow the shingles to soften in the mix. Other production temperatures may be approved by the Engineer.
- The mix compaction temperature will be 10 °F lower than the temperature shown on the JMF. The compaction range will be the compaction temperature ± 5 °F

NCDOT has been working with CAPA and contractors to develop a 4.75-mm mix that can be used at a higher traffic volume than our current S4.75A (sand asphalt) mix. The current sand asphalt mix can continue to be used under a new contract special provision with the new designation SA-1.

The new 4.75-mm mix should be placed in a **3/4 inch lift** and will be a preservation treatment placed on roads in **fair to good condition.** We are looking to evaluate the new 4.75-mm mix on roadways with traffic in the range of **300,000 to 1 million ESALs** (equivalent single axle loads over the life).

We are looking for four Divisions to try this mix on NC routes or SRs that fall within this traffic range. We are hoping for roads that are already in the resurfacing packages to move the process forward, although a Division can propose a trial on any roadway. Each trial section should be a **minimum of two miles long** and the Division can choose to try the mix on **up to 3 roads** per Division as part of the trial. This will result in up to 12 roads which will be monitored during laydown and for early performance following placement.

To coordinate the monitoring of these trial sections, send specific section location information to Nilesh Surti (Construction Unit) prior to placement. This monitoring will include: skid trailer testing of the sections after placement, testing of the production mix for rutting susceptibility, and detailed tracking of early pavement performance. If these trials perform well, the observations will be used to improve the specifications and expansion to higher traffic volumes may be considered.

Contractors must submit mix designs and rut test specimens to Todd Whittington (Asphalt Laboratory) for approval of JMFs prior to using the new mix. Rutting susceptibility will be evaluated prior to approval of each mix, with comparison tests performed on production mix.

The following distress criteria should be used when deciding if a given road is an acceptable candidate for use of the new 4.75-mm mix. Any localized areas of distress should be evaluated and appropriately repaired. The criteria are general guidelines – as with any preservation treatment, prior to treatment selection, each road should be properly assessed for condition and the causes of any distress.

Road Selection CRITERIA – New 4.75-mm Superpave Mix

DISTRESS TYPE	*MAXIMUM ALLOWABLE*
ALLIGATOR (EDGE) CRACKING	Less than 10% Low Severity (no moderate or high severity) *Note: this category includes Longitudinal cracking in the wheelpaths.*
TRANSVERSE CRACKING	Moderate (up to 1/2" wide)
LONGITUDINAL CRACKING	Light (Longitudinal cracking NOT in the wheelpaths)
RUTTING	Light (up to 1/2" deep)
RAVELING	Moderate
OXIDATION	Severe
BLEEDING	Severe

Questions concerning specific site selection criteria should be directed to either Judith Corley-Lay or Nilesh Surti.

North Carolina Department of Transportation
Approved Products Listing

APPROVED WARM MIX ASPHALT (WMA) PROCESSES

Prior to any approval, the WMA process manufacturer must submit documentation from a minimum of three (3) successfully constructed projects using the WMA process that includes the following:

- Product Name & Supplier;
- Contact Name & Telephone Number;
- WMA Process Material Safety Data Sheet (MSDS);
- Documentation from each successfully constructed project, including: project type, project owner, location, tonnage placed, mix design used, field density and performance data.

After the initial review, the WMA process can be given the following approval statuses based on the construction and performance of NCDOT-approved job mix formulas (JMFs) using the WMA process:

WMA Manufacturer	WMA Process	Current Approval Status
Astec Industries	Double Barrel Green	Unlimited
Gencor Industries	Ultrafoam GX	Unimited
MeadWestvaco	Evotherm 3G	Unimited
Aqua Foam, LLC	Aqua Foam WMA	Trial
ArrMaz Custom Chemicals	ADhere LOF65-00 + CecaBase RT945	Trial
Maxam Equipment	AQUABlack WMA	Trial
PQ Corporation	Advera	Trial
Sasol Wax	Sasobit	Trial
Terex Roadbuilding	Terex WMA	Trial

1) Trial Approval – one or more NCDOT-let projects have been successfully constructed using the WMA process and monitored through a minimum of one winter season.

- WMA processes with **Trial** status may be used on NC and Secondary routes.

2) Limited Approval – a minimum of 75,000 tons of mix using the WMA process have been successfully constructed on NCDOT-let projects.

- WMA processes with **Limited** status may be used on US, NC, and Secondary routes.

3) Unlimited Approval – a minimum of 250,000 tons of mix using the WMA process have been successfully constructed on NCDOT-let projects.

- WMA processes with **Unlimited** status may be used on any route, including Interstate routes.

Contact the Materials & Tests Unit at (919) 329-4060 for any information and current approval status.

xx-yyyy-abc-defg

where, xx = Calendar Year
yyyy = sequential number assigned by HiCAMS System
a = plant number, when JMF is issued to multiple plants
b = anti-strip percentage
c = JMF revision number

defg = Mix Type Code [see table below]

CODE	Mix Type Description
HMAC	*Hot-Mix Asphalt Concrete [Default]*
WMDB	Warm Mix Astec Double Barrel Green
WMUF	Warm Mix Gencor Ultrafoam
WMAB	Warm Mix Maxam AquaBlack
WM3G	Warm Mix Evotherm 3G
WMAF	Warm Mix Meeker AquaFoam
WMSB	Warm Mix Sasol Sasobit
WMAD	Warm Mix PQ Corp. Advera
WMTX	Warm Mix Terex WMA
MRAS	Manufacturer RAS
PRAS	Post-Consumer RAS
RPAS	RAP-RAS Mixture
RP15	RAP Mix 15%
RP20	RAP Mix 20%
RP21	RAP Mix 21%
RP25	RAP Mix 25%
RP30	RAP Mix 30%
RP40	RAP Mix 40%
FC1F	OGFC Type FC-1 w/Fibers
FC1S	OGFC Type FC-1 w/Shingles
FC2F	OGFC Type FC-2 w/Fibers
FC2S	OGFC Type FC-2 w/Shingles
UBWC	Ultra-thin Bonded Wearing Course
DC78	Permeable Asphalt Drainage Course, Type P-78M
DC57	Permeable Asphalt Drainage Course, Type P-57
MCSB	Micro-surfacing, Type B
MCSC	Micro-surfacing, Type C

Recommendations to Help Reduce Segregation
During Mix Design

Segregation can be reduced by:

1. Sufficient AC content
   - regardless of the gradation, a lower asphalt content makes the mix more prone to segregation
   - so, don't reduce the amount of AC to increase air voids in the mix

2. A good choice of aggregate(s) having:
   - lower dust (passing #200) content
   - smaller maximum size (MSA)
     - so, avoid a very large difference between the maximum and minimum sizes in the blend
   - more fine and well graded blend gradations within the allowable specification range, with adequate (not low) VMA in the aggregate structure
     - use blend gradations that pass somewhat above (and therefore away from) the maximum density line and that generally follow a smooth straight line plot
     - avoid gap graded (some sizes missing) and blends that fall on, or are very near to, the maximum density line (MDL)
   - somewhat similar specific gravities:
     - don't design mixes that use aggregates from different sources that have large differences in specific gravities

3. Adequate VMA for *cohesion*
   - a mix design having a typical VMA curve (a plot of VMA vs. Asphalt Cement Content) should be shaped somewhat like a "U"
   - use the curve to find the minimum VMA value (at the bottom of the "U") and it's corresponding AC content
     - a mix with a design AC content slightly to the left of the value given by the minimum VMA will be elastic and cohesive
     - and as a general rule, mixes with a design AC content within 0.5% below the value given by the minimum VMA should not segregate

Ref.: USACE HMA Paving Handbook 2000

QMS-6A
Revised 06-12-09

NCDOT Request For New AMD Based on JMF

AMD No. _____

Contractor _____ Type of Mix _____
Plant Location _____ Existing JMF# _____
Plant Id # _____ Division _____

Asphalt Binder

Original PG Binder Source (AT #)	New PG Binder Source (AT #)	Binder Specific Gravity	Old %	New %

Anti Strip Additive

Current Brand / Grade	New Brand / Grade	TSR Results	Old %	New %

Aggregate Sources and Blend Percentages

Supplier	*Material*	*Source*	*Old Blend %*	*New Blend %*
		TOTAL		

Gradations

Sieve Size	JMF Blend Gradation	*Current RAP Gradation*
37.5mm		
25.0mm		
19.0mm		
12.5mm		
9.50mm		
4.75mm		
2.36mm		
1.180mm		
0.600mm		
0.300mm		
0.150mm		
0.075mm		
	RAP %AC	

Volumetric Properties

Property	JMF Value	Change to
Gsb (Bulk Dry S.G.)		
Gse (Effective S.G.)		
Gsa (Apparent S.G.)		
% Pba (Absorption)		
% RAP / Virgin		
Gmm (Rice S.G.)		
Gmb (Lab S.G.)		
VTM%		
VMA%		
VFA%		
Virgin Binder %		
Binder From RAP %		
Other % Binder		
Total % Binder		
Binder Grade		
Mix Temp		

QC Remarks:

Change Requested By: _____ Change Date: _____
QC Level II Technician Date

I have checked that these changes meet the allowable adjustments outlined in Section 7 of the HMA/QMS Manual

*****Asphalt Laboratory Approval *****

Approved By: _____ New AMD No.: _____

Date Approved: _____ New JMF No.: _____

Slides

NCDOT
Superpave Mix Design Certification Class

October 15, 2014
Raleigh, NC

NCDOT Mix Design Personnel

TODD WHITTINGTON, PE –
STATE ASPHALT MATERIALS ENGINEER
JAMES BUDDAY, PE –
ASPHALT MATERIALS QUALITY ENGINEER
CHARLES COLGATE
ASPHALT MATERIALS DESIGN ENGINEER

REQUIREMENT FOR *SUPERPAVE* MIX DESIGN CERTIFICATION

- As outlined in the NCDOT Superpave HMA/QMS Asphalt Technician Certification Program
- Certification type: Superpave Mix Design Technician

REQUIREMENT FOR *SUPERPAVE* MIX DESIGN CERTIFICATION

- ***"A Technician Trained and Competent in the Area of Superpave Asphalt Mix Design Procedures"***
- **Certification will be effective for *four* years beginning from the date of passing the exam**

REQUIREMENTS FOR *SUPERPAVE* MIX DESIGN CERTIFICATION

- **Prerequisite(s):**
- **Level I Plant Certification or**
- **Completion of OJT Program or**
- **Equivalent Experience as Approved by the Asphalt Design Engineer**

REQUIREMENTS FOR *SUPERPAVE* MIX DESIGN CERTIFICATION

- **Training Requirements:**
- **NCDOT Approved Superpave Mix Design Course (1 week – Trimat/NCSU, NCAT, AI, etc.) with passing exam and**
- **NCDOT Mix Design Certification Class with passing exam (this class) and**
- **Check off on Aggregate Consensus Properties by Local QA Supervisors**

COURSE AGENDA

- Specification Review
- Different Mix Types/Specialty Mixes
- Mix Design Steps and Lab Equipment Calibrations/Verifications
- Mix Design Programs……

COURSE AGENDA
Continued

- Mix Design Procedures
- TSR Test Procedures
- Aggregate Consensus Properties and Sand Source Changes
- Mix Design Submittal and Approval

COURSE OVERVIEW

- This course was designed to make Contractor and DOT personnel familiar with the North Carolina Department of Transportation Superpave Mix Design Procedures and Specifications
- We will cover the fundamentals of the NCDOT Superpave Mix Design System

WHAT IS *SUPERPAVE*?

- ***Super***ior Performing ***Pave***ment - Results of a $150 million project by the National Cooperative Highway Research Program (NCHRP)

WHAT IS *SUPERPAVE*?

- Major differences from the Marshall Mix Method are:
  - Originally, Coarser Mix Designs
  - The Gyratory Compactor
  - Traffic Design Levels (ESALs)
  - Aggregate Consensus Property Tests

Purposes of Mix Designs

- From Section 4.2 of the QMS Manual:

  "…to determine an economical blend and gradation of aggregates (within the spec limits) and corresponding asphalt content that yields a mix having…."
  - durability
  - rut resistance
  - sufficient voids
  - workability

How to Achieve These Properties

- Durability
  - More asphalt creates thicker film coatings!
  - Dense aggregate grading and well compacted layers decrease permeability
- Rut Resistance
  - Optimum asphalt, more stone, better particle shape, adequate aggregate fineness, controlled void content

How to Achieve These Properties

- Sufficient Voids
  - Generally, 4% as designed in the lab and 8% as compacted in the field
- Workability
  - Placing and compacting are influenced by sand and fine aggregate properties

VMA: One Key to Mixture Performance

- For surface mixes aggregate fineness modulus is the key
  - There is a minimum aggregate fineness requirement for rut resistance and permeability (and also a maximum limit) for a known percent VMA
  - The limits are determined by the FM_{300}
  - FM_{300} = sum of percents passing #50, #100, and #200 sieves of the aggregate blend

Minimum Aggregate Fineness Requirements for Rut Resistance and Permeability

VMA	Surface Area (min) m^2/kg	Min. FM_{300}	Max. FM_{300}
14	4.3	22	38
15	4.8	25	42
16	5.4	27	46
20	7.4	38	64

Aggregate Surface Area

- The surface area is about equal to the FM_{300} divided by five
  $SA \approx FM_{300} \div 5$
- Note that changes in aggregate proportions can change the FM_{300}, which can change the surface area, which can change the demand for asphalt in the mix
  - Increasing the aggregate surface area may require more asphalt to be added to maintain the asphalt film thickness

Keys to Remember

- Liquid asphalt binds the pavement together, water proofs, and can add some stiffness to the mix
- Aggregates carry the load

2012 Standard Specifications for Roads and Structures

Section 609 - QMS for Asphalt Pavements

Section 610 - Asphalt Concrete Plant Mix Pavements

2012 Specifications
Highlights on Section 610

- Prepare the asphalt mix design using a mixture of coarse and fine aggregate, asphalt binder, mineral filler and other additives when required
- Size, uniformly grade and combine the several aggregate fractions in such proportions that the resulting mixture meets the grading and physical requirements of the Specifications for the specified mix type

2012 Specifications
Highlights on Section 610

- Materials that will not produce a mixture within the design criteria required by the Specifications will be rejected, unless otherwise approved

2012 Specifications
Highlights on Section 610

- At least 10 days before the start of production submit the mix design and proposed JMF targets (in writing and in electronic form) for review and approval to:
  - Asphalt Design Engineer
  - NCDOT Materials and Tests Unit
  - 1801 Blue Ridge Road
  - Raleigh, NC 27607

2012 Specifications
Highlights on Section 610

- Prepare the design using a Department certified mix design technician in an approved mix design lab and in accordance with the procedures outlined in Section 4.5 of the HMA QMS Manual

2012 Specifications
Highlights on Section 610

- For the final surface layer of the specified mix type, use a mix design with an aggregate blend gradation above the maximum density line on the 2.36 mm and larger sieves

Section 610 - Reclaimed Asphalt Materials (Standard Specifications)

- Reclaimed Asphalt Pavement (RAP) or Reclaimed Asphalt Shingles (RAS) may be incorporated into asphalt plant mixes in accordance with Article 1012-1 and the following applicable requirements:

Section 610 - Reclaimed Asphalt Materials (Standard Specifications)

- RAP may constitute up to 50% of the total material used in recycled mixtures, except for mix types S 12.5D, S 9.5D, and mixes with RAS
- RAS material may constitute up to 6% by weight of total mix for any mix
- When both RAP and RAS are used, do not use a combined percentage of RAS and RAP greater than 20% by weight of total mix, unless otherwise approved

Section 610 - Reclaimed Asphalt Materials (Standard Specifications)

- When the percent of binder contributed from RAS, or a combination of RAS and RAP, exceeds 20% but not more than 30% of the total binder in the completed mix, the virgin binder PG grade shall be one grade below (both high and low temperature grade) the grade specified in Table 610-3 for the specified mix type, unless otherwise approved

Section 610 - Reclaimed Asphalt Materials (Standard Specifications)

- When the percent of binder contributed from RAS, or a combination of RAS and RAP, exceeds 30% of the total binder in the completed mix, the Engineer will establish and approve the virgin binder PG grade
  - Use approved methods to determine if any binder grade adjustments are needed to achieve the performance grade for the specified mix type (blending charts, dynamic modulus, etc.)

Section 610 - Reclaimed Asphalt Materials (Standard Specifications)

- For type S 12.5D and S 9.5D mixes, the maximum percentage of reclaimed asphalt material is limited to 20% and shall be produced using virgin asphalt binder grade PG 76 -22
- For all other recycled mix types, the virgin binder grade shall be as specified in Table 610-4 for the specified mix type

Section 610 - Reclaimed Asphalt Pavement (Standard Specifications)

- When the percentage of RAP is greater than 20% but not more than 30% of the total mixture, use RAP meeting the requirements for processed or fractionated RAP in accordance with Section 1012-1

Section 610 - Reclaimed Asphalt Pavement (Standard Specifications)

- When the percentage of RAP is greater than 30% of the total mixture, use an approved stockpile of RAP in accordance with Subarticle 1012-1(F)
- Use approved test methods to determine if any binder grade adjustments are necessary to achieve the performance grade for the specified mix type
- The Engineer will establish and approve the virgin asphalt binder grade to be used

Section 610 - Reclaimed Asphalt Materials (Standard Specifications)

- If a change in the source of RAP or RAS is made, a new mix design and JMF may be required in accordance with Article 1012-1

Section 610 - Reclaimed Asphalt Materials (Standard Specifications)

- Samples of the completed recycled mixture may be taken by the Department on a random basis to determine the PG grading on the recovered asphalt binder in accordance with AASHTO M320
- If the grading is determined to be a value other than required for the specified mix type, the Engineer may require the Contractor to adjust any combination of the grade, the percentage of the additional asphalt binder or the blend of reclaimed material to bring the grade to the specified value

2012 Specifications
Highlights on Section 610

- Design and produce mixes that conform to the gradations and design criteria shown in Tables 610-2 and 610-3 for the mix type specified
- The mix type designates the nominal maximum aggregate size and the design traffic level

2012 Specifications
Highlights on Section 610

- Surface mixes shall be tested by the Department for rutting susceptibility
- Rut depth requirements for each surface type mix and traffic level are specified in table 610-3
- Mix designs that fail to meet these requirements will be unacceptable and shall be redesigned by the Contractor such that rut depths are acceptable

2012 Specifications
Highlights on Section 610

- Table 610-2 provides gradation control points to be adhered to in the development of the design aggregate structure for each mix type
- Aggregate gradations shall be equal to or pass between the control points, unless approved in writing
- Table 610-3 provides the mix design criteria for the various mix types

2012 Specifications
Highlights on Section 610

- Use an antistrip additive in all Superpave asphalt mixes
- It may be hydrated lime or a chemical additive or a combination of both as needed to meet the retained strength requirements as specified in table 610-3

2012 Specifications
Highlights on Section 610

- When a chemical additive is used, add at a rate of not less than 0.25% by weight of the binder in the mix
- When hydrated lime is used, add at a rate of not less than 1% by weight of the total dry aggregate

2012 Specifications
Highlights on Section 610

- When WMA is used, submit the mix design being sure to include the WMA technology, dosage rate and plant production temperature

Table 610-2 Superpave Aggregate
Gradation Criteria (Percent Passing Control Points)

	Mix Type (Nominal Maximum Aggregate Size)							
	9.5 mm[A]		12.5 mm[A]		19.0 mm		25.0 mm	
	Min	Max	Min	Max	Min	Max	Min	Max
50.0								
37.5							100	
25.0					100		90.0	100
19.0			100		90.0	100		90.0
12.5	100		90.0	100				
9.50	90.0	100		90.0				
4.75		90						
2.36	32.0[B]	67.0[B]	28.0	58.0	23.0	49.0	19.0	45.0
1.18								
0.075	4.0	8.0	4.0	8.0	3.0	8.0	3.0	7.0

Table 610-2 Notes on Superpave Aggregate Gradation Criteria
(Percent Passing Control Points)

A. For the final surface layer of the specified mix type, use a mix design with an aggregate blend gradation above the maximum density line on the 2.36 mm and larger sieves

B. For type SF9.5A, the percent passing the 2.36 mm sieve shall be a minimum of 60% and a maximum of 70%

Table 610-3 Superpave Mix Design Criteria

Mix Type	Design ESAL millions (A)	Binder PG Grade (B)	Compaction levels No. Gyrations @ Nini	Ndes	Maximum Rut Depth (mm)
S-4.75A	0.3 – 1.0	64 -22	NA	50	TBD
SF-9.5A	< 0.3	64 -22	6	50	11.5
S-9.5B	0.3 - 3	64 -22	7	65	9.5
S-9.5C	3 - 30	70 -22	7	75	6.5
S-9.5D	> 30	76 -22	8	100	4.5
S-12.5C	3 - 30	70 -22	7	75	6.5
S-12.5D	> 30	76 -22	8	100	4.5
I-19.0B	< 3	64 -22	7	65	
I-19.0C	3 - 30	64 -22	7	75	
I-19.0D	> 30	70 -22	8	100	
B-25.0B	< 3	64 -22	7	65	
B-25.0C	> 3	64 -22	7	75	

Table 610-3 Superpave Mix Design Criteria

	Volumetric Properties			
Mix Type	VMA % Min.	VTM %	VFA Min. – Max.	%Gmm @ Nini
S-4.75A	16.0	4.0 – 6.0	65 - 80	≤ 91.5
SF-9.5A	16.0	3.0 – 5.0	70 - 80	≤ 91.5
S-9.5B	15.5	3.0 – 5.0	65 - 80	≤ 90.5
S-9.5C	15.5	3.0 – 5.0	65 - 78	≤ 90.5
S-9.5D	15.5	3.0 – 5.0	65 - 78	≤ 90.0
S-12.5C	14.5	3.0 – 5.0	65 - 78	≤ 90.5
S-12.5D	14.5	3.0 – 5.0	65 - 78	≤ 90.0
I-19.0B	13.5	3.0 – 5.0	65 - 78	≤ 90.5
I-19.0C	13.5	3.0 – 5.0	65 - 78	≤ 90.0
I-19.0D	13.5	3.0 – 5.0	65 - 78	≤ 90.0
B-25.0B	12.5	3.0 – 5.0	65 - 78	≤ 90.5
B-25.0C	12.5	3.0 – 5.0	65 - 78	≤ 90.0

Table 610-3 Superpave Mix Design Criteria

All Mix Types	Design Parameter	Design Criteria
	Dust to Binder Ratio	0.6 – 1.4 (except 1.0 – 2.0 for S4.75A)
	Tensile Strength Ratio (TSR)	85% Min. [C, D]
A.	Design EASLs based on 20 year design traffic	
B.	Volumetric properties based on specimens compacted to Ndes as modified by the Department	
C.	TSR for Type B25.0B and Type B25.0C mixes is 80% minimum	
D.	AASHTO T 283 Modified (No freeze-thaw cycle required)	

Table 610-4 Superpave Applicable Virgin Asphalt Grades

	Percentage of RAP in the mix		
	Category 1[A]	Category 2[B]	Category 3[C]
Mix Type	%RAP ≤ 20	21 ≤ %RAP ≤ 30	%RAP > 30
All A and B Level Mixes, I19.0C, B25.0C	PG 64 -22	PG 64 -22	Established by Engineer
S9.5C, S12.5C, I19.0D	PG 70 -22	PG 64 -22	Established by Engineer
S9.5D and S12.5D	PG 76 -22	-	-

Table 610-4 Notes on Superpave Applicable Virgin Asphalt Grades

A. Category 1 RAP has been processed to a maximum size of 2 inches

B. Category 2 RAP has been processed to a maximum size of 1 inch by either crushing or screening to reduce variability in the gradations

C. Category 3 RAP has been processed to a maximum size of 1 inch, fractionating the RAP into 2 or more sized stockpiles

Some Different Mix Types

NCDOT Type 4.75 mm Mixes

- There is a new Superpave mix type that will replace NCDOT's sand asphalt mix type F-1
  - The old mix type will now be referred to as type SA-1 (sand asphalt, type one)
- The new mix type will be designed using Superpave criteria and will designated as NCDOT type S 4.75A (or RS 4.75A if it contains reclaimed asphalt materials)
- The new 4.75 mm mixes will be project specific and Provisionally Approved

NCDOT Type SA-1 Mixes

- **Mix requirements include:**
  - PG 64 -22 liquid asphalt
  - 11% target air voids (7 to 15% range)
  - Gyrations: 50
  - Max rut depth not specified
  - TSR run @ 13 ± 0.5% voids (need 80% min. ratio)
  - Minimum density required:
    - 85% of G_{mm} when applied at 100 lbs/sy or greater
  - Accepted on Specification Section 105-3: *Conformance with Plans and Specifications*

NCDOT Type SA-1 Mixes

Sieve Size	Min.	Max.
12.5mm (1/2")	-	-
9.50mm (3/8")	100	-
4.75mm (#4)	90	100
2.36mm (#8)	65	90
1.18mm (#16)	-	-
0.075mm (#200)	4	8

NCDOT Type SA-1 Mixes

	Min.	Max.
VMA	20.0	-
VFA	n/a	n/a
VTM	7.0	15.0
Dust to Binder	0.6	1.4
%Gmm @ Nini	-	n/a
Min. Density	85%	

NCDOT Type S 4.75A Mix

- Mix requirements include:
  - Traffic level: 300,000 to 1 million ESALs
  - PG 64 -22 liquid asphalt
  - 5% target air voids (4 to 6% range)
  - Gyrations: 6/50
  - Max rut depth to be determined
    - Target VTM for rut pills: 5.0 ± 0.5% (or design voids)
    - Height 75 ± 2mm
    - Rutting will be evaluated prior to approval of each mix, with comparison tests performed on production mix

NCDOT Type S 4.75A Mix

- Mix requirements include:
  - Reclaimed asphalt materials (RAP and RAS) are permitted
    - RAP will be fine fractionated RAP
    - Use 20% RAP or less with no change in binder PG grade
    - Use from 20.1 to 30% RAP with one PG grade bump lower
    - If %RAP is more than 30% then PG grade is established by the Engineer
    - Use no more than 6% RAS or PRAS and no more than 20% RAP and RAS combined by total weight of mix
    - If %Binder contributed by reclaimed materials is more 20% of the total liquid then bump PG one grade lower

NCDOT Type S 4.75A Mix

- Mix requirements include:
  - TSR run @ 7 ± 0.5% air voids and 95 ± 5 mm ht.
    - Passing TSR is 80%
  - Consensus Property Limits
    - Fine Aggregate Angularity: 40% min
    - Sand Equivalent: 40% min
    - Flat and Elongated @ 5:1 Ratio: not specified
  - Placement depth is ¾ to 7/8 inch lift thickness
  - These mixes will be referred to as ‘thin lifts” in the contract proposals

NCDOT Type S 4.75A Mixes

Sieve Size	Min.	Max.
12.5mm (1/2")	100	-
9.50mm (3/8")	95	100
4.75mm (#4)	90	100
2.36mm (#8)	-	-
1.18mm (#16)	30	60
0.075mm (#200)	6	12

NCDOT Type S 4.75A Mixes

	Min.	Max.
VMA	16.0	-
VFA	65	80
VTM	4.0	6.0
Dust to Binder	1.0	2.0
%Gmm @ Nini	-	91.5
Min. Density VTM Target	85% when applied at ≥ 100 psy 5% for mix design pills	

NCDOT Type SF 9.5A Mixes

- Similar to an I-2 Marshall mix, it replaced S 9.5A, and is used as a resurfacing mix of 1 to 2 inch lift thickness
- Gradation requirements from Table 610-2 note "B" states that 60 to 70% pass the no. 8 (#2.36 mm) sieve

NCDOT Type SF 9.5A Mixes

- Mix Requirements from Table 610-3
  - Traffic level less than 0.3 million ESAL
  - PG binder grade 64 -22
  - Gyrations at N_{ini} / N_{des} are 6 / 50
  - Maximum rut depth is 11.5 mm
  - VMA = 16% minimum
  - VTM range is 3.0 to 5.0%
  - VFA range (min. to max.) from 70 to 80%
  - $\%G_{mm}$ @ $N_{ini} \leq 91.5$

Standard Specifications NCDOT Type S 9.5D and S 12.5D

- For the final surface layer use a design with the aggregate blend gradation above the Maximum Density Line on the no. 8 (2.36 mm) and larger sieves
- When a recycled mix is used, the maximum amount of recycled asphalt material is limited to 20% of the total mix

NCDOT Mix Types S 9.5D and S 12.5D

- Design Traffic: > 30 million ESALs
- PG Binder Grade: 76 -22
- Compaction levels: 8/100 @ N_{ini} / N_{des}
- Maximum rut depth: 4.5 mm
- Min. VMA for S 9.5D: 15.5%
- Min. VMA for S 12.5D: 14.5%
- VTM range: 3.0 - 5.0%
- VFA range (min. to max.): 65 - 78%
- $\%G_{mm}$ @ N_{ini} is ≤ 90.0

NCDOT Mix Types S 9.5D and S 12.5D Aggregate Consensus Properties

- Coarse Aggregate Angularity for one face/two faces: 100/100
- Fine Aggregate Angularity: 45% min.
- Sand Equivalent: 50% minimum
- Flat & Elongated @ 5:1 ratio: 10% max.
  - Note: the aggregate consensus property requirements apply to the coarse or the fine fraction of the aggregate blend

Open Graded Friction Course Designs

Standard Specifications
Section 650

OGFC

Specialty Mixes - OGFC
Specifications Section 650

- There are three types of open graded friction course mixes:
  - FC-1
  - FC-1 modified
  - FC-2 modified
- Typical placement depth is ¾ inch
- Minimum placement depth is 3/8 inch at joints and for transitions
- RAP is not allowed in the mix

Specialty Mixes - OGFC Specifications Section 650

- Add chemical anti-strip to all mixes @ 0.5% by weight of binder or hydrated lime @ 1% by weight of dry aggregate
- If needed to prevent drain down, add fibers by total weight of the mix
  - Recommended rate is between 0.2 and 0.4%
  - or use shingles (RAS) in place of fibers
- RAS can be used up to 6% by weight of the total mix
  - Maximum recycled binder contributed by RAS should be 20% of the total binder in the mix

OGFC Design Criteria

Tables 650-1 and 650-2

Gradation		Ndes Gyrations = 50		
Sieve Designation		FC-1	FC-1 Mod	*FC-2 Mod
¾ inch	19.0 mm			100
½ inch	12.5 mm	100	100	*80 - 100
3/8 inch	9.5 mm	75 - 100	75 - 100	55 - *80
No. 4	4.75 mm	25 - 45	25 - 45	15 - *30
No. 8	2.36 mm	5 - 15	5 - 15	5 - *15
No. 200	0.075 mm	1.0 - 3.0	1.0 - 3.0	2.0 - 4.0
PG Grade		64 -22	76 -22	76 -22
Binder % Range		5 - 8	5 - 8	5 - 8
*Mix Temperature Actual JMF Temps		265 - 300ºF	300 - 335ºF	300 - 335ºF (one 280°F)
Draindown (T305), %		0.3 max	0.3 max	0.3 max

Design Procedure for OGFC

- Use NCDOT Test Method A-101 to design the mix (see the supplemental hand-out book)
- NCDOT FC-2 mixes use some combination of:
  - Coarse aggregates: #57, #67, #78M, #7, #8
  - Fine aggregates: screenings, RAS
- NCDOT FC-1 mixes use some combination of:
  - Coarse aggregates: #78M, 78 special
  - Fine aggregates: screenings, RAS

Design Procedure for OGFC

- If possible choose a coarse aggregate with a micro-deval less than 18%
- Three AC contents should be used: begin with 5.5, 6.0, and 6.5% increments
  - Or maybe 5.0, 5.5 and 6.0% for mixes with shingles
- Start by compacting three 150 mm diameter gyratory pills @ 50 gyrations for N_{des} at each increment

Design Procedure for OGFC

- Use a Corelok to measure the bulk specific gravity of the pills
  - Or measure the dimensions of the pill to determine it's volume (the pill is shaped like a cylinder) and use it along with the dry weight to calculate the density, and then the bulk specific gravity
  - Density = Dry Weight of the pill ÷ Volume of the pill

  Dry Weight is measured in grams

  Volume of a gyratory pill = 17.67 x height in mm.
  - Sp. Gr. = Density ÷ 0.99707

Design Procedure for OGFC

- Running the lab permeameter test using NCDOT Test Method A-100 (see the supplemental hand-out book) is optional
- Submit all the design pills (after drying them) to the M&T Lab to run the Cantabro Abrasion Test for loss of material on un-aged specimens
- Run the drain-down tests at all increments to check for potential asphalt run-off problems

OGFC Designs

- The specified mix design criteria are gradation, asphalt binder grade, an AC content range, and maximum drain-down
  - The mix design method adds criteria for VTM, permeability/porosity, and Cantabro percent loss on un-aged specimens
- Note: the maximum LA Abrasion loss is 45% for aggregates used in OGFC
  - CAA (fractured faces) is 100/100
  - FAA (fine aggregate angularity) is 45% min
  - SE (sand equivalent) is 45% min
  - F&E (flat and elongated @ 5:1 ratio) is 10 max
    - Micro-deval on coarse aggregate will be run for information

OGFC Designs

Compare the following information from the three increments to determine the optimum AC content

- VTM = 18% minimum (dimensional) or 16% minimum (by corelok)
- Permeability = 100 meters/day minimum (optional)
- Porosity = 15% minimum (recommended)
- Cantabro abrasion loss on un-aged asphalt specimens is 20% maximum
- Percent drain-down is 0.3% maximum
- No TSR requirement at this time
- Some mixes are designed using shingles

OGFC Designs

- Voids/porosity are measured best by using the Corelok machine
- Permeability is measured using the Karol-Warner lab permeameter following NCDOT Test Method A-100 or the manufacturer's instructions
- Percent loss is measured by the Cantabro Test using an LA Abrasion machine with no steel balls and for a duration of 300 revolutions

OGFC Designs

After determining the optimum AC content ….

- The drain-down is performed at two temperatures for lab prepared samples at optimum AC content:
  - 2 tests @ mix production temperature
  - 2 tests @ mix production temperature plus 15 °C (as per AASHTO T305)
- See QMS Manual Chapter 7 for details on the drain down test equipment and method

OGFC Designs

- By definition, the maximum size aggregate is the smallest sieve through which all the aggregate is required to pass, and the nominal maximum size (NMSA) is one sieve size smaller than the maximum size
  - For FC-1 mixes, ½" is the maximum size and 9.5 mm is the NMSA so burn 1200 to 1700 grams in the ignition oven and use 1500 to 1700 grams for the rice or corelok test
  - For FC-2 mixes, 3/4" is the maximum size and ½" is the NMSA so burn 1500 to 2000 grams in the ignition oven and use 1500 to 1700 grams for the rice or corelok test

OGFC During Production

- The JMF temperature will be set at 300°F or 335°F for HMA and in the range of 225-275°F or 260-310°F for WMA depending on the binder grade used in the mix
- Sample and test the mix at the following minimum frequency:
  - Accumulative production increment: 500 tons
  - No. of samples per increment: 1
- For each increment:
  - a drain down test should be run at the plant production temperature - the maximum drain-down amount is 0.3%
  - test for gradation and binder content - so you will need an ignition oven calibration factor

Ultra-thin Bonded Wearing Course Designs

Standard Specifications Section 661

UBWC

UBWC

- This pavement is constructed using a specialized paver that sprays a warm polymer modified emulsion membrane (PMEM) onto the existing pavement immediately before placing the UBWC hot mix asphalt overlay

UBWC Designs

- These mixes are not driven by volumetric criteria
- Voids should be used as a tool to assure proper drainage and macro-texture
- Higher air voids will assist in drainage and help this mix work similar to an OGFC

UBWC Designs

- Use either PG 70 -28 or PG 76 -22 in the mix design
- Ensure that the asphalt binder is compatible with the PMEM and the existing pavement
- Do not use crystalline limestone, crystalline – dolomitic limestone or marble for aggregates
- Do not use RAP

UBWC Designs

- Use a mixture of coarse and fine aggregate, asphalt binder, mineral filler and other additives when required
- Size, uniformly grade and combine in such proportions such that the resulting mixture meets the requirements of Tables 661-1 and 661-2
- RAS is allowed – however, the percent of RAS binder contributed can not exceed 20% of the total binder

UBWC Designs

- Use the mix design and optimum asphalt content for "UBWC Mix Design Guidelines" on file with the M&T Unit (or, see this mix design manual)
- Submit in writing a mix design and proposed JMF targets for each mix type and combination of aggregates to the Engineer at least 20 days before the start of mix production

UBWC Designs

- UBWC Gradation Criteria Table 661-1

Sieves (mm)	%Passing by Weight
12.5	100
9.5	85 - 100
4.75	28 - 44
2.36	17 - 34
1.18	13 - 23
0.600	8 - 18
0.300	6 - 13
0.150	4 – 10
0.075	3.0 – 7.0

UBWC Designs

- UBWC Mix Design Criteria Table 661-2:

Property Gyrations	Requirement 100
Asphalt Content, %	4.6 – 5.8
Drain-down Test, AASHTO T 305	0.1% max
Moisture Sensitivity, AASHTO T 283[A]	85% min
Application Rate , lb/sy	70 lb/sy
Approximate Application Depth, in.	5/8”
Asphalt PG Grade, AASHTO M 320	PG 70 -28 or PG 76 -22

A. Specimens for T 283 testing are to be compacted using the Superpave gyratory compactor. The mixes shall be compacted using 100 gyrations to achieve specimens approximately 95 mm in height. Use mixture and compaction temperatures recommended by the binder supplier.

UBWC Designs

- Mix Design Procedure
  - VTM shall be greater than 6% as a general rule
    - VTM values for NC should be near to 10 or 11% for the typical aggregate blend gradations that result from the % passing design criteria given for the mix design
  - Film thickness should be 9 to 11 microns minimum (as calculated by the mix design program, etc.)
  - Use mixing and compaction temperatures as recommended by the binder supplier
    - As a guide: use 303 – 312 ºF (150.6 - 155.6 ºC) compaction temperature for PG 70 -28

UBWC Designs

- Coarse Aggregates:
  - LA Abrasion: 35% maximum loss
  - Flat and Elongated: 10% maximum at 5:1 length to thickness ratio run on plus no. 4 material
  - Micro-Deval: 18% maximum loss**
    - The machine works similar to the LA abrasion tumblers, however the steel balls are not used to impact the stone sample (so it is more of a durability test)
    - The stone is soaked in water before the test and the test is run with water and steel balls added to the bucket along with the sample

Micro Deval Test Machine

UBWC Designs

- Coarse Aggregates:
  - Sodium Sulfate Soundness Loss: 15% maximum
  - Fractured particles, single face: 100% minimum
  - Fractured particles, two or more faces: 85% minimum

UBWC Designs

- Fine Aggregate (material passing the no. 4 sieve in the blend) shall be from approved sources and shall meet the following requirements:
  - Sand Equivalent: 45% minimum
  - Uncompacted Voids: 45% minimum
- Mineral Fillers, use if needed:
  - Limestone dust
  - Dolomite dust
  - Portland cement
  - Or other inert mineral matter conforming to AASHTO M17

UBWC Designs

- In general, use a standard or modified 78M stone (with a lower %passing the #4 sieve to get a gap gradation) and a washed screening (to limit the %passing #200 sieve)
- *Either PG 70 -28 or PG 76 -22 is allowed*
  - Base the binder selection on the geographic location
  - Generally, use PG 70 -28 in the west and PG 76 -22 in the central and eastern part of the state
  - The standard specs state that where PG 76 -22 is used, the grade of binder to be paid will be PG 70 -28, unless otherwise approved. However the line item is now generic for "polymer modified binder"
- Anti-strip additive is required in the mix

UBWC Design Method

"UBWC Mix Design Guidelines"

- Estimate the trial binder content so that the dust to binder ratio is approximately equal to one (1.0)
  - Recommend an upper limit of 5.5% passing the #200 so as not to extend the binder with too much dust
  - Also use the binder content range from the Mix Design Criteria as a guideline
  - Start at 4.5 to 5.0% passing the #200 and use 5.0 to 5.3% AC to allow for asphalt absorption

UBWC Design

- Batch 3 increments, one at the trial AC content, one 0.5% above trial AC, and one 0.5% below trial AC content
  - Note: An increment at 4.5% will be below the minimum specified AC content of 4.6%
- Use about 4700 grams of blended aggregate for a pill
- Age the mix for two hours at the compaction temperature before gyrating the pills
- Age the mix for two hours at 275 ± 9 ºF (135 ± 5 ºC) for the rice test specimens
- Gyrate three 150 mm diameter pills to 100 gyrations at each increment
- Follow the Superpave design procedure for compacting the specimens (heights are 115 ± 5 mm, etc.)

UBWC Design

- Measure G_{mb} using either the Corelok or the theoretical method (AASHTO T-269) if the design voids are high
- Measure G_{mb} using the SSD method if the design voids are nearer to 6%
- Measure G_{mm} using AASHTO T209 (rice test) or the Corelok using ASTM D6857 on 2 hour aged samples of loose mix
- Enter the gravities into the UBWC program and it will auto-calculate the mix properties including the design film thickness

UBWC Design

- The TSR test shall be run using 150 mm diameter specimens compacted using 100 gyrations and to a height of 95 ± 5 mm
  - Adjust the weight of the mix; the voids are not specified, however, they should be about the same as the voids obtained at the optimum AC content in the mix design
  - Saturate the specimens to 70 - 80% when the voids are near to 6%
  - Saturate the specimens for 10 minutes at a partial vacuum of 26 inches of mercury when the voids are nearer to 11%, to whatever saturation is achieved
- Passing TSR is 85%

UBWC Design

- Perform the drain-down test on lab mix where the AC content is at the optimum plus 0.5% and the temperature is 15 °C hotter than the mixing temperature, not to exceed 180 °C (356 °F)
- Drain-down test time is 1 hour ± 5 minutes unless the mix has cooled to 25 ºC below the test temperature then the time is 70 ± 5 minutes
- See the QMS Manual Chapter 7 for details on the draindown test equipment and method

UBWC Designs

Choose the optimum AC based on the design meeting all of these criteria:

- Drain-down: 0.10% maximum
- Film thickness: 9 microns minimum
- Air voids: 6% minimum
- TSR test results meeting or exceeding 85% at optimum binder content

Note: RAP is not allowed in these mixes since it is too coarse, however, RAS is permitted at up to 6% by total weight of the mix (the fibers in the shingles can help to limit the drain-down)

UBWC Designs

- By definition, the maximum size aggregate is the smallest sieve through which all the aggregate is required to pass, and the nominal maximum size aggregate (NMSA) is one sieve size smaller than the maximum size
  - For UBWC mixes, ½" is the maximum size and 9.5 mm is the NMSA so burn 1200 – 1700 grams in the ignition oven and use 1500 – 1700 grams for the rice or corelok test

UBWC During Production

- The JMF temperature will be set at 315°F or 335°F for HMA and in the range of 240-290°F or 260-310°F for WMA depending on the binder grade used in the mix
- Sample and test the mix at the following minimum frequency:
  - Accumulative production increment: 500 tons
  - No. of samples per increment: 1
- For each increment:
  - a drain down test should be run at the plant production temperature - the maximum drain-down amount is 0.1%
  - burn samples are tested for gradation and binder content

Hot In-Place Recycled Designs

Standard Specifications Section 663

HIR

HIR Designs

- The HIR process consists of preheating and hot milling an existing asphalt pavement surface then adding a plant produced HMA and rejuvenator to the millings to complete the bituminous mixture
- The HIR asphalt mix is re-mixed, relayed, and compacted in a continuous, single train, single pass, multi-step process

HIR Designs

HIR Pre-design

- The Contract will provide the mix type, milling depth, admixture rate, and proposed rejuvenator rate
- The QA Lab will test cores from the existing pavement for gradation and binder content and submit the results to M&T
- The M&T Lab will determine if the specified mix design type can be formulated based on the RAP aggregate gradation and RAP binder content test results

HIR Designs

- The mix designer will obtain a representative sample of the existing roadway (core, saw, etc.) at a minimum of one sample every 2000 linear feet of each lane for gradation, AC content, and layer type of the existing pavement
- Core samples shall be taken in the presence of the Engineer and at approved locations
- The total design (including TSR and APA samples) will require that about 75 to 100 six inch diameter cores be drilled from the existing pavement

HIR Designs

- The top surface of the cores are saw cut to the proposed milling depth and this asphalt is used in the mix design process
- Submit two proposed designs, one for the complete HIR, and one for the virgin plant produced admixture

HIR Designs

- Send the designs to the M&T Asphalt Lab at least 20 days prior to beginning the work
- The gradations of milled RAP and virgin aggregate admixture, total binder content, amount of rejuvenator, and all volumetric properties of the completed mix shall be reported on the appropriate M&T forms

HIR Designs

- The aggregate blend gradation shall meet the requirements of Table 610-2 of the Specifications for the specified mix type
- The HIR Mixture shall meet the Mix Design Criteria listed in Table 610-3 of the Specifications for the specified mix type
- Important: a minimum of 0.25% liquid anti-strip shall be used in the admixture

HIR Materials

- The aggregate in the admixture may be a single standard size or a combination of sizes
- Add enough binder to the admixture to fully coat the aggregate particles (generally at least 2% AC)
- Add an asphalt rejuvenating agent at a rate that yields a completed mixture with the required penetration as specified in Table 663-1, unless otherwise approved

HIR Design Calculations
Example

From Contract: New HIR layer depth = 2" (of *S12.5C)
Admixture added at 45 lb/sy

Total remixed weight: 2" @ *112 lbs/sy/in = 224.0 lbs/sy

Admixture: @ 45 lbs/sy = 45 ÷ 224 = 0.20 x 100 = 20.1%

RAP(millings): 224 - 45 = 179 ÷ 224 = 0.799 x 100 = 79.9%

*Note: Thickness rate for each layer type is given in HMA/QMS Manual Table 3.4

HIR Design Calculations
Example

Rejuvenator Calculations:

0.08 to 0.10 gal/sy should be used as a target for the estimated rejuvenator. The actual rate is determined from a penetration test run on the recovered binder in the RAP

From above: 0.08 gal/sy x 8.33 lb/gal = 0.6664 lbs/sy

Approximate weight of a gallon of rejuvenator

HIR Design Calculations
Example

Binder Calculations:

0.6664 lbs of rejuvenator ÷ 224 lbs/sy x 100 =	0.3%
% Binder in RAP (5.4 ÷ 100) x %RAP (79.9) =	4.3%
% Binder in Admix (4.0 ÷ 100) x %Admix (20.1) =	0.9%
Total Binder in Completed mix design =	5.5%

Notes: %Binder in RAP is a measured lab value and total binder is fixed by the mix design procedure @ the optimum AC content

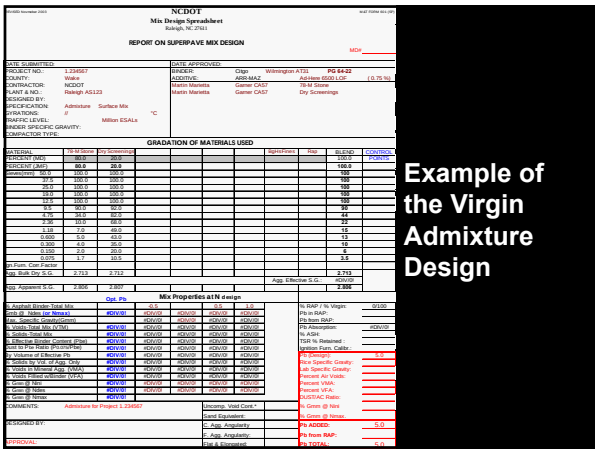
The AC in the admixture should be sufficient to coat the admixture (about 2%minimum)

HIR Designs

- In the admixtures, a PG 64 -22 may be specified in place of a higher binder grade
  - For example, a PG 64 -22 may be used in the admixture for a HIR S 12.5C (instead of the a PG 70 -22 that is specified for this mix type)
  - However, the mixing and compaction temperatures and the number of gyrations will be based on the final HIR mix type and not the PG binder grade used in the admixture

HIR Designs

- Two separate designs will be submitted and approved
  - One design is for the plant produced virgin admixture
  - The other design is for the completed mix showing the combined recycled asphalt and the virgin admixture
- Two separate mix designs and JMF numbers will be issued after approval



NCDOT

Mix Design Spreadsheet

Raleigh, NC 27611

REPORT ON SUPERPAVE MIX DESIGN

MD#

DATE SUBMITTED:		DATE APPROVED:	
PROJECT NO.:	1.234567	BINDER:	Citgo Wilmington AT31 PG 64-22
COUNTY:	Wake	ADDITIVE:	ARR-MAZ Ad-Here 6500 LOF (0.75 %)
CONTRACTOR:	NCDOT		Martin Marietta Garner CA57 78-M Stone
PLANT & NO.:	Raleigh AS123		Martin Marietta Garner CA57 Dry Screenings
DESIGNED BY:			
SPECIFICATION:	Admixture Surface Mix		
GYRATIONS:	// °C		
TRAFFIC LEVEL:	Million ESALs		
BINDER SPECIFIC GRAVITY:			
COMPACTOR TYPE:			

GRADATION OF MATERIALS USED

MATERIAL	78-M Stone	Dry Screenings							BLEND	CONTROL POINTS
PERCENT (MD)	80.0	20.0							100.0	
PERCENT (MF)	**80.0**	**20.0**							**100.0**	
Sieve(mm)	50.0	100.0	100.0						**100**	
	37.5	100.0	100.0						**100**	
	25.0	100.0	100.0						**100**	
	19.0	100.0	100.0						**100**	
	12.5	100.0	100.0						**100**	
	9.5	90.0	92.0						**90**	
	4.75	34.0	82.0						**44**	
	2.36	10.0	66.0						**22**	
	1.18	7.0	49.0						**15**	
	0.600	5.0	43.0						**13**	
	0.300	4.0	35.0						**10**	
	0.150	2.0	20.0						**6**	
	0.075	1.7	10.5						**3.5**	
Ign.Furn. Corr.Factor										
Agg. Bulk Dry S.G.	2.713	2.712							**2.713**	
								Agg. Effective S.G.	#DIV/0!	
Agg. Apparent S.G.	2.806	2.807							**2.806**	

Mix Properties at N design

	Opt. Pb				
% Asphalt Binder-Total Mix		6.5		6.5	7.0
Gmb @ Ndes **(or Nmax)**	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Max. Specific Gravity(Gmm)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Voids-Total Mix (VTM)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Solids-Total Mix	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Effective Binder Content (Pbe)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Dust to Pbe Ratio (P0.075/Pbe)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
By Volume of Effective Pb	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Solids by Vol. of Agg. Only	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Voids in Mineral Agg. (VMA)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Voids Filled w/Binder (VFA)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Gmm @ Nini	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Gmm @ Ndes	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Gmm @ Nmax	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

% RAP / % Virgin:	0/100
Pb in RAP:	
Pb from RAP:	
Pb Absorption:	#DIV/0!
% ASH:	
TSR % Retained :	
Ignition Furn. Calib.:	
Pb (Design):	5.0
Rice Specific Gravity:	
Lab Specific Gravity:	
Percent Air Voids:	
Percent VMA:	
Percent VFA:	
DUST/AC Ratio:	
% Gmm @ Nini	
% Gmm @ Nmax	
Pb ADDED:	5.0
Pb from RAP:	
Pb TOTAL:	5.0

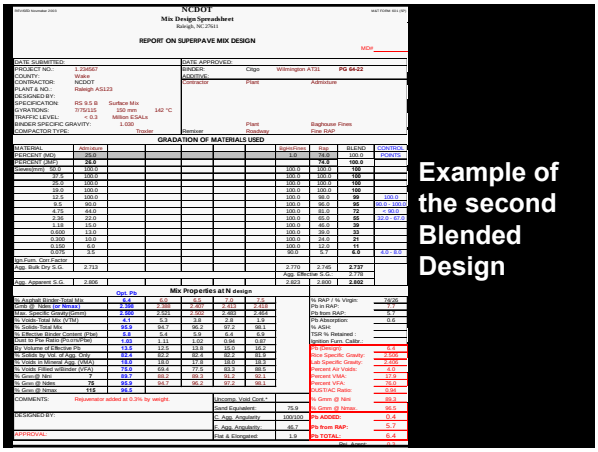
COMMENTS: Admixture for Project 1.234567

DESIGNED BY:

APPROVAL:

Uncomp. Void Cont.*	
Sand Equivalent:	
C. Agg. Angularity:	
F. Agg. Angularity:	
Flat & Elongated:	

Example of the Virgin Admixture Design



NCDOT

Mix Design Spreadsheet

Raleigh, NC 27611

REPORT ON SUPERPAVE MIX DESIGN

MD#

DATE SUBMITTED:		DATE APPROVED:	
PROJECT NO.:	1.234567	BINDER:	Citgo Wilmington AT31 PG 64-22
COUNTY:	Wake	ADDITIVE:	
CONTRACTOR:	NCDOT		Contractor Plant Admixture
PLANT & NO.:	Raleigh AS123		
DESIGNED BY:			
SPECIFICATION:	RS 9.5 B Surface Mix		
GYRATIONS:	7/75/115 150 mm 142 °C		
TRAFFIC LEVEL:	< 0.3 Million ESALs		
BINDER SPECIFIC GRAVITY:	1.030		
COMPACTOR TYPE:	Troxler		Reimbeer Plant Baghouse Fines
			Roadway Roadway Fine RAP

GRADATION OF MATERIALS USED

MATERIAL	Admixture						Sand/Fines	Rap	BLEND	CONTROL POINTS
PERCENT (MD)	25.0						1.0	74.0	100.0	
PERCENT (MF)	**25.0**							**74.0**	**100.0**	
Sieve(mm)	50.0	100.0					100.0	100.0	**100**	
	37.5	100.0					100.0	100.0	**100**	
	25.0	100.0					100.0	100.0	**100**	
	19.0	100.0					100.0	100.0	**100**	
	12.5	100.0					100.0	98.0	**99**	100.0
	9.5	90.0					100.0	96.0	**98**	90.0 - 100.0
	4.75	44.0					100.0	81.0	**72**	< 90.0
	2.36	22.0					100.0	65.0	**50**	32.0 - 67.0
	1.18	15.0					100.0	46.0	**39**	
	0.600	13.0					100.0	39.0	**33**	
	0.300	10.0					100.0	24.0	**21**	
	0.150	6.0					100.0	12.0	**11**	
	0.075	3.5					99.0	5.7	**6.9**	4.0 - 8.0
Ign.Furn. Corr.Factor										
Agg. Bulk Dry S.G.	2.713						2.770	2.745	**2.737**	
							Agg. Effective S.G.		2.770	
Agg. Apparent S.G.	2.806						2.823	2.800	**2.802**	

Mix Properties at N design

	Opt. Pb				
% Asphalt Binder-Total Mix	**6.4**	6.0	6.5	7.0	7.5
Gmb @ Ndes **(or Nmax)**	**2.388**	2.388	2.407	2.419	2.418
Max. Specific Gravity(Gmm)	**2.555**	2.531	2.532	2.483	2.464
% Voids-Total Mix (VTM)	**6.1**	5.9	3.8	2.8	1.9
% Solids-Total Mix	**93.9**	94.7	96.2	97.2	98.1
% Effective Binder Content (Pbe)	**6.8**	5.4	5.9	6.4	6.9
Dust to Pbe Ratio (P0.075/Pbe)	**1.03**	1.11	1.02	0.94	0.87
By Volume of Effective Pb	**13.5**	12.5	13.8	15.0	16.2
% Solids by Vol. of Agg. Only	**82.4**	82.2	82.4	82.2	81.9
% Voids in Mineral Agg. (VMA)	**18.0**	18.0	17.8	18.0	18.3
% Voids Filled w/Binder (VFA)	**78.9**	69.4	77.5	83.3	89.5
% Gmm @ Nini	**7**	**89.7**	88.2	89.3	91.2	92.1
% Gmm @ Ndes	**75**	**93.9**	94.7	96.2	97.2	98.1
% Gmm @ Nmax	**115**	**96.5**				

% RAP / % Virgin:	74/26
Pb in RAP:	5.7
Pb from RAP:	5.7
Pb Absorption:	0.6
% ASH:	
TSR % Retained :	
Ignition Furn. Calib.:	
Pb (Design):	6.4
Rice Specific Gravity:	2.555
Lab Specific Gravity:	2.406
Percent Air Voids:	3.0
Percent VMA:	17.9
Percent VFA:	78.0
DUST/AC Ratio:	0.86
% Gmm @ Nini	89.2
% Gmm @ Nmax	96.5
Pb ADDED:	0.4
Pb from RAP:	5.7
Pb TOTAL:	6.4
Dry Aggr.	93.6

COMMENTS: Rejuvenator added at 0.3% by weight

DESIGNED BY:

APPROVAL:

Uncomp. Void Cont.*	
Sand Equivalent:	75.9
C. Agg. Angularity:	100/100
F. Agg. Angularity:	46.7
Flat & Elongated:	1.9

Example of the second Blended Design

Warm Mix Asphalt

WMA

Warm Mix Asphalt

- Warm Mix Asphalt (WMA) is defined as additives or processes that allow a reduction in the temperature at which asphalt mixtures are produced and placed
  - Originally only used on regional and Sub regional tier roads
  - WMA is allowed for use at the Contractor's option when included in the project provisions

Warm Mix Asphalt

- Benefits
  - Anticipated lower costs for production
  - LEED credit
  - Fuel savings at the plant
  - Reduced oxidation of binder through the plant (stay darker longer)
  - Better coating of aggregates and RAP

Warm Mix Asphalt

- WMA produces an asphalt mix that is up to 100 ºF lower than normal HMA production temperatures
  - For PG 64 -22 the plant mixing temperature is from 225 to 275 ºF
  - For PG 70 -22 the plant mixing temperature is from 240 to 290 ºF
  - For PG 76 -22 the plant mixing temperature is from 260 to 310 ºF
- The lower temperature can result in less fuel burned, lower emissions at the plant, a cooler environment and less fumes during lay-down operations

Warm Mix Asphalt

- WMA can be easier to compact than HMA
- The reduced viscosity of WMA binders and the slower cooling rate of WMA mixes can allow for later season paving and longer hauls
- Lower mix temperatures decrease the severity of bumps in overlays caused by cracks treated with sealant
- Heat build-up will be less when multiple layers of WMA are placed on top of each within the same day (or night) operation

Warm Mix Asphalt

- There are three basic technologies:
  - Organic additives or waxes
  - Chemical additives or surfactants
  - Water for foaming
- Organic additives or waxes have lower viscosities that allow for better mixing and coating
- Chemical additives or surfactants work to disperse the ingredients and improve the wetting ability of the asphalt
- Water steams and expands the binder
  - Water can be added by foaming it, through materials containing internal water (such as zeolite), or from a moist aggregate

Warm Mix Asphalt

- Research Needs:
  - A comprehensive specification
  - A WMA mix design procedure
    - Originally HMA designs were converted to WMA designs
    - Now the designs are to be done using the specific WMA process at the anticipated production temperature
    - However, lab foaming devices are not common
    - For more information refer to NCHRP Report 691 Mix Design Practices for WMA - 2011

Warm Mix Asphalt

- Potential performance issues:
  - Increased rutting
  - Increased moisture damage due to the reduction in binder aging at lower production temperatures
  - Long term durability – WMA must perform as well as HMA to be cost effective

Warm Mix Asphalt

- There are no extra special limits for RAP in these mixes
- Warm mixes containing RAS are allowed
  - For mixes specifying PG 64 -22, JMF production temperatures will be set at 275 ºF (135 ºC) so that the shingles can soften in the mix
  - Other production temperatures may be approved by the Engineer
- Compact specimens at 10ºF lower than the mixing temperature shown on the JMF
  - The compaction temperature range is the compaction temperature ± 5°F

Warm Mix Asphalt

- Dry ignition oven samples to constant mass before the ignition oven test
- A passing TSR is required for MD/JMF approval
  - Additional TSR testing may be required when WMA is being produced – See revisions to the QMS Manual in Section 7.14.1 or the class hand-out for more details

Warm Mix Asphalt

- Restrictions on use:
  - See the NCDOT Approved Products Listing for WMA for technologies that are approved for use on Department projects

Warm Mix Asphalt

- New WMA mix design approval:
  - Submit the request for a new WMA mix design using an already approved HMA design/JMF
  - State which WMA method will be used along with the additive dosage rate and the proposed plant production temperature

Permeable Asphalt Drainage Course

PADC
Types P-78M and P-57
SSRS Section 652

Permeable Asphalt Drainage Course (PADC) Types P-78M and P-57

- Formulate the PADC from a mixture of crushed aggregate, asphalt binder, anti-strip additive and other additives as required to produce a mix meeting Table 652-1
- Submit in writing a mix design (M&T 601 only) and proposed JMF targets to the Engineer for review and approval at least 10 days before the start of asphalt mix production
- Establish the asphalt binder content at the midpoint of the range specified in Table 652-1 or as approved

Permeable Asphalt Drainage Course (PADC) Types P-78M and P-57

- Formulate the PADC from a mixture of
  - Crushed coarse aggregate shall meet Sect. 1012-1(B)
    - Except the plus #4 material shall contain at least 60% by weight of crushed pieces having 2 or more mechanically induced fractured faces
  - Asphalt binder PG Grade 64 -22
  - Use an anti-strip additive in all PADC mixes
    - Hydrated lime at a rate of 1.0% by weight of dry aggregate
    - Chemical at a rate of 0.5% by weight of asphalt binder
    - Or both lime and chemical
  - Other additives as needed to meet Table 652-1

Table 652-1
Permeable Asphalt Drainage Course

Sieve Size	Total Percent Passing	
mm, in.	Type P 78M	Type P 57
37.5, 1 1/2"		100
25, 1"		95 - 100
19, 3/4"	100	
12.5, 1/2"	95 - 100	25 - 60
9.5, 3/8"	75 - 100	
4.75, #4	20 - 45	10 - 20
2.36, #8	3 - 15	5 - 10
0.075, #200	1.0 – 3.0	1.0 – 3.0
Binder Content	2.5 – 3.5%	2.0 – 3.0%
Plant Mix Temp	240 – 270 ºF	260 – 290 ºF

Permeable Asphalt Drainage Course (PADC) Types P-78M and P-57

- Note: standard aggregate sizes #78M and #57 may not meet the standard criteria for gradations
  - so for example, a #67 stone and a dry screening may be used for a type P57 mix in some cases
- RAP and RAS are not currently specified

Permeable Asphalt Drainage Course (PADC) Types P-78M and P-57

- Submit a mix design in writing (M&T 601 only) and the proposed JMF targets for approval
- The binder content will be set at the midpoint of the specified range, or as approved
  - For type P 78M the default is 3.0%
  - For type P 57 the default is 2.5%
  - Be sure that there is enough binder added to thoroughly coat the aggregate
- Include the temperature that the mix is to be discharged from the plant for the JMF

Permeable Asphalt Drainage Course (PADC) Types P-78M and P-57 During Production

- Sample and test the mix at the following minimum frequency:
  - Accumulative production increment: 500 tons
  - No. of samples per increment: 1
- For each increment:
  - Samples are tested for gradation and binder content so you need an ignition oven calibration factor
  - For P-78M burn 1500 to 2000 grams of mix
  - For P-57 (using 5 or 57 stone) burn 3000 to 3500 grams
  - For P-57 (using 67 stone) burn 2000 to 2500 grams

MIX DESIGN STEPS

Equipment Calibrations and Verifications

Basic Steps to Mix Designs

1. Determine the mix type and the corresponding design criteria
2. Select the source of materials: binder, aggregate(s), recycled asphalt (RAP), shingles (RAS), anti-strip, and other additives as needed

Basic Steps to Mix Designs

3. Compare Trial Blends with similar binder contents and different aggregate gradations, then choose the best design aggregate structure
4. Adjust the initial binder content to an estimated binder content that will roughly approximate the design air void content (usually 4%)

Basic Steps to Mix Designs

5. Complete a four increment design by using the design aggregate structure and varying the binder content
6. Select the optimum binder content for the mix - It is the percent binder that yields the design air void content
7. Check that the other volumetric criteria are met at the design binder content

Basic Steps to Mix Designs

8. Verify the moisture susceptibility of the mix by running TSR Tests (as required)
9. Perform Rut Tests on surface mixes (as required)
10. Run the other performance tests such as drain-down, permeability or porosity, Cantabro, etc., (as required)

Lab Equipment Requirements

- Section 7.2.2 in the HMA/QMS manual lists the required QC/QA lab equipment and outlines the calibration and verification methods and frequency (see the supplemental hand-out book for copies of these pages)
- All of the equipment used in a mix design lab should follow these same standard guidelines

Step 1: Aggregate Weigh Up

- Balances are used for weighing aggregate, liquid asphalt and mix
- QMS requires general purpose balances to be calibrated annually by a registered scale technician using NIST class “F” traceable weights
- The balances shall also be verified weekly by QC/QA lab personnel

Step 2: Combined Aggregate

- Combine the separate aggregate sources and sizes together and place the samples in an oven
  - Heat them in the oven set to about 15°C (25°F) higher than the mixing temperature for 2 to 4 hours to allow the aggregate to reach mixing temperature
  - Increase the heat to 30°C (50°F) above mixing temperature before mixing
    - A 115 mm high gyratory specimen requires about 4700 grams of aggregate
    - A 95 mm high TSR specimen requires about 3700 grams of aggregate

Asphalt Mix Ovens

- Asphalt mix ovens shall be forced draft ovens and will be verified every six months using a calibrated NIST traceable thermocouple thermometer
- If the temperature readout does not match the NIST thermometer, the readout shall be adjusted so the temperature readout matches the thermometer

RAP and RAS Specifications

- Use RAP and/or RAS <u>without</u> a change in PG binder grade when:
  - RAP is less than or equal to 20% of the total mix, or when…..
  - RAS or a combination of RAS and RAP contributes less than 20% of the total AC to the mix

[Note: up to 50% RAP may be used in most recycled mixes]

- RAS is limited to 6% by weight of total mixture for any mix

RAP Aggregate Specific Gravity
Method 1 the Gmm Method

- As per AASHTO R35-04, back-calculate the G_{sb} of the RAP using the G_{mm} of the RAP and an assumed percent asphalt absorption of the RAP aggregate.
  - Measure the RAP G_{mm} using the Rice test
    - The size of the sample will depend on the NMSA
  - Estimate % asphalt absorption of RAP aggregate based on past test experience RAP Agg. Pba = 0.1 to 0.5% or as high as 1.5%
  - Calculate effective specific gravity G_{se} of the RAP aggregate
  - Solve for G_{sb} of the RAP aggregate

RAP Aggregate Specific Gravity
Method 1 the Gmm Method

$$G_{se} = \frac{100 - Pb}{\frac{100}{G_{mm}} - \frac{Pb}{G_b}}$$

$$G_{sb} = G_{se} \div \left[\left(\frac{Pba \times G_{se}}{100 \times G_b} \right) + 1 \right]$$

•All values Gse, Pb, Gmm, Gb, Gsb, and Pba are for the RAP or RAP Aggregate

RAP Aggregate
Effective Specific Gravity Example

- Calculate the RAP G_{se} given the following information:
  - RAP Pb = 5.3% (from ignition oven test)
    - Note: Default for RAP Ignition oven CF = 0.5
  - G_{mm} = 2.464 (from rice test on RAP)
  - G_b (specific gravity of RAP binder) = 1.02
- Note that the size of the burn sample for the RAP will depend on the NMSA

RAP Aggregate
Effective Specific Gravity Example

$$G_{se} = \frac{100 - 5.3}{\frac{100}{2.464} - \frac{5.3}{1.02}} = 2.676$$

RAP Aggregate
Work Problem #1

- Calculate the RAP G_{sb} given the following information:
  - G_{se} (RAP Agg.) = 2.676
  - Pba (RAP aggregate) = 0.1%
  - G_b (specific gravity of RAP AC) = 1.02

RAP Aggregate Work Problem #1 Answer

$$G_{sb} = G_{se} \div \left[\left(\frac{Pba \times G_{se}}{100 \times G_b} \right) + 1 \right]$$

$$G_{sb} = 2.676 \div \left[\left(\frac{0.1 \times 2.676}{100 \times 1.02} \right) + 1 \right]$$

$$G_{sb} = 2.676 \div \left[\left(\frac{0.2676}{102} \right) + 1 \right]$$

$$G_{sb} = 2.676 \div \left[(0.00262) + 1 \right]$$

$$G_{sb} = 2.676 \div \left[1.00262 \right] = \boxed{2.669}$$

RAP Aggregate Work Problem Continued

- Next find the RAP aggregate apparent specific gravity G_{sa} using the formula from the appendix of AASHTO T85 - Specific Gravity and Absorption of Coarse Aggregate

$$Gsa = \frac{Gsb}{1 - \frac{A \times Gsb}{100}}$$

Where A is the water absorption of the aggregate

RAP Aggregate Work Problem Continued

- Since the asphalt absorption was 0.1, let A, the water absorption of the RAP aggregate equal a higher amount, 0.2

$$Gsa = \frac{2.669}{1 - \frac{0.2 \times 2.669}{100}} = \frac{2.669}{1 - \frac{0.534}{100}}$$

$$Gsa = \frac{2.669}{1 - 0.00534} = \frac{2.669}{0.99466} = 2.683$$

Summary of RAP Aggregate Specific Gravities

- RAP Agg G_{sb} = 2.669
- RAP Agg G_{se} = 2.676
- RAP Agg G_{sa} = 2.683

RAP Aggregate Weighted Average Specific Gravity - Method 2

- Generally, burn (2000 gram) samples of the RAP to recover the RAP aggregate
- Split the unwashed aggregate sample over the no. 8 (2.36 mm) sieve
- Measure the fine aggregate specific gravities (G_{sb} and G_{sa}) by AASHTO T84
- Measure the coarse aggregate specific gravities (G_{sb} and G_{sa}) by AASHTO T85
- Use a weighted average based on the percent passing the no. 8 sieve to calculate the specific gravity

RAP Aggregate Weighted Average Specific Gravity - Method 2

RAP Aggregate	Bulk Specific Gravity	Percent by weight of total aggregate split over the no. 8 sieve
Coarse Fraction	2.670	37.0% retained on No. 8
Fine Fraction	2.700	63.0% passing No.8

**Note: this method may also be used for a virgin aggregate stockpile where the split is made over the no. 4 (or maybe the no. 8) sieve*

RAP Aggregate Weighted Average

Specific Gravity - Method 2

$$G_{sb} = \frac{37.0 + 63.0}{\frac{37.0}{2.670} + \frac{63.0}{2.700}}$$

$$G_{sb} = \frac{100}{13.86 + 23.33} = \frac{100}{37.19}$$

$$G_{sb} = 2.689$$

- Repeat the calculation using the apparent gravities in place of the bulk gravities to find Gsa (averaged)

RAS Aggregate

- Use the G_{mm} method to find the RAS aggregate specific gravities
  - Run a rice or corelok test on the shingles material to find G_{mm}
    - The sample size is 1500 – 1700 grams
    - Use a fine spray of alcohol to sink any fines during the rice test
  - Burn a dry sample of the shingles to determine the AC content
    - Burn no more than 500 grams – FIRE HAZARD
    - RAS ignition oven CF = 0.5

RAS Aggregate

- RAS aggregate specific gravities, continued...
  - Calculate G_{se} and substitute it for G_{sb}
    - Use $G_{se} = G_{sb}$ since the asphalt absorption of the RAS aggregate is very low
  - Calculate G_{sa} using a default of 0.1% for the water absorption (see the previous RAP aggregate example)

Virgin Aggregate
Weighted Average Specific Gravity

#78 Aggregate	Bulk Specific Gravity	Percent by weight of total aggregate split over the no. 4 sieve
Coarse Fraction	2.623	70.0% retained on No. 4
Fine Fraction	2.657	30.0% passing No.4

**Note: in this example a #78 aggregate that contains a significant amount of both coarse and fine fractions is split over the no. 4 sieve (may be used for #7, #8, #9)*

Virgin Aggregate
Weighted Average Specific Gravity

$$G_{sb} = \frac{30.0 + 70.0}{\frac{30.0}{2.657} + \frac{70.0}{2.623}}$$

$$G_{sb} = \frac{100}{11.291 + 26.687} = \frac{100}{37.978}$$

$$G_{sb} = 2.633$$

- Repeat the calculation using the apparent gravities in place of the bulk gravities to find Gsa (averaged)

Step 3: Adding Asphalt Cement

- Binder shall be heated in an oven to the proper mixing temperature
  - Binder viscosity depends on temperature
  - Limit the time for binder at mixing temperature to 1 hr.
  - The time required to heat binder to temperature will depend on the amount of binder being heated and the method of heating
- Use the binder supplier's recommended temperatures for all grades of asphalt
- Don't forget to add liquid anti-strip additive to the binder just before final mixing
- For WMA foamed binder, start with the machine set at 285 ºF
- Add WMA additive on top of the liquid binder

Preparing RAP and RAS

- Before batching, dry the RAP in an oven set at 60 °C (140 °F)
- Then heat the RAP separately to 110 °C (230 °F) for a maximum of 2 hours for batching
- RAS should be added to the batch at ambient temperature
- Dry mix the RAP (and/or RAS) with the heated aggregate just before adding the heated virgin binder

Other Preparations

- Do not preheat cellulose or mineral fibers, just add them to the mixing bowl with the aggregate before adding the binder
- Remember to preheat the mixing bowl and the other tools
  - Heat the bowls and tools to not more than 50 ºF (28 ºC) above the mixing temperature

Step 4: Mixing and Conditioning

- Combine the aggregates, fibers, RAP, RAS, and binder then mix them together thoroughly
  - Mix only until the aggregate is thoroughly coated (no time limit is specified for HMA)
- Place the mix for the gyratory pills in a pan, and spread it to an even thickness of one to two inches
- Place the mixture and pan in a forced draft oven for 2 hours ± 5 minutes at the compaction temperature ± 3ºC

Step 4: Mixing and Conditioning

- Stir the mix at 1 hour ± 5 minutes to insure uniform heating and check the mix temperature
- Condition the mix for 4 hours (for aggregates with more than 2% water absorption) for added asphalt absorption
- Remember for mix design that the mixing and compaction temperatures are based on the viscosity of the liquid asphalt

Mix Compaction Temperatures

From the QMS Manual for Gyratory Samples

Mixes Using Binder Grades	Compaction Temperature ± 5ºF
PG 64 -22 & PG 58 -28	290ºF (143ºC) 285 - 295°F
PG 70 -22	305ºF (152ºC) 300 - 310°F
PG 76 -22	315ºF (157ºC) 310 - 320°F

Mix Compaction Temperatures

Mixing and compaction temperatures are based on the specified PG binder grade for each mix type in Table 610-3.

When using RAP or RAS mixes with a different binder specified, use mixing and compaction temps based on the original binder grade for that mix type shown in Table 610-3

- For example, a RS 9.5C mix with 25% RAP will require PG 64 -22 instead of 70 -22, however, continue to use the higher compaction range of 300 to 310 ºF

For WMA compact at 10ºF lower than the plant mixing temperature shown on the JMF

The compaction range will be the compaction temperature ± 5°F

Step 5: Charge the Molds

- Place the entire mix sample into a preheated mold using one lift
- A funnel will help to avoid segregation
- Check the mix temperature
- Level the mix, and place it into compactor
- Molds shall be verified annually and meet the standards listed in QMS Section 7.2.2
  - The average inside diameter shall be 149.90 to 150.00* mm measured at room temperature

*This spec is for the manufacturer.

The diameter due to wear should not exceed 150.2 mm.

Step 6: Gyrate

- Place the mold into the superpave gyratory compactor (SGC), apply the load and angle, and allow it to run to the set number of gyrations @ N_{des}
- Do not use any dwell gyrations!
- The pills can be extruded from the mold immediately after compaction for most mixes
  - a cooling period of 5 to 10 minutes in front of a fan may be necessary for base mixes, TSR specimens, etc.

Gyratory Calibration

- QMS Manual Section 7.2.2:
  - SGC yearly maintenance is performed by the manufacturer or manufacturer's certified representative.
  - Internal Angle (1.16 ± 0.02°) is set according to AASHTO T344 and verified annually

Rapid Angle Measurement RAM (or DAV II with HMS)

Gyratory Calibration

- From the QMS Manual Section 7.2.2:
  - Pressure: 600 ± 18 kPa (verified/calibrated every 12 months)
  - Rotation: 30.0 ± 0.5 gyrations per minute (calibrated every 12 months)
  - Height: ± 0.1 mm of plug height (verified daily when used)

Extruded Specimens

- Allow the specimens to cool to room temperature
- Measure the bulk specific gravity using either AASHTO T166 (SSD method) or ASTM D 6752 (Corelok)
- Or for high void mixes, measure the dimensions of the specimen and calculate the *theoretical density* and convert it to bulk specific gravity by dividing it by 0.99707 g/cm^3

Step 7: Bulk Specific Gravity G_{mb}

- The Corelok is recommended for OGFC, UBWC, and any other high void or large stone mixes (some base mixes for example)

Bulk Gravity Setup

- All water in tanks will be heated and circulated and the water level will be maintained at a constant height
- Use a Recording Thermometer to measure the water tank temperature
- The diameter of the suspension cables will be the smallest practical size for under water weighing. (No Chains Allowed!)
- The suspension hook should be fully submerged during under water weighing

Bulk Gravity Setup

- Maintain the water temperature at 77 ± 2 ºF (25 ± 1 ºC)
- Visually inspect the water tanks every week and replace the water in the tank at least once per month

Bulk Gravity, G_{mb} = A ÷ (B – C)

A – Weight of dry specimen in air (grams)

B – Weight of SSD specimen in air (grams)

C – Weight of sample in water (grams)

Bulk Gravity Setup

- For mixes with high voids use the corelok machine to find G_{mb}
  - The spreadsheet program will calculate the voids based on the measured weights
- G_{mb} can also be found theoretically

Density = W ÷ V

W – Weight of dry specimen in air (grams)

V – Volume of a cylinder (the pill) $\pi r^2 h$

G_{mb} = Density ÷ 0.99707

Step 8: Maximum Specific Gravity

- For lab prepared specimens for G_{mm}
  - cure the samples at 275 ± 9ºF (135 ± 5ºC) for a minimum of 2 hours
- Measure the maximum specific gravity G_{mm} of the mixture using the rice test or the corelok machine
- For mix design
  - batch two samples, run the max gravity tests and average the test results
- The equipment shall meet the requirements of Section 7.12 of the QMS Manual

Step 8: Maximum Specific Gravity

- Note: use ASTM D-6857 for the corelok maximum specific gravity test
- See the following slide for the equipment set-up for the conventional rice test according to AASHTO T209:

Step 8: Maximum Specific Gravity

Maximum Gravity G_{mm} = A ÷ (A – C)

A = Weight of oven dried sample in air (grams)

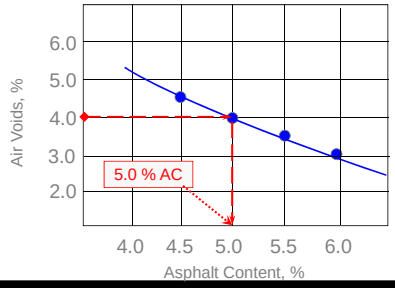
C = Weight of sample in water after vacuum (grams)

Find the Optimum AC Content

- After all of the tests are complete, and all data is recorded, the optimum AC content can be found at the design air void content
- Plot the Air void content versus the AC content to find the amount of asphalt needed to obtain the design air void content (generally 4% voids in the mix)

Optimum AC Content

DETERMINE THE DESIGN ASPHALT CONTENT AT 4% AIR VOIDS.



Checking Volumetric Properties

- Use the optimum binder content to find the other volumetric properties for the mix: VFA, VMA, and $\%G_{mm}$ @ N_{ini}
- Check the volumetric properties against the requirements of Table 610-2 to be sure they meet the specifications

Mix Adjustments

- To increase VMA
  - Lower the amount of material passing the #200 sieve
  - Move the blend gradation further away from the maximum density line (especially for mixes with no natural sand)
    - Make a fine blend finer or a coarse blend coarser
  - Increase the amount of manufactured sand and decrease the natural sand to increase the FAA and change the surface texture

Mix Adjustments

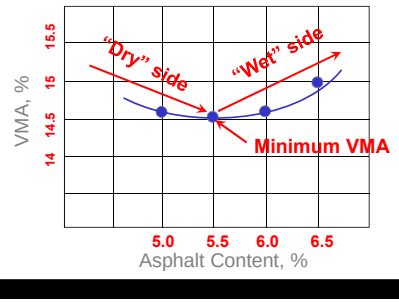
- To lower VMA
  - Increase the amount of material passing the #200 sieve
  - Move the blend gradation closer to the maximum density line (especially for mixes with no natural sand)
    - Make a fine blend coarser or a coarse blend finer
  - Increase the amount of natural sand and decrease the manufactured sand to decrease the FAA and change the surface texture

Mix Adjustments

- Note on VMA
  - Mixtures with VMA exceeding the minimum design value by more than 2% may be prone to flushing and rutting and should be avoided unless they have demonstrated good in-place performance

Percent VMA

VMA DECREASES to a minimum on the "dry" side and then INCREASES on the "wet" side



Notes on Percent VMA

- The minimum VMA is 14.5% and occurs at an asphalt content of 5.5%.
- Mixes that have an asphalt content less than 5.5% are on the "dry" side of the VMA curve and are said to be elastic
  - For maximum cohesion where the mix sticks together well, the asphalt content should be slightly lower than 5.5% (from 5 to 5.5%)
- Mixes with an asphalt content more than 5.5% are on the "wet" side of the VMA curve and are said to be plastic
  - Plastic mixes can rut and shove

Mix Adjustments

- Adjusting VFA - the lower limit of the VFA range should always be met at 4% air voids if the VMA meets requirements
- If the VFA is too high, then lower the VMA since the mix may not support a heavy load
- So, to reduce VFA, first reduce the VMA by:
  - increasing the minus #200 material
  - changing to a gradation that is closer to the maximum density line
  - using more natural sand and less manufactured sand

Mix Adjustments

- To adjust VTM
  - Raise the VTM by reducing the material passing the #200 sieve and/or reducing the AC content
  - Lower the VTM by increasing the material passing the #200 sieve and/or adding AC

Step 9: TSR Tests

- The NCDOT modified TSR test requires that you use the Superpave gyratory compactor to make eight 150 mm specimens at the optimum binder content
- Gyrate the samples to a target height of 95 mm (from 90 to 100 mm) in height mode
- The target air void content is 7 ± 0.5% voids for most mixes
- or, 13 ± 0.5% air voids for SA-1 mixes

Step 9: TSR Tests

- Find the tensile strengths of the conditioned (saturated/wet) and unconditioned (dry) samples
- A minimum tensile strength ratio of 85% is required for most conventional mix types and UBWC
- TSR for Type S4.75A and Type B25.0 mixes is 80% minimum

Step 10: Rut Pills (Surface Mixes Only)

- Beginning in 2006, rut pills need to be submitted with all new surface mix designs (except SA-1 mixes)
- Submit six of the 150 mm superpave gyratory specimens, made from lab produced mix that has been conditioned in a forced air draft oven at 135ºC (275 ºF) for four hours ± five minutes
  - Spread the mix evenly in a pan to a thickness of 25 to 50 mm and stir every hour
  - Condition the mix for four hours regardless of the absorption then immediately compact the samples in height mode to:
    75 ± 2 mm in height
    4 ± 0.5% air voids (or 5 ± 0.5% for S 4.75A)

APA Rut Testing

- The rut pills will be preheated for six to twenty four hours at 64 °C (147.2 °F) before testing and will be tested at 64 °C
- The APA test will run for 8000 cycles using a downward force of 120 lbf and a hose pressure of 120 psi.
  - Preprogrammed seating cycles are 50

APA Rut Testing

- Rut Depth Specifications (includes recycled mix types also)

Mix Type	Max Rut Depth, mm
S 4.75A	11.5
SF 9.5A	11.5
S 9.5B	9.5
S 9.5C	6.5
S 9.5D	4.5
S 12.5C	6.5
S 12.5D	4.5

APA Rut Testing

Estimated maximum weight of rut specimen, g

$$= \frac{(3.1416 \times h \times d^2)}{4} \times G_{mm} \times 0.96 \times 0.001$$

0.96 ← 4% voids

If h = 75 mm, then the Weight = 1272.348 x G_{mm}

where:

h = height of specimen (75 ± 2 mm)

d = diameter of specimen (150 mm)

G_{mm} = maximum density of the mix

APA Rut Testing 4.75 mm Mix

Estimated maximum weight of rut specimen, g

$$= \frac{(3.1416 \times h \times d^2)}{4} \times G_{mm} \times 0.95 \times 0.001$$

0.95 ← 5% voids

If h = 75 mm, then the Weight = 1259.094 x G_{mm}

where:

h = height of specimen (75 ± 2 mm)

d = diameter of specimen (150 mm)

G_{mm} = maximum density of the mix

APA Rut Testing

- Increase the rut resistance by:
  - Increasing the binder high temperature grade
  - If the binder is not modified consider using a polymer modified binder of the same grade or one temperature grade lower
  - Increase the amount of mineral filler, and adjust the aggregate gradation if needed to maintain VMA
  - Decrease the design VMA by adjusting the aggregate gradation
  - Replace existing aggregate sources with others that are more angular

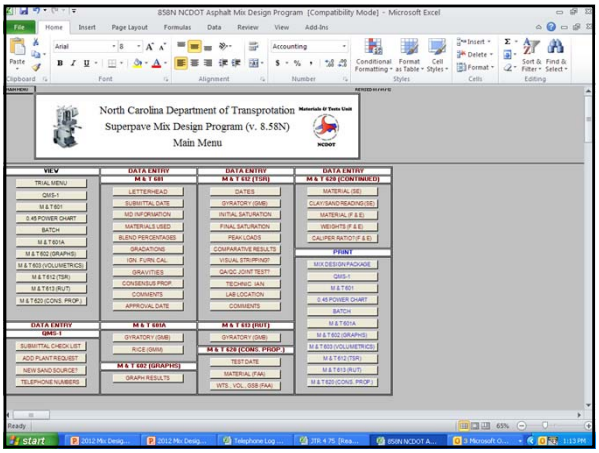
APA Rut Testing

- If rut testing is required during production then obtain the mix, reduce the obtained sample to the appropriate test size and compact the mix while it is within the specified compaction temperature range
- Do not sample the mix, let it cool and then reheat it and compact the rut pills

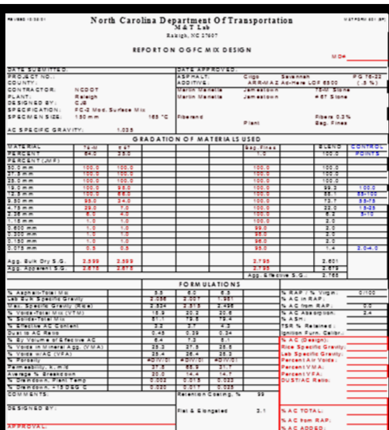
MIX DESIGN PROGRAMS

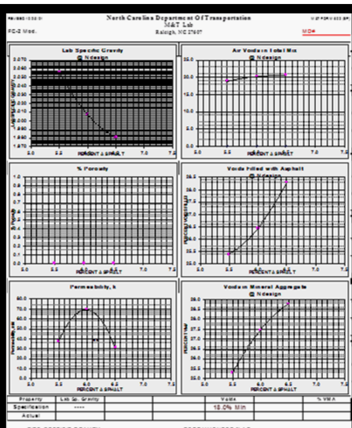
Mix Design Program 858N

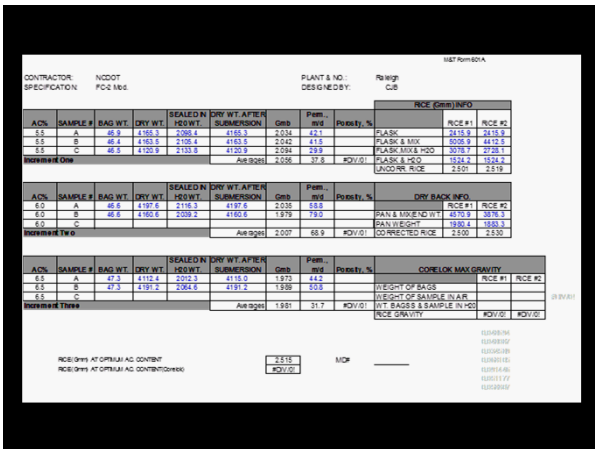
- 858N is the newest Mix Design Program for Virgin and RAP mixes
- The latest additions to 858N include:
  - Multiple sources of reclaimed materials: fractionated RAP, MRAS and PRAS
  - S 4.75A mixes
- Other programs available are:
  - OGFC for friction course designs
  - UBWC for Ultra-thin designs



OGFC Program


North Carolina Department Of Transportation
M&T Lab
REPORT ON OGFC MIX DESIGN


North Carolina Department Of Transportation
M&T Lab



M&T Form 601A

CONTRACTOR: NCDOT
SPECIFICATION: FC-2 Mod.

PLANT & NO.: Raleigh
DESIGNED BY: CJB

AC%	SAMPLE #	BAG WT.	DRY WT.	SEALED IN H20 WT.	DRY WT. AFTER SUBMERSION	Gmb	Perm., m/d	Porosity, %
5.5	A	46.9	4166.3	2066.4	4165.3	2.034	42.1	
5.5	B	46.4	4163.5	2105.4	4163.5	2.042	41.5	
5.5	C	46.5	4120.9	2133.8	4120.9	2.094	29.9	
Increment One					Averages	2.056	37.8	#DIV/0!

RICE (Gmm) INFO.	RICE #1	RICE #2
FLASK	2415.9	2415.9
FLASK & MIX	5005.9	4412.5
FLASK,MIX & H2O	3078.7	2728.1
FLASK & H2O	1524.2	1524.2
UNCORR. RICE	2.501	2.519

AC%	SAMPLE #	BAG WT.	DRY WT.	SEALED IN H20 WT.	DRY WT. AFTER SUBMERSION	Gmb	Perm., m/d	Porosity, %
6.0	A	46.6	4197.6	2116.3	4197.6	2.035	58.8	
6.0	B	46.6	4160.6	2039.2	4160.6	1.979	79.0	
6.0	C							
Increment Two					Averages	2.007	68.9	#DIV/0!

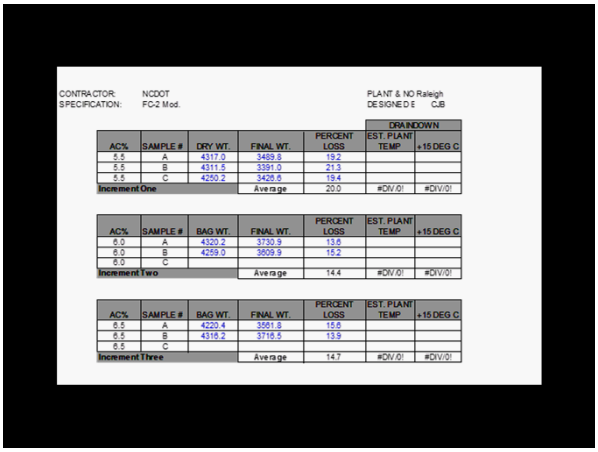
DRY BACK INFO.	RICE #1	RICE #2
PAN & MIXEND WT	4570.9	3876.3
PAN WEIGHT	1990.4	1883.3
CORRECTED RICE	2.500	2.530

AC%	SAMPLE #	BAG WT.	DRY WT.	SEALED IN H20 WT.	DRY WT. AFTER SUBMERSION	Gmb	Perm., m/d	Porosity, %
6.5	A	47.3	4112.4	2012.3	4116.0	1.973	44.2	
6.5	B	47.3	4191.2	2064.6	4191.2	1.998	50.8	
6.5	C							
Increment Three					Averages	1.991	31.7	#DIV/0!

CORELOK MAX GRAVITY	RICE #1	RICE #2
WEIGHT OF BAGS		
WEIGHT OF SAMPLE IN AIR		
WT. BAGS'S & SAMPLE IN H20		
RICE GRAVITY	#DIV/0!	#DIV/0!

RICE(Grms AT OPTIMUM AC CONTENT: 2.515
RICE(Grms AT OPTIMUM AC CONTENT(Corrected): #DIV/0!

MDF: _____



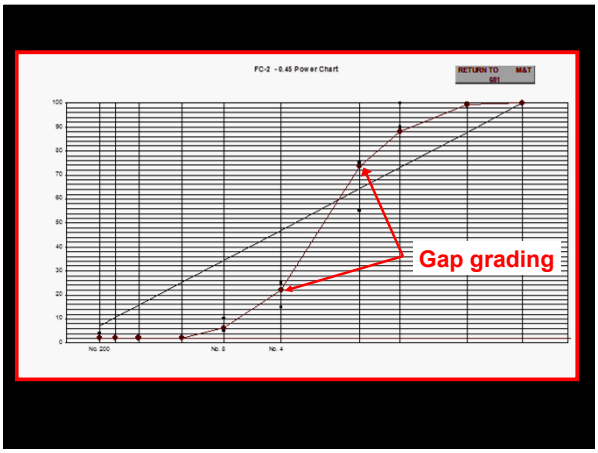
CONTRACTOR: NCDOT
SPECIFICATION: FC-2 Mod.

PLANT & NO Raleigh
DESIGNED E CJB

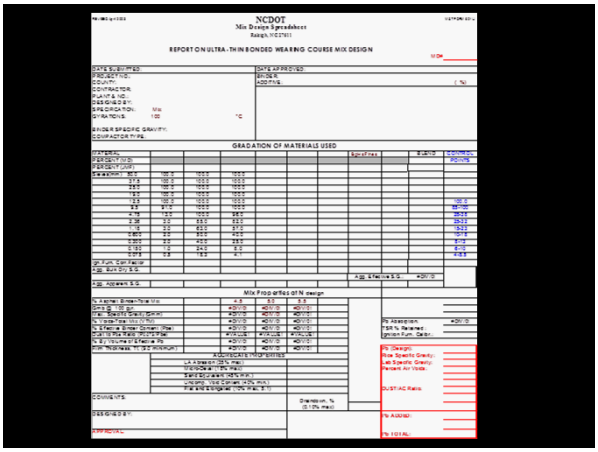
AC%	SAMPLE #	DRY WT.	FINAL WT.	PERCENT LOSS	DRAINDOWN EST. PLANT TEMP.	DRAINDOWN +15 DEG C
5.5	A	4317.0	3489.8	19.2		
5.5	B	4311.5	3391.0	21.3		
5.5	C	4250.2	3426.6	19.4		
Increment One			Average	20.0	#DIV/0!	#DIV/0!

AC%	SAMPLE #	BAG WT.	FINAL WT.	PERCENT LOSS	EST. PLANT TEMP.	+15 DEG C
6.0	A	4320.2	3730.9	13.6		
6.0	B	4259.0	3609.9	15.2		
6.0	C					
Increment Two			Average	14.4	#DIV/0!	#DIV/0!

AC%	SAMPLE #	BAG WT.	FINAL WT.	PERCENT LOSS	EST. PLANT TEMP.	+15 DEG C
6.5	A	4220.4	3561.8	15.6		
6.5	B	4316.2	3716.5	13.9		
6.5	C					
Increment Three			Average	14.7	#DIV/0!	#DIV/0!



UBWC Program



NCDOT
Mix Design Spreadsheet
Raleigh, NC27611

REPORT ON ULTRA-THIN BONDED WEARING COURSE MIX DESIGN

VOA

DATE SUBMITTED:
PROJECT NO.:
COUNTY:
CONTRACTOR:
PLANT & NO.:
DESIGNED BY:
PREPORATION: Mix
GYRATIONS: 100 °C
BINDER SPECIFIC GRAVITY:
COMPACTOR TYPE:

DATE APPROVED:
BINDER:
+200 PAS: (%)

GRADATION OF MATERIALS USED

STOCKPILE										
PERCENT (%)										
PERCENT (JMF)										
Sieve (mm)	95.0	100.0	100.0							
37.5	100.0	100.0	100.0							
25.0	100.0	100.0	100.0							
19.0	100.0	100.0	100.0							
12.5	100.0	100.0	100.0							100.0
9.5	91.0	100.0	100.0							95-100
4.75	13.0	100.0	98.0							28-53
2.36	3.0	65.0	63.0							25-33
1.18	3.0	43.0	41.0							19-23
0.600	3.0	30.0	28.0							13-18
0.300	3.0	24.0	22.0							8-12
0.150	3.0	24.0	8.0							6-9
0.075	3.0	19.0	4.7							4.0-6
Agr Fun. Con Factor										
Agg. Bulk SG's										
Agg. Apparent S.G.										

Agg. Effective S.G. #DIV/0!

Mix Properties of N design

% Asphalt Binder/Total Mix		7.0	6.5	6.0
Gmm @ 135 gyr.		#DIV/0!	#DIV/0!	#DIV/0!
Mix Specific Gravity (Gmb)		#DIV/0!	#DIV/0!	#DIV/0!
% Voids/Total Mix (V Ma)		#DIV/0!	#DIV/0!	#DIV/0!
% Effective Binder Content (Pbe)		#DIV/0!	#DIV/0!	#DIV/0!
Void in the Field (Pilot Plant)		#VALUE!	#VALUE!	#VALUE!
% Air Voids at Effective Pb		#DIV/0!	#DIV/0!	#DIV/0!
Film Thickness, ft (by Weight)		#DIV/0!	#DIV/0!	#DIV/0!

Pb Absorption: #DIV/0!
TSR % Retained:
Ignition Furn. Calib:

Pb (Design):
Rice Specific Gravity:
Lab Specific Gravity:
Percent Air Voids:

DUST/AC Ratio:

Pb Added:
Pb TOTAL:

AGGREGATE PROPERTIES

LA Abrasion (30% max)	
Unsound Soundness (15% max)	
Sand Equivalent (45% min)	
Uncomp. Void Content (47% min)	
Fine Aggregate Angularity (43% min, 2.1)	

COMMENTS:

Dimension, % (0.15% max)

DESIGNED BY:

APPROVAL:

MIX DESIGN PROCEDURES

MIX DESIGN OUTLINE

1. Determine the Compaction Level
2. Select the aggregate(s) for each mix type
3. Select the binder
4. Explore the possible trial blend gradations to find the design aggregate structure

MIX DESIGN OUTLINE
(continued)

5. Complete a Four Increment Design
6. Select the Optimum Binder Content
7. Perform TSR Tests
8. Perform lab performance tests (rut, permeability/porosity, drain-down, Cantabro loss, etc.)

COMPACTION LEVEL

- Compaction level is determined by the number of *ESALs*
- *What are ESALs?*
  - *E*quivalent *S*ingle *A*xle *L*oads
  - 18,000 lbs. or 18 kips (the weight of a tandem axle truck)
- Four Traffic Levels - A, B, C, and D

Aggregate Selection

- What size mix is being designed?
  - 4.75, 9.5, and 12.5 mm surface - Similar to HDS and I-2 Marshall mixes
  - 19.0 mm Intermediate - replaced HDB
  - 25.0 mm Base - replaced HB
- Currently there are 12 types of conventional virgin mixes
- Mix Designations

  S - Surface

  I - Intermediate

  B - Base

13 Types of Virgin Mixes

Mix Type (mm)	Design ESAL (millions)
SA-1	< 0.3
S 4.75A	< 0.3
S F9.5A	< 0.3
S 9.5B	0.3 - 3
S 9.5C	3 – 30
S 9.5D	> 30
S 12.5C	3 – 30
S 12.5D	> 30
I 19.0B	< 3
I 19.0C	3 – 30
I 19.0D	> 30
B 25.0B	< 3
B 25.0C	> 3

- Plus the recycled mixes

Aggregate Size Selection

Aggregate Size Selection

- Once it is determined which type of mix is to be designed, the type of aggregate(s) is selected.
- Typical aggregates include:
  #78m, #67, #5, #467, #57, sand, washed and dry screenings, bag-house fines, RAP and RAS (aggregate)

Aggregate Size Selection

(Dense Mixes - Suggested Coarse Aggregate Sizes)

NMSA of Mix				
37.5 mm (1.5 in.)	25 mm (1 in.)	19 mm (0.75 in.)	12.5 mm (0.5 in.)	9.5 mm (3/8 in.)
Coarse Aggregate Sizes				
4 and 67 or 4 and 68 (or 467M)	5 and 7 or 57 (or 5, 67 & 78M)	67 or 68 or 6 and 8 (or 67 and 78M)	7 or 78 (or 67 and 78M)	8 (or 78M)

Aggregate Size Selection

- The cumulative aggregate blend percents passing are plotted versus the individual sieve sizes on a FHWA 0.45 Power Chart
- The resulting blend gradation line must pass between the specified Control Points

Aggregate Specifications & Evaluations

- Mix design gradations are all washed gradations to insure that the amount of minus #200 material is accurate
- Use AASHTO T11 "Materials Finer than #200 by Washing" to find the fines in coarse aggregate
- The fine aggregates (screenings and natural sands) are washed, then sieved, and the gradation is used for the mix design

Aggregate Specifications & Evaluations

- For coarse and fine aggregates see the following sections in the NCDOT Standard Specifications:
  - 1005 - General Requirements for Aggregates, and
  - 1012 - Aggregate for Asphalt Pavements and Surface Treatments

Aggregates for Asphalt Plant Mixes 1012-1(A) General

- For all dense graded surface mixes that are the top or final layer, limit the amount of coarse or fine aggregate produced from crystalline limestone, crystalline-dolomitic limestone, or marble to no more than 50% of the total amount of coarse or fine aggregate in the mix
- Do not use aggregates from crystalline limestone, crystalline- dolomitic limestone, or marble in OGFC or UBWC

Coarse Aggregate Specifications

- General
  - Use aggregate from sources that participate in the NCDOT Aggregate QC/QA Program
  - Use standard gradations meeting the requirements of Table 1005-1
  - Coarse Aggregate Angularity (Fractured Faces) shall meet the requirements of Table 1012-1

Coarse Aggregate Specifications

- General
  - Flat and Elongated Pieces shall meet the requirements of Table 1012-1 when tested on the no. 4 sieve and larger with a 5:1 aspect ratio for all pavement types, except Types S 4.75A, SF 9.5A and S 9.5B
  - Soundness loss when subjected to five cycles using sodium sulfate is 15%

Coarse Aggregate Specifications

- General
  - Toughness (Resistance to Abrasion) The maximum allowable loss for each individual aggregate source for all plant mixes, except OGFC and UBWC, is 55%
    - All NCDOT approved aggregate sources meet this LA specification
  - The maximum loss for aggregate used in OGFC is 45% and for UBWC is 35%
  - The maximum allowable weight of clay lumps and friable particles in individual aggregates is 0.3%

Fine Aggregate Specifications

- General
  - Use fine aggregate that is consistently graded from coarse to fine and consists of natural sand, stone screenings, or a blend of natural sand and stone screenings
  - Use aggregate composed of rough surfaced and angular grains of quartz or other hard durable rock

Fine Aggregate Specifications

- General
  - Use aggregate from sources that participate in the NCDOT Aggregate QC/QA Program
  - If a natural sand source is owned by the same owner as the asphalt plant where the material is used, participation in the Aggregate QC/QA Program is not required

Fine Aggregate Specifications

- Gradation
  - Use stone screenings that are consistently graded with not more than 20% by weight passing the no. 200 sieve when tested by dry sieving in accordance with AASHTO T27
  - Use natural sand that is consistently graded
  - Clay Content (Sand Equivalent) of the blend shall meet the requirements of Table 1012-1 when tested in accordance with AASHTO T176

Fine Aggregate Specifications

- Gradation
  - The soundness loss of individual sources when subject to five cycles using sodium sulfate is 15%
  - The maximum weight of clay lumps and friable particles in individual sources is 0.3%
  - Use a fine aggregate blend that has a minimum fine aggregate angularity as indicated in Table 1012-1 when tested according to AASHTO T 304, Method A

Mineral Filler Specifications

- Use mineral filler consisting of limestone dust, dolomite dust, Portland cement, or other mineral matter conforming to AASHTO M17

Anti-strip Additive

- Use an anti-strip additive in all Superpave mixes
- Use either hydrated lime, chemical additive, or both
- The additive shall prevent the separation of the asphalt binder from the aggregate and achieve the required TSR
- Chemical anti-strip shall be added to the asphalt binder before it is added to the mix
- Do not use any chemical additive, or concentration of additive, that is harmful to the mix or which changes the PG grade
- Add a chemical additive at a rate of not less than 0.25% by weight of the total binder in the mix

Anti-strip Additive

- Add hydrated lime (for anti-strip purposes) at a rate of not less than 1.0% by weight of the total dry aggregate
- For lab mix design – prepare a slurry of 50% hydrated lime and 50% water by weight and apply it to the aggregate prior to heating

RAP and RAS Aggregates

- For RAP and RAS at least five samples of each stockpile should be obtained, burned and tested before starting the mix design process
- Reduce the samples to test weight by splitting and dry them to constant weight before the burns

RAP and RAS Aggregates

- The weight of the RAP burn samples is based on the NMSA in the RAP

NMSA RAP (mm)	Wt. Range (g)
37.5	4000 - 4500
25.0	3000 - 3500
19.0	2000 - 2500
12.5	1500 - 2000
9.5	1200 - 1700
4.75	1200 - 1700

RAP and RAS Aggregates

- For RAS burn around 500 gram samples
- The default furnace calibration factor for RAP and RAS is 0.5%
- Average all the test results to determine the final gradation and AC content to be used in the design

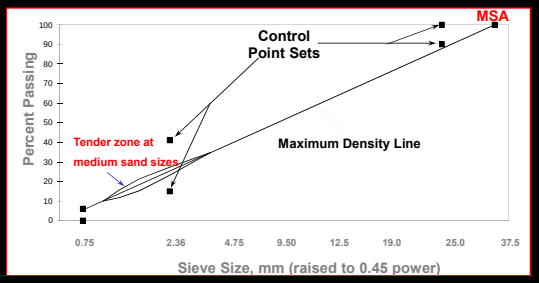
Table 610-1 Superpave Aggregate Gradation Design Criteria

	Mix Type (Nominal Maximum Aggregate Size)							
	9.5 mm[A]		12.5 mm[A]		19.0 mm		25.0 mm	
	Min	Max	Min	Max	Min	Max	Min	Max
50.0								
37.5							100	
25.0					100		90.0	100
19.0			100		90.0	100		90.0
12.5	100		90.0	100				
9.50	90.0	100		90.0				
4.75		90						
2.36	32.0[B]	67.0[B]	28.0	58.0	23.0	49.0	19.0	45.0
1.18								
0.075	4.0	8.0	4.0	8.0	3.0	8.0	3.0	7.0

Table 610-2 Superpave Aggregate Gradation Design Criteria - Notes

- For type S4.75A, a minimum of 50% of the aggregate components shall be material manufactured from the crushing of stone
- For Type SF 9.5A the percent passing the 2.36 sieve shall be a minimum of 60% and a maximum of 70%
- For the final surface layer of the specified mix type, use a design with an aggregate blend gradation above the maximum density line on the 2.36 mm and larger sieves

0.45 Power Grading Chart



I 19.0C Sample Blend

- For a 19 mm intermediate mix, “C” traffic level, we will use some #57, #78m, dry screenings, natural sand, and bag-house fines
- Use PG 64 -22 Binder
- What percent of each aggregate should we use in the mix?

Sample Gradations

#57	#78m	D. Scrng	N.Sand	BHF	Blend	Control
P1?	P2?	P3?	P4?	Pn?	100	Points
100.0	100.0	100.0	100.0	100.0		100
97.0	100.0	100.0	100.0	100.0		90 - 100
46.0	100.0	100.0	100.0	100.0		< 90
20.0	92.0	100.0	100.0	100.0		
4.0	28.0	97.0	95.0	100.0		
3.0	5.0	83.0	90.0	100.0		23 - 49
2.0	3.4	65.0	65.0	100.0		
1.5	3.0	45.0	42.0	100.0		
1.0	1.9	30.0	14.0	100.0		
0.8	1.0	18.0	7.0	96.0		
0.7	0.7	12.0	4.0	94.0		3-8
2.630	2.620	2.626	2.612	2.660		
2.665	2.660	2.655	2.631	2.660		

Blend Calculations

- After you choose the percentage of each aggregate in the mix, then calculate the amount that each aggregate contributes to the blend on each sieve
- Blend percentages for Aggregate #1

= P1 x Percent Passing Each Sieve ÷ 100

where, P1 is the percentage of aggregate number one in the mix

Blend Calculations

- So, start by calculating the percent of material contributed by Aggregate #1 to each of the sieves
- Repeat the calculations for all the other aggregates including RAP agg., RAS agg., and don't forget the BHF
- Add the percentages from all aggregate sources for each of the sieves to find the cumulative blend percentages passing each sieve

Specific Gravity Calculations for the Blend

Bulk (or Apparent) Aggregate Specific Gravity for the Blend:

Gsb or Gsa =

(P1 ÷ 100 x G1) + (P2 ÷ 100 x G2) + ….. + (Pn ÷ 100 x Gn)

- P1, P2, … Pn are the percentages of each aggregate in the mix for aggregates number one, number two, etc. until the last aggregate (n) in the mix
- G1 is the specific gravity of aggregate number one, number two, etc. until the last aggregate in the mix (n)
  - Substitute using either G_{sa} or G_{sb} for the G values

Specific Gravity Calculations

- Specific Gravity tests for G_{sb} and G_{sa} should be run for each aggregate to insure that the volumetric calculations are accurate
  - AASHTO T84 - Fine Specific Gravity
    - Immersion method
  - AASHTO T85 - Coarse Specific Gravity
    - SSD method
  - AASHTO T100 - Baghouse Fines
    - Soil specific gravity boil test
  - See the Supplemental Hand-out Book for specific gravity test procedures

Data for Individual Aggregate Gradations and Specific Gravities

Material	#57	#78m	Dry Scrngs	N.Sand	Baghouse
Percent	P1?	P2?	P3?	P4?	Pn?
25.0mm	100.0	100.0	100.0	100.0	100.0
19.0mm	97.0	100.0	100.0	100.0	100.0
12.5mm	46.0	100.0	100.0	100.0	100.0
9.5mm	20.0	92.0	100.0	100.0	100.0
4.75m	4.0	28.0	97.0	95.0	100.0
2.36mm	3.0	5.0	83.0	90.0	100.0
1.18mm	2.0	3.0	65.0	65.0	100.0
0.600mm	2.0	3.0	45.0	42.0	100.0
0.300mm	1.0	2.0	30.0	14.0	100.0
0.150mm	1.0	1.0	18.0	7.0	96.0
0.075mm	0.7	0.7	12.0	4.0	94.0
Gsb	2.630	2.620	2.626	2.612	2.660
Gsa	2.665	2.660	2.655	2.631	2.660

Example

For the I 19.0C mix, try the following amounts of each aggregate:

- 20% of #57 stone
- 40% of #78m stone
- 30% of Dry Screenings
- 9% of Natural Sand
- 1% of Baghouse Fines

Individual Aggregate Gradations and Specific Gravities

Material	#57	#78m	Dry Scrngs	N.Sand	Baghouse
Percent	20	40	30	9	1
25.0mm	100.0	100.0	100.0	100.0	100.0
19.0mm	97.0	100.0	100.0	100.0	100.0
12.5mm	46.0	100.0	100.0	100.0	100.0
9.5mm	20.0	92.0	100.0	100.0	100.0
4.75m	4.0	28.0	97.0	95.0	100.0
2.36mm	3.0	5.0	83.0	90.0	100.0
1.18mm	2.0	3.0	65.0	65.0	100.0
0.600mm	2.0	3.0	45.0	42.0	100.0
0.300mm	1.0	2.0	30.0	14.0	100.0
0.150mm	1.0	1.0	18.0	7.0	96.0
0.075mm	0.7	0.7	12.0	4.0	94.0
Gsb	2.630	2.620	2.626	2.612	2.660
Gsa	2.665	2.660	2.655	2.631	2.660

Blend Percentage for the 1.18 mm sieve

Mix % — % Passing the 1.18 sieve

#57	(20 x 2.0) ÷ 100 =	0.40
#78m	(40 x 3.0) ÷ 100 =	1.20
D.Scrngs	(30 x 65) ÷ 100 =	19.50
N. Sand	(9 x 65) ÷ 100 =	5.85
BHF	(1 x 100) ÷ 100 =	1.00
		27.95

Cumulative blend total for the 1.18 sieve = 28%

Repeat for all the other sieves! Round to the nearest 1% except round to the nearest 0.1% for the 0.075 sieve

Example continued

- For Cumulative Blend Gsb:

Blend Gsb = (20 ÷ 100 x 2.630) + (40 ÷ 100 x 2.620) + (30 ÷ 100 x 2.626) + (9 ÷ 100 x 2.612) + (1 ÷ 100 x 2.660)

Blend Gsb = 0.526 + 1.048 + 0.788 + 0.235 + 0.027

Blend Gsb = 2.624

- For Cumulative Blend Gsa:

Blend Gsa = (20 ÷ 100 x 2.665) + (40 ÷ 100 x 2.660) + (30 ÷ 100 x 2.655) + (9 ÷ 100 x 2.631) + (1 ÷ 100 x 2.660)

Blend Gsa = 0.533 + 1.064 + 0.797 + 0.237 + 0.027

Blend Gsa = 2.658

Blend Gradation Example
Work Problem #2

- Find an acceptable blend for an S 9.5B mix using #78m, dry screenings, washed screenings, natural sand, and bag-house fines
- Combine at percentages so that the blend falls within the Control Points.
- Calculate the Cumulative Aggregate Blend Gravities G_{sb} and G_{sa}
- Plot the blend on the 0.45 power chart

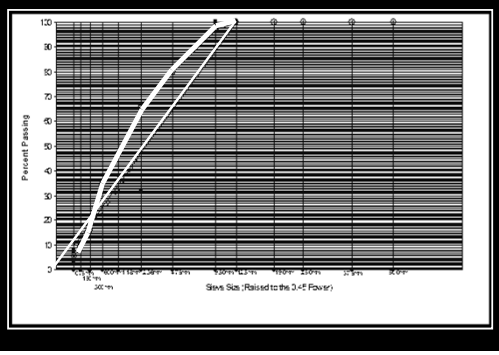
Work Problem #2
Individual Source Gradations & Gravities

Material	#78M	W Scrg	D Scrg	N Sand	BHF	Blend	Control
Percent							Points
25 mm	100	100	100	100	100		
19 mm	100	100	100	100	100		
12.5 mm	100	100	100	100	100		100
9.5 mm	91	100	100	100	100		90 - 100
4.75 mm	28	99	100	100	100		< 90
2.36 mm	4	88	86	100	100		32 - 67
1.18 mm	1	54	58	98	100		
0.60 mm	1	36	42	73	100		
0.30 mm	1	13	26	34	100		
0.15 mm	1	8	16	12	98		
0.075mm	0.5	4.0	11	6.9	94.5		4 - 8
Gsb	2.740	2.700	2.678	2.565	2.800		
Gsa	2.781	2.799	2.786	2.620	2.800		

Work Problem #2 Suggested Percent MD…
28% of #78M, 32% washed screenings, 24% dry screenings, 15% natural sand, and 1% BHF

Material	#78M	W Scrg	D Scrg	N Sand	BHF	Blend	Control
Percent	28	32	24	15	1	100	Points
25 mm	100	100	100	100	100		
19 mm	100	100	100	100	100		
12.5 mm	100	100	100	100	100	100	100
9.5 mm	91	100	100	100	100	97	90 - 100
4.75 mm	28	99	100	100	100	80	< 90
2.36 mm	4	88	86	100	100	66	32 - 67
1.18 mm	1	54	58	98	100	47	
0.60 mm	1	36	42	73	100	34	
0.30 mm	1	13	26	34	100	17	
0.15 mm	1	8	16	12	98	9	
0.075mm	0.5	4.0	11	6.9	94.5	6.0	4 - 8
Gsb	2.740	2.700	2.678	2.565	2.800	2.687	
Gsa	2.781	2.799	2.786	2.620	2.800	2.764	

0.45 Gradation Chart for Example



Trial Blends

Trial Blends…

- If needed, repeat the procedures from the work problem for three trial blends, one fine, one coarse, and one in between
- Calculate the percent trial binder content using the procedure in the *Asphalt Institute's Superpave Mix Design SP-2* or get it from the *NCDOT 858 program trial blend sheet*
- Check all the volumetric properties, pick a design binder content, and batch out a four increment design using your design aggregate structure

Batching of Aggregates

- The finished compacted asphalt pill heights should be 115 ± 5 mm (between 110 and 120 mm)
- Generally, 4500 to 4700 grams of aggregate is sufficient for aggregates with combined bulk specific gravities of 2.55 to 2.70, respectively

Batching of Aggregates

- If you started with 4600 grams of aggregate and your pill height was too high, say 120.1 instead of 115.0 mm, then adjust the total weight of the aggregate sample and remake the pill
- Use 115.0 ÷ 120.1 x 4600 = 4404.7 grams of aggregate instead
- For our example, use a 4600 gram aggregate sample….

Material	#57	#78m	Dry Scrngs	N.Sand	Fines	Blend	Control
Percent	29	41	15	14	1	100	Points
25.0mm	100.0	100.0	100.0	100.0	100.0	100.0	100
19.0mm	97.0	100.0	100.0	100.0	100.0	99.0	90 - 100
12.5mm	46.0	100.0	100.0	100.0	100.0	84.0	< 90
9.5mm	20.0	92.0	100.0	100.0	100.0	74.0	
4.75mm	4.0	28.0	97.0	95.0	100.0	42.0	
2.36mm	3.0	5.0	83.0	90.0	100.0	29.0	23 - 49
1.18mm	2.0	3.0	65.0	65.0	100.0	22.0	
0.600mm	2.0	3.0	45.0	42.0	100.0	15.0	
0.300mm	1.0	2.0	30.0	14.0	100.0	9.0	
0.150mm	1.0	1.0	18.0	7.0	96.0	5.0	
0.075mm	0.7	0.7	12.0	4.0	94.0	3.8	2 - 8
Gsb	2.630	2.620	2.626	2.612	2.660	2.623	
Gsa	2.665	2.660	2.655	2.631	2.660	2.657	

For this example, we only need to look at these two columns to find the stone factors...

Material	#57	#78m	Dry Scrngs	N.Sand	Fines	Blend	Control
Percent	29	41	15	14	1	100	Points
25.0mm	100.0	100.0	100.0	100.0	100.0	100.0	100
19.0mm	97.0	100.0	100.0	100.0	100.0	99.0	90 - 100
12.5mm	46.0	100.0	100.0	100.0	100.0	84.0	< 90
9.5mm	20.0	92.0	100.0	100.0	100.0	74.0	
4.75mm	4.0	28.0	97.0	95.0	100.0	42.0	
2.36mm	3.0	5.0	83.0	90.0	100.0	29.0	23 - 49
1.18mm	2.0	3.0	65.0	65.0	100.0	22.0	
0.600mm	2.0	3.0	45.0	42.0	100.0	15.0	
0.300mm	1.0	2.0	30.0	14.0	100.0	9.0	
0.150mm	1.0	1.0	18.0	7.0	96.0	5.0	
0.075mm	0.7	0.7	12.0	4.0	94.0	3.8	2 - 8
Gsb	2.630	2.620	2.626	2.612	2.660	2.623	
Gsa	2.665	2.660	2.655	2.631	2.660	2.657	

…these 3 fine aggregates do not use stone factors

Calculating Stone Factors

- You only need stone factors for the coarse aggregate fraction, which are the particles retained on the 2.36 mm (no. 8) sieve and above
- Sand and screenings are scooped in by weight
- Calculate the *percent retained* on each sieve starting with the first to retain material
- Multiply by the %aggregate in the mix

Calculating Stone Factors

- *In this example*, add up the stone factors for the coarse aggregates to get the combined stone factor since *the coarse aggregates are from the same source*
- For the minus #8 material, simply multiply the %passing by the %aggregate
- For this mix, we will start with the 19.0 mm sieve…..

Calculating Stone Factors

Material	#57	#78m
Percent	29	41
25 mm	100	100
19 mm	97	100
12.5 mm	46	100
9.5 mm	20	92
4.75 mm	4	28
2.36 mm	3	5
1.18 mm	2	3
0.600 mm	2	3
0.300 mm	1	2
0.150 mm	1	1
0.750 mm	0.7	0.7
Gsb	2.630	2.620
Gsa	2.665	2.660

Begin here

Calculating Stone Factors for 19.0 and 12.5 mm Sieves

Material	#57	#78m
Percent	29%	41%
25.0mm	100.0	100.0
19.0mm	97.0	100.0
12.5mm	46.0	100.0
9.5mm	20.0	92.0
4.75mm	4.0	28.0
2.36mm	3.0	5.0

- For the 19.0 mm sieve:
  - For #57: 100 - 97 = 3 3 x 29% = 0.87
- For the 12.5 mm sieve:
  - For #57: 97 - 46 = 51 51 x 29% = 14.79

Calculating Stone Factors for 9.5 mm Sieve

Material	#57	#78m
Percent	29%	41%
25.0mm	100.0	100.0
19.0mm	97.0	100.0
12.5mm	46.0	100.0
9.5mm	20.0	92.0
4.75mm	4.0	28.0
2.36mm	3.0	5.0

- For the 9.5 mm sieve:
  - For #57: 46 - 20 = 26 26 x 29% = 7.54
  - For #78m: 100 - 92 = 8 8 x 41% = 3.28
  - Stone factor for 9.5 mm = 10.82

Calculating Stone Factors for 4.75 mm Sieve

Material	#57	#78m
Percent	29%	41%
25.0mm	100.0	100.0
19.0mm	97.0	100.0
12.5mm	46.0	100.0
9.5mm	20.0	92.0
4.75mm	4.0	28.0
2.36mm	3.0	5.0

- For the 4.75 mm sieve:
  - For #57: 20 - 4 = 16 16 x 29% = 4.64
  - For #78m: 92 - 28 = 64 64 x 41% = 26.24
  - Stone factor for 4.75 mm = 30.88

Calculating Stone Factors for 2.36 mm Sieve

Material	#57	#78m
Percent	29%	41%
25.0mm	100.0	100.0
19.0mm	97.0	100.0
12.5mm	46.0	100.0
9.5mm	20.0	92.0
4.75mm	4.0	28.0
2.36mm	3.0	5.0

- For the 2.36 mm sieve:
  - For #57: 4 - 3 = 1 1 x 29% = 0.29
  - For #78m: 28 - 5 = 23 23 x 41% = 9.43
  - Stone factor for 2.36 mm = 9.72

Calculating Stone Factors for - 2.36 mm

Material	#57	#78m
Percent	29%	41%
25.0mm	100.0	100.0
19.0mm	97.0	100.0
12.5mm	46.0	100.0
9.5mm	20.0	92.0
4.75m	4.0	28.0
2.36mm	3.0	5.0
1.18mm	2.0	3.0
0.600mm	2.0	3.0

For the - 2.36 mm (minus No.8) material, simply multiply the % passing by the blend % in the mix.

For #57: 3 x 29% = 0.87

For #78: 5 x 41% = 2.05

Stone Factor - 2.36 = 2.92

Calculating Stone Factors

- Total Stone factors for each sieve:

Sieve Size	Stone Factors
19.0	0.87
12.5	14.79
9.5	10.82
4.75	30.88
2.36	9.72
-2.36	2.92

Note: the sum of the stone factors = 70

Calculating Stone Factors

For a 4600 gram total aggregate sample the….

Weight for each sieve size = 4600 x stone factor ÷ 100

Sieve Size	Stone Factors, %	Weight, g
19.0	0.87	40.0
12.5	14.79	680.3
9.5	10.82	497.7
4.75	30.88	1420.5
2.36	9.72	447.1
-2.36	2.92	134.3
	Sum =	3219.9

Quick check: 3219.9 ÷ 4600 = 70%, which is correct since we have 70% coarse aggregate (29% of #57 + 41% of #78m) in the design blend….

Work Problem #3

Material	#467	#57
Percent	20%	25%
37.5	100.0	100.0
25	100.0	100.0
19	80.0	92.0
12.5	38.0	38.0
9.5	14.0	17.0
4.75	7.0	3.0
2.36	2.0	1.0
1.18	1.0	1.0
0.6	1.0	1.0
0.3	1.0	1.0
0.15	1.0	1.0
0.075	0.9	1.0

- Calculate the Stone Factors and the individual weights for a 4700 gram total aggregate weight sample
- Note: these #467 & #57 aggregates are from the same quarry source

Work Problem #3 Answer

Sieve Size	Stone Factor	Weight (gm)
37.5	0	0
25.0	0	0
19.0	6	282
12.5	21.90	1029.3
9.5	10.05	472.4
4.75	4.90	230.3
2.36	1.50	70.5
- 2.36	0.65	30.6
Totals	45.00	2115.1

Batch Weights

- The total aggregate batch weight is entered into the AMD Program on the "batch 1" sheet along with the %AC at the second design increment to obtain your batch weights for the pills in your design

Batch Weights

- If you begin with a final asphalt mix batch weight
  - Say 5000 grams of asphalt mix containing 5.7% total AC content
- Then you should calculate the aggregate batch weight to enter

5000 x (1 – 5.7/100)
5000 x (1 – 0.057)
5000 x (0.943) = 4715.0 grams

Binder Selection

Binder Selection

- In North Carolina, we typically use three types of binder:
  - PG 64 -22 is most common
  - PG 70 -22 and PG 76 -22 are used less often and in special mix types
- PG 64 -22 has a 98% reliability factor for use in North Carolina
- PG 70 -22 and 76 -22 are used mostly for interstates and other high traffic areas.

Binder Selection

- The choice of PG grade is based on the environment, traffic, and a desired reliability factor
- Environmental factors are the high and low pavement temperatures for a particular geographic area
- These values can be found in the FHWA Long Term Pavement Performance (*LTPP*) Software Program

Binder Specifications

- See Sections 620 and 1020-2 of the Standard Specifications for the binder specs
- The binders are performance graded according to AASHTO M320 Table 1 specifications
- Asphalt cement is tested by the supplier

Binder Specifications

- Air blown asphalt will not be permitted
- PMA is polymer modified asphalt
- Polymer modifications will be performed by using a SBS, SBR, or SB additive for 70 -22 or 76 -22 PG grades
  - S is for styrene
  - B is for butadiene
  - R is for rubber
- Increasing the percent of styrene polymer should increase the high temperature stiffness and the stress/strain recovery of the mix

Mixing and Compaction Temperatures for Superpave PG 64 -22, 70 -22 & 76 -22

- *Mixing Temp.* - the temperature to which asphalt must be heated to produce a viscosity of 0.150 to 0.190 Pa-s
- *Compaction Temp.* - the temperature to which asphalt must be heated to produce a viscosity of 0.250 to 0.310 Pa-s
- The supplier will provide this information and the recommended temperatures for PG 76 -22
  - Mixing temperatures are higher than compaction temperatures

Binder Content
Initial AC Content

Get initial asphalt binder contents from:

- Past experience with the mix materials
- HMA/QMS Manual Section 3.6 - *Typical Asphalt Binder Contents*
- NCDOT mix design program blend sheet tab (for trial blends) – type in the NMSA at the top of the page and the program calculates Pbi
- A. I. Superpave Mix Design (SP-2) section on *Select Design Aggregate Structure*

Typical Binder Contents
HMA/QMS Section 3.5

PG 64 -22 Asphalt

SA-1	6.8%
S 4.75A	7.0%
SF 9.5A	6.7%
S 9.5 B	6.0%
I 19B, I 19C	4.8%
B 25B, B 25C	4.5%

Percent by total weight of the mix

Typical Binder Contents
HMA/QMS Section 3.6

PG 64 -22 Asphalt

OGFC FC-1	6.1%
PADC P-57	2.5%
PADC P-78M	3.0%

Percent by total weight of the mix

Typical Binder Contents
HMA/QMS Section 3.6

PG 70 -22 Asphalt

S 9.5C	5.9%
S 12.5C	5.6%
I 19.0D	4.5%

Percent by total weight of the mix

Typical Binder Contents
HMA/QMS Section 3.6

PG 76 -22 Asphalt

S 9.5D	5.7%
S 12.5D	5.2%
OGFC FC-1 Mod	6.1%
OGFC FC-2 Mod	6.1%

Percent by total weight of the mix

Mixing of Aggregates

- Binder shall be placed in an oven at the mixing temperature specified by the supplier
- Prior to heating the binder for mixing, anti-strip shall be added to the binder at a rate of not less than 0.25% by weight of the binder
- Combine the binder and aggregates together and mix them thoroughly

For Trial Blends...

- At least two pills shall be made for each trial blend
- Gyrate the pills to N_{des} in an approved gyratory compactor
- Check the volumetric properties
- Use calculations from *AI SP-2 Superpave Mix Design Manual* along with cost considerations to determine the best trial for your design

Four Increment Design...

- After the best trial aggregate gradation blend is chosen, estimate the binder content needed to achieve the design air void content
- Then proceed with a four increment design

Four Increment Design...

- One increment is at the estimated design binder content (the second increment)
- The others are at - 0.5%, + 0.5%, and + 1% asphalt binder contents from the estimated design binder content

Four Increment Design…

- Weigh up the batch specimens:
  - Eight for gyratory pills
  - Two for the Rice tests made at the estimated design binder content (at the second increment), the test results will be averaged
    - *Note: a rice sample should weigh 1500 to 1700 grams for a surface mix, or 2500 to 2700 grams for an intermediate or base mix.*
    - *Note: the final rice value is the average of the two rice test results*
  - Some aggregate should be weighed up, blended and used for the Aggregate Consensus Property tests (no asphalt cement added)

Four Increment Design…

- Rice samples shall weigh no more than 200 grams above these minimum recommended sample weights

NMSA (mm)	Min. Rice Weight (g)
25	2500
19	2500
12.5	1500
9.5	1500
4.75	1500

Four Increment Design…

- Corelok vacuum device samples shall weigh no more than 200 grams above these minimum recommended sample weight

NMSA (mm)	Minimum Gmm Weight (g)
25	2000
19	2000
12.5	1500
9.5	1500
4.75	1500

Four Increment Design...

- Prior to compaction, the mix shall be placed in the oven for *2 hours* at the compaction temperature
  - *Age the asphalt for 4 hours if the aggregate has more than 2% water absorption
- Rice samples from the second increment are cured, removed from the oven, and allowed to cool
  - the maximum specific gravity (G_{mm}) test is run by either AASHTO T209 Rice or ASTM D6857 Corelok

Four Increment Design...

- Gyrate the pills from the various binder contents to N_{des} in an approved gyratory compactor
- The Bulk Specific Gravity (G_{mb}) of the pills can be run by AASHTO T166 after the pills are cooled to room temperature
- Then calculate the volumetric properties using the G_{mb} and G_{mm} test results

Volumetrics

- Looking at the 601(SP) Mix Design Form, calculate all the necessary variables for each increment:
- Maximum Specific Gravity (G_{mm})
- % Voids - Total Mix (VTM)
- % Solids - Total Mix
- % Effective Binder Content (P_{be})
- P_b Absorption (or P_{ba})

Volumetrics

- Dust to P_{be} Ratio ($P_{0.075}/P_{be}$)
- By Volume Effective P_b
- % Solids by Vol. of Agg. Only
- % Voids in Mineral Agg. (VMA)
- % Voids Filled w/Binder (VFA)
- % G_{mm} @ N_{ini} and % G_{mm} @ N_{des}

Back-Calculating Maximum Specific Gravity, G_{mm}

$$G_{mm} = \frac{100}{\frac{100 - P_b}{G_{se}} + \frac{P_b}{G_b}}$$

For each increment (G_{se} and G_b are constant; only P_b varies)

G_{se} = effective gravity of the aggregate blend

G_b = specific gravity of the binder

P_b = percent asphalt of the increment

*Remember only the asphalt content is changing. The aggregate stays the same

% Voids Total Mix, VTM

$$VTM = ((G_{mm} - G_{mb}) \div G_{mm}) \times 100$$

Where for each increment:

G_{mm} = maximum specific gravity of the mix (from the previous calculation)

G_{mb} = bulk specific gravity of the mix (average of 2 or more pills)

% Solids Total Mix

% Solids Total Mix = $(G_{mb} \div G_{mm}) \times 100$

Where for each increment:

- G_{mm} = maximum specific gravity of the mix (from the previous calculation)
- G_{mb} = bulk specific gravity of the mix (average of 2 or more pills)

Or, % Solids Total Mix = 100 - VTM

Effective Specific Gravity of Aggregate Blend, G_{se}

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

Where, at the second increment, at the estimated design AC content:

- P_b = percent binder
- G_{mm} = maximum specific gravity of mix from the rice test
- G_b = specific gravity of the binder

Estimated Effective Specific Gravity of Aggregate Blend, Est. G_{se}

For absorptive aggregates….

Est. G_{se} = $G_{sb} + (0.5 \text{ or } 0.6 \times (G_{sa} - G_{sb}))$

or, for normal weight aggregates….

Est. G_{se} = $G_{sb} + (0.8 \times (G_{sa} - G_{sb}))$

Where, G_{sb} = bulk dry specific gravity of the aggregate blend

G_{sa} = apparent specific gravity of the aggregate blend

Rules for Aggregate Specific Gravities

As a rule: $G_{sb} < G_{se} < G_{sa}$

If Gse is <u>not</u> between Gsb and Gsa then:

Recheck the aggregate gravities and the maximum gravity test procedures and calculations for errors

Rules for Aggregate Specific Gravities

As a rule: Gse does not change when the aggregate blend is the same and the asphalt content changes

Or in other words, asphalt absorption does not change when binder content changes and the aggregates stay the same

Asphalt Absorption, P_{ba}

$$P_{ba} = 100 \times \left(\frac{G_{se} - G_{sb}}{G_{se} \times G_{sb}} \right) \times G_b$$

Where:

G_{se} = effective specific gravity (of the aggregate blend)

G_{sb} = bulk specific gravity (of the aggregate blend)

G_b = specific gravity of the binder

Asphalt Absorption, P_{ba}

As a Rule: aggregate absorbs less asphalt than it does water

The water absorption (H_2O Abs) for an aggregate is measured during the aggregate specific gravity test(s)

Apply the following formula as a check:

$(0.5 \times H_2O \text{ Abs}) < P_{ba} < (0.8 \times H_2O \text{ Abs})$

% Effective Binder Content, P_{be}

$$P_{be} = P_b - [(P_{ba} \div 100) \times P_s]$$

Where for each increment:

P_b = percent binder (for the increment)

P_{ba} (is from the previous calculation)

$P_s = 100 - P_b$ (for the increment)

Dust to Binder Ratio, DP

- *Defined:* The Percent of Material Passing the #200 Sieve of the Aggregate Blend divided by the Effective Asphalt Cement Content
- Effective Binder Content is that Amount of binder on the Surface of the Aggregate.
  - *Therefore, using it in the Dust to Binder Ratio gives a truer indication of asphalt film thickness*
- Excessive fines (dust) can lower the quality of the asphalt film on the aggregate
  - Depending on the size of the dust particles, the mix may be stiffer or it may be more tender

Dust to P_{be} Ratio
$P_{0.075} / P_{be}$

$P_{0.075} / P_{be}$ Ratio = %passing #200 of blend ÷ P_{be}

Where:

- % passing #200 is from the aggregate blend
- % effective binder content, P_{be} of the increment (from the previous calculation)
- *Note: The NCDOT design specification range for Dust to P_{be} Ratio is 0.6 to 1.4 for all mixes*

By Volume of Effective P_b

By Volume of Effective P_b = (P_{be} x G_{mb}) ÷ G_b

Where for each increment:

P_{be} = % effective binder content

G_{mb} = bulk specific gravity of the mix

G_b = specific gravity of binder

% Solids By Vol. of Agg. Only

% Solids by Vol. of Agg. Only =

% Solids Total Mix - By Volume Effective P_b

Where for each increment:

% Solids Total Mix and By Volume Effective P_b are from the previous calculations

% Voids in the Mineral Agg.
VMA

$$VMA = 100 - [(G_{mb} \times P_s) \div G_{sb}]$$

Where for each increment:

G_{mb} = bulk specific gravity of the mix

$P_s = 100 - P_b$

G_{sb} = bulk specific gravity of the total aggregate blend

% Voids Filled w/Binder
VFA

$$VFA = (VMA - VTM) \div VMA \times 100$$

Where for each increment,

VMA and VTM are from the previous calculations

Note: VFA is a percentage of VMA

GRADATION OF MATERIALS USED

MATERIAL	78m	W Scrngs	D Scrgs	Sand			BgHsFines		BLEND	CONTROL
PERCENT (MD)	28.0	24.0	32.0	15.0			1.0		100.0	POINTS
PERCENT (JMF)	28.0	25.0	32.0	15.0			0.0		100.0	
Sieves(mm) 50.0	100.0	100.0	100.0	100.0			100.0		100	
37.5	100.0	100.0	100.0	100.0			100.0		100	
25.0	100.0	100.0	100.0	100.0			100.0		100	
19.0	100.0	100.0	100.0	100.0			100.0		100	
12.5	100.0	100.0	100.0	100.0			100.0		100	
9.5	91.0	100.0	100.0	100.0			100.0		97	90-100
4.75	28.0	99.0	100.0	100.0			100.0		80	<90
2.36	4.0	88.0	86.0	100.0			100.0		66	32-67
1.18	1.0	54.0	58.0	98.0			100.0		47	
0.600	1.0	36.0	42.0	73.0			100.0		34	
0.300	1.0	13.0	26.0	34.0			100.0		17	
0.150	1.0	8.0	16.0	12.0			98.0		9	
0.075	0.5	4.0	11.0	6.9			94.5		6.0	4.0 - 8.0
Ign.Furn. Corr.Factor										
Agg. Bulk Dry S.G.	2.740	2.700	2.678	2.565			2.800		2.686	
							Agg. Effective S.G.:			
Agg. Apparent S.G.	2.781	2.799	2.786	2.620			2.800		2.764	

		Opt. Pb	Mix Properties at N design					
% Asphalt Binder-Total Mix			5.0	5.5	6.0	6.5		
Gmb @ Ndes (or Nmax)			2.375	2.400	2.421	2.434		
Max. Specific Gravity(Gmm)			2.512	2.493	2.475	2.457		
% Voids-Total Mix (VTM)								
% Solids-Total Mix								
% Effective Binder Content (Pbe)								
Dust to Pbe Ratio (P0.075/Pbe)								
By Volume of Effective Pb								
% Solids by Vol. of Agg. Only								
% Voids in Mineral Agg. (VMA)								
% Voids Filled w/Binder (VFA)								
% Gmm @ Nini	8							
% Gmm @ Ndes	100							
% Gmm @ Nmax	160							
COMMENTS:								
DESIGNED BY:								
APPROVAL:								

% RAP / % Virgin:	0/100
Pb in RAP:	
Pb from RAP:	0.0
Pb Absorption:	
% ASH:	
TSR % Retained :	
Ignition Furn. Calibr.:	
Pb (Design):	
Rice Specific Gravity:	
Lab Specific Gravity:	
Percent Air Voids:	
Percent VMA:	
Percent VFA:	
DUSTAC Ratio:	
% Gmm @ Nini	
% Gmm @ Nmax:	
Pb ADDED:	
Pb from RAP:	
Pb TOTAL:	

Sand Equivalent:	80.6	
C. Agg. Angularity:	100/100	
F. Agg. Angularity:	46.3	
Flat & Elongated:	3.7	

Work Problem #4

Calculate Pba and the missing values from the column at 5.5% AC

Use 1.03

for the AC specific gravity

Note: Gsb = 2.686

Gse = 2.718

Mix Properties at N Design

Gsb = 2.686
Gse = 2.718

%AC - Total mix	5.0	5.5	6.0	6.5		%RAP/%virgin	0/100
Gmb @ N_{des}	2.375	2.400	2.421	2.434		Pb in RAP:	
Gmm	2.512	2.493	2.475	2.457		Pb from RAP	0.0
VTM						Pb Abs	
%solids total mix							
P_{be}							
$P_{0.075}/P_{be}$							
By volume of Effective P_b							
%solids by volume agg. only							
VMA							
VFA							

Calculate the missing values in the shaded areas

Mix Properties at N Design

%AC - Total mix	5.0	5.5	6.0	6.5		%RAP/%virgin	0/100
Gmb @ N_{des}	2.375	2.400	2.421	2.434		Pb in RAP:	
Gmm	2.512	2.493	2.475	2.457		Pb from RAP	0.0
VTM		3.7				Pb Abs	0.5
%solids total mix		96.3					
P_{be}		5.0					
$P_{0.075}/P_{be}$		1.2					
By volume of Effective P_b		11.7					
%solids by volume agg. only		84.6					
VMA		15.6					
VFA		76.3					

N initial, $\%G_{mm}$ @ N_{ini}

- N initial is a function of how well the mix will compact and it is measured as a percent of the maximum specific gravity, G_{mm}
- If a mix has a N_{ini} which is too high, then the mix may compact too easily and be unstable in the field
  - Causes can be too much sand or a gradation designed that passes through the tender zone.
- If a mix has a N_{ini} which is too low, then the mix may be harsh (contain too much coarse aggregate)
- N_{ini} is listed in the Superpave Mix Design Criteria Table 610-3

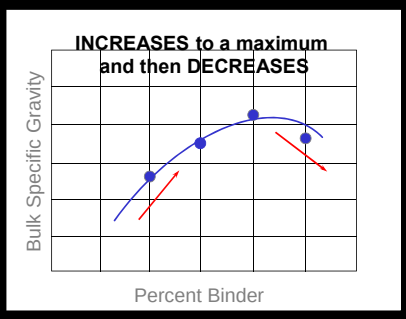
N maximum
N_{max}

- Beginning in 2006, compacting pills to N_{max} (at the optimum binder content) was no longer required
- However, you should still compact pills to N_{des} (at the optimum binder content) and enter the data on the mix design form 603A

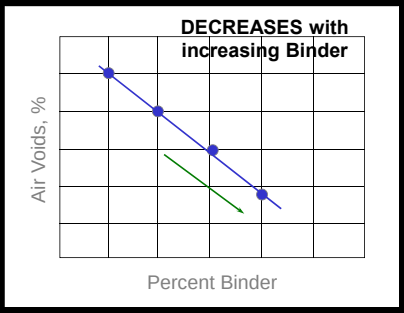
Selection of Optimum Binder

- After the four increment design is completed and all mix gravities (bulk and rice) are measured and the volumetric data is calculated, then the points can be plotted and the curves drawn on the graphs
- There are 5 graphs:
  - Bulk Specific Gravity
  - Voids
  - $N_{initial}$ and Compaction curve
  - VFA and VMA

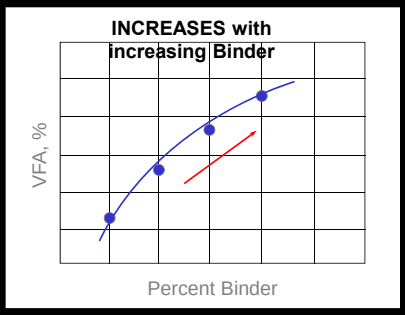
Bulk Specific Gravity



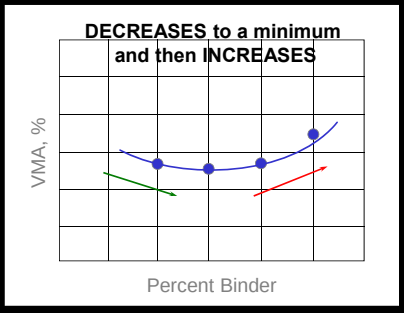
Air Voids



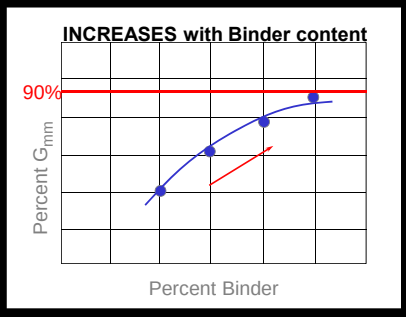
Percent VFA



Percent VMA



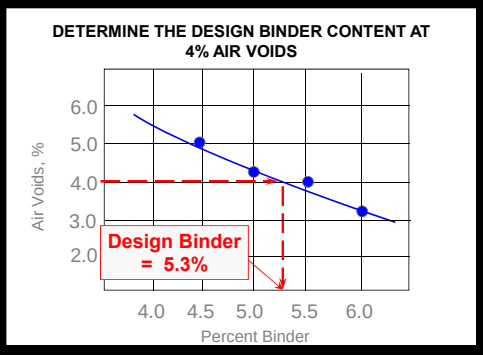
Percent G_{mm} @ N initial



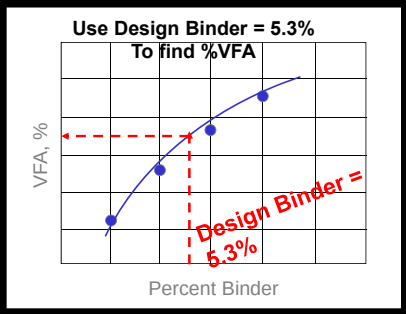
Optimum Binder

- After the percent binder content is determined for the designed 4% air voids, all the other mix design parameters must be checked to see that they meet the specification requirements for that mix type at that Design Binder Content
  - Design air voids is 11% for Type SA-1
  - Design air voids is 5% for Type S 4.75A

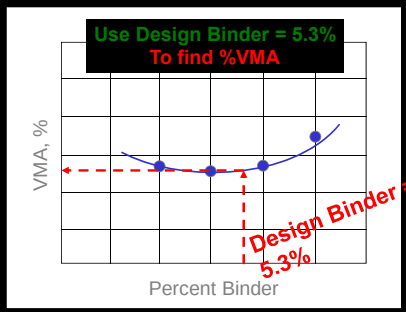
Optimum Binder



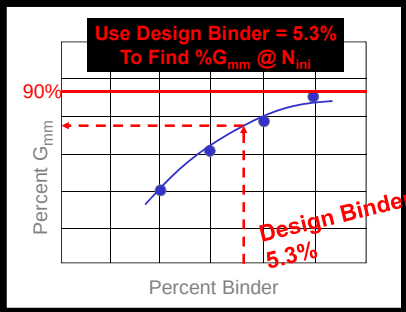
Percent VFA



Percent VMA



Percent G_{mm} @ N initial



Interpolate Rice Specific Gravity

% Asphalt-Total Mix	4.0	4.5	5.0	5.5
Lab Bulk Specific Gravity	2.356	2.358	2.387	2.404
Max. Specific Gravity (Rice)	2.530	2.511	2.492	2.474
% Voids-Total Mix (VTM)	6.9	6.1	4.2	2.8
% Solids-Total Mix	93.1	93.9	95.8	97.2
% Effective AC Content	3.7	4.2	4.7	5.2
Dust to AC Ratio	1.24	1.09	0.98	0.88
% By Volume of Effective AC	8.5	9.7	11.0	12.2
% Solids by Vol. of Agg. Only	84.6	84.2	84.8	85.0
% Voids in Mineral Agg. (VMA)	15.4	15.8	15.2	15.0
% Voids w/AC (VFA)	55.4	61.4	72.2	81.3
% Gmm @ N initial 7	88.4	89.1	90.9	92.1
% Gmm @ N design 75	93.1	93.9	95.8	97.2

Note: G_{se} = 2.693

Calculating Rice Specific Gravity

%AC Total mix	5.0	5.3	5.5
Lab G_{mb}	2.387		2.404
Rice G_{mm}	2.492	?	2.474

Must interpolate between the 2 increments, at the AC content of 5.3%, to get the proper rice gravity

Calculating Rice Specific Gravity

To interpolate: 2.492 - 2.474 = 0.018

Divide 0.018 by 0.5 (the difference between the increments)

0.018 ÷ 0.5 = 0.036

Multiply by 0.3, where 5.3 - 5.0 = 0.3

0.036 x 0.3 = 0.0108 = 0.011

Subtract from the higher Rice at 5.0% AC (2.492)

2.492 - 0.011 = **2.481**

This is the Rice gravity for the optimum AC at 5.3%

Or, Back-Calculate the Rice Specific Gravity

(As you would for your mix design increments)

- Given design AC = 5.3% and G_{se} = 2.693

$$G_{mm} = \frac{100}{\frac{100 - 5.3}{2.693} + \frac{5.3}{1.03}}$$

G_{mm} = 2.481✓

Calculating the Lab Specific Gravity

Using the calculated Rice gravity, we calculate the new Lab gravity (G_{mb})….

2.481 x 0.96 = 2.382

Designed at 4% VTM

Where, 1 - 0.04 = 0.96

Calculating the Lab Specific Gravity for a 4.75 mm Mix

Using the calculated Rice gravity, we calculate the new Lab gravity (G_{mb})….

2.481 x 0.95 = 2.357

Designed at 5% VTM

Where, 1 - 0.05 = 0.95

Reclaimed Asphalt Pavement
Material Specifications

RAP Specs
Section 1012-1(F)

Reclaimed Asphalt Pavement
RAP Specifications

- RAP will be classified as Mix Design RAP or Mix Production RAP
- Mix Design RAP shall be tested for uniform gradation and binder content before it is used in a mix design

Reclaimed Asphalt Pavement
Mix Design RAP Specifications

- Millings
  - Removed from the original location by a milling process and has a uniform gradation and binder content
  - All materials will pass a 2” sieve before introduction into the plant mixer unit
- Processed RAP
  - Crushed or blended to produce a uniform gradation and binder content
  - All material will pass a 1” sieve before going into the plant mixer unit

Reclaimed Asphalt Pavement Mix Design RAP Specifications

- Fractionated RAP
  - It has two or more RAP stockpiles where the RAP is divided into coarse and fine fractions
  - Grade RAP so that all materials will pass a 1" sieve
  - The coarse pile shall only contain material retained on the 3/8" screen, unless otherwise approved
  - The fine pile shall only contain material passing the 3/8" screen, unless otherwise approved

Reclaimed Asphalt Pavement Mix Design RAP Specifications

- Fractionated RAP, (continued)
  - The Engineer may allow an alternate to the 3/8" screen to fractionate the RAP
  - The maximum percentages of fractionated RAP may be comprised of coarse, fine, or a combination of both
  - Use a separate cold feed bin for each stockpile of fractionated RAP introduced into the mix

Reclaimed Asphalt Pavement Mix Design RAP Specifications

- Approved Stockpiled RAP
  - It has been isolated and tested for asphalt content, gradation, and asphalt binder properties
  - It is intended for use in mixes with more than 30% RAP
  - It shall be fractionated (see description in previous slide)
  - Use a separate cold feed bin for each approved stockpile of RAP used

Reclaimed Asphalt Pavement Mix Design RAP Specifications

- Approved Stockpiled RAP (continued)
  - Perform extraction tests at a rate of 1 per 1000 tons of RAP, with at least 5 tests per stockpile to determine the asphalt content and gradation
  - Separate stockpiles of RAP by fine and coarse fractions
  - ID each pile with a sign and keep the piles clean
  - The gradation and binder contents shall be uniform and individual tests, when compared to the mix design, will be accepted if they are within the required tolerances (see next slide)

Table 1012-3 Approved Stockpiled RAP Gradation and Binder Tolerances (Apply to Mix Design)

Pb%	± 0.3%
Sieve Size (mm)	Percent Passing
25.0	± 5%
19.0	± 5%
12.5	± 5%
9.5	± 5%
4.75	± 5%
2.36	± 4%
1.18	± 4%
0.300	± 4%
0.150	± 4%
0.075	± 1.5%

Reclaimed Asphalt Pavement Mix Design RAP Specifications

- Approved Stockpiled RAP Gradation and Binder Tolerances (apply to mix design)
  - If more than 20% of the individual sieves are out of tolerance, or if more than 20% of the asphalt binder content tests are out of tolerance, then the RAP shall not be used unless the RAP representing the failing tests is removed from the pile
  - Do not add material to any approved stockpile, unless approved by the Engineer
  - Maintain at the plant a record system for all approved stockpiles at the plant site

Composition of Recycled HMA

- Recycled asphalt pavement (RAP) may be 50% of the total material used in recycled mixes, except for S 12.5D and mixtures containing RAS
- Recycled asphalt shingles (RAS) may be used at a maximum of 6% of the total mix
- When both RAP and RAS are used do not use a combined percentage greater than 20% of the total mix, unless approved by the Engineer

Composition of Recycled HMA

- When the % binder contributed by RAS or a combination of RAS and RAP exceeds 20% but not more than 30% of the total binder in the completed mix, then the virgin PG grade must be one grade below the specified grade from Table 610-3, *unless otherwise approved

PG 64 -22 → PG 58 -28

PG 70 -22 → *PG 64 -22

Table 610-3 Superpave Mix Design Criteria

Mix Type	Binder PG Grade	Bumped Binder PG Grade
S4.75A	64 -22	58 -28
SF9.5A	64 -22	58 -28
S9.5B	64 -22	58 -28
S9.5C	70 -22	64 -22
S9.5D	76 -22	NA
S12.5C	70 -22	64 -22
S12.5D	76 -22	NA
I19.0B	64 -22	58 -28
I19.0C	64 -22	58 -28
I19.0D	70 -22	64 -22
B25.0B	64 -22	58 -28
B25.0C	64 -22	58 -28

Composition of Recycled HMA

- When the % binder contributed by RAS or a combination of RAS and RAP exceeds 30% of the total binder in the completed mix, then the Engineer will establish and approve the virgin binder PG grade based on additional mix evaluation testing like blending charts, dynamic modulus, etc.

Composition of Recycled HMA

Standard Specifications updated by PSP

- For type RS-12.5D and RS-9.5D mixes the maximum % of reclaimed asphalt material is limited to 20% and the mix must contain virgin PG 76 -22
- For all other recycled mix types, the virgin binder PG grade shall be as specified in Table 610-4 for the specified mix type

Table 610-4 Superpave Applicable Virgin Asphalt Grades

	Percentage of RAP in the mix		
	Category 1[A]	Category 2[B]	Category 3[C]
Mix Type	%RAP ≤ 20	21 ≤ %RAP ≤ 30	%RAP > 30
All A and B Level Mixes, I19.0C, B25.0C	PG 64 -22	PG 64 -22	Established by Engineer
S9.5C, S12.5C, I19.0D	PG 70 -22	PG 64 -22	Established by Engineer
S9.5D and S12.5D	PG 76 -22	-	-

Table 610-4 Notes on Superpave Applicable Virgin Asphalt Grades

A. Category 1 RAP has been processed to a maximum size of 2 inches

B. Category 2 RAP has been processed to a maximum size of 1 inch by either crushing or screening to reduce variability in the gradations

C. Category 3 RAP has been processed to a maximum size of 1 inch, fractionating the RAP into 2 or more sized stockpiles

Composition of Recycled HMA

- When the percent RAP is greater than 20% but not more than 30% of the total mixture, (or when the percent binder contributed by the RAP to the total mix is greater than 20% but not more than 30% of the total asphalt cement content in the mix), then use RAP meeting the requirements for processed or fractionated RAP

Composition of Recycled HMA

- When the percentage of RAP is greater than 30% of the total mixture, use an approved stockpile of RAP in accordance with Subarticle 1012-1(C)
- Use approved test methods to determine if any binder grade adjustments are necessary to achieve the performance grade for the specified mix type
- The Engineer will establish and approve the virgin asphalt binder grade to be used

Composition of Recycled HMA

- If a change in the source of RAP or RAS is made, a new mix design and JMF may be required in accordance with Article 1012-1

Composition of Recycled HMA

- Samples of the completed recycled mixture may be taken by the Department on a random basis to determine the PG grading on the recovered asphalt binder in accordance with AASHTO M320
- If the grading is determined to be a value other than required for the specified mix type, the Engineer may require the Contractor to adjust any combination of the grade, the percentage of the additional asphalt binder or the blend of reclaimed material to bring the grade to the specified value

Composition of Recycled HMA

- During the mix design process, the producer may use either blending charts or performance tests (e.g. dynamic modulus testing) to determine the PG grade of virgin binder to be used to give the overall performance characteristics desired
- For mix design obtain RAP samples (at least five) from stockpiles of the RAP after final processing

RAP in Superpave

Formulas to use for RAP by the total weight of the mix

Pb from RAP = %RAP x Pb in RAP

%RAP Agg = %RAP - Pb from RAP

Virgin Pb = Pb Total - Pb from RAP

%Pb Contributed by the RAP = Pb from RAP ÷ Pb Total x 100

% Virgin Agg = 100 - %RAP – Pb Added

RAP in Superpave

Given 6.1% total asphalt cement and 25% RAP by total weight, with 5.6% asphalt cement in the RAP

Pb from RAP = %RAP x Pb in RAP = 25% x 5.6 = 0.25 x 5.6 = 1.4%

%RAP Agg = %RAP - Pb from RAP = 25 – 1.4 = 23.6%

Virgin Pb = Pb Total – Pb from RAP = 6.1 – 1.4 = 4.7%

%Pb Contributed by the RAP = Pb from RAP ÷ Pb Total x 100 = 1.4 ÷ 6.1 x 100 = 23%

% Virgin Agg = 100 - %RAP – Virgin Pb = 100 – 25 – 4.7 = 70.3%

RAP in Superpave

- Next find the %RAP aggregate by the total weight of the aggregate, Ps
- Where, Ps = 100 – Pb = 100 – 6.1 = 93.9%

%RAP Aggregate by total weight of the aggregate = %RAP Agg ÷ Ps x 100 = 23.6 ÷ 93.9 x 100 = 25.1%

- This *%RAP Aggregate by total weight of the aggregate* is the fixed value shown for Percent (MD) on the M&T 601 Form in the "Gradation of Materials Used" Section in the RAP column

Reclaimed Asphalt Shingles
RAS Specifications
Manufacturer–Waste (MRAS) and Post Consumer (PRAS) Section 1012-1(E)

Reclaimed Asphalt Shingles
MRAS and PRAS Specifications

- MRAS are processed shingle materials discarded from the manufacture of new asphalt shingles
  - It may include rejected asphalt shingles or shingle tabs
- PRAS are processed shingle materials recovered from mixed roofing material scrap removed from existing structures
  - Tear-off shingle scrap must be sorted and cleaned prior to grinding

Reclaimed Asphalt Shingles
MRAS and PRAS Specifications

- Sample and test PRAS for asbestos
  - Results must show that bulk samples contain less than 1% of asbestos containing material
  - Use NC-accredited Asbestos Inspectors or Roofing Supervisors to sample the PRAS
  - Maintain on-site records for shingle sources, an approved asbestos operating plan and analytical reports for review by the Department

Reclaimed Asphalt Shingles
RAS and PRAS Specifications

- Process the RAS by ambient grinding or granulating so that 100% of the ground shingles will pass the 3/8 inch (9.5 mm) sieve
  - Perform this sieve analysis on processed shingles prior to extraction of the binder
- RAS shall contain no more than 0.5% by total cumulative weight of deleterious materials
  - No excessive dirt, debris, concrete, metal, glass, paper, rubber, wood, nails etc.

Reclaimed Asphalt Shingles
RAS and PRAS Specifications

- Blend RAS with fine aggregate or RAP, if needed, to keep the processed material workable
- MRAS and PRAS shall not be blended together for production of HMA
- For mix design incorporate RAS from stockpiles that have been tested for uniformity of gradation and binder content prior to use in a mix design

Recycled Mix Design Example

Determine the PG binder grade required for an RS 9.5B mix having a total asphalt content of 6.1% and using the maximum allowable amounts of RAS and RAP

(6% RAS and 20% maximum combined RAS and RAP)

RAS is 6% of the total mix and has an asphalt content of 18.5%

RAP is 14% of the total mix and has an asphalt content of 4.6%

Recycled Mix Design Example

For the RAS

6 x 18.5 ÷ 100 = *1.11% Pb contributed by RAS*

For the RAP

14 x 4.6 ÷ 100 = *0.64% Pb contributed by RAP*

Total Pb contributed from recycled materials

1.11 + 0.64 = *1.75% = 1.8%*

Recycled Mix Design Example

Pb contributed by the RAP and RAS as a percent of the total Pb in the mix

1.75 ÷ 6.1 x 100 = *28.7%*

Since 28.7% is greater than 20%, bump the specified binder of 64 -22 one grade from both the high and low temperatures

The mix requires PG 58 -28

Next…

- After the mix design is complete then TSR tests need to be done at the Design Optimum AC content

SUPERPAVE TSR TESTING PROCEDURES FOR MIX DESIGNS

Materials & Tests Unit

NCDOT

What is Stripping?

- The most common form of stripping is the loss of bond between the asphalt binder and the surface of the aggregate(s) due to water in the mix
- It is more easily seen by looking at the surface of the coarse aggregate particles, however it may occur with the fine aggregate also
- Do not confuse stripping with the breaking (into two parts) of the coarse aggregate particles

Purpose of TSR Test

- The TSR test is an indirect tension test for dry and wet-conditioned specimens to predict long term stripping susceptibility of asphalt mixtures and to evaluate the effects of anti-stripping additives
- TSR is required as part of the mix design process and is reported on M&T Form 612

Current Mix Design TSR Specs

- The Contractor prepares one set of specimens from lab produced mix to be tested by QC personnel at the QC mix design or field lab
- Gyrate the 150 mm diameter specimens to 95 ± 5 mm in height mode
- The completed specimens shall have a void content VTM of 7.0 ± 0.5% except SA-1 mixes shall have a VTM of 13 ± 0.5%
  - Use G_{mm} from the mix design process to determine VTM of the compacted specimens

Current Mix Design TSR Specs

- Follow the latest test procedures and specifications during the process which include:
  - After mixing, cool the mix at room temperature for 2 ± 0.5 hours.
  - Then place the mix in an oven heated to 140 ± 5 ºF (60 ± 3 ºC) for 16 ± 1 hours for curing
  - Note: the Engineer can waive the curing requirements if acceptable TSR results can be obtained without it
  - For conditioned specimens, there is <u>not</u> a freeze/thaw requirement and the saturation range is from 70 to 80%
  - Submit the test data to the Asphalt Design Engineer on M&T Form 612 (along with the other mix design sheets)
  - Include a copy of the TSR test break graphs

TSR TEST EQUIPMENT NEEDED

- A complete set of rice testing equipment (ASTM D 2041, preferably a Type E container)
- Two water baths
  - One able to maintain a temperature of 140° ± 2° F (60° ± 1° C) for 24 hours
  - One able to maintain a temperature of 77° ± 1° F (25° ± 0.5° C)
- Approved Gyratory Compactor

TSR TEST EQUIPMENT
Continued

- Marshall test press with metric graph paper
  - Use a test press meeting the requirements of AASHTO T 283 modified
  - 6" specimen breaking head consisting of two 0.75" inch wide metal strips.
- An infrared non-contact thermometer with a range from 50 to 400 °F (10 to 204 °C) with a sensitivity of 0.5 °F (0.3 °C) or better to use for checking the internal temperature of the specimens

PREPARATION OF TSR TEST SPECIMENS

- Prepare at least <u>eight</u> (8) gyratory test specimens using the same aggregate blend and optimum binder content as the mix design
- After mixing, the asphalt shall be cooled, cured *(if necessary)* then placed in an oven set within ± 5 °F (3 °C) of the compaction temperature for 2 hours ± 10 minutes prior to compaction
- The oven temperature for each specimen is dependent on the grade of asphalt...

PREPARATION OF TSR TEST SPECIMENS

PG Grade	Oven Temp. ºF
58 -28 & 64 -22	285 to 295
70 -22	300 to 310
76 -22	310 to 320

• Generally, for most mixes the plant mixing temperature for WMA will be set between 225 and 275 ºF (107 - 135 ºC)

• The compaction temperature for WMA is 10 ºF lower than the plant mixing temperature set on the JMF, then use a range of ± 5 ºF

PREPARATION OF TSR SPECIMENS
Continued

- Compaction should be performed with an approved gyratory compactor
- Each specimen should be compacted to a height of 95 ± 5 mm with 7 ± 0.5% air voids (except SA-1 mix voids are 13 ± 0.5%)
- Prepare the mixture in accordance with the weights and percentages of the mix design
- The following formulas can be used as a guideline for specimen weights…..

PREPARATION OF TSR SPECIMENS
Continued

General formula for TSR specimen weight:

$$\frac{(\pi h d^2)}{4} \times G_{mm} \times 0.93 \times 0.001$$

0.93 → 7% voids

If h = 95 mm, then the Weight = 1561.28 x G_{mm}

Where:

π = 3.1416
h = desired height of specimen, 95 mm
d = diameter of specimen, 150 mm
G_{mm} = maximum gravity (Rice) at optimum AC content

PREPARATION OF TSR SPECIMENS
Continued

- If you take into account that the surface of the compacted specimens are not truly solid, and that they contain about 1.5% more voids, then the formulas become:
- To target 7% voids (use 8.5% total voids)

  If h = 95 mm, then the Weight = 1536.1 x G_{mm}
- For SA-1 mixes with target 13% voids (use 14.5% total voids)

  If h = 95 mm, then the Weight = 1435.4 x G_{mm}

PREPARATION OF TSR SPECIMENS
Continued

- Finally, target the air voids by adjusting the amount of mix placed into the mold – add more mix to lower the voids, or take mix out to increase the voids
- See "Targeting Air Voids for TSR Specimens" in the last section of this manual for more information

EVALUATION OF TSR TEST SPECIMENS

- After removal from the molds, the specimens shall be stored for 24 ± 3 hours at room temperature
- Then determine the height of each specimen from the gyratory printout
- Determine the bulk gravity of each specimen using the methods described in AASHTO T 166
- Use G_{mm} at the optimum AC content from the mix design to calculate the voids

EVALUATION OF TSR TEST SPECIMENS

- Calculate the percent air voids for each specimen

$$\text{Voids} = [(G_{mm} - G_{mb}) \div G_{mm}] \times 100$$

- Evaluate air voids on all 8 specimens and separate them into 2 subset groups of four so that both groups have approximately the same average void content

PRECONDITIONING OF TSR SPECIMENS - DRY SET

- The four specimens selected for dry conditioning are left undisturbed at room temperature.
- Then they are *wrapped in plastic* or placed in *heavy duty leak proof plastic bags* and placed in a 77 ± 1°F (25 ± 0.5°C) water bath for a minimum of 2 hours ± 10 min.
  - *Note:* be sure there is a minimum of 1 in. (25 mm) of water above the surface of the specimens

PRECONDITIONING OF TSR SPECIMENS - WET SET

- For the four specimens selected for wet-conditioning:

  Determine volume of air voids on each specimen

  (% air voids x bulk volume) ÷ 100
- Calculate 70% and 80% saturation weight limits:

  (0.70 x volume of air voids) + dry weight of specimen = 70% saturation limit

  (0.80 x volume of air voids) + dry weight of specimen = 80% saturation limit

PRECONDITIONING OF TSR SPECIMENS - WET SET

- The specimens are placed in a container along with enough potable water at room temperature to cover the specimen by at least one inch
- Apply a vacuum of 10 to 26 in. of mercury (13 to 67 kPa) for approximately 5 to 10 minutes
- Remove the vacuum and leave the specimen submerged in water for approximately 5 to 10 minutes

PRECONDITIONING OF TSR SPECIMENS - WET SET

- The partially saturated specimens are then removed from the water, dried, weighed, and this SSD mass is recorded
- Then the specimen is suspended in water (for 3 to 5 min), re-weighed, and this mass in water is recorded
- The volume is the SSD mass minus the mass in water
- The volume of absorbed water is the SSD mass minus the dry mass in air

PRECONDITIONING OF TSR SPECIMENS - WET SET

The % saturation is 100 times the volume of the absorbed water divided by the volume of the air voids

- If the saturation is greater than 80%, the specimen is damaged, and should be discarded and replaced
- If the saturation is less than 70% repeat the vacuum procedure using more vacuum and/or time
- If the saturation is between 70 and 80% then continue with the test

PRECONDITIONING OF TSR SPECIMENS - WET SET

- Place the correctly saturated specimens in a hot water bath at 140 ± 2 °F (60 ± 1 °C) for 24 ± 1 hr.
- The specimens should have at least 1 inch of water above their surface while in the bath
- After 24 hours, the specimens are placed into a water-bath where the temperature is maintained at 77 ± 1°F (25 ± 0.5°C) for 2 hours ± 10 minutes
- The specimens should have at least 1 inch of water above their surface while in the bath

PRECONDITIONING OF TSR SPECIMENS - WET SET

- Adding ice to maintain the temperature of the water in the cool water bath is ok
- Note that not more than 15 minutes should be required for the water bath to reach 77 ± 1ºF (25 ± 0.5ºC) when ice is used
- Remove each specimen from the water bath after the approximate 2 hour time period, dry them to SSD, place them on a scale and weigh and record the SSD mass
- Then place each one under water on the weighing basket, wait 3 to 5 minutes, and record the mass in water

PRECONDITIONING OF TSR SPECIMENS - WET SET

- The volume is the SSD mass minus the mass in water
- The volume of absorbed water is the SSD mass minus the dry mass in air
- The % saturation is 100 times the volume of absorbed water divided by the volume of air voids

TSR TESTING

- Samples from both the wet and dry sets are each removed from the cool water baths, turned on their sides between the loading strips, and are placed between the bearing plates on the test press
- The load is applied to the specimen until it breaks and the peak load (in Newtons) is recorded to the nearest 100N (or one fourth of a square on 44000N chart paper)
  - The rate of loading during the break should be constant at 50 mm/min. (2in/min.)

TSR TESTING

Calculate the wet and dry tensile strengths (TS) by:

$$TS\ (kPa) = \frac{2000 \times \text{peak load}}{\text{diameter} \times \text{thickness} \times 3.1416}$$

- TS is calculated in kilopascals
- Peak load is measured in newtons
- Specimen diameter (a) and thickness (b) are measured in millimeters
- If a = 150 mm and b = 95 mm then
  TS = 0.04467 x peak load

TSR TESTING

- After loading, remove the broken specimen from the press and pull it apart at the crack so the specimen is in two parts
- Using the infrared thermometer, immediately measure and record the internal temperature of the specimen.
- Inspect the interior surface and visually estimate the degree of moisture damage (record as either none, moderate, intermediate, or severe)…...

- SEVERE STRIPPING

- MODERATE STRIPPING

- MINOR STRIPPING

- NO STRIPPING

INDIRECT TENSION TEST CALCULATIONS - Median Method

- The high and low tensile strengths from each of the wet and dry subsets will be discarded
- They will not be used to calculate the average wet and dry tensile strengths of the two subsets
- The average tensile strength of the two remaining conditioned (wet) specimens shall be divided by the average tensile strength of the two remaining dry specimens
- Then multiply by 100 to get the tensile strength ratio (TSR)

INDIRECT TENSION TEST CALCULATION

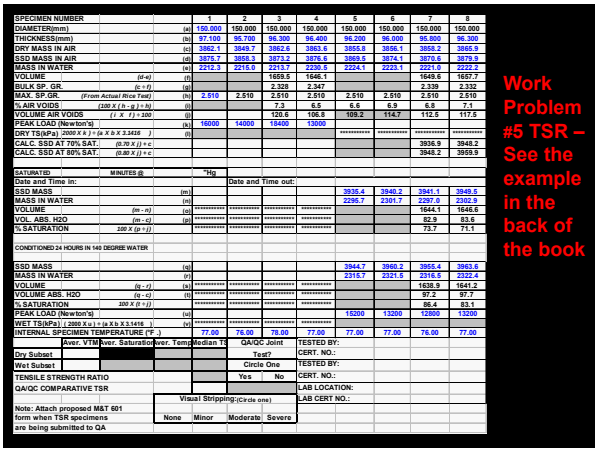
- TSR = Wet median tensile strength ÷ Dry median tensile strength x 100
- The TSR ratio should be calculated to the nearest 0.1 decimal place (ex. 85.2%) and rounded to the nearest 1% (ex. 85%)
- The interior surface temperature is recorded to the nearest 1.0 °F or better for each specimen

INDIRECT TENSION TEST CALCULATION

- The average VTM, Saturation, and Temp (internal temperature) is calculated separately for each of the wet and dry subsets using all four values from each subset
- All information required on the M&T 612 should be completed including the technician(s) responsible for the test

If TSR Testing Fails Then Modify the Mix

- Increase the AC content
- Use a higher viscosity binder
- Provide a cleaner or different aggregate source
- Increase the amount of liquid anti-strip
- Add hydrated lime
- Change the aggregate blend to improve gradation and density



SPECIMEN NUMBER		1	2	3	4	5	6	7	8
DIAMETER(mm)	(a)	150.000	150.000	150.000	150.000	150.000	150.000	150.000	150.000
THICKNESS(mm)	(b)	97.100	95.700	96.300	96.400	96.200	96.000	95.800	96.300
DRY MASS IN AIR	(c)	3862.1	3849.7	3862.6	3863.6	3855.8	3856.1	3858.2	3866.9
SSD MASS IN AIR	(d)	3875.7	3858.3	3873.2	3876.6	3869.6	3874.1	3870.6	3879.9
MASS IN WATER	(e)	2212.3	2215.0	2213.7	2230.5	2224.1	2223.1	2221.0	2222.2
VOLUME	(d-e)	(f)			1659.5	1646.1			1649.6	1657.7
BULK SP. GR.	(c ÷ f)	(g)			2.328	2.347			2.339	2.332
MAX. SP.GR.	(From Actual Rice Test)	(h)	2.510	2.510	2.510	2.510	2.510	2.510	2.510	2.510
%AIR VOIDS	(100 X (h - g) ÷ h)	(i)			7.3	6.5	6.6	6.9	6.8	7.1
VOLUME AIR VOIDS	(i X f) ÷ 100	(j)			120.6	106.8	109.2	114.7	112.5	117.5
PEAK LOAD (Newton's)		(k)	16000	14000	18400	13000				
DRY TS(kPa)	(2000 X k) ÷ (π X b X 3.1416)	(l)					**********	**********	**********	**********
CALC. SSD AT 70% SAT.	(0.70 X j) + c								3936.9	3948.2
CALC. SSD AT 80% SAT.	(0.80 X j) + c								3948.2	3959.9
SATURATED	MINUTES @	"Hg								
Date and Time in:			Date and Time out:							
SSD MASS		(m)					3935.4	3940.2	3941.1	3949.5
MASS IN WATER		(n)					2296.7	2301.7	2297.0	2302.9
VOLUME	(m - n)	(o)	**********	**********	**********	**********			1644.1	1646.6
VOL. ABS. H2O	(m - c)	(p)	**********	**********	**********	**********			82.9	83.6
% SATURATION	100 X (p ÷ j)		**********	**********	**********	**********			73.7	71.1
CONDITIONED 24 HOURS IN 140 DEGREE WATER										
SSD MASS		(q)					3944.7	3960.2	3955.4	3963.6
MASS IN WATER		(r)					2315.7	2321.5	2316.5	2322.4
VOLUME	(q - r)	(s)	**********	**********	**********	**********			1638.9	1641.2
VOLUME ABS. H2O	(q - c)	(t)	**********	**********	**********	**********			97.2	97.7
% SATURATION	100 X (t ÷ j)		**********	**********	**********	**********			86.4	83.1
PEAK LOAD (Newton's)		(u)					15200	13200	12800	13200
WET TS(kPa)	(2000 X u) ÷ (π X b X 3.1416)	(v)	**********	**********	**********	**********				
INTERNAL SPECIMEN TEMPERATURE (°F .)			77.00	76.00	78.00	77.00	77.00	77.00	76.00	77.00

	Aver. VTM	Aver. Saturation	Aver. Temp	Median TS
Dry Subset				
Wet Subset				
TENSILE STRENGTH RATIO				
QA/QC COMPARATIVE TSR				

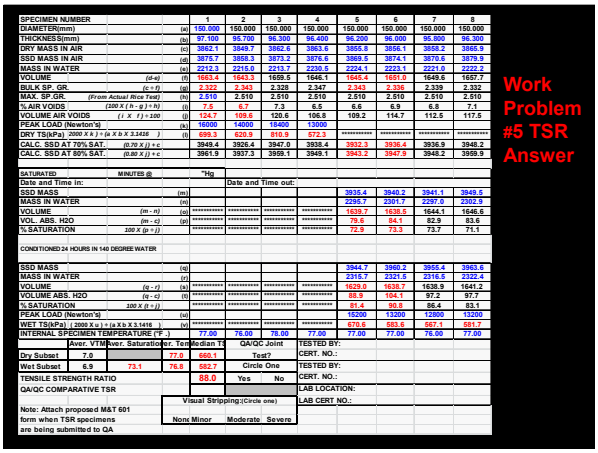
QA/QC Joint Test?	
Circle One	
Yes	No

TESTED BY:
CERT. NO.:
TESTED BY:
CERT. NO.:
LAB LOCATION:
LAB CERT NO.:

Visual Stripping (Circle one)			
None	Minor	Moderate	Severe

Note: Attach proposed M&T 601 form when TSR specimens are being submitted to QA

Work Problem #5 TSR – See the example in the back of the book



SPECIMEN NUMBER		1	2	3	4	5	6	7	8
DIAMETER(mm)	(a)	150.000	150.000	150.000	150.000	150.000	150.000	150.000	150.000
THICKNESS(mm)	(b)	97.100	95.700	96.300	96.400	96.200	96.000	95.800	96.300
DRY MASS IN AIR	(c)	3862.1	3849.7	3862.6	3863.6	3855.8	3856.1	3858.2	3866.9
SSD MASS IN AIR	(d)	3875.7	3858.3	3873.2	3876.6	3869.6	3874.1	3870.6	3879.9
MASS IN WATER	(e)	2212.3	2215.0	2213.7	2230.5	2224.1	2223.1	2221.0	2222.2
VOLUME	(d-e)	(f)	1663.4	1643.3	1659.5	1646.1	1645.4	1651.0	1649.6	1657.7
BULK SP. GR.	(c ÷ f)	(g)	2.322	2.343	2.328	2.347	2.343	2.336	2.339	2.332
MAX. SP.GR.	(From Actual Rice Test)	(h)	2.510	2.510	2.510	2.510	2.510	2.510	2.510	2.510
%AIR VOIDS	(100 X (h - g) ÷ h)	(i)	7.5	6.7	7.3	6.5	6.6	6.9	6.8	7.1
VOLUME AIR VOIDS	(i X f) ÷ 100	(j)	124.7	109.6	120.6	106.8	109.2	114.7	112.5	117.5
PEAK LOAD (Newton's)		(k)	16000	14000	18400	13000				
DRY TS(kPa)	(2000 X k) ÷ (π X b X 3.1416)	(l)	699.3	620.9	810.9	572.3	**********	**********	**********	**********
CALC. SSD AT 70% SAT.	(0.70 X j) + c		3949.4	3926.4	3947.0	3938.4	3932.3	3936.4	3936.9	3948.2
CALC. SSD AT 80% SAT.	(0.80 X j) + c		3961.9	3937.3	3959.1	3949.1	3943.2	3947.5	3948.2	3959.9
SATURATED	MINUTES @	"Hg								
Date and Time in:			Date and Time out:							
SSD MASS		(m)					3935.4	3940.2	3941.1	3949.5
MASS IN WATER		(n)					2296.7	2301.7	2297.0	2302.9
VOLUME	(m - n)	(o)	**********	**********	**********	**********	1639.7	1638.5	1644.1	1646.6
VOL. ABS. H2O	(m - c)	(p)	**********	**********	**********	**********	79.6	84.1	82.9	83.6
% SATURATION	100 X (p ÷ j)		**********	**********	**********	**********	72.9	73.3	73.7	71.1
CONDITIONED 24 HOURS IN 140 DEGREE WATER										
SSD MASS		(q)					3944.7	3960.2	3955.4	3963.6
MASS IN WATER		(r)					2315.7	2321.5	2316.5	2322.4
VOLUME	(q - r)	(s)	**********	**********	**********	**********	1629.0	1638.7	1638.9	1641.2
VOLUME ABS. H2O	(q - c)	(t)	**********	**********	**********	**********	88.9	104.1	97.2	97.7
% SATURATION	100 X (t ÷ j)		**********	**********	**********	**********	81.4	90.8	86.4	83.1
PEAK LOAD (Newton's)		(u)					15200	13200	12800	13200
WET TS(kPa)	(2000 X u) ÷ (π X b X 3.1416)	(v)	**********	**********	**********	**********	670.6	583.6	567.1	581.7
INTERNAL SPECIMEN TEMPERATURE (°F .)			77.00	76.00	78.00	77.00	77.00	77.00	76.00	77.00

	Aver. VTM	Aver. Saturation	Aver. Temp	Median TS
Dry Subset	7.0		77.0	660.1
Wet Subset	6.9	73.1	76.8	582.7
TENSILE STRENGTH RATIO				88.0
QA/QC COMPARATIVE TSR				

QA/QC Joint Test?	
Circle One	
Yes	No

TESTED BY:
CERT. NO.:
TESTED BY:
CERT. NO.:
LAB LOCATION:
LAB CERT NO.:

Visual Stripping (Circle one)			
None	Minor	Moderate	Severe

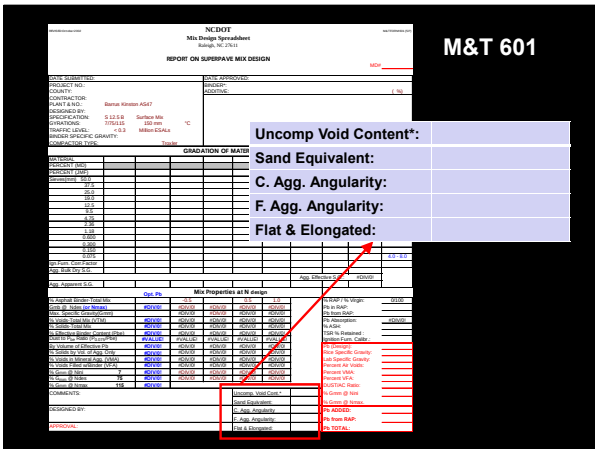
Note: Attach proposed M&T 601 form when TSR specimens are being submitted to QA

Work Problem #5 TSR Answer

SUPERPAVE AGGREGATE CONSENSUS PROPERTIES AND SAND SOURCE CHANGES

Purpose

- NCDOT Superpave Mix Designs require that the aggregate <u>blend</u> must meet specific consensus properties for the mix to perform well
- So four new tests were introduced:
  - Fine Aggregate Angularity (FAA)
  - Flat and Elongated Particle Test (F&E)
  - Sand Equivalency Test (SE)
  - Coarse Aggregate Angularity (CAA)


NCDOT
Mix Design Spreadsheet
Raleigh, NC 27611
REPORT ON SUPERPAVE MIX DESIGN
Uncomp Void Content*:
Sand Equivalent:
C. Agg. Angularity:
F. Agg. Angularity:
Flat & Elongated:
Mix Properties at N design

M&T 601

Aggregate Testing Procedure

- Use a dry aggregate sample that is weighed up according to the blend percentages shown on the mix design
- Split the sample on a no. 4 sieve (screen)
- Retain the coarse portion for the CAA and the F&E test
- Retain the fine portion for FAA and SE tests

Aggregate Testing Procedure

- When RAP and/or RAS is used in the mix, extract the aggregate using the ignition oven, as long as the aggregate is not affected by high temps in the oven
- Include the RAP and/or RAS aggregate in tests for gradation, CAA, F&E and FAA
- Do not include the RAP and/or RAS aggregate in the SE test

Superpave Consensus Properties

	Aggregate Properties			
Mix Type	CAA (min)	FAA (min)	SE (min)	F&E (max)
S4.75A	75/-	40	40	-
SF9.5A	75/-	40	40	-
S9.5B	75/-	40	40	-
S9.5C	95/90	45	45	10
S9.5D	100/100	45	50	10
S12.5C	95/90	45	45	10
S12.5D	100/100	45	50	10
I19.0B	75/-	40	40	10
I19.0C	95/90	45	45	10
I19.0D	100/100	45	50	10
B25.0B	75/-	40	40	10
B25.0C	95/90	45	45	10
OGFC	100/100	45	45	10
UBWC	100/85	40	45	10

Aggregate Coarse Fraction

- Shake the coarse fraction over the appropriate sieves: 37.5, 25, 19, 12.5, 9.5, and 4.75 mm (as needed for the mix type)
- The particles retained on each sieve are kept separate and then used for the CAA and F&E tests
- The minimum sample mass needed for the coarse fraction for each NMSA is:

9.5 mm (3/8 in.)	1 kg (4 lb)
12.5 mm (1/2 in.)	2 kg (4 lb)
19.0 mm (3/4 in.)	5 kg (11 lb)
25.0 mm (1 in.)	10 kg (22 lb)

Flat And Elongated Particles

- Flat or elongated particles may interfere with consolidation and may result in harsh mix that is difficult to place
- F&E is measured on the + 4.75 mm (plus no. 4) material of the aggregate blend
- It is based on the dimensional ratio of particles, length to thickness, maximum to minimum
  - for NCDOT a max. to min. dimension less than 5 : 1

Flat And Elongated Particles

- Use ASTM D4791 for the test
- The minimum sample mass needed for each NMSA is:

9.5 mm (3/8 in.)	1 kg (4 lb)
12.5 mm (1/2 in.)	2 kg (4 lb)
19.0 mm (3/4 in.)	5 kg (11 lb)
25.0 mm (1 in.)	10 kg (22 lb)

- The specification requirements vary depending on the traffic level
  - S 4.75A, SF 9.5A and S 9.5B have no limit
  - the other mixes are limited to 10% maximum F&E

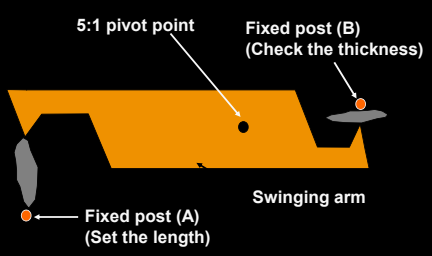
Flat And Elongated Particles

- Find the percent retained for each sieve
  - Go to the M&T 601 Form and find the %passing for the blend
  - For example, the % retained on the ¾ inch sieve = the %passing the 1 inch sieve minus the %passing the ¾ inch sieve
- Sieve the blended coarse fraction on each of the coarse sieves
  - Discard the aggregate from any sieve size fractions that don't retain 10% on them
- Reduce the usable material by splitting or quartering it down and then remove and weigh out about 100 pieces for the test from each of the sieves

Flat And Elongated Particles

- The 100 pieces are checked with the caliper (that is set on the 5:1 ratio) to find the flat and elongated particles
  - Set the particle length in the wide opening - If the thickness passes through the small opening then the particle is F&E
- The particles identified as flat and elongated are weighed separately for each sieve
- The percent F&E is then calculated using the measured weights and the F&E worksheet

Flat And Elongated Particles



Flat And Elongated Particles

Traffic ESALs	Percent
all levels	10

Maximum percentage of flat and elongated particles

S4.75A, SF9.5A and S9.5B mixes don't have an F&E spec.

Flat and Elongated Example

Material	M&T 601 Blend	Control Points
Sieves (mm)	%Passing	
25.0	100	100
19.0	100	90 - 100
12.5	87	< 90
9.5	81	
4.75	60	
2.36	46	23 - 49
1.18	36	
0.600	26	
0.300	16	
0.150	9	
0.075	5.2	3.0 - 8.0

Flat and Elongated Example

Material	M&T 601 Blend	Individual
Sieves (mm)	%Passing	%Retained
25.0	100	0
19.0	100	100 – 100 = 0%
12.5	87	100 – 87 = 13%
9.5	81	87 – 81 = 6%
4.75	60	81 – 60 = 21%
2.36	46	Not needed
1.18	36	Not needed
0.600	26	Not needed
0.300	16	Not needed
0.150	9	Not needed
0.075	5.2	Not needed

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0					
19.0	0					
12.5	13					
9.5	6					
4.75	21					
[B] = 40 = Total %Retained = 13 + 6 + 21						

Insert the Individual %Retained for each sieve into the table. Add them all together to get [B], the Total %Retained

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0	0				
19.0	0	0				
12.5	13	13/40 = 0.325				
9.5	6	6/40 = 0.150				
4.75	21	21/40 = 0.525				
[B] = 40 = Total %Retained						

The Ratio [C] = [A]/[B], the Individual %Retained divided by the Total %Retained

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0	0				
19.0	0	0				
12.5	13	0.325	752.6			
9.5	6	0.150	------			
4.75	21	0.525	89.7			
[B] = 40 = Total %Retained						

Weigh approximately one hundred pieces from each sieve size that retains at least 10% of material. In this case the 9.5mm sieve does not retain enough material. Enter the weights in column [D].

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0	0				
19.0	0	0				
12.5	13	0.325	752.6	10.4		
9.5	6	0.150	--------	--------		
4.75	21	0.525	89.7	3.0		
[B] = 40 = Total %Retained						

For each sieve where you weighed out one hundred particles: use the calipers to measure which ones are flat and elongated and weigh them together. Enter the weights of the flat and elongated pieces into column [E].

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0	0			[F] = [E]/[D]x100	
19.0	0	0				
12.5	13	0.325	752.6	10.4	1.382	
9.5	6	0.150	--------	--------	????	
4.75	21	0.525	89.7	3.0	3.344	
[B] = 40 = Total %Retained						

For each sieve calculate [F], which is the Wt. Flat & Elong. [E], divided by the Weight [D], and multiply by 100

For the 12.5 mm sieve: 10.4 ÷ 752.6 x 100 = 1.382

For the 4.75 mm sieve: 3.0 ÷ 89.7 x 100 = 3.344

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0	0			[F] = [E]/[D]x100	
19.0	0	0				
12.5	13	0.325	752.6	10.4	1.382	
9.5	6	0.150	--------	--------	?????	
4.75	21	0.525	89.7	3.0	3.344	
[B] = 40 = Total %Retained						

What about the 9.5mm sieve?

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0	0			[F] = [E]/[D]x100	
19.0	0	0				
12.5	13	0.325	752.6	10.4	1.382	
9.5	6	0.150	--------	--------	3.344	
4.75	21	0.525	89.7	3.0	3.344	
[B] = 40 = Total %Retained						

In this example, the 9.5mm sieve is the same as the 4.75mm sieve because it did not retain at least 10% (it only retained 6%).

Aside: If the 4.75mm sieve does not retain at least 10% then use [F] from the 9.5mm sieve.

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0	0				
19.0	0	0				
12.5	13	0.325	752.6	10.4	1.382	0.449
9.5	6	0.150	--------	--------	3.344	0.502
4.75	21	0.525	89.7	3.0	3.344	1.756
[B] = 40 = Total %Retained						

Calculate [F] x [C] and enter the result in the last column:

For the 12.5 mm sieve: 1.382 x 0.325 = 0.449

For the 9.5mm sieve: 3.344 x 0.150 = 0.502

For the 4.75 mm sieve: 3.344 x 0.525 = 1.756

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0	0			[F] = [E]/[D]x100	
19.0	0	0				
12.5	13	0.325	752.6	10.4	1.382	0.449
9.5	6	0.150	--------	--------	3.344	0.502
4.75	21	0.525	89.7	3.0	3.344	1.756
[B] = 40 = Total %Retained						
					Total %Flat & Elongated = ?	

Add all the numbers in the last column.

Total %Flat & Elongated = 0.449 + 0.502 + 1.756 = 2.707

Flat and Elongated Example

Sieve (mm)	Individual %Retained [A]	Ratio [C] =[A]/[B]	Weight [D]	Wt. Flat & Elong. [E]	%Flat & Elong. [F] ***	[F] x [C]
25.0	0	0			[F] = [E]/[D]x100	
19.0	0	0				
12.5	13	0.325	752.6	10.4	1.382	0.449
9.5	6	0.150	--------	--------	3.344	0.502
4.75	21	0.525	89.7	3.0	3.344	1.756
[B] = 40 = Total %Retained						
					Total %Flat & Elongated = 2.7	

Round 2.707 to the nearest 0.1%

The Flat & Elongated is 2.7%

Coarse Aggregate Angularity

- CAA is measured using the plus no. 4 material of the coarse aggregate blend
- It is based on fractured faces
  - a fractured surface larger than 25% of the aspect ratio
- Run it as per ASTM D 5821
- The requirements depend on:
  - the traffic level
  - higher traffic levels require more fractured faces

Coarse Aggregate Angularity

- The purpose of fractured faces is to maximize shear strength and stability by increasing inter-particle friction and texture
- CAA is most important for mixes using crushed gravels

Coarse Aggregate Angularity

- Wash and dry the blended coarse sample over the no. 4 sieve
- Then reduce the retained portion to test size using a mechanical splitter
- The test size is as follows:

NMSA mm. (in.)	Min. Test Sample g (lb)
9.5 (3/8)	200 (0.5)
12.5 (½)	500 (1)
19 (3/4)	1500 (3)
25 (1)	3000 (6.5)

Coarse Aggregate Angularity

- Dry the test sample to constant mass and weigh it
- Visually inspect the individual particles and separate them according to the number of fractured faces
- Determine the percent fractured faces by dividing the mass of the particles with the required fractured faces by the total mass of the sample

Coarse Aggregate Angularity

Traffic ESALs	Coarse Aggregate Angularity
3 to 30 million	95 / 90

95% one fractured face

90% two fractured faces

Fine Fraction

- The fine fraction is split for the FAA and the SE tests
- FAA requires 1000 grams (further split, washed, and graded to the standard sample test size of 190 g)
  - the FAA test also requires another 1000 g for a specific gravity test on an unwashed part of the fine fraction
- Each of the three SE tests requires a 3 oz. cup full (± 80 grams) of unwashed fine aggregate blend

Fine Aggregate Angularity

- FAA is performed on the - 4.75 mm (minus no. 4) material washed over the #200 sieve
  - You must also perform the Fine Aggregate Specific Gravity test (ASTM C 128) on an unwashed portion of the fine fraction of the aggregate blend as part of this process to find G_{sb} of the fine fraction (unwashed)
- Use AASHTO T304, Method A (a standard graded sample) to perform the FAA test

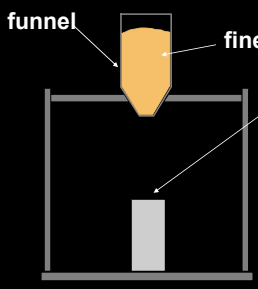
Fine Aggregate Angularity

- The test measures the uncompacted void content (UVC) of fine aggregate
- It is run on the combined fine aggregate blend to be sure that the criteria of Table 1012-1 Aggregate Consensus Properties are met
- FAA is an indicator of stability and voids in the mineral aggregate
- The standard graded sample is used to make three trial runs and the three results are averaged for the final answer

FAA Standard Graded Sample

Sieve	Individual Wt. (g)	Accumulated Wt. (g)
No. 16	44	44
No. 30	57	101
No. 50	72	173
No. 100	17	190

Fine Aggregate Angularity



uncompacted voids =

$$\frac{V - (W \div G_{sb})}{V} \times 100$$

G_{sb} is the Sp. Gr. of the minus #4 blend (unwashed) and not G_{sb} from the mix design blend!

Fine Aggregate Angularity

ESALs	Uncompacted Void Content
3 - 30 million	45

Minimum % of air voids in loose sample

Sand Equivalent

- SE is measured using a sample of the unwashed minus no. 4 blend of the fine aggregate blend
- The test indicates the amount of clay (detrimental material) in the sample
- Use AASHTO T176 to run the test
- The design requirements depend on the traffic level
  - –Higher traffic levels require cleaner sands
- Do not include lime in the sample for SE

Sand Equivalent

- The beginning sample size is 1000 to 1500 grams of dry, unwashed, minus no. 4 blend
  - –Important - Further quarter the sample to a test size of 500 to 750 grams!
  - –Then split or quarter enough material to slightly overfill the 3 oz (85 ml) tin measuring cup three times for the three SE tests
  - –Tap the tin can on the counter while filling it and strike off the excess material with a spatula or straightedge

Sand Equivalent

- The working solution that is mixed from the stock solution is used to suspend the clay above the sand
  - –The working solution should be discarded if it is more than 30 days old
  - –It should be held in a container that is placed 36 inches above the work surface
- Add working solution to the 4 ± 0.1 inch mark on the graduated cylinder
- Add the sand sample that fills the tin can to the cylinder tube

Sand Equivalent

- Strike the bottom of the tube sharply several times and allow the wetted sample to sit undisturbed for 10 ± 1 minutes
- Stopper the tube and invert and shake it to loosen the material from the bottom of the tube
- Place the stoppered tube in the mechanical shaker to mix the sand sample and the solution together for 45 ± 1 seconds
- Remove the tube from the shaker, remove the stopper, and set the tube upright on the counter

Sand Equivalent

- Irrigate the clay from the sand and wash down the sides of the tube while filling the tube up to, but not over, the 15 inch mark
- Allow the clay to settle undisturbed
  - The clay reading is normally taken at 20 minutes ± 15 seconds after mixing and when the solution is clear
  - However, the time may be extended to 30 minutes if the clay is fine and settles slowly
  - Record the final clay reading and the time required for the solution to clear and the clay to settle

Sand Equivalent

- The sand reading is taken after the clay reading using a weighted foot assembly
  - The sand reading is first taken from the disk on the weighted foot, then subtract 10 inches
- Round up all readings taken from the scale on the tube to the next higher mark on the scale
- Calculate each sand equivalent to the nearest 0.1% then round the answer to the next higher whole number

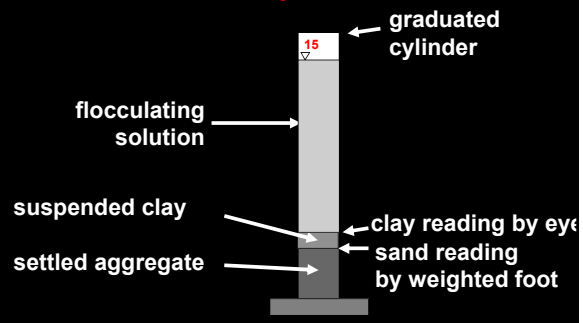
Sand Equivalent

- **The final SE result is the average of three tests, rounded to the next highest whole number**

Sand Equivalent (for each of the three tests)

SE = (sand reading ÷ clay reading) x 100

Sand Equivalent



Sand Equivalent

Traffic ESALs	Percent
3 - 30 million	45

Minimum SE value

Natural Sand Source Change Requests

Sand Source Change Requests

- This policy applies when a Contractor needs to change the source of natural sand that is listed on the original mix design
- It is only intended for designs with less than 25% natural sand, however, the 25% limit may be waived by the Engineer

Sand Source Change Requests

- The Contractor submits the following items to M&T for approval:
  - New paperwork (see next slide)
  - A sample of the new sand (20 to 25 lb) and the following test results on the sand:
    - Specific gravity: G_{sb} and G_{sa}
    - Sand Equivalent
    - Fine Aggregate Angularity
  - APA rut test samples for surface mixes, as required

Sand Source Change Requests

- The paperwork should include:
  - a new QMS-1, an updated M&T 601 (with new gradations, specific gravities and blend calculations), a 0.45 power chart, M&T 620 Consensus Sheet (with FAA and SE results for the blend), a satisfactory mix verification using the new sand with results shown on QA/QC-1, a passing TSR test using the new sand and shown on M&T 612, and a copy of the mining permit

Sand Source Change Requests

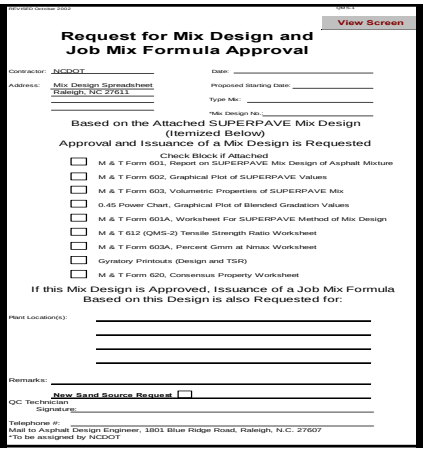
- If the new material is considered to be reasonably close to the old, the mix verification test results are acceptable, and the TSR and rut tests pass, then the new design will be approved
- New Mix Design (MD#) and Job Mix Formula (JMF#) numbers will then be assigned

Mix Design Submittal and Approval

What should be included in the mix design submittal?

- Follow the checklist on the QMS-1 form and include:
  - M&T 601
  - M&T 601A
  - M&T 602
  - M&T 603
  - M&T 603A
  - M&T 612
  - 0.45 FHWA Power Chart
  - M&T 620
  - Gyratory Printouts
  - TSR Graphs

QMS-1



View Screen

Request for Mix Design and Job Mix Formula Approval

Contractor: NCDOT
Address: Mix Design Spreadsheet, Raleigh, NC 27611

Date:
Proposed Starting Date:
Type Mix:
*Mix Design No.:

Based on the Attached SUPERPAVE Mix Design (Itemized Below) Approval and Issuance of a Mix Design is Requested

Check Block if Attached

- ☐ M & T Form 601, Report on SUPERPAVE Mix Design of Asphalt Mixture
- ☐ M & T Form 602, Graphical Plot of SUPERPAVE Values
- ☐ M & T Form 603, Volumetric Properties of SUPERPAVE Mix
- ☐ 0.45 Power Chart, Graphical Plot of Blended Gradation Values
- ☐ M & T Form 601A, Worksheet For SUPERPAVE Method of Mix Design
- ☐ M & T 612 (QMS-2) Tensile Strength Ratio Worksheet
- ☐ M & T Form 603A, Percent Gmm at Nmax Worksheet
- ☐ Gyratory Printouts (Design and TSR)
- ☐ M & T Form 620, Consensus Property Worksheet

If this Mix Design is Approved, Issuance of a Job Mix Formula Based on this Design is also Requested for:

Plant Location(s):

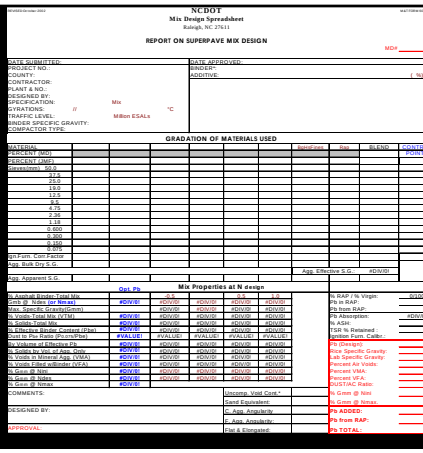
Remarks:

New Sand Source Request ☐

QC Technician Signature:

Telephone #:
Mail to Asphalt Design Engineer, 1801 Blue Ridge Road, Raleigh, N.C. 27607
*To be assigned by NCDOT

M&T 601



NCDOT
Mix Design Spreadsheet
Raleigh, NC 27611

REPORT ON SUPERPAVE MIX DESIGN

MD#

DATE SUBMITTED:
PROJECT NO.:
COUNTY:
CONTRACTOR:
PLANT & NO.:
DESIGNED BY:
SPECIFICATION:
GYRATIONS: Mix
TRAFFIC LEVEL: Million ESALs
BINDER SPECIFIC GRAVITY:
COMPACTOR TYPE:

DATE APPROVED:
BINDER*:
ADDITIVE: (%)

GRADATION OF MATERIALS USED

MATERIAL							Blend Form	Mix	BLEND	CONSTRAINT POINTS
PERCENT (MD)										
PERCENT (JMF)										
Sieves(mm)	SCS									
25	37.5									
19	25.0									
12.5	19.0									
9.5	12.5									
4.75	9.5									
2.36	4.75									
1.18	2.36									
0.600	1.18									
0.300	0.600									
0.150	0.300									
0.075	0.075									
Gin Form. Corr Factor										
Agg. Bulk Dry S.G.										
Agg. Apparent S.G.								Agg. Effective S.G.:	#DIV/0!	

Mix Properties at N design

	Opt. Pb					
% Asphalt Binder Total Mix	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Pb @ Nini (or Nmin)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Max. Specific Gravity(Gmm)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Voids Total Mix (VTM)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Solids-Total Mix	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Effective Binder Content (Pbe)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Point to Pbe Ratio (Pi:r=s/Pbe)	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
% Volume of Effective Pb	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Solids by Vol. of Agg. Only	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Voids in Mineral Agg. (VMA)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Voids Filled w/Binder (VFA)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Gmm @ Nini	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Gmm @ Ndes	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
% Gmm @ Nmax	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

% RAP / % Virgin:	0/100
Pb in RAP:	
Pb from RAP:	
Pb Absorption:	#DIV/0!
% ASH:	
TSR % Retained :	
Ignition Furn. Calibr.:	
Pb (Design):	
Mixe Specific Gravity:	
Lab Specific Gravity:	
Percent Air Voids:	
Percent VMA:	
Percent VFA:	
RUSTIAC Ratio:	
% Gmm @ Nini:	
% Gmm @ Nmax:	
Pb ADDED:	
Pb from RAP:	
Pb TOTAL:	

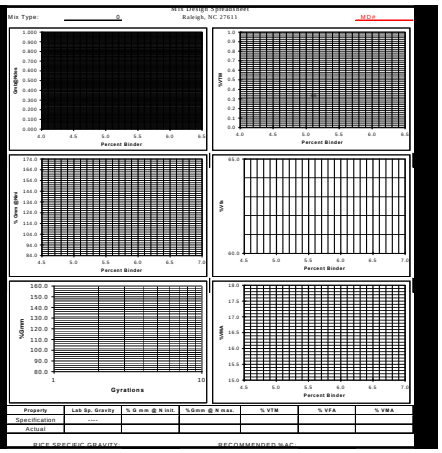
COMMENTS:

DESIGNED BY:

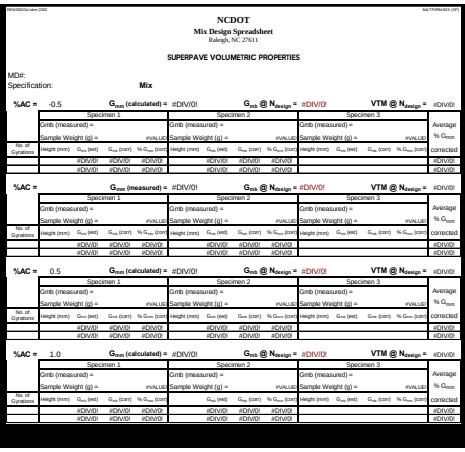
APPROVAL:

Dmcomp. Void Cont.*	
Sand Equivalent:	
C. Agg. Angularity:	
F. Agg. Angularity:	
Flat & Elongated:	

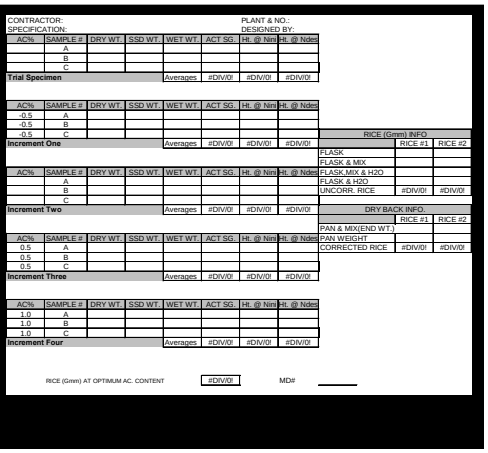
M&T 602



M&T 603



M&T 601A

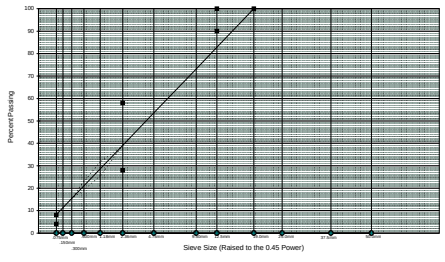


0.45 Power Chart

NCDOT

Mix Design Spreadsheet
Raleigh, NC 27611
FHWA 0.45 Power Chart

Mix Type _____
Mix Design # _____



M&T 612 TSR

NCDOT
TENSILE STRENGTH RATIO (TSR) TEST WORKSHEET
Gyratory Compactive Method
M&T 612 (QMS-2)

Mix Design #:

Date Mix Produced:	Mix Type:	JMF No: Pending	
Contractor:	Plant Location:	Plant Cert. No.:	
Additive Supplier:	Additive Grade:	Additive Dosage: (%)	
Date Compacted:	No. Gyrations: To height	Date Test Completed:	

SPECIMEN NUMBER		1	2	3	4	5	6	7	8
DIAMETER(mm)	(a)								
THICKNESS(mm)	(b)								
DRY MASS IN AIR	(c)								
SSD MASS IN AIR	(d)								
MASS IN WATER	(e)								
VOLUME (d-e)	(f)	**********	**********	**********	**********	**********	**********	**********	**********
BULK SP. GR. (c ÷ f)	(g)	**********	**********	**********	**********	**********	**********	**********	**********
MAX. SP. GR. (Optimum Binder Content Rice Test)	(h)								
% AIR VOIDS (100 X (h - g) ÷ h)	(i)	**********	**********	**********	**********	**********	**********	**********	**********
VOLUME AIR VOIDS (c X (f ÷ c) ÷ 100)	(j)	**********	**********	**********	**********	**********	**********	**********	**********
PEAK LOAD (Newtons)	(k)								
DRY TS(kPa) (2000 X k) ÷ (π X 0.5 X 3.1416)	(l)	**********	**********	**********	**********	**********	**********	**********	**********
CALC. SSD AT 65% SAT. (0.65 X g) + c		**********	**********	**********	**********	**********	**********	**********	**********
CALC. SSD AT 80% SAT. (0.80 X g) + c		**********	**********	**********	**********	**********	**********	**********	**********

SATURATED — MINUTES @ "Hg
Date and Time in: 11/16/09 1:00 PM — Date and Time out: 11/17/09 1:00 PM

SSD MASS	(m)							
MASS IN WATER	(n)							
VOLUME (m - n)	(o)	**********	**********	**********	**********	**********	**********	**********
VOL. ABS. H2O (m - c)	(p)	**********	**********	**********	**********	**********	**********	**********
% SATURATION 100 X (o ÷ j)		**********	**********	**********	**********	**********	**********	**********

CONDITIONED 24 HOURS IN 140 DEGREE WATER

SSD MASS	(q)							
MASS IN WATER	(r)							
VOLUME (q - r)	(s)	**********	**********	**********	**********	**********	**********	**********
VOLUME ABS. H2O (q - c)	(t)	**********	**********	**********	**********	**********	**********	**********
% SATURATION 100 X (t ÷ j)		**********	**********	**********	**********	**********	**********	**********
PEAK LOAD (Newtons)	(u)							
WET TS(kPa) (2000 X u) ÷ (π X 0.5 X 3.1416)	(v)	**********	**********	**********	**********	**********	**********	**********
INTERNAL SPECIMEN TEMPERATURE (°F)								

	Aver. VTM	Aver. Saturation	Aver. Temp.	Median TS
Dry Subset	**********	**********	**********	#NUM!
Wet Subset	**********	**********	**********	#NUM!

QA/QC Joint
Test?
Circle One
(Yes) No

TENSILE STRENGTH RATIO
QA/QC COMPARATIVE TSR

Visual Stripping-place x in appropriate box

None	Minor	Moderate	Severe

Note: Attach proposed M&T 601 form when TSR specimens are being submitted to QA

M&T 603A N_{max}

Pills to be Compacted to Nmax. Pills are compacted using the Optimum Binder Content. M & T Form 603A

Mix Type 0 Mix Design # _____

Pb	SAMPLE #	DRY WT	SSD WT.	WET WT.	ACT SG.	Ht. @ Nini	Ht. @ Ndes	Ht. @ Nmax
	A							
0.0	B							
0.0	C							
				Averages				

•Re-enter the heights at Ndes into the spaces for the heights at Nmax

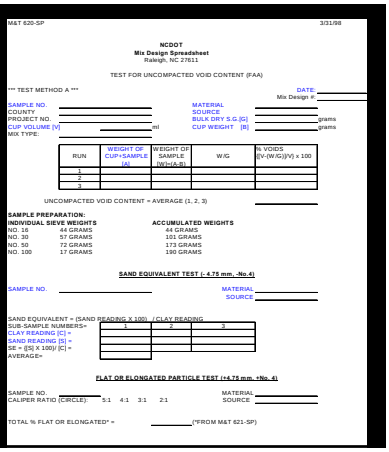
Pb = 0.0 **G_{mm} (measured) =** **G_{mb} @ N_{Design} =** **VTM @ N_{design} =** ########

	Specimen 1				Specimen 2				Specimen 3				
	Gmb (measured) =				Gmb (measured) =				Gmb (measured) =				Average
	Sample Weight (g) = 0.0			#VALUE!	Sample Weight (g) = 0.0			#VALUE!	Sample Weight (g) = 0.0			#VALUE!	% G_{mm}
No. of Gyrations	Height (mm)	G_{mb} (est)	G_{mb} (corr)	% G_{mm} (corr)	Height (mm)	G_{mb} (est)	G_{mb} (corr)	% G_{mm} (corr)	Height (mm)	G_{mb} (est)	G_{mb} (corr)	% G_{mm} (corr)	corrected
0	0.0	#DIV/0!	#DIV/0!	#DIV/0!	0.0	#DIV/0!	#DIV/0!	#DIV/0!	0.0				#DIV/0!
0	0.0	#DIV/0!	#DIV/0!	#DIV/0!	0.0	#DIV/0!	#DIV/0!	#DIV/0!	0.0				#DIV/0!
0	0.0	#DIV/0!	#DIV/0!	#DIV/0!	0.0	#DIV/0!	#DIV/0!	#DIV/0!	0.0				#DIV/0!

%VMA @Ndes	#DIV/0!	Agg. Eff. Gr. (Gse)	#DIV/0!	Comments:	
% VFA @Ndes	#DIV/0!	Eff. Binder(Pbe)	#DIV/0!		
%VTM @Ndes	########	Absorbed Binder	#DIV/0!		

- *Note: Gyrating pills to N_{max} is not required*
- *However, do gyrate pills to N_{des} at the optimum AC content and enter the data in the top fields of the form*

M&T 620 Consensus Properties



M&T 620-SP 3/31/98

NCDOT
Mix Design Spreadsheet
Raleigh, NC 27611

TEST FOR UNCOMPACTED VOID CONTENT (FAA)

*** TEST METHOD A ***

DATE:
Mix Design #:

SAMPLE NO.
COUNTY
PROJECT NO.
CUP VOLUME [V] ml
MIX TYPE:

MATERIAL SOURCE
BULK DRY S.G.[G]
CUP WEIGHT [B] grams

RUN	WEIGHT OF CUP+SAMPLE [A]	WEIGHT OF SAMPLE [W]=[A-B]	W/G	% VOIDS [(V-(W/G))/V] x 100
1				
2				
3				

UNCOMPACTED VOID CONTENT = AVERAGE (1, 2, 3)

SAMPLE PREPARATION:

INDIVIDUAL SIEVE WEIGHTS		ACCUMULATED WEIGHTS
NO. 16	44 GRAMS	44 GRAMS
NO. 30	57 GRAMS	101 GRAMS
NO. 50	72 GRAMS	173 GRAMS
NO. 100	17 GRAMS	190 GRAMS

SAND EQUIVALENT TEST (- 4.75 mm, -No.4)

SAMPLE NO.
MATERIAL SOURCE

SAND EQUIVALENT = (SAND READING X 100) / CLAY READING

SUB-SAMPLE NUMBERS=	1	2	3
CLAY READING [C] =			
SAND READING [S] =			
SE = ([S] X 100)/ [C] =			
AVERAGE=			

FLAT OR ELONGATED PARTICLE TEST (+4.75 mm, +No. 4)

SAMPLE NO.
CALIPER RATIO (CIRCLE): 5:1 4:1 3:1 2:1
MATERIAL SOURCE

TOTAL % FLAT OR ELONGATED* = (*FROM M&T 621-SP)

The Complete Mix Design Package

- Do not forget the following items:
  - Gyratory print-outs
  - TSR graphs
  - Rut pills for all surface mixes, except SA-1 mixes
    - Note: The rut pills need to be labeled with proper identification
    - Paper work must accompany the rut samples - use the top part of the TSR worksheet M&T 612 (or a similar worksheet) with the data filled in up to, and including, the void content

Design Submittal and Approval

- Generally, designs are to be submitted to the M&T Asphalt Lab at least 10 days before start of asphalt mix production
- Submit raw batch materials to M&T for mix check verification if they are requested
- The Asphalt Lab will approve, reject, or send back mix designs for corrections

Design Submittal and Approval

- When approved the design is assigned a job mix formula (JMF) which will add the following information:
  - Plant production temperature
  - Required field density
  - The amount of WMA additive
- The time frame to complete the entire acceptance process can vary depending on the work load, time of year, etc.

See NAPA's Virtual Superpave Laboratory CD ROM for more info

- An Interactive CD ROM
- From the National Asphalt Paving Association (NAPA), copyright 2005
- Search Virtual Superpave Laboratory
- CD ROM (single user)
- Item ED-001
- Cost $50 US

Questions/Comments?

Specs

DIVISION 6
ASPHALT PAVEMENTS

SECTION 600
PRIME COAT

600-1 DESCRIPTION

Perform the work covered by this section including, but not limited to, treating an existing non-asphalt base course with asphalt material by furnishing and applying the prime, furnishing and placing granular material to protect the prime and maintaining the prime coat in accordance with these Specifications.

Treat all non-asphalt bases beneath an asphalt surface treatment with a prime coat.

600-2 MATERIALS

Refer to Division 10.

Item	Section
Prime Coat Materials	1020-5

Use materials for prime coat application that are on the Materials and Tests Unit's Approved Product List for prime coats available on the Department's website. Materials shall meet the manufacturer's specifications as submitted to and approved by the Department.

Where the grade of prime coat material is not established by the contract, the Contractor may select the grade to be used from the Approved Product List. All prime coat materials shall be delivered to the project ready for use.

600-3 WEATHER LIMITATIONS

Apply prime coat only when the surface to be treated is free of standing water, at proper moisture content and the atmospheric temperature in the shade away from artificial heat is 40°F or above for plant mix and 50°F or above for asphalt surface treatment.

Do not apply prime coat on a frozen surface or when the weather is foggy or rainy.

600-4 BASE PREPARATION

Clean the base of objectionable debris, excessive dust and any other deleterious matter before placing the prime coat.

When directed, dampen the surface of the base before application of the prime coat.

600-5 APPLICATION EQUIPMENT

Provide, maintain and operate a pressure distributor that is designed and equipped such that the asphalt material remains at a constant temperature and may be applied uniformly on variable widths of surface at predetermined and controlled rates. Use a distributor equipped with a tachometer or synchronizer, pressure gauges, accurate volume measuring devices or a calibrated tank and a mounted thermometer for measuring temperature.

Use a distributor equipped with a power driven pump of sufficient capacity to distribute the required quantity of asphalt material at constant flow and uniform pressure. Provide a full circulation spray bar adjustable laterally and vertically and adjustable in length to conform to the required width of application without overlapping. Provide and maintain nozzles designed to provide equal and uniform application at all times. Provide a hand spray hose and nozzle to cover areas inaccessible to the spray bars. Equip the distributor with a positive shut-off control for the spray bar and hand hose.

600-6 APPLICATION RATES AND TEMPERATURES

Apply the prime coat at a rate from 0.20 to 0.50 gal/sy. The exact rate for each application will be established by the Engineer before application, in accordance with the limits shown in the Approved Product List referenced in Article 600-2.

The required rate of application of asphalt materials will be based on the volume of material measured at the application temperature. Apply the prime coat material at a temperature that is in accordance with the manufacturer's recommendations or as approved.

600-7 APPLICATION OF PRIME COAT

When the plans require the base course to be constructed with side slopes flatter than 1:1, apply prime to the full width of the base including the side slopes.

Apply the prime coat only when the base to be treated has been approved.

Place a string line to provide alignment control for the distributor during prime coat application unless waived by the Engineer.

Cover bridge floors, curbs and handrails of structures and all other appurtenances to protect them from tracking or splattering of prime coat.

After the prime coat has penetrated sufficiently and when directed, roll the primed surface until all loose base material is thoroughly bonded.

600-8 MAINTENANCE AND PROTECTION

Allow the prime coat to thoroughly penetrate the base. When directed, apply blotting sand in accordance with Section 818.

Maintain the prime coat in an acceptable condition until such time as the pavement is placed. Replace any damaged prime coat.

600-9 MEASUREMENT AND PAYMENT

Ensure the volume of the distributor tank is calibrated by a commercial laboratory or the manufacturer before use. Provide a calibration chart with an accurately calibrated measuring stick graduated in increments of not more than 25 gallons on the distributor at all times for use by the Engineer.

Prime Coat will be paid at the contract unit price per gallons of prime coat material satisfactorily placed on the roadway. Each distributor load of prime coat material delivered and used on the project will be measured. Replaced damaged prime coat at no cost to the Department.

Blotting Sand will be paid in accordance with Article 818-4.

Payment will be made under:

Pay Item	Pay Unit
Prime Coat	Gallon

SECTION 605
ASPHALT TACK COAT

605-1 DESCRIPTION

Apply tack coat material to existing asphalt or concrete surfaces in accordance with these Specifications.

Apply tack coat beneath each layer of asphalt plant mix to be placed, unless otherwise approved. Where a prime coat or a newly placed asphalt surface treatment mat coat has been applied, apply tack coat as directed.

605-2 MATERIALS

Refer to Division 10.

Item	Section
Asphalt Binder, Grade PG 64-22	1020-2
Emulsified Asphalt, Grade CRS-1	1020-3
Emulsified Asphalt, Grade CRS-1H	1020-3
Emulsified Asphalt, Grade CRS-2	1020-3
Emulsified Asphalt, Grade HFMS-1	1020-3
Emulsified Asphalt, Grade RS-1H	1020-3

Do not dilute or mix the tack coat material with water, solvents or other materials before application.

Unless otherwise specified in the contract, use any of the grades of tack coat material specified in this article.

For tack coat beneath an open-graded asphalt friction course, the asphalt grade and rate of application to be used on the project will be specified in accordance with Section 650-5.

605-3 WEATHER LIMITATIONS

Apply tack coat only when the surface to be treated is dry and when the atmospheric temperature in the shade away from artificial heat is 35°F or above.

Do not apply tack coat when the weather is foggy or rainy.

605-4 SURFACE PREPARATION

Ensure that the existing asphalt or concrete surface is free of all dust and foreign material before applying the tack coat.

Remove grass, dirt and other materials from the edge of the existing pavement before the placement of tack coat.

605-5 ACCEPTANCE OF ASPHALT MATERIALS

The acceptance of asphalt materials will be in accordance with Article 1020-1.

605-6 APPLICATION EQUIPMENT

Provide equipment for heating and uniformly applying the asphalt material in accordance with Article 600-5.

605-7 APPLICATION RATES AND TEMPERATURES

Apply tack coat uniformly at a rate from 0.04 to 0.08 gal/sy. The exact rate for each application will be established by the Engineer. A different rate of application for different layers or surfaces may be established.

The established rates of application will be based on the volume of material at the actual application temperature. Apply tack coat at a temperature within the ranges shown in Table 605-1.

TABLE 605-1
APPLICATION TEMPERATURE FOR TACK COAT

Asphalt Material	Temperature Range
Asphalt Binder, Grade PG 64-22	350 - 400°F
Emulsified Asphalt, Grade RS-1H	90 - 150°F
Emulsified Asphalt, Grade CRS-1	90 - 150°F
Emulsified Asphalt, Grade CRS-1H	90 - 150°F
Emulsified Asphalt, Grade HFMS-1	90 - 160°F
Emulsified Asphalt, Grade CRS-2	125 - 185°F

605-8 APPLICATION OF TACK COAT

Apply only as much tack coat material as can be covered with base, intermediate or surface course material during the next day's operation except where public traffic is being maintained.

If public traffic is being maintained, cover the tack coat in the same day's operation. Provide safe traffic conditions. If needed, apply suitable granular material so it bonds to the tack coat. In addition, the Engineer may limit the application of tack coat in advance of the paving operation depending on traffic conditions, project location, proximity to business or residential areas or other reasons.

Take necessary precautions to limit the tracking or accumulation of tack coat on either existing or newly constructed pavements. Excessive accumulation of tack coat requires corrective measures.

Apply tack coat with a distributor spray bar that can be adjusted to uniformly coat the entire surface at the directed rate. Use a hand hose attachment only on irregular areas and areas inaccessible to the spray bar. Cover these areas uniformly and completely.

Apply tack coat as directed by and in the presence of the Engineer. Do not place any asphalt mixture until the tack coat has sufficiently cured.

Apply tack coat to all exposed transverse and longitudinal edges of each course before mixture is placed adjacent to such surfaces. Apply tack coat to contact surfaces of headers, curbs, gutters, manholes and vertical faces of old pavements.

Cover bridge floors, curbs and handrails of structures and all other appurtenances to protect them from tracking or splattering tack coat material.

605-9 PROTECTION OF TACK COAT

After the tack coat has been applied, protect it until it has cured for a sufficient length of time to prevent it from being picked up by traffic.

605-10 MEASUREMENT AND PAYMENT

There will be no direct payment for the work covered by this section.

Payment at the contract unit prices for the various mix items covered by Sections 610, 650 and 654 will be full compensation for all work covered by this section.

SECTION 607
MILLING ASPHALT PAVEMENT

607-1 DESCRIPTION

Perform the work covered by this section including, but not limited to, milling and re-milling the pavement at locations, depths, widths and typical sections indicated in the contract; cleaning the milled surface; loading, hauling and stockpiling the milled material for use in recycled asphalt mixtures; and disposal of any excess milled material.

Except where the milled material is used in the work or where otherwise directed, provide areas outside the right of way to dispose of milled material, which shall be property of the Contractor.

607-2 EQUIPMENT

Use a self-propelled unit capable of removing the existing asphalt pavement to the depths, widths and typical sections shown in the contract. Use milling machines designed and built exclusively for pavement milling operations and with sufficient power, traction and stability to accurately maintain depth of cut and slope. Use milling machines equipped with an electronic control system that will automatically control the longitudinal profile and cross slope of the milled pavement surface. Accomplish this through the use of a mobile grade reference, an erected string line, joint matching shoe, slope control systems or a combination of approved methods. Use an erected fixed stringline when required by the contract. Otherwise, use a mobile grade reference system capable of averaging the existing grade or pavement profile over at least 30 ft. Use either a non-contacting laser or sonar type ski systems with at least 4 referencing stations mounted on the milling machine at a length of at least 24 ft. Coordinate the position of the grade control system such that the grade sensor is at the approximate midpoint of the mobile reference system. Use a machine capable of leaving a uniform surface suitable for handling traffic without damage to the underlying pavement structure. Use a milling machine and other loading equipment capable of loading milled material to be used in other parts of the work without segregation.

Provide additional equipment necessary to satisfactorily remove the pavement in the area of manholes, water valves, curb, gutter and other obstructions.

Equip the milling equipment with a means of effectively limiting the amount of dust escaping from the removal operation in accordance with Federal, State and local air pollution control laws and regulations.

607-3 CONSTRUCTION METHODS

Mill the existing pavement to restore the pavement surface to a uniform longitudinal profile and cross section in accordance with typical sections shown in the plans. Where indicated in the contract, remove pavement to a specified depth and produce a specified cross slope. Mill intersections and other irregular areas unless otherwise directed by the Engineer.

The Contractor may elect to make multiple cuts to achieve the required depth of cut or cross slope required by the plans.

Establish the longitudinal profile of the milled surface by a mobile string line on the side of the cut nearest the centerline of the road. Establish the cross slope of the milled surface by an automatic cross slope control mechanism or by a second skid sensing device located on the opposite edge of the cut. The Engineer may waive the requirement for automatic grade and cross slope controls where conditions warrant.

Operate the milling equipment so as to prevent damage to the underlying pavement structure, utilities, drainage facilities, curb and gutter, paved surfaces outside the milled area and any other appurtenances. Produce milled pavement surfaces that are reasonably smooth and free of excessive scarification marks, gouges, ridges, continuous grooves or other damage. Repair any leveling or patching required as a result of negligence by the Contractor with hot asphalt plant mix in a manner acceptable to the Engineer. Coordinate the adjustment of manholes, meter boxes and valve boxes with the milling operation in accordance with Article 858-3 including a temporary asphalt ramp.

When necessary, the contractor may remove the top section of a utility and use a bridge steel plate placed to cover the entire width of the structure, ensuring no debris is dropped inside the structure. Backfill with compacted material and hot mix asphalt as a temporary riding surface as well as any further necessary requirements of the utility owner. This steel plate must be capable of carrying any traffic load carried by the facility. Where necessary, double-reference the location of each structure that has been removed and maintain a map of their location. Construct a temporary ramp of asphalt plant mix to extend a minimum of 3 ft around raised structures before opening to traffic.

The Engineer may require re-milling of any area exhibiting laminations or other defects. Thoroughly clean the milled pavement surface of all loose aggregate particles, dust and other objectionable material. Disposing or wasting of oversize pieces of pavement or loose aggregate material will not be permitted within the right of way.

Conduct pavement removal operations so as to effectively minimize the amount of dust being emitted. Plan and conduct the operation so it is safe for persons and property adjacent to the work including the traveling public.

607-4 TOLERANCE

Remove the existing pavement to the depth required by the contract. The Engineer may vary the depth of milling.

607-5 MEASUREMENT AND PAYMENT

(A) Milled Asphalt Pavement

Milled Asphalt Pavement, __" Depth and *Milling Asphalt Pavement, __" to __"* to be paid will be the actual number of square yards of pavement surface milled in accordance with this Specification. In measuring this quantity, the length will be the actual length milled, measured along the pavement surface. The width will be the width required by the plans or directed, measured along the pavement surface.

(B) Milled Asphalt Pavement Depth Varies from Required Depth

Where the depth of milling varies from the required depth, no adjustment in the contract unit price for *Milling Asphalt Pavement, __" Depth* and *Milling Asphalt Pavement, __" to __"* will be made, except if the Engineer directs the depth of milling per cut to be altered by more than 1". In this case, either the Department or the Contractor may request an adjustment in unit price in accordance with Article 104-3. In administering Article 104-3, the Department will give no consideration to value given to RAP due to the deletion or reduction in quantity of milling. Article 104-3 will not apply to the item of *Incidental Milling*.

For each square yard that the Engineer directs to be milled, including, but not limited to, the mainline, turn lanes, bus loading and unloading areas, widening for bus or truck U-turns, shoulders, intersections and crossovers requiring any additional equipment necessary to remove pavement in the area of manholes, water valves, curb, gutter and other obstructions, compensation will be made at the contract unit price per square yard for *Milling Asphalt Pavement, __" Depth* or *Milling Asphalt Pavement, __" to __"*.

(C) Incidental Milling

Where the Contractor is required to re-mill areas that are not due to the Contractor's negligence and whose length is less than 100 ft or butt joints that are not a portion of the milling areas outlined in Subarticle 607-5(B), measurement will be made as provided in Subarticle 607-5(A) for each cut he is directed to perform. Where the Contractor elects to make multiple cuts to achieve the final depth, no additional measurement will be made. Compensation will be made at the contract unit price per square yard for *Incidental Milling.*

(D) Milling of Defects

If defects are determined to be the result of the Contractor's negligence, then measurement for the re-milling or repairs will not be made. If the Engineer directs re-milling of an area that is equal to or greater than 100 ft and is not due to the Contractor's negligence, the re-milled area will be measured as provided in Subarticle 607-5(A) and paid at the contract unit price per square yard for *Milled Asphalt Pavement, __" Depth* or *Milling Asphalt Pavement, __" to __"*.

Payment will be made under:

Pay Item	Pay Unit
Milling Asphalt Pavement, __" to __"	Square Yard
Milling Asphalt Pavement, __" Depth	Square Yard
Incidental Milling	Square Yard

SECTION 609
QUALITY MANAGEMENT SYSTEM FOR ASPHALT PAVEMENTS

609-1 DESCRIPTION

Produce and construct asphalt mixtures and pavements in accordance with a quality management system as described herein. Apply these *Standard Specifications* to all materials and work performed in accordance with Division 6. Perform all QC activities in accordance with the Department's *Hot Mix Asphalt Quality Management System (HMA/QMS) Manual* in effect on the date of contract advertisement, unless otherwise approved.

(A) Quality Control (QC)

Define a "quality control (QC) program" as all activities, including mix design, process control, plant and equipment calibration, sampling and testing and necessary adjustments in the process that are related to production of a pavement that meet the *Standard Specifications*. Provide and conduct a QC program in accordance with this section.

(B) Quality Assurance (QA)

Define a "quality assurance (QA) program" as all activities, including inspection, sampling and testing related to determining that the quality of the completed pavement conforms to specification requirements. The Department will conduct a QA program in accordance with Article 609-10.

609-2 MIX DESIGN/JOB MIX FORMULA REQUIREMENTS

Apply all requirements of Article 610-3.

609-3 FIELD VERIFICATION OF MIXTURE AND JOB MIX FORMULA ADJUSTMENTS

Conduct field verification of the mix at each plant within 30 calendar days before initial production of each mix design, when required by the Allowable Mix Adjustment Policy and when directed as deemed necessary.

Field verification testing consists of performing a minimum of one full test series on mix sampled and tested in accordance with Subarticle 609-6(B). When producing warm mix asphalt (WMA), field verification testing will include performing a tensile strength ratio (TSR) testing in accordance with AASHTO T 283 as modified by the Department. Mix obtained from Department or non-Department work may be used for this purpose provided it is sampled, tested and the test data handled in accordance with the *HMA/QMS Manual* and this article.

Obtain the mix verification sample and split in accordance with procedures in the *HMA/QMS Manual.* Do not begin normal plant production until all field verification test results have been completed and the mix has been satisfactorily verified by the Contractor's Level II technician. Verification is satisfactory for HMA when all volumetric properties except percent maximum specific gravity at initial number of gyrations ($\%G_{mm}@N_{ini}$) are within the applicable mix design criteria, and the gradation, binder content and $\%G_{mm}@N_{ini}$ are within the individual limits for the mix type being produced. Verification is satisfactory for WMA when all volumetric properties except $\%G_{mm}@N_{ini}$ are within the applicable mix design criteria, the TSR is equal to or above the minimum design criteria, and the gradation, binder content and $\%G_{mm}@N_{ini}$ are within the individual limits for the mix type being produced.

In addition to the required sampling and testing for field verification, perform all preliminary inspections and plant calibrations as outlined in the *HMA/QMS Manual*. Retain records of these calibrations and mix verification tests, including superpave gyratory compactor printouts, at the QC laboratory. Furnish copies, including superpave gyratory compactor printouts, to the Engineer for review and approval within one working day after beginning production of the mix.

Conduct the initial mix verification of all new mix designs with the plant set up to produce the aggregate blend and binder content in accordance with the initially approved JMF. If the Contractor or the Engineer determines from results of QC tests conducted during mix verification that adjustments to the JMF are necessary to achieve specified mix properties, adjustments to the JMF may be made within tolerances permitted by the *Standard Specifications* for the mix type being produced, subject to approval. No reduction of asphalt binder content will be made when the average production VMA computes below the minimum specification requirement. Obtain written approval by the Engineer for all JMF adjustments.

Failure by the Contractor to fully comply with the above mix verification requirements will result in immediate production stoppage by the Engineer. Do not resume normal production until all mix verification sampling, testing, calibrations and plant inspections have been performed and approved.

609-4 CONTRACTOR'S QUALITY CONTROL PERSONNEL REQUIREMENTS

Obtain all certifications in accordance with the Department's QMS Asphalt Technician Certification Program as outlined in the *HMA/QMS Manual*. Perform all sampling, testing, data analysis and data posting by or under the direct supervision of a certified QMS asphalt plant technician.

Provide a certified asphalt plant technician Level I to perform QC operations and activities at each plant site at all times during production of material for the project. A plant operator who is a certified asphalt plant technician Level I may be used to meet this requirement when daily production for each mix design is less than 100 tons provided the randomly scheduled increment sample as defined in Subarticle 609-6(B) is not within that tonnage. When performing in this capacity, the plant operator will be responsible for all QC activities that are necessary and required. Absences of the Level I technician, other than those for normal breaks and emergencies shall be pre-approved by the appropriate QA supervisor or his designated representative. Any extended absence of the technician that has not been approved will result in immediate suspension of production by the Engineer. All mix produced during this absence will be accepted in accordance with Article 105-3.

Provide and have readily available a certified asphalt plant technician Level II to supervise, coordinate and make any necessary adjustments in the mix QC process in a timely manner. The Level II technician may serve in a dual capacity and fulfill the Level I technician requirements specified above.

Provide a certified QMS roadway technician with each paving operation at all times during placement of asphalt. This person is responsible for monitoring all roadway paving operations and all QC processes and activities, to include stopping production or implementing corrective measures when warranted. Provide a certified density gauge operator when density control is being used.

Post in the QC laboratory an organizational chart, including names, telephone numbers and current certification numbers of all personnel responsible for the QC program while asphalt paving work is in progress.

609-5 CONTRACTOR'S QUALITY CONTROL FIELD LABORATORY REQUIREMENTS

For a contract with 5,000 or more total tons of asphalt mix, furnish and maintain a Department certified laboratory at the plant site. A minimum of 320 sf of floor space exclusive of toilet facilities, equipment and supplies necessary for performing Contractor QC testing is required. Provide convenient telephone and fax machine access for QMS personnel at the plant site.

For a contract with less than 5,000 total tons of asphalt mix, the QC testing may be conducted in a Department certified off-site laboratory meeting the requirements herein.

Provide testing equipment required in the test methods in Subarticle 609-6(B). Provide equipment that is properly calibrated and maintained. Allow all measuring and testing devices to be inspected to confirm both calibration and condition. If at any time the Engineer determines that the equipment is not operating properly or is not within the limits of dimensions or calibration described in the applicable test method, the Engineer may stop production until corrective action is taken. Maintain and have available a record of all calibration results at the laboratory.

609-6 PLANT MIX QUALITY CONTROL

(A) General

Include in the QC process the preliminary inspections, plant calibrations and field verification of the mix and JMF in accordance with Article 609-4. Conduct at a minimum the sampling, testing and determination of all parameters outlined in these *Standard Specifications* using test methods and minimum frequencies as specified. Perform additional sampling and testing when conditions dictate. Obtain all scheduled samples at randomly selected locations in accordance with the *HMA/QMS Manual*. Log all samples taken on forms provided by the Department. Split and retain all samples taken in accordance with the *HMA/QMS Manual*. Provide documentation as required in Subarticle 609-8. Identify any additional QC samples taken and tested on the appropriate forms. Process control test results shall not be plotted on control charts nor reported to the QA Laboratory.

Retain the untested split portion of QC aggregate and mix samples and the tested TSR specimens for 5 calendar days at the plant site, commencing the day the samples are tested. Retain the QC compacted volumetric test specimens for 5 calendar days, commencing the day the specimens are prepared. Permission for disposal may be given by QA personnel before these minimum storage periods. Retain the split portion of the Contractor’s mix verification and referee mix samples until either procured by QA personnel or permission for disposal is given by QA personnel. Store all retained samples in a dry and protected location.

(B) Required Sampling and Testing Frequencies

Maintain minimum test frequencies as established in the schedule below. Complete all tests within 24 hours of the time the sample is taken, unless specified otherwise within these provisions. If the specified tests will not be completed within the required time frame, cease production at that point until such time the tests are completed.

If the Contractor’s testing frequency fails to meet the minimum frequency requirements as specified, all mix without the specified test representation will be unsatisfactory. The Engineer will evaluate if the mix may remain in place in accordance with Article 105-3.

If desired, innovative equipment or techniques not addressed by these *Standard Specifications* to produce or monitor the production of mix may be used, subject to approval.

Sample and test the completed mixture from each JMF at the following minimum frequency during mix production:

Accumulative Production Increment	Number of Samples per Increment
750 tons	1

If production is discontinued or interrupted before the accumulative production increment tonnage is completed, continue the increment on the next production day(s) until the increment tonnage is completed. Obtain a random sample within the specified increment at the location determined in accordance with the *HMA/QMS Manual*. Conduct QC testing on each random sample in accordance with Section 7.3 of the *HMA/QMS Manual*. When daily production of each mix design exceeds 100 tons and a regularly scheduled full test series on a sample from a random sample location for that JMF does not occur during that day’s production, perform at least one partial test series in

accordance with Section 7.3 of the *HMA/QMS Manual*. These partial test series and associated tests do not substitute for the regularly scheduled random sample for that increment.

(C) Control Charts

Maintain standardized control charts furnished by the Department at the field laboratory. For mix incorporated into the project, record full test series data from all regularly scheduled random samples or directed samples that replace regularly scheduled random samples, on control charts the same day the test results are obtained.

In addition, partial test series results obtained due to reasons outlined in Subarticle 609-6(B) will be reported to QA personnel on the proper forms, but will not be plotted on the control charts.

Results of QA tests performed by the Engineer will be posted on the Contractor's control charts as data becomes available.

Record QC sample data on the standardized control charts in accordance with Section 7.4 of the *HMA/QMS Manual*.

Both the full test series individual test values and the moving average of the last 4 data points will be plotted on each chart. The Contractor's test data will be shown in black and the moving average in red. The Engineer's assurance data will be plotted in blue. Denote the moving average control limits with a dash green line and the individual test limits with a dash red line.

Maintain a continuous moving average with the following exceptions.

Re-establish a new moving average only when:

(1) A change in the binder percentage, aggregate blend or G_{mm} is made on the JMF, or

(2) When the Contractor elects to stop or is required to stop production after one or two moving average values, respectively, fall outside the moving average limits as outlined in Subarticle 609-6(E), or

(3) If failure to stop production after 2 consecutive moving averages exceed the moving average limits occurs, but production does stop at a subsequent time, re-establish a new moving average beginning at the actual production stop point.

In addition, re-establish the moving averages for all mix properties. Moving averages will not be re-established when production stoppage occurs due to an individual test result exceeding the individual test limits or the *Standard Specifications*.

All individual test results for regularly scheduled random samples or directed samples that replace regularly scheduled samples are part of the plant QC record and shall be included in moving average calculations with the following exception.
When the Contractor's testing data has been proven incorrect, use the correct data as determined by the Engineer instead of the Contractor's data to determine the appropriate pay factor in accordance with Subarticle 609-6(E). In this case, replace the data in question and any related data proven incorrect.

(D) Control Limits

Establish control limits for mix production in accordance with Table 609-1. Control limits for the moving average limits are based on a moving average of the last 4 data points. Apply all control limits to the applicable target source.

TABLE 609-1
CONTROL LIMITS

Mix Control Criteria	Target Source	Moving Average Limit	Individual Limit
2.36 mm Sieve	JMF	± 4.0%	± 8.0%
0.075 mm Sieve	JMF	± 1.5%	± 2.5%
Binder Content	JMF	± 0.3%	± 0.7%
VTM @ N_{des}	JMF	± 1.0%	± 2.0%
VMA @ N_{des}	Min. Spec. Limit	Min. Spec. Limit	- 1.0%
$P_{0.075}$/ P_{be} Ratio	Max. Spec. Limit	± 0.4 %	± 0.8%
% G_{mm} @ N_{ini}	Max. Spec. Limit	-	+ 2.0%
TSR	Min. Spec. Limit	-	- 15%

(E) Corrective Actions

All required corrective actions are based upon initial test results and shall be taken immediately upon obtaining those results. If more than one corrective action or adjustment applies, give precedence to the more severe of these

actions. Stopping production when required takes precedence over all other corrective actions. Document all corrective actions.

If the process adjustment improves the property in question such that the moving average after 4 additional tests is on or within the moving average limits, the Contractor may continue production.

When any of the following occur, production of a mix shall cease immediately:

(1) An individual test result for a mix control criteria (including results for required partial test series on mix) exceeds both the individual test control limits and the applicable specification design criteria, or

(2) Two consecutive field TSR values fail to meet the minimum specification requirement, or

(3) Two consecutive binder content test results exceed the individual limits, or

(4) Two consecutive moving average values for any one of the mix control criteria fall outside the moving average limits.

Do not resume normal plant production until one of the following has occurred.

Option 1: Approval has been granted by the appropriate QA supervisor.

Option 2: The mix in question has been satisfactorily verified in accordance with Article 609-3. Normal production may resume based on the approval of the contractor's Level II technician, provided notification and the verification test results have been furnished to the QA Laboratory.

Failure to fully comply with any of the above corrective actions will result in immediate production stoppage by the Engineer. Normal production shall not resume until a complete verification process has been performed and approved by the Engineer.

Failure to stop production when required will make all mix unacceptable from the stop point tonnage to the point when Option 1 or Option 2 occurs or to the tonnage point when production is actually stopped, whichever occurs first.

In any case, remove and replace this mix with materials that comply with the *Standard Specifications*, unless otherwise approved. The Engineer will evaluate acceptance of the mix in question based on Articles 105-3 and 609-11.

Immediately notify the Engineer when any moving average value exceeds the moving average limit. If 2 consecutive moving average values for any one of the mix control criteria fall outside the moving average limits, immediately notify the Engineer of the stoppage and make adjustments. The Contractor may elect to stop production after only one moving average value falls outside the moving average limits. In either case, do not determine a new moving average until the fourth test after the elective or mandatory stop in production.

(F) Allowable Retesting for Mix Deficiencies

The Contractor may elect to resample and retest for plant mix deficiencies when individual QC test(s) exceed one or more mix property target(s) by more than the tolerances indicated below. Perform the retesting within 10 days after initial test results are determined. Retesting shall be approved before being performed and in accordance with the *HMA/QMS Manual*. The Contractor, under the supervision of the Department's QA personnel, will perform these retests. Retests for any mix deficiency other than as listed below will not be allowed, unless otherwise permitted. Acceptance of the mix in question will be based on the retest data in accordance with Article 105-3.

The Department reserves the right to require the Contractor to resample and retest at any time or location as directed.

TABLE 609-2
RETEST LIMITS FOR MIX DEFICIENCIES

Property	Limit
VTM	by more than ± 2.5%
VMA	by more than ± 2.0%
% Binder Content	by more than ± 1.0%
0.075 mm sieve	by more than ± 3.0%
2.36 mm sieve	exceeds both the Specification mix design limits and one or more of the above tolerances
TSR	by more than - 15% from Specification limit

609-7 FIELD COMPACTION QUALITY CONTROL

(A) General

Perform QC of the compaction process in accordance with these provisions and applicable requirements of Article 610-10. The Contractor may elect to use either cored sample density procedures or density gauge procedures. Provide to the Department at the pre-construction conference the method of density QC that will be used on the project.

Establish acceptable control strips when required at locations approved by the Engineer. Construct control strips that are 300 ft in length at the paver laydown width being placed. When using core sample control, place control strips anytime placement is proceeding on limited production due to failing densities. When using density gauge control, place control strips at the minimum frequencies specified in the Department's *Density Gauge Operator's Manual*. In addition, place control strips anytime deemed necessary by the Engineer.

Conduct density sampling and testing by either method based on test sections consisting of not more than 2,000 lf or fraction thereof per day on pavement placed at the paver laydown width. Perform density sampling and testing on all pavements as outlined in Section 10.4 of the *HMA/QMS Manual* unless otherwise approved.

Perform the sampling and testing at the minimum test frequencies as specified above. If the density testing frequency fails to meet the minimum frequency as specified above, all mix without the required density test representation will be unsatisfactory. The Engineer will evaluate if the mix may remain in place in accordance with Article 105-3.

Conduct all QC density gauge testing the same day that the mix being tested is placed and compacted. Obtain all core samples no later than the beginning of the next production day, not to exceed 3 calendar days. Test QC core samples and submit test results within one working day of the time the samples are taken. If the specified density tests will not be completed within the allowable time, cease production at that point until such time the required tests are completed. Failure to provide samples may result in suspension of all project operations.

Retain QC density core samples at the plant site for 5 calendar days, commencing the day the samples are tested, or until permission for disposal is granted by the QA personnel, whichever occurs first. Retain the Department's QA comparison and verification core samples in a sealed container at the plant site until obtained by QA personnel. Store all retained density samples on a smooth, flat surface in a cool, dry and protected location.

Check core samples may be taken by the Contractor for any of the following reasons:

(1) When core sample control is being used and a test section core sample(s) is more than 2.0% below the average of all core samples from the same lot, that core(s) samples may be checked,

(2) When a control strip fails and a core sample(s) is more than 2.0% below the average of the control strip, that core(s) may be checked.

For each core sample that is to be checked, take 3 check samples as follows: one adjacent to the initial sample and one 10 ft in each direction, longitudinally, from the initial sample. The results of these 3 check samples will be averaged, and this average will be used instead of the initial core results in question. The initial core sample results will not be used if check samples are taken.

Check samples shall be taken within 2 calendar days of the date of the initial sample. Only one set of check samples per sample location will be allowed. If full depth cores are necessary at these check sample locations, separation of the layer to be tested will be the responsibility of the Contractor. Take all check samples in the presence of a representative of the Engineer. In addition, a QA comparison core sample(s) may be taken adjacent to one or more of these check samples.

(B) Pavement Samples (Cores)

When cored samples are required by either density method, obtain cores from the full layer depth of the compacted pavement at random locations determined in accordance with procedures in the *HMA/QMS Manual*. If full depth cores are taken, the Contractor is responsible for separating the layer of mix to be tested so it is not damaged. The use of a separator medium beneath the layer to be tested is prohibited.

Obtain core samples and repair the existing pavement as outlined in Section 10.4 of the *HMA/QMS Manual*.

(C) Core Sample Density Procedures

In addition to the above requirements, perform core sample density control procedures as noted herein. When cored sample control is being used, the testing frequency will be a minimum of one random 6" core sample taken from each test section, except take a minimum of at least 3 core samples from each mix type and/or lot placed on a given day.

An initial control strip is not required at the beginning of placement of each JMF but may be performed by the Contractor for use in determining the necessary compactive effort and roller patterns. Cored sample control strips will be required if production and placement is being performed under limited production procedures due to failing densities.

(D) Density Gauge Procedures

In addition to the requirements in Subarticle 609-7(A) perform density gauge control procedures in accordance with the *Density Gauge Operator's Manual*. This manual may be obtained through the Materials and Tests Soils Laboratory. Furnish an operator certified by the Department.

Provide a gauge calibrated within the previous 12 months by an approved calibration service. Maintain documentation of such calibration service for a 12 month period.

(E) Limited Production Procedures

Define "resurfacing" as the first new uniform layer placed on an existing pavement. Proceed on limited production when, for the same mix type and on the same contract, one of the following conditions occur (except as noted below).

(1) Two consecutive failing lots, except on resurfacing,

(2) Three consecutive failing lots on resurfacing, or

(3) Two consecutive failing density gauge control strips.

As exceptions to the above, pavement within each construction category (New and Other), as defined in Article 610-13, and pavement placed simultaneously by multiple paving crews will be evaluated independently for limited production purposes.

Limited production is defined as being restricted to the production, placement and compaction of a sufficient quantity of mix necessary to construct only a 300 ft control strip plus 100 ft of pavement adjacent to each end of the control strip.

Remain on limited production until such time as satisfactory density results are achieved or until 2 control strips have been attempted without achieving acceptable density test results. If the Contractor fails to achieve satisfactory density after 2 control strips have been attempted, cease production of that mix type until such time as the cause of the failing density test results can be determined. As an exception, the Engineer may grant approval to produce a different mix design of the same mix type if the cause is related to mix problem(s) rather than compaction related problems.

If the Contractor does not operate by the limited production procedures when conditions as specified in Subarticles 609-7(E)(1) to 609-7(E)(3) occur, all mix produced thereafter will be unacceptable. Remove this material and replace with material that complies with the *Standard Specifications*, unless otherwise approved.

609-8 CONTRACTOR QUALITY CONTROL DOCUMENTATION (RECORDS)

Document all QC activities, records of inspection, samples taken, adjustments to the mix and test results on a daily basis. Note the results of observations and records of inspection as they occur in a permanent field record. Record adjustment to mix production and test results on forms provided. Process control sample test results are for the Contractor's informational purposes only.

Make all such records available to the Engineer, upon request, at any time during project construction. Complete and maintain all QC records and forms and distribute in accordance with the *HMA/QMS Manual*. Submit data electronically using the Department's software. Failure to maintain QC records and forms as required, or to provide these records and forms to the Engineer upon request, may result in production stoppage, placement stoppage, removal from the NCDOT Certified Asphalt Laboratory List and removal from the NCDOT Certified Asphalt Plant List until the problem is resolved.

Falsification of test results, documentation of observations, records of inspection, adjustments to the process, discarding of samples and/or test results or any other deliberate misrepresentation of the facts will result in the revocation of the applicable person's QMS certification. The Engineer will determine acceptability of the mix and/or pavement represented by the falsified results or documentation. If the mix and/or pavement in question is determined to be acceptable, the Engineer may allow the mix to remain in place at no pay for the mix, asphalt binder and other mix components. If the mix or pavement represented by the falsified results is determined not to be acceptable, remove and replace with mix, that complies with the *Standard Specifications*.

609-9 QUALITY ASSURANCE

The Department's QA program will be conducted by a certified QMS technician(s) and will be accomplished in the following ways:

(A) Plant Mix Quality Assurance

(1) By conducting assurance testing of split samples obtained by the Contractor at a frequency equal to or greater than 5% of the frequency required of the Contractor;

(2) By periodically observing sampling and testing procedures performed by the Contractor;

(3) By monitoring required control charts exhibiting test results of control parameters;

(4) By directing the Contractor to take additional samples at any time and any location during production (instead of the next scheduled random sample for that increment);

(5) By conducting verification sampling and testing on samples taken independently of the Contractor's QC samples; at a frequency equal to or greater than 10% of the QC sample frequency; or

(6) By any combination of the above.

The Engineer will periodically obtain QA and verification mix samples for testing independently of the Contractor's QC process. The Engineer will conduct assurance tests on both split QC samples taken by the Contractor and verification samples taken by the Department. These samples may be the regular QC samples, a sample selected by the Engineer from any location in the process or verification samples taken at random by the Department. The Engineer may select any or all split samples for assurance testing.

(B) Density Quality Assurance

(1) By retesting randomly selected QC test sections (either cores or gauge) at a frequency equal to or greater than 5% of the frequency required of the Contractor.

(2) By periodically observing tests performed by the Contractor;

(3) By testing randomly selected comparison core samples taken adjacent to the Contractor's QC core samples (8" center-to-center) at a frequency equal to or greater than 5% of the frequency required of the Contractor; and

(4) By conducting verification sampling and testing on test sections (either core or gauge) independently of the Contractor's QC test sections at a frequency equal to or greater than 10% of the QC sample frequency.

(5) By periodically directing the recalculation of random locations for the QC core or density gauge test sites. The original QC test locations may be tested by QA personnel and evaluated as verification tests.

(6) By retesting QC core samples from control strips (either core or gauge) at a frequency of 100% of the frequency required of the Contractor;

(7) By observing the Contractor perform all standard counts of the QC gauge before usage each density testing day; or

(8) By any combination of the above.

Comparison and verification core samples will be taken in the presence of a Department technician, and either delivered directly to the appropriate QA Laboratory by a Department technician or placed in a sealed container and delivered to the Contractor's QC Laboratory for QA personnel to obtain.

Results of QA tests for plant mix and density will be provided to the Contractor within 3 working days after the sample has been obtained, except for verification TSR test results that will be provided within 7 calendar days.

(C) Limits of Precision

Differences between the Contractor's and the Department's split sample test results will be acceptable if within the limits of precision in Table 609-3.

TABLE 609-3
LIMITS OF PRECISION FOR TEST RESULTS

Mix Property	Limits of Precision
25.0 mm sieve (Base Mix)	± 10.0%
19.0 mm sieve (Base Mix)	± 10.0%
12.5 mm sieve (Intermediate Mix)	± 6.0%
9.5 mm sieve (Surface Mix)	± 5.0%
4.75 mm sieve (Surface Mix)	± 5.0%
2.36 mm sieve (All Mixes)	± 5.0%
0.075 mm sieve (All Mixes)	± 2.0%
Asphalt Binder Content	± 0.5%
Maximum Specific Gravity (G_{mm})	± 0.020
Bulk Specific Gravity (G_{mb})	± 0.030
TSR	± 15.0%
QA retest of prepared QC Gyratory Compacted Volumetric Specimens	± 0.015
Retest of QC Core Sample	± 1.2% (% Compaction)
Comparison QA Core Sample	± 2.0% (% Compaction)
QA Verification Core Sample	± 2.0% (% Compaction)
Density Gauge Comparison of QC Test	± 2.0% (% Compaction)
QA Density Gauge Verification Test	± 2.0% (% Compaction)

The Engineer will immediately investigate the reason for differences if any of the following occur: QA test results of QC split sample does not meet above limits of precision, QA test results of QC split sample does not meet the individual test control limits or the specification requirements or QA verification sample test results exceed the allowable retesting tolerances.

If the potential for a pavement failure exist, the Engineer may suspend production, wholly or in part, in accordance with Article 108-7 while the investigation is in progress. The Engineer's investigation may include, but not be limited to joint testing of any remaining split samples, review and observation of the QC technician's sampling and testing procedures, evaluation and calibration of QC testing equipment, and comparison testing of other retained QC samples and additional density core samples.

If additional mix samples or core samples are necessary to resolve the difference, these samples will be taken as directed and tested jointly by the Contractor's QC personnel and the Department's QA personnel. If reasons for the difference cannot be determined, payment for the mix in question will be determined in accordance with Article 105-3. If the reason for the difference is determined to be an error or other discrepancy in the QC test results, the applicable QA test results or verification test results will be used to determine compliance with the applicable mix or density specification requirements.

The Engineer will periodically witness the sampling and testing being performed by the Contractor. If the Engineer observes that the sampling and QC tests are not being performed in accordance with the applicable test procedures, the Engineer may stop production until corrective action is taken. The Engineer will promptly notify the Contractor of observed deficiencies, both verbally and in writing. The Engineer will document all witnessed samples and tests.

609-10 ACCEPTANCE

Final acceptance of the asphalt pavement will be made by the Department in accordance with the following:

(A) Mix Acceptance

The Engineer will base final acceptance of the mix on the results of random testing made on split samples during the QA process and validation of the Contractor's QC process as outlined in Articles 609-6 and 609-7.

(B) Density Acceptance

The Department will evaluate the asphalt pavement for density compliance after the asphalt mix has been placed and compacted using the Contractor's QC test results, the Department's QA test results and by observation of the Contractor's density QC process as outlined in Articles 609-7 and 610-14.

609-11 MEASUREMENT AND PAYMENT

Any mix produced that is not verified may be assessed a price reduction at the Engineer's discretion in addition to any reduction in pay due to mix or density deficiencies.

Produce and construct all asphalt mixtures and pavements in accordance with these *Standard Specifications*. There will be no direct payment for work covered by this Specification. Payment at the contract unit prices for the various asphalt items will be full compensation for all work covered by these specifications.

If the mix or pavement represented by the falsified results is removed and replaced, payment will be made for the actual quantities of materials required to replace the falsified quantities, not to exceed the original amounts.

SECTION 610
ASPHALT CONCRETE PLANT MIX PAVEMENTS

610-1 DESCRIPTION

Perform the work covered by this section including, but not limited to, the construction of one or more courses of asphalt mixture placed on a prepared surface in accordance with these Specifications and in reasonably close conformity with the lines, grades, thickness and typical sections shown on the plans. This work includes producing, weighing, transporting, placing and compacting the plant mix; furnishing aggregate, asphalt binder, anti-strip additive and all other materials for the plant mix; furnishing and applying tack coat as specified; furnishing scales; maintaining the course until final acceptance of the project; making any repairs or corrections to the course that may become necessary; providing and conducting QC as specified in Section 609; and surface testing of the completed pavement. The design requirements for the various mix types are given in Section 610 for Superpave mix types, Section 650 for OGAFC, Section 652 for PADC and Section 661 for UTBWC.

Provide and conduct the QC and required testing for acceptance of the asphalt mixture in accordance with Section 609.

Define "warm mix asphalt (WMA)" as additives or processes that allow a reduction in the temperature at which asphalt mixtures are produced and placed. WMA is allowed for use at the Contractor's option when shown in the contract or as approved by the Engineer.

610-2 MATERIALS

Refer to Division 10.

Item	Section
Anti-Strip Additives	1012-1(G)
Asphalt Binder, Performance Grade	1020-2
Coarse Aggregate	1012-1(B)
Fine Aggregate	1012-1(C)
Mineral Filler	1012-1(D)
Reclaimed Asphalt Pavement (RAP)	1012-1(F)
Reclaimed Asphalt Shingles (RAS)	1012-1(E)
Silicone	1012-1(H)

Use only WMA additives or processes listed on the NCDOT Approved Product List maintained by the Materials and Tests Unit.

610-3 COMPOSITION OF MIXTURES (MIX DESIGN AND JOB MIX FORMULA)

(A) Mix Design-General

Prepare the asphalt mix design using a mixture of coarse and fine aggregate, asphalt binder, mineral filler and other additives when required. Size, uniformly grade and combine the several aggregate fractions in such proportions that the resulting mixture meets the grading and physical requirements of the Specifications for the specified mix type. Materials that will not produce a mixture within the design criteria required by the Specifications will be rejected, unless otherwise approved.

At least 10 days before start of asphalt mix production, submit, in writing and in electronic form, the mix design and proposed JMF targets for each required mix type and combination of aggregates to the Engineer for review and approval. Prepare the mix design using a Department certified mix design technician in an approved mix design laboratory and in accordance with the procedures outlined in Section 4.5 of the *HMA/QMS Manual.*

For the final surface layer of the specified mix type, use a mix design with an aggregate blend gradation above the maximum density line on the 2.36 mm and larger sieves.

Reclaimed Asphalt Pavement (RAP) or Reclaimed Asphalt Shingles (RAS) may be incorporated into asphalt plant mixes in accordance with Article 1012-1 and the following applicable requirements.

RAP may constitute up to 50% of the total material used in recycled mixtures, except for mix types S12.5D, S9.5D and mixtures containing RAS. RAS material may constitute up to 6% by weight of total mixture for any mix. When both RAP and RAS are used, do not use a combined percentage of RAS and RAP greater than 20% by weight of total mixture, unless otherwise approved. When the percent of binder contributed from RAS or a combination of RAS and RAP exceeds 20% but not more than 30% of the total binder in the completed mix, the virgin binder PG grade shall be one grade below (both high and low temperature grade) the binder grade specified in Table 610-3 for the mix type, unless otherwise approved. When the percent of binder contributed from RAS or a combination of RAS and RAP exceeds 30% of the total binder in the completed mix, the Engineer will establish and approve the virgin binder PG grade. Use approved methods to determine if any binder grade adjustments are necessary to achieve the performance grade for the specified mix type.

For type S12.5D and S9.5D mixes, the maximum percentage of reclaimed asphalt material is limited to 20% and shall be produced using virgin asphalt binder grade PG 76-22. For all other recycled mix types, the virgin binder PG grade shall be as specified in Table 610-4 for the specified mix type.

When the percentage of RAP is greater than 20% but not more than 30% of the total mixture, use RAP meeting the requirements for processed or fractionated RAP in accordance with Section 1012-1.

When the percentage of RAP is greater than 30% of the total mixture, use an approved stockpile of RAP in accordance with Subarticle 1012-1(C). Use approved test methods to determine if any binder grade adjustments are necessary to achieve the performance grade for the specified mix type. The Engineer will establish and approve the virgin asphalt binder grade to be used.

If a change in the source of RAP or RAS be made, a new mix design and JMF may be required in accordance with Article 1012-1. Samples of the completed recycled mixture may be taken by the Department on a random basis to determine the PG grading on the recovered asphalt binder in accordance with AASHTO M 320. If the grading is determined to be a value other than required for the specified mix type, the Engineer may require the Contractor to adjust any combination of the grade, the percentage of additional asphalt binder or the blend of reclaimed material to bring the grade to the specified value.

(B) Mix Design Criteria

Design and produce asphalt concrete mixtures that conform to the gradation requirements and design criteria in Table 610-2 and Table 610-3 for the mix type specified. The mix type designates the nominal maximum aggregate size and the design traffic level.

Surface mix designs will be tested by the Department for rutting susceptibility. Rut depth requirements for each surface mix type and traffic level are specified in Table 610-3. Mix designs that fail to meet these requirements will be unacceptable and shall be redesigned by the Contractor such that rut depths are acceptable.

Table 610-2 provides gradation control points to be adhered to in the development of the design aggregate structure for each mix type. Aggregate gradations shall be equal to or pass between the control points, unless approved in writing. Table 610-2 provides the mix design criteria for the various mix types.

Use an anti-strip additive in all Superpave asphalt mixes. It may be hydrated lime or a chemical additive or a combination of both as needed to meet the retained strength requirements as specified in Table 610-3. When a chemical additive is used, add at a rate of not less than 0.25% by weight of binder in the mix. When hydrated lime is used, add at a rate of not less than 1.0% by weight of the total dry aggregate.

When WMA is used, submit the mix design without including the WMA technology.

(C) Job Mix Formula (JMF)

Establish the JMF gradation target values within the design criteria specified for the particular type of asphalt mixture to be produced. Establish the JMF asphalt binder content at the percentage that will produce voids in total mix (VTM) at the midpoint of the specification design range for VTM, unless otherwise approved. The formula for each mixture will establish the following: blend percentage of each aggregate fraction, the percentage of reclaimed aggregate, if applicable, a single percentage of combined aggregate passing each required sieve size, the total percentage and grade of asphalt binder required for the mixture (by weight of total mixture), the percentage and grade of asphalt binder to be added to the mixture (for recycled mixtures), the percentage of chemical anti-strip additive to be added to the asphalt binder or percentage of hydrated lime to be added to the aggregate, the temperature at that the mixture is to be discharged from the plant, the required field density and other volumetric properties.

When WMA is used, document the additive or process used and recommended rate on the JMF submittal. Verify the JMF based on plant produced mixture from the trial batch.

The mixing temperature at the asphalt plant will be established on the JMF. Unless otherwise requested, refer to Table 610-1 to establish the JMF temperature.

TABLE 610-1
MIXING TEMPERATURE AT THE ASPHALT PLANT

Binder Grade	JMF Temperature
PG 64-22	300°F
PG 70-22	315°F
PG 76-22	335°F

When using RAP or RAS with a different binder than specified, use mixing and compaction temperatures in Table 610-1 based on the original binder grade for that mix type shown in Table 610-3.

When WMA is used, the Asphalt Design Engineer (after consultation with the Contractor) will set the mixing temperature at the plant within the allowable temperature range of 225°F to 275°F. When WMA is used in conjunction with RAS, the Asphalt Design Engineer will set the mixing temperature at 275°F.

Have on hand at the asphalt plant the approved mix design and JMF issued by the Department, before beginning the work.

The JMF for each mixture will remain in effect until modified in writing, provided the results of QMS tests performed in accordance with Section 609 on material currently being produced conform with specification requirements. When a change in sources of aggregate materials is to be made, a new mix design and JMF will be required before the new mixture is produced, unless otherwise approved. When a change in sources of RAP or RAS material is to be made, a new mix design and/or JMF may be required in accordance with Article 1012-1. When unsatisfactory results or other conditions make it necessary, the Engineer may revoke the existing JMF or establish a new JMF.

TABLE 610-2
SUPERPAVE AGGREGATE GRADATION CRITERIA
(Percent Passing Control Points)

Standard Sieves (mm)	Mix Type (Nominal Max. Aggregate Size)							
	9.5 mm[A]		12.5 mm[A]		19.0 mm		25.0 mm	
	Min	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
50.0	-	-	-	-	-	-	-	-
37.5	-	-	-	-	-	-	100	-
25.0	-	-	-	-	100	-	90.0	100
19.0	-	-	100	-	90.0	100	-	90.0
12.5	100	-	90.0	100	-	90.0	-	-
9.50	90.0	100	-	90.0	-	-	-	-
4.75	-	90.0	-	-	-	-	-	-
2.36	32.0[B]	67.0[B]	28.0	58.0	23.0	49.0	19.0	45.0
1.18	-	-	-	-	-	-	-	-
0.075	4.0	8.0	4.0	8.0	3.0	8.0	3.0	7.0

A. For the final surface layer of the specified mix type, use a mix design with an aggregate blend gradation above the maximum density line on the 2.36 mm and larger sieves.

B. For Type SF9.5A, the percent passing the 2.36 mm sieve shall be a minimum of 60% and a maximum of 70%.

TABLE 610-3
SUPERPAVE MIX DESIGN CRITERIA

Mix Type	Design ESALs[A] millions	Binder PG Grade[B]	Compaction Levels G_{mm} @		Max. Rut Depth (mm)	Volumetric Properties			
			N_{ini}	N_{des}		VMA % Min.	VTM %	VFA Min.-Max.	$\%G_{mm}$ @ N_{ini}
SF9.5A	< 0.3	64 - 22	6	50	11.5	16.0	3.0 - 5.0	70 - 80	≤ 91.5
S9.5B	0.3 - 3	64 - 22	7	65	9.5	15.5	3.0 - 5.0	65 - 80	≤ 90.5
S9.5C	3 - 30	70 - 22	7	75	6.5	15.5	3.0 - 5.0	65 - 78	≤ 90.5
S9.5D	> 30	76 - 22	8	100	4.5	15.5	3.0 - 5.0	65 - 78	≤ 90.0
S12.5C	3 - 30	70 - 22	7	75	6.5	14.5	3.0 - 5.0	65 - 78	≤ 90.5
S12.5D	> 30	76 - 22	8	100	4.5	14.5	3.0 - 5.0	65 - 78	≤ 90.0
I19.0B	< 3	64 - 22	7	65	-	13.5	3.0 - 5.0	65 - 78	≤ 90.5
I19.0C	3 - 30	64 - 22	7	75	-	13.5	3.0 - 5.0	65 - 78	≤ 90.0
I19.0D	> 30	70 - 22	8	100	-	13.5	3.0 - 5.0	65 - 78	≤ 90.0
B25.0B	< 3	64 - 22	7	65	-	12.5	3.0 - 5.0	65 - 78	≤ 90.5
B25.0C	> 3	64 - 22	7	75	-	12.5	3.0 - 5.0	65 - 78	≤ 90.0
	Design Parameter					**Design Criteria**			
All Mix Types	Dust to Binder Ratio ($P_{0.075}$ / P_{be})					0.6 - 1.4			
	Tensile Strength Ratio (TSR)					85% Min.[C,D]			

A. Based on 20 year design traffic.
B. Volumetric Properties based on specimens compacted to Ndes as modified by the Department.
C. TSR for Type B 25.0 and Type B 25.0C mixes is 80% minimum.
D. AASHTO T 283 Modified (No Freeze-Thaw cycle required).

TABLE 610-4
SUPERPAVE APPLICABLE VIRGIN ASPHALT GRADES

Mix Type	Percentage of RAP in Mix		
	Category 1[A]	Category 2[B]	Category 3[C]
	% RAP ≤ 20%	*21% ≤ % RAP ≤ 30%*	*% RAP > 30%*
All A and B Level Mixes, I19.0C, B25.0C	PG 64-22	PG 64-22	Established by Engineer
S9.5C, S12.5C, I19.0D	PG 70-22	PG 64-22	Established by Engineer
S9.5D and S12.5D	PG 76-22	-	-

A. Category 1 RAP has been processed to a maximum size of 2".
B. Category 2 RAP has been processed to a maximum size of 1" by either crushing and or screening to reduce variability in the gradations.
C. Category 3 RAP has been processed to a maximum size of 1", fractionating the RAP into 2 or more sized stockpiles.

610-4 WEATHER, TEMPERATURE AND SEASONAL LIMITATIONS FOR PRODUCING AND PLACING ASPHALT MIXTURES

Do not produce or place asphalt mixtures during rainy weather, when the subgrade or base course is frozen or when the moisture on the surface to be paved would prevent proper bond. Do not place asphalt material when the air temperature, measured in the shade away from artificial heat at the location of the paving operation and the road surface temperature in the shade is less than the temperatures shown in Table 610-5.

Do not place surface course material that is to be the final layer of pavement between December 15 and March 16 of the next year if it is 1" or greater in thickness or between November 15 and April 1 of the next year if it is less than 1" in thickness, unless otherwise approved. Do not place open-graded asphalt friction course between October 31 and April 1 of the next year, unless otherwise approved.

As an exception to the above, when in any day's operations the placement of a layer of asphalt base course material or intermediate material 2" or greater in thickness has started, it may continue until the temperature drops to 32°F.

Do not place plant mix base course or intermediate course that will not be covered with surface course during the same calendar year or within 15 days of placement if the plant mix is placed in January or February. Failure by the Contractor to cover the plant mix as required above will result in the Engineer notifying the Contractor in writing to cover the plant mix with a sand seal. Apply the sand seal in accordance with Section 660, except that Articles 660-3 and 660-11 will not apply. In the event the Contractor fails to apply the sand seal within 72 hours of receipt of such notice, the Engineer may proceed to have such work performed with Department forces and equipment.

TABLE 610-5 PLACEMENT TEMPERATURES FOR ASPHALT		
Asphalt Concrete Mix Type	**Minimum Air Temperature**	**Minimum Surface Temperature**
B25.0B, C	35°F	35°F
I19.0B, C, D	35°F	35°F
SF9.5A, S9.5B	40°F	50°F[A]
S9.5C, S12.5C	45°F	50°F
S9.5D, S12.5D	50°F	50°F

A. 35°F if surface is soil or aggregate base for secondary road construction.

610-5 ASPHALT MIXTURE PRODUCTION

(A) General

Use plants that are either of the batch mixing, continuous mixing or drum mixing type, and so designed, equipped and operated that the weighing, proportioning and mixing of the materials will result in a uniform and satisfactory asphalt mixture meeting these Specifications. All plants shall conform to requirements of Subarticle 610-5(B) for the preparation of asphalt mixtures. In addition, batch mixing and drum mixing plants shall conform to the specific requirements of Sections 6.5 and 6.6, respectively, of the *HMA/QMS Manual*.

Before production of the mix, stockpile aggregates for a sufficient period of time to facilitate the drainage of free moisture. Keep the different aggregate sizes separated until they have been delivered to the cold feeders. Keep the separate stockpiles readily accessible for sampling. When mineral filler is required in the mix, feed or weigh-in separately from the other aggregates.

Introduce the asphalt binder and other additives, when required, into the mixture at the amounts and percentages specified by the JMF. No working tolerance will be allowed. Introduce the dried and heated aggregates and mineral filler, when required, in amounts and at temperatures such that the mixture produced is within the production control limits of Subarticle 609-6(D). Provide a positive means of controlling mixing time to obtain complete and uniform coating of the aggregate particles and thorough distribution of the asphalt binder throughout the aggregate. Produce the mixture at the asphalt plant within ± 15°F of the temperature established on the JMF.

All asphalt plants shall be certified by the Department as meeting these *Standard Specifications*. Certification is effective from the date of issuance and is non-expiring subject to continued compliance. The Department will check the plant on an annual basis or as deemed necessary by the Engineer. Any plant that is relocated, modified or changes ownership shall be recertified before use.

Any completely automatically controlled asphalt plant that, due to the basic design of the plant, does not meet all these Specifications for conventional batch mixing, continuous mixing or drum mixing may be used on a project by project basis provided a uniformly consistent mix meeting all mix requirements can be produced and the plant has been approved in writing.

(B) Requirements for All Plants

(1) Equipment for Preparation of Asphalt Binder

Equip tanks for the supplying of asphalt binder to the plant to uniformly heat and hold the material at the required temperature before introduction into the mixer unit. Provide a circulating system for asphalt materials, that is capable of the proper mixing of additives. Provide a system with adequate pump or pumps to charge the mixing unit and unload asphalt material simultaneously. Include provisions for measuring and sampling plant supply tanks.

(2) Anti-Strip Additive Equipment

When chemical anti-strip additive is to be added to the asphalt binder at the asphalt plant instead of at the terminal, equip the plant with an in-line blending system capable of metering the additive within plus or minus 10% of the amount specified. Provide a thermostatically controlled heating system capable of heating and maintaining the additive tanks, contents and distribution system at the additive supplier's recommended temperature for the additive being used. Interlock the additive metering system with the asphalt binder control equipment so as to automatically vary the additive feed rate to maintain the required proportions. Provide a system that will automatically indicate in the plant control room the amount or rate of flow, when flow is occurring and when flow is obstructed or stops. Inject the additive into the asphalt binder feed line before introduction into the aggregate. Equip the feed line with an in-line blending device capable of thoroughly mixing the additive with the asphalt binder before mixing with the aggregate. Provide a metering system capable of being calibrated, checked and monitored for accuracy and amount of additive used.

Equip the system with an in-line totalizing flow meter capable of measuring the actual quantity in gallons of anti-strip additive that is injected into the asphalt binder being introduced into the aggregate. Provide a system that is capable of being easily read but not capable of being reset. Install the totalizer meter in the anti-strip feedline beyond the calibration bypass and as close to the actual point of additive introduction into the feedline as practical.

When hydrated lime anti-strip additive is used, provide a separate bin or tank and feeder system to store and proportion the lime into the aggregate in either dry or slurry form. Mix the lime and aggregate by pugmill or other approved means to achieve a uniform lime coating of the aggregate before entering the drier. When the lime is added in dry form, the aggregate shall contain at least 3% free moisture. The stockpiling of lime treated aggregate will not be permitted. Control the lime feeder system by a proportioning device that is accurate to within ± 10% of the specified amount. Provide a proportioning device with a convenient and accurate means of calibration and that is interlocked with the aggregate feed or weigh system so as to maintain the correct proportion. Provide a flow indicator or sensor that is interlocked with the plant controls such that production of the mixture will be interrupted if there is a stoppage or reduction of the lime feed.

(3) Aggregate Cold Feed Equipment

Use cold bins and a feeder system to proportion the aggregates and feed them to the dryer. Use separate cold bins for each size aggregate and each natural sand being used to provide a uniform and continuous flow. Provide separate dry storage when mineral filler is required. Equip cold aggregate bins with feeder units having interlocking controls capable of maintaining a constant ratio between the relative quantities of each size aggregate at varying plant production rates.

Provide cold feeders that are capable of being easily and accurately calibrated to ensure full control of the mix gradation.

(4) Dryer

Use a plant with a dryer or dryers that continuously agitate the aggregate during the heating and drying process.

(5) Control Unit for Asphalt Binder

Provide satisfactory means, either by weighing or metering to introduce the proper amount of asphalt binder into the mix.

(6) Thermometric Equipment

(a) Asphalt Binder Thermometric Equipment

Provide a thermometric device of adequate temperature range fixed in the asphalt binder feed line.

(b) Dryer Thermometric Equipment

Equip the dryer with an automatic burner control device that uses an approved thermometric instrument located in the discharge chute to actuate the automatic controls.

(7) Pollution Control Equipment

Equip all plants with such pollution control equipment as is necessary to meet all applicable Federal, State and local pollution requirements. Register and certify all plants by applicable environmental regulatory agencies before being certified by the Department.

(8) Safety Requirements

Provide adequate safety devices at all points where accessibility to plant operations is required. Provide accessibility to the top of truck bodies by a platform or other suitable device to enable QC and QA personnel to obtain samples and mixture temperature data. Thoroughly guard and protect all gears, pulleys, chains, sprockets and other dangerous moving parts. Provide ample and unobstructed space on the mixing platform. Maintain a clear and unobstructed passage at all times in and around the truck loading area. Keep all work areas free from asphalt drippings.

(9) Production Consistency

Any asphalt plant that cannot consistently produce a high quality mix meeting these Specifications will be in non-compliance with these Specifications and may have its certification revoked.

Upon a malfunction of required automatic equipment on a batch mixing plant, the plant may continue to operate manually for the following 2 consecutive working days, provided acceptable mixture is being produced.

When a malfunction of required automatic equipment on a drum mixer or continuous plant occurs, manual operation of the plant will not be allowed except that if, in the opinion of the Engineer, an emergency traffic condition exists, the plant may be allowed to operate manually until the unsafe traffic condition is corrected. All mix produced by manual operation will be subject to Section 609.

610-6 HOT MIX STORAGE SYSTEMS

When a storage system is used, provide a system capable of conveying the mix from the plant to the storage bin and storing the mix without a loss in temperature, segregation or oxidation of the mix. Limit storage time to the ability of the storage system to maintain the mix within the Specification requirements. Material may be stored in storage bins without an approved heating system for no more than 24 hours.

Provide a continuous type or skip bucket type conveyor system. Enclose continuous type conveyors so that the mix temperature is maintained within specification requirements. Provide a system designed in such manner as to prevent segregation of the mix during discharge from the conveyor into the bins and equipped with discharge gates that will not cause segregation of the mix while loading the mix into trucks.

610-7 HAULING OF ASPHALT MIXTURE

Transport the mixture from the mixing plant to the point of use in vehicles that have tight, clean, smooth beds approved by the Department, that have been sprayed with an approved release agent material to prevent the mixture from adhering to the beds. Remove excess release agent before loading. Cover each load of mixture with a solid, waterproof tarp constructed of canvas, vinyl, or other suitable material. Securely fasten each tarp so as to overlap the top of the truck bed and prevent the entrance of moisture and the rapid loss of temperature Provide a 3/8" to 5/8" diameter hole on each side of the vehicle body near the center of the body and above the bed of the vehicle for the purpose of inserting a thermometer.

Assure temperature of the mixture immediately before discharge from the hauling vehicle is within a tolerance of +15°F to -25°F of the specified JMF temperature.

610-8 SPREADING AND FINISHING

Apply tack coat in accordance with Section 605.

Mixtures produced simultaneously from different plant sources cannot be intermingled by hauling to the same paver on the roadway unless the mixtures are being produced from the same material sources and same JMF.

Perform this work in accordance with and using equipment meeting Section 9.5 of the *HMA/QMS Manual.*

Use a material transfer vehicle (MTV) when placing all asphalt concrete plant mix pavements which require the use of asphalt binder grade PG 76-22 and for all types of OGAFC, unless otherwise approved. Use a MTV for all surface mix regardless of binder grade placed on Interstate and US routes that have 4 or more lanes and median divided. Where required above, use the MTV when placing all full width travel lanes and collector lanes. Use MTV for all ramps, loops, Y-line travel lanes, full width acceleration lanes, full width deceleration lanes and full width turn lanes that are greater than 1,000 ft in length. Use a MTV meeting Section 9.5(E) of the *HMA/QMS Manual.*

Request the Engineer to waive the requirement for use of pavers for spreading and finishing where irregularities or obstacles make their use impractical. Spread, rake and lute the mixture by hand methods or other approved methods in these areas.

Operate the paver as continuously as possible. Pave intersections, auxiliary lanes and other irregular areas after the main line roadway has been paved, unless otherwise approved.

Repair any damage caused by hauling equipment across structures at no additional cost to the Department.

610-9 COMPACTION

Immediately after the asphalt mixture has been spread, struck off and surface and edge irregularities adjusted, thoroughly and uniformly compact the pavement. Compact the mix to the required degree of compaction for the type of mixture being placed.

Provide sufficient number and weight of rollers, except as noted, to compact the mixture to the required density while it is still in a workable condition. Obtain approval of equipment used in compaction from the Engineer before use. Where uniform density is not being obtained throughout the depth of the layer of material being tested, change the type and/or weight of the compaction equipment as necessary to achieve uniform density even though such equipment has been previously approved.

Compact all final wearing surfaces, except open-graded asphalt friction course, using a minimum of 2 steel-wheel tandem rollers, unless otherwise approved. Pneumatic-tire rollers with 2 tandem axles and smooth tread tires may be used for intermediate rolling.

Limit rolling for open-graded asphalt friction course to one coverage with a tandem steel-wheel roller weighing a maximum of 10 tons, with additional rolling limited to one coverage with the roller where necessary to improve the riding surface.

Steel-wheel tandem vibratory rollers specifically designed for the compaction of asphalt pavements may be used on all layers 1" or greater in thickness during the breakdown and intermediate rolling phase. Do not operate vibratory rollers in the vibratory mode during the finish rolling phase on any mix type or pavement course, open-graded asphalt friction course or on permeable asphalt drainage course.

When vibratory rollers are used, use rollers that have variable amplitude and frequency capabilities and that are designed specifically for asphalt pavement compaction. Provide rollers equipped with controls that automatically disengage the vibration mechanism before the roller stops when being used in the vibratory mode.

The Engineer may prohibit or restrict the use of vibratory rollers where damage to the pavement being placed, the underlying pavement structure, drainage structures, utilities or other facilities is likely to occur or is evident.

Do not use rolling equipment that results in excessive crushing of the aggregate or excessive displacement of the mixture.

In areas inaccessible to standard rolling equipment, thoroughly compact the mixture by the use of hand tampers, hand operated mechanical tampers, small rollers or other approved methods.

Use rollers that are in good condition and capable of being reversed without backlash to compact the mixture. Operate rollers with the drive wheels nearest the paver and at uniform speeds slow enough to avoid displacement of the mixture. Equip steel-wheel rollers with wetting devices that will prevent the mixture from sticking to the roller wheels.

Begin compaction of the material immediately after the material is spread and shaped to the required width and depth. Carry out compaction in such a manner as to obtain uniform density over the entire section. Perform compaction rolling at the maximum temperature at which the mix will support the rollers without moving horizontally. Complete the compaction (including both intermediate rolling) before the mixture cooling below a workable temperature. Perform finish rolling to remove roller marks resulting from the compaction rolling operations.

610-10 DENSITY REQUIREMENTS

TABLE 610-6
SUPERPAVE DENSITY REQUIREMENTS

Superpave Mix Type	Minimum % G_{mm} (Maximum Specific Gravity)
SF9.5A	90.0
S9.5X, S12.5X, I19.0X, B25.0X	92.0

Compact the asphalt plant mix to at least the minimum percentage of the maximum specific gravity listed in Table 610-6, except as noted below. Perform density sampling and testing on all pavements listed below unless otherwise approved:

(A) Full width travel lane pavements, including normal travel lanes, turn lanes, collector lanes, ramps and loops and temporary pavements;

(B) Pavement widening 4.0 ft or greater;

(C) Uniform width paved shoulders 2.0 ft or greater; and

(D) Wedging as outlined in the *HMA/QMS Manual*.

Compact base and intermediate mix types (surface mixes not included) used for pavement widening of less than 4.0 ft and all mix types used in tapers, irregular areas and intersections (excluding full width travel lanes of uniform thickness), using equipment and procedures appropriate for the pavement area width and/or shape. Compaction with equipment other than conventional steel drum rollers may be necessary to achieve adequate compaction. Occasional density sampling and testing to evaluate the compaction process may be required. Densities lower than that specified in Table 610-6 may be accepted, in accordance with Article 105-3, for the specific mix types and areas listed directly above.

610-11 JOINTS

(A) Transverse Joints

When the placing of the mixture is to be suspended long enough to permit the mixture to become chilled, construct a transverse joint.

If traffic will not pass over the end of the paving, a butt joint will be permitted, provided proper compaction is achieved. If traffic will pass over the joint, construct a sloped wedge ahead of the end of the full depth pavement to provide for proper compaction and protection of the full depth pavement. Construct the joint square to the lane

alignment and discard all excess material. Place a paper parting strip beneath this wedge to facilitate joint construction unless waived by the Engineer.

Before paving operations are resumed, remove the sloped wedge and cut back into the previously constructed pavement to the point of full pavement depth. Coat the exposed edge of the previously constructed pavement with tack coat.

When laying of the mixture is resumed at the joint, complete and then test the construction of the joint in accordance with Article 610-12 while the mixture is still in a workable condition.

(B) Longitudinal Joints

Tack the exposed edge of all longitudinal joints before placing the adjoining pavement.

Form longitudinal joints by allowing the paver to deposit the mixture adjacent to the joint to such depth that maximum compaction can be obtained along the joint. Pinch the joint by rolling immediately behind the paver.

When multi-lane multi-layer construction is required, offset the longitudinal joints in each layer from that in the layer immediately below by approximately 6". Construct the joints in the final layer, where possible, between designated travel lanes of the final traffic pattern.

610-12 SURFACE REQUIREMENTS AND ACCEPTANCE

Construct pavements using quality-paving practices as detailed herein. Construct the pavement surface smooth and true to the plan grade and cross slope. Immediately correct any defective areas with satisfactory material compacted to conform with the surrounding area.

Pavement imperfections resulting from unsatisfactory workmanship such as segregation, improper longitudinal joint placement or alignment, non-uniform edge alignment or excessive pavement repairs will be unsatisfactory. Pavement imperfections will be evaluated for acceptance in accordance with Article 105-3.

When directed due to unsatisfactory laydown or workmanship, operate under the limited production procedures. Limited production for unsatisfactory laydown is defined as being restricted to the production, placement, compaction and final surface testing (if applicable) of a sufficient quantity of mix necessary to construct only 2,500 ft of pavement at the laydown width.

Remain on limited production until such time as satisfactory laydown results are obtained or until 3 consecutive 2,500 ft sections have been attempted without achieving satisfactory laydown results. If the Contractor fails to achieve satisfactory laydown results after 3 consecutive 2,500 ft sections have been attempted, cease production of that mix type until such time as the cause of the unsatisfactory laydown results can be determined. As an exception, the Engineer may grant approval to produce a different mix design of the same mix type if the cause is related to mix problems rather than laydown procedures.

Mix placed under the limited production procedures for unsatisfactory laydown or workmanship will be evaluated for acceptance in accordance with Article l05-3.

Each pavement layer will be tested by the Contractor and the Engineer using a 10-ft stationary straightedge furnished by the Contractor. Any location on the pavement selected by the Department shall be tested as well as all transverse joints. Apply the straightedge parallel to the centerline of the surface. Do not exceed 1/8" variation of the surface being tested from the edge of the straightedge between any 2 contact points. Correct areas found to exceed this tolerance by removal of the defective work and replacement with new material, unless other corrective measures are permitted. Provide the work and materials required in the correction of defective work.

610-13 FINAL SURFACE TESTING AND ACCEPTANCE

On portions of this project where the typical section requires two or more layers of new pavement, perform smoothness acceptance testing of the longitudinal profile of the finished pavement surface using either an Inertial Profiler or a North Carolina Hearne Straightedge (Model No. 1).

Use an Inertial Profiler (Option 1) to perform smoothness acceptance testing of the longitudinal profile of the finished pavement surface. Furnish an inertial profiler(s) necessary to perform this work. Maintain responsibility for all costs related to the procurement, handling, and maintenance of these devices.

Furnish and operate the Hearne straightedge (Option 2) to determine and record the longitudinal profile of the pavement on a continuous graph.

Before beginning any paving operations, the Contractor shall select one of the above options and submit documentation to the Engineer on the selected option for smoothness acceptance.

(A) Option 1 - Inertial Profiler

Use an Inertial Profiler to measure the longitudinal pavement profile for construction quality control and smoothness acceptance. Use a profiler with line laser technology as single-point laser technology will not be allowed. Produce International Roughness Index (IRI) and Mean Roughness Index (MRI) values for measuring smoothness.

Use testing and recording software to produce electronic inertial road profiles in a format compatible with the latest version of FHWA's ProVAL (Profile Viewing and Analysis) software.

The Inertial Profiler shall be calibrated and verified in accordance with the most current version of AASHTO M 328. Provide certification documentation that the profiler meets AASHTO M 328 to the Engineer before the first day the Inertial Profiler is used on the project.

Configure the profiler to record the actual elevation of the pavement surface. Do not use the profiler's internal IRI calculation mode. The profile data shall be filtered with a cutoff wavelength of 300 ft. The interval at which relative profile elevations are reported shall be 1".

Provide IRI data in accordance with most current version of ASTM E1926. Use personnel trained to record and evaluate IRI data.

Provide a competent operator, trained in the operation of the Inertial Profiler Operation of the Inertial Profiling system shall conform to AASHTO R 57.

Provide the user selected Inertial Profiler settings to the Engineer for the project records. Certification of the Inertial Profiling system shall conform to AASHTO R 56.

Remove all objects and foreign material on the pavement surface prior to longitudinal pavement profile testing.

Operate the profiler at any speed as per the manufacturer's recommendations, however, the speed must be constant to within ± 3 mph of the intended speed and any required acceleration should be as gradual as possible. For example, if the intended speed were 30 mph, the acceptable range of speed for testing would be 27 to 33 mph.

Operate the Inertial Profiler in the direction of the final traffic pattern. Collect IRI data from both wheel paths during the same run. It is permissible to collect data one wheel path at a time if each wheel path is tested and evaluated separately. Define a "wheel path" as the 3 ft from the edge of the travel lane. MRI values are the average of the IRI values from both wheel paths. When using an inertial profiler that collects a single trace per pass, take care to ensure that the measurements from each trace in a travel lane start and stop at the same longitudinal locations. Unless otherwise specified, multiple runs are not necessary for data collection.

Operate the automatic triggering method at all times unless impractical. A tape stripe or traffic cone wrapped with reflective material may be used to alert the profiler's automatic triggering sensor to begin data collection. The profiler shall reach the intended operating speed before entering the test section. The runup and runout distances should be sufficient to obtain the intended operating speed and to slow down after testing is completed.

Divide the pavement surface for the project into sections which represent a continuous placement (i.e. the start of the project to bridge, intersection to intersection). Terminate a section 50 ft before a bridge approach, railroad track, or similar interruption. (Separate into 0.10-mile sections).

The evaluation of the profiles will be performed on a section basis. A section is 0.10 mile of a single pavement lane. For any section, which is less than 0.10 mile in length, the applicable pay adjustment incentive will be prorated on the basis of the actual length.

Mark the limits of structures and other special areas to be excluded from testing using the profiler's event identifier such that the exact locations can be extracted from the profile data file during processing.

Unless otherwise authorized by the Engineer, perform all smoothness testing in the presence of the Engineer. Perform smoothness tests on the finished surface of the completed project or at the completion of a major stage of construction as approved by the Engineer. Coordinate with and receive authorization from the Engineer before starting smoothness testing. Perform smoothness tests within 7 days after receiving authorization. Any testing performed without the Engineer's presence, unless otherwise authorized, may be ordered retested at the Contractor's expense.

After testing, transfer the profile data from the profiler portable computer's hard drive to a write once storage media (DVD-R or CD-R) or electronic media approved by the Engineer. Label the disk or electronic media with the Project number, Route, file number, date, and termini of the profile data. Submit the electronic data on the approved media to the Engineer immediately after testing and this media will not be returned to the Contractor.

Submit documentation and electronic data of the evaluation for each section to the Engineer within 10 days after completion of the smoothness testing. Submit the electronic files compatible with ProVAL and the evaluation in tabular form with each 0.10 mile segment occupying a row. Include each row with the beginning and ending station

for the section, the length of the section, the original IRI values from each wheel path, and the MRI value for the section. Each continuous run for a section will occupy a separate table and each table will have a header that includes the following: the project contract number, county, the roadway number or designation, a lane designation, the JMF used for the final lift, the dates of the smoothness runs, and the beginning and ending station of the continuous run. Summarize each table at the bottom.

Traffic control and all associated activities included in the pavement smoothness testing of the pavement surface will be the responsibility of the Contractor.

(1) Acceptance for New Construction

IRI and MRI numbers recorded in inches per mile will be established for each 0.10-mile section for each travel lane of the surface course designated by the contract. Areas excluded from testing by the profiler will be tested using a 10-ft straightedge in accordance with Article 610-12.

Table 610-7 provides the acceptance quality rating scale of pavement based on the final rideability determination.

TABLE 610-7
MRI PRICE ADJUSTMENT PER 0.10-MILE SECTION

MRI after Completion (Inches Per Mile)	Price Adjustment Per Lane (0.10-Mile Section)
45.0 and Under	$200.00
45.1-55.0	PA = 600 – (10 * MRI)
55.1-70.0	Acceptable (No Pay Adjustment)
70.1-90.0	PA = 650 – (10 * MRI)
Over 90.1	Corrective Action Required

This price adjustment will apply to each 0.10-mile section based on the Mean Roughness Index (MRI), the average IRI values from both wheel paths.

When corrections to the pavement surface are required, the Engineer shall approve the Contractor's method of correction. Methods of correction shall be milling and inlay, remove and replace or other methods approved by the Engineer. To produce a uniform cross section, the Engineer may require correction to the adjoining traffic lanes or shoulders. Corrections to the pavement surface, the adjoining traffic lanes and shoulders will be at no cost to the Department.

Where corrections are made after the initial smoothness testing, the pavement will be retested by the Contractor to verify that corrections have produced the acceptable ride surface. No incentives will be provided for sections on which corrective actions have been required. The Contractor will have one opportunity to perform corrective action(s).

(2) Localized Roughness

Areas of localized roughness shall be identified through the "Smoothness Assurance Module" provided in the ProVAL software. Use the "Smoothness Assurance Module" to optimize repair strategies by analyzing the measurements from profiles collected using inertial profilers. The ride quality threshold for localized roughness shall be 125"/mile at the continuous short interval of 25 ft. Submit a continuous roughness report to identify sections outside the threshold and identify all localized roughness, with the signature of the Operator included with the submitted IRI trace and electronic files.

The Department will require that corrective action be taken regardless of final IRI. Re-profile the corrected area to ensure that the corrective action was successful. If the corrective action is not successful, the Department will assess a penalty or require additional corrective action.

Corrective work for localized roughness shall be approved by the Engineer before performing the work and shall consist of either replacing the area by milling and inlaying or other methods approved by the Engineer. Any corrective action performed shall not reduce the integrity or durability of the pavement that is to remain in place. Milling and inlay or any corrective actions shall meet the specifications requirements for ride quality over the entire length of the correction. Notify the Engineer 5 days before commencement of the corrective action.

Localized roughness correction work shall be for the entire traffic lane width. Pavement cross slope shall be maintained through corrective areas.

(B) Option 2 - North Carolina Hearne Straightedge

Push the straightedge manually over the pavement at a speed not exceeding 2 mph. For all lanes, take profiles in the right wheel path approximately 3 ft from the right edge of pavement in the same direction as the paving operation, unless otherwise approved due to traffic control or safety considerations. As an exception, lanes adjacent to curb and gutter, expressway gutter, or shoulder berm gutter may be tested in the left wheel path. Make one pass of the straightedge in each full width travel lane. The full lane width should be comparable in ride quality to the area evaluated with the Hearne Straightedge. If deviations exist at other locations across the lane width, use a 10-ft non-mobile straightedge or the Hearne Straightedge to evaluate which areas may require corrective action. Take profiles as soon as practical after the pavement has been rolled and compacted, but no later than 24 hours following placement of the pavement, unless otherwise authorized by the Engineer. Take profiles over the entire length of final surface travel lane pavement exclusive of Y-line travel lanes less than or equal to 1,000 ft in length, ramps less than or equal to 1,000 ft in length, turn lanes less than or equal to 1,000 ft in length, structures, approach slabs, paved shoulders, loops and tapers or other irregular shaped areas of pavement, unless otherwise approved by the Engineer. Test in accordance with this provision all mainline travel lanes, full width acceleration or deceleration lanes, Y-line travel lanes greater than 1,000 ft in length, ramps, full width turn lanes greater than 1,000 ft in length and collector lanes.

At the beginning and end of each day's testing operations, and at such other times as determined by the Engineer, operate the straightedge over a calibration strip so that the Engineer can verify correct operation of the straightedge. The calibration strip shall be a 100-ft section of pavement that is reasonably level and smooth. Submit each day’s calibration graphs with that day’s test section graphs to the Engineer. Calibrate the straightedge in accordance with the current NCDOT procedure titled *North Carolina Hearne Straightedge - Calibration and Determination of Cumulative Straightedge Index*. Copies of this procedure may be obtained from the Department's Pavement Section in the Construction Unit.

Plot the straightedge graph at a horizontal scale of approximately 25 ft/in with the vertical scale plotted at a true scale. Record station numbers and references (bridges, approach slabs, culverts, etc.) on the graphs. Distances between references/stations shall not exceed 100 ft. Have the operator record the Date, Project No., Lane Location, Wheel Path Location, Type Mix and Operator’s Name on the graph.

Upon completion of each day's testing, evaluate the graph, calculate the Cumulative Straightedge Index (CSI) and determine which lots, if any, require corrective action. Document the evaluation of each lot on a QA/QC-7 form. Submit the graphs along with the completed QA/QC-7 forms to the Engineer, within 24 hours after profiles are completed, for verification of the results. The Engineer will furnish results of their acceptance evaluation to the Contractor within 48 hours of receiving the graphs. In the event of discrepancies, the Engineer’s evaluation of the graphs will prevail for acceptance purposes. The Engineer will retain all graphs and forms.

Use blanking bands of 0.2", 0.3" and 0.4" to evaluate the graph for acceptance. The 0.2" and 0.3" blanking bands are used to determine the Straightedge Index (SEI), which is a number that indicates the deviations that exceed each of the 0.2" and 0.3" bands within a 100 ft test section. The Cumulative Straightedge Index (CSI) is a number representing the total of the SEIs for one lot, which consist of not more than 25 consecutive test sections. In addition, the 0.4" blanking band is used to further evaluate deviations on an individual basis. The CSI will be determined by the Engineer in accordance with the current procedure titled *North Carolina Hearne Straightedge - Calibration and Determination of Cumulative Straightedge Index.*

The pavement will be accepted for surface smoothness on a lot by lot basis. A test section represents pavement one travel lane wide not more than 100 ft in length. A lot will consist of 25 consecutive test sections, except that separate lots will be established for each travel lane, unless otherwise approved by the Engineer. In addition, full width acceleration or deceleration lanes, ramps, turn lanes and collector lanes will be evaluated as separate lots. For any lot that is less than 2,500 ft in length, the applicable pay adjustment incentive will be prorated on the basis of the actual lot length. For any lot which is less than 2,500 ft in length, the applicable pay adjustment disincentive will be the full amount for a lot, regardless of the lot length.

If during the evaluation of the graphs, 5 lots require corrective action, then proceed on limited production for unsatisfactory laydown in accordance with Article 610-12. Proceeding on limited production is based upon the Contractor’s initial evaluation of the straightedge test results and shall begin immediately upon obtaining those results. Additionally, the Engineer may direct the Contractor to proceed on limited production in accordance with Article 610-12 due to unsatisfactory laydown or workmanship.

Limited production for unsatisfactory laydown is defined as being restricted to the production, placement, compaction and final surface testing of a sufficient quantity of mix necessary to construct only 2,500 ft of pavement at the laydown width. Once this lot is complete, the final surface testing graphs will be evaluated jointly by the Contractor and the Engineer. Remain on limited production until such time as acceptable laydown results are obtained or until 3 consecutive 2,500 ft sections have been attempted without achieving acceptable laydown results. The Engineer will determine if normal production may resume based upon the CSI for the limited production lot and any adjustments to the equipment, placement methods, and/or personnel performing the work. Once on limited production, the Engineer may require the Contractor to evaluate the smoothness of the previous asphalt layer and take appropriate action to reduce and/or eliminate corrective measures on the final surface course. Additionally, the Contractor may be required to demonstrate acceptable laydown techniques off the project limits before proceeding on the project.

If the Contractor fails to achieve satisfactory laydown results after 3 consecutive 2,500 ft sections have been attempted, cease production of that mix type until such time as the cause of the unsatisfactory laydown results can be determined.

As an exception, the Engineer may grant approval to produce a different mix design of the same mix type if the cause is related to mix problem(s) rather than laydown procedures. If production of a new mix design is allowed, proceed under the limited production procedures detailed above.

After initially proceeding under limited production, the Contractor shall immediately notify the Engineer if any additional lot on the project requires corrective action. The Engineer will determine if limited production procedures are warranted for continued production.

If the Contractor does not operate by the limited production procedures as specified above, the 5 lots, which require corrective action, will be considered unacceptable and may be subject to removal and replacement. Mix placed under the limited production procedures for unsatisfactory laydown will be evaluated for acceptance in accordance with Article l05-3.

The pay adjustment schedule for the Cumulative Straightedge Index (CSI) test results per lot is in Table 610-8.

TABLE 610-8
PAY ADJUSTMENT SCHEDULE FOR CUMULATIVE STRAIGHTEDGE INDEX
(Obtained by adding SE Index of up to 25 consecutive 100 ft test sections)

CSI[A]	Acceptance Category	Corrective Action	Pay Adjustment Before Corrective	Pay Adjustment After Corrective Action
0-0	Acceptable	None	$300 Incentive	None
1-0 or 2-0	Acceptable	None	$100 Incentive	None
3-0 or 4-0	Acceptable	None	No Adjustment	No Adjustment
1-1, 2-1, 5-0 or 6-0	Acceptable	Allowed	$300 Disincentive	$300 Disincentive
3-1, 4-1, 5-1 or 6-1	Acceptable	Allowed	$600 Disincentive	$600 Disincentive
Any other Number	Unacceptable	Required	Per CSI after Correction(s) (not to exceed 100% Pay)	

A. Either Before or After Corrective Actions

Correct any deviation that exceeds a 0.4" blanking band such that the deviation is reduced to 0.3" or less.

Corrective actions shall be performed at the Contractor's expense and shall be presented for evaluation and approval by the Engineer prior to proceeding. Any corrective action performed shall not reduce the integrity or durability of the pavement that is to remain in place. Corrective action for deviation repair may consist of overlaying, removing and replacing, indirect heating and rerolling. Scraping of the pavement with any blade type device will not be allowed as a corrective action. Provide overlays of the same type mix, full roadway width, and to the length and depth established by the Engineer. Tapering of the longitudinal edges of the overlay will not be allowed.

Corrective actions will not be allowed for lots having a CSI of 4-0 or better. If the CSI indicates Allowed corrective action, the Contractor may elect to take necessary measures to reduce the CSI instead of accepting the disincentive. Take corrective actions as specified if the CSI indicates Required corrective action. The CSI after corrective action shall meet or exceed Acceptable requirements.

Where corrective action is allowed or required, the test section(s) requiring corrective action will be retested, unless the Engineer directs the retesting of the of the entire lot. No disincentive will apply after corrective action if the CSI is 4-0 or better. If the retested lot after corrective action has a CSI indicating a disincentive, the appropriate disincentive will be applied.

Test sections and/or lots that are initially tested by the Contractor that indicate excessive deviations such that either a disincentive or corrective action is necessary, may be re-rolled with asphalt rollers while the mix is still warm and in a workable condition, to possibly correct the problem. In this instance, reevaluation of the test section(s) shall be completed within 24 hours of pavement placement and these test results will serve as the initial test results.

Incentive pay adjustments will be based only on the initially measured CSI, as determined by the Engineer, before any corrective work. Where corrective actions have been taken, payment will be based on the CSI determined after correction, not to exceed 100% payment.

Areas excluded from testing by the N.C. Hearne Straightedge will be tested by using a non-mobile 10-ft straightedge. Assure that the variation of the surface from the testing edge of the straightedge between any 2 contact points with the surface is not more than 1/8". Correct deviations exceeding the allowable tolerance in accordance with the corrective actions specified above, unless the Engineer permits other corrective actions.

Furnish the North Carolina Hearne Straightedge(s) necessary to perform this work. Maintain responsibility for all costs relating to the procurement, handling, and maintenance of these devices. The Department has entered into a license agreement with a manufacturer to fabricate, sell and distribute the N.C. Hearne Straightedge. The Department's Pavement Construction Section may be contacted for the name of the current manufacturer and the approximate price of the straightedge.

610-14 DENSITY ACCEPTANCE

The Department will evaluate the asphalt pavement for density acceptance after the asphalt mix has been placed and compacted using the Contractor's QC test results, the Department's QA test results (including verification samples) and by observation of the Contractor's density QC process conducted in accordance with Section 609. Minimum density requirements for all mixes will be as specified in Table 610-6. Density acceptance will be as provided herein. Core sample densities will be determined by use of the average maximum specific gravity (G_{mm}), until a moving average of the last 4 maximum specific gravities is established. Once a moving average of the last 4 maximum specific gravities is established, the last G_{mm} moving average in effect at the end of the same day's production will then be used to determine density acceptance.

The pavement will be accepted for density on a lot by lot basis. A lot will consist of one day's production of a given JMF on a contract. As an exception, separate lots will be established when one of the following occurs:

(A) Portions of pavement are placed in both New and Other construction categories as defined below. A lot will be established for the portion of the pavement in the New construction category and a separate lot for the portion of pavement in the Other construction category.

(B) Pavement is placed on multiple resurfacing maps. Unless otherwise approved before paving, a lot will be established for each individual resurfacing map or portion thereof.

(C) Pavement is placed by multiple paving crews. A lot will be established for the pavement placed by each paving crew.

(D) Pavement is placed in different layers. A lot will be established for each layer.

(E) Control strips are placed during limited production.

The Engineer will determine the final category and quantity of each lot for acceptance purposes. The New construction category will be defined as pavements of uniform thickness, exclusive of irregular areas, meeting all 3 of the following criteria:

(1) Pavement placed on a new aggregate or soil base compacted to the specified density or pavement placed on a new asphalt mix layer (excluding wedging and leveling);

(2) Pavement that is within a designated travel lane of the final traffic pattern; and

(3) Pavement that is 4.0 ft or wider.

As an exception, when the first layer of mix is a surface course and is being placed directly on an unprimed aggregate or soil base, the layer will be included in the Other construction category.

The Other construction category will include all pavements except as described above.

A failing lot for density acceptance purposes is defined as a lot for which the average of all test sections, and portions thereof, fails to meet the minimum specification requirement. If additional density sampling and testing, beyond the minimum requirement, is performed and additional test sections are thereby created, then all test results shall be included in the lot average. In addition, any lot or portion of a lot that is obviously unacceptable will be rejected for use in the work.

If the Engineer determines that a given lot of mix that falls in the New category does not meet the minimum specification requirements but the work is reasonably acceptable, the lot will be accepted at a reduced pay factor in accordance with the following formula. The reduced pay factor will apply only to the mix unit price.

$$\textbf{Reduced Pay Factor} = 100 + \left[\left(\frac{Actual\ \ Density - Specified\ \ Density}{2} \right) x30 \right]$$

Where:

Actual Density = the lot average density, not to exceed 2.0% of the specified density

Specified Density = the density in Table 610-6 or as specified in the contract

All failing lots in the Other category will be evaluated for acceptance in accordance with Article 105-3.

Any density lot not meeting minimum density requirements detailed in Table 610-6 will be evaluated for acceptance in accordance with Article 105-3. If the lot is determined not to be acceptable, the mix will be removed and replaced with mix meeting and compacted to the requirement of these *Standard Specifications.*

610-15 MAINTENANCE

Maintain the plant mix pavement in an acceptable condition until final acceptance of the project. Immediately repair any defects or damage that may occur. Perform maintenance to damaged or defective pavement and repeat as often as may be necessary to keep the base or pavement in an acceptable condition.

610-16 MEASUREMENT AND PAYMENT

Hot Mix Asphalt Pavement will be paid at the contract unit price per ton that will be the actual number of tons of each type of hot mix asphalt pavement incorporated into the completed and accepted work in accordance with Article 106-7.

No direct payment will be made for providing and using the materials transfer vehicle or any associated equipment, as the cost of providing same will be included in the contract unit bid price per ton for the mix type to be placed.

Any reduction in pay due to failing density will be in addition to any reduction in pay due to failing mix property test results on the same mix.

A high frequency of asphalt plant mix or density deficiencies may result in future deficient asphalt being excluded from acceptance at an adjusted contract unit price in accordance with Article 105-3. This acceptance process will apply to all asphalt produced or placed and will continue until the Engineer determines a history of quality asphalt production and placement is reestablished.

Furnishing asphalt binder will be paid as provided in Article 620-4 for *Asphalt Binder for Plant Mix* for each grade required.

Provide the work and materials required in the correction of defective work or sand seal base course as required at no cost to the Department. If the Engineer has such work performed with Department forces and equipment, the cost of such work performed by Department forces will be deducted from monies due or to become due to the Contractor.

No direct payment will be made for final surface testing covered by this section. Payment at the contract unit prices for the various items covered by those sections of the *Standard Specifications* directly applicable to the work constructed will be full compensation for all work covered by Article 660-11 including, but not limited to, performing testing in accordance with this Specification, any corrective work required as a result of this testing and any additional traffic control as may be necessary.

Payment will be made under:

Pay Item	Pay Unit
Asphalt Concrete Base Course, Type B25.0B	Ton
Asphalt Concrete Base Course, Type B25.0C	Ton
Asphalt Concrete Intermediate Course, Type I19.0B	Ton
Asphalt Concrete Intermediate Course, Type I19.0C	Ton
Asphalt Concrete Intermediate Course, Type I19.0D	Ton
Asphalt Concrete Surface Course, Type SF9.5A	Ton
Asphalt Concrete Surface Course, Type S9.5B	Ton
Asphalt Concrete Surface Course, Type S9.5C	Ton
Asphalt Concrete Surface Course, Type S9.5D	Ton
Asphalt Concrete Surface Course, Type S12.5C	Ton
Asphalt Concrete Surface Course, Type S12.5D	Ton

SECTION 620
ASPHALT BINDER FOR PLANT MIX

620-1 DESCRIPTION

Perform the work covered by this section including, but not limited to, furnishing of asphalt binder, with anti-strip additive when required, at an asphalt plant and incorporating the asphalt binder and anti-strip additive into the asphalt plant mix.

620-2 MATERIALS

Refer to Division 10.

Item	Section
Anti-strip Additives	1012-1(G)
Asphalt Binder, All Grades	1020-2
Silicone	1012-1(H)

The asphalt binder for the mixture will be accepted at the source subject to Article 1020-1.

Use a brand of silicone from the NCDOT Approved Products List. Submit a sample and manufacturer's data to the Engineer for approval before use, if proposing to use a brand not on the NCDOT Approved Products List.

620-3 GENERAL REQUIREMENTS

The requirements of Section 610 that pertain to handling of asphalt binder will be applicable to the work covered by this section.

Add silicone to all asphalt binder used in surface courses and open-graded asphalt friction course, unless otherwise directed. The amount of silicone added will range from one ounce per 2,000 gallons of asphalt binder to one ounce per 2,500 gallons. Add silicone to the asphalt binder at the plant site unless added at the source and it is so noted on the delivery ticket.

Do not heat the asphalt binder to a temperature in excess of the supplier’s recommendation while stored or when being used in production of mix at the asphalt plant.

Introduce the actual quantity of asphalt binder at the established percentage shown on the applicable JMF into the mix by the plant weighing or metering system. No working tolerance for asphalt binder percentage will be allowed during production.

When required, incorporate an anti-strip additive. It may be either chemical additive mixed with the asphalt binder or hydrated lime added to the aggregate or a combination of both. Furnish the brand name of the type (lime or chemical), supplier and shipping point of anti-strip additive. Note on the asphalt binder delivery ticket the rate (or quantity), brand of chemical additive when added at the supplier’s terminal. Introduce and mix chemical anti-strip additive into the asphalt binder at either the supplier's terminal or at the asphalt plant site at the dosage required by the JMF. Use in-line blending equipment at either location. When added at the asphalt plant, use equipment that meets Subarticle 610-5(B). When added at the

supplier's terminal, use equipment that in-line blends with a constant flow of the additive for a minimum of 80% of the asphalt binder loading time. When hydrated lime is used, use equipment to introduce the lime that meets Subarticle 610-5(B). Thoroughly mix chemical anti-strip additive and asphalt binder together before incorporating into the asphalt plant mix.

620-4 MEASUREMENT AND PAYMENT

Asphalt Binder for Plant Mix and *Polymer Modified Asphalt Binder for Plant Mix* will be measured and paid as the theoretical number of tons required by the applicable JMF based on the actual number of tons of plant mix completed and accepted on the job.

Such price and payment will be full compensation for all work covered by this section.

There will be no direct payment for anti-strip additive. Payment at the contract unit prices for the various asphalt plant mix items will be full compensation for the work.

Adjustments will be made to the payments due the Contractor for each grade of asphalt binder when it has been determined that the monthly average terminal F.O.B. Selling Price of asphalt binder, Grade PG 64-22, has fluctuated from the Base Price Index for Asphalt Binder included in the contract. The methods for calculating a base price index, for calculating the monthly average terminal F.O.B. selling price and for determining the terminals used are in accordance with procedures on file with the Construction Unit.

When it is determined that the monthly selling price of asphalt binder on the first business day of the calendar month during which the last day of the partial payment period occurs varies either upward or downward from the base price index, the contract unit price for asphalt binder for plant mix will be adjusted. The adjusted contract unit price will be determined by adding the difference between the selling price and the base price index to the contract unit bid price for asphalt binder.

The adjusted contract unit price will then be applied to the theoretical quantity of asphalt binder authorized for use in the plant mix placed during the partial payment period involved, except that where recycled plant mix is used, the adjusted unit price will be applied only to the theoretical number of tons of additional asphalt binder materials required by the JMF.

Adjusted contract unit prices for all grades of asphalt binder, including additional asphalt binder materials in recycled mixtures, will be based on the average selling price and base price index for asphalt binder, Grade PG 64-22, regardless of the actual grade required by the JMF.

In determining the adjusted contract unit price for any material specified in this section the following formula will be used:

$$\mathbf{A} = \mathbf{B + (D - C)}$$

Where:

A = Adjusted Contract Unit Price
B = Contract Unit Price
C = Base Price Index
D = Monthly Average Terminal F.O.B. Selling Price

In the event the Department is unable to secure an F.O.B. selling price from at least 4 terminals in a given month, payment will be at the contract unit price for each ton of asphalt binder used in the work during that month.

Payment will be made under:

Pay Item	Pay Unit
Asphalt Binder for Plant Mix	Ton
Polymer Modified Asphalt Binder for Plant Mix	Ton

SECTION 650
OPEN-GRADED ASPHALT FRICTION COURSE, TYPES FC-1, FC-1 MODIFIED AND FC-2 MODIFIED

650-1 DESCRIPTION

Perform the work covered by this section including, but not limited to, construction of a plant mixed open-graded asphalt friction course (OGAFC) properly laid upon a prepared surface in accordance with these Specifications and in conformity with the lines, grades, thickness and typical sections shown on the plans; producing, weighing, transporting, placing and rolling the plant mix as specified in Section 610; furnishing the asphalt binder, anti-strip additive, fiber stabilizing additive and all other materials for the plant mix; furnishing and applying tack coat as specified; providing QC as specified in Section 609 as modified for OGAFC; surface testing of the completed pavement; furnishing scales; making any repairs or corrections to the friction course that may become necessary and maintaining the friction course until final acceptance of the project.

650-2 MATERIALS

Refer to Division 10.

Item	Section
Anti-strip Additives	1012-1(G)
Asphalt Binder, Grade PG 64-22, PG 76-22	1020-2
Coarse Aggregate	1012-1(B)
Fiber Stabilizing Additives	1012-1(I)
Fine Aggregate	1012-1(C)
Mineral Filler	1012-1(D)
Reclaimed Asphalt Shingles (RAS)	1012-1(F)

650-3 COMPOSITION OF MIXTURE (MIX DESIGN AND JOB MIX FORMULA)

(A) General

Design the open-graded asphalt friction course using a mixture of coarse and fine aggregate, asphalt binder, mineral filler, fiber stabilizing additive and other additives as required to produce a mix meeting Table 650-1.

Submit in writing a mix design and proposed JMF targets for each required mix type and combination of aggregates to the Engineer for review and approval at least 20 days before start of asphalt mix production. The mix design shall be prepared by a mix design technician approved by the Department in an approved mix design laboratory. Perform the mix design in accordance with Article 610-3 and the Department's mix design procedures. Copies of these procedures can be obtained through the Materials and Tests Unit. Submit the mix design and proposed JMF targets on forms and in a format approved by the Department.

The mix design and JMF target values will be established within the mix design criteria specified in Table 650-1 for the particular type of mixture to be produced. The formula for each mixture will indicate the blend percentage of each aggregate fraction to be used, a single percentage of combined aggregate passing each required sieve, the percentage and grade of asphalt binder (by weight of total mixture) to be incorporated into the mixture, the percentage of anti-strip additive to be added to the asphalt binder, the percentage of fiber stabilizing additive (by weight of total mix) and the temperature at which the mixture is to be discharged from the plant.

Have on hand at the asphalt plant the approved mix design and JMF issued by the Department, before beginning the work.

The JMF for each mixture shall remain in effect until modified in writing, provided the results of tests performed on material currently being produced conform with specification requirements.

If a change in sources of aggregate materials needs to be made, a new mix design and JMF will be required before the new mixture is produced.

When unsatisfactory results or other conditions make it necessary, the Engineer may establish a new JMF.

(B) Mix Design Criteria

Design open-graded asphalt friction course (OGAFC) mixtures conforming to the gradation requirements and other mix design criteria in Table 650-1 for the mix type specified.

Use the asphalt binder grade shown in Table 650-1 for the mix type specified. RAS may be used in accordance with Subarticle 610-3(A).

Use an anti-strip additive in all OGAFC mixes. It may be hydrated lime or a chemical additive or both. Add chemical anti-strip additive at a rate of 0.5% by weight of asphalt binder. Add hydrated lime at a rate of 1.0% by weight of dry aggregate. Use an approved source and grade.

If needed to prevent asphalt draindown, incorporate a fiber stabilizing additive into all OGAFC types. Add the fiber at a dosage rate by weight of the total mix as approved.

When requested, submit to the Materials and Tests Unit in Raleigh, samples of mix components. Submit sample sizes as noted below or as requested. Provide the samples at least 20 days before the anticipated beginning placement of OGAFC mixture.

250 lb of each coarse aggregate
150 lb of each fine aggregate
1 gal. of mineral filler and/or baghouse fines
1 gal. of hydrated lime OR 1 pint of chemical anti-strip additive
4 lb of fiber stabilizing additive (if used)

Aggregate samples when combined according to the Contractor's proposed aggregate blend percentages shall be within the gradation range defined by the target values of Table 650-1 for each sieve or the samples will not be representative.

The mixing temperature at the asphalt plant will be established on the JMF.

Add the anti-strip additive to the asphalt binder in accordance with Article 620-3.

TABLE 650-1
OGAFC GRADATION CRITERIA

Grading Requirements	**Total Percent Passing**		
Sieve Size (mm)	*Type FC-1*	*Type FC-1 Modified*	*Type FC-2 Modified*
19.0	-	-	100
12.5	100	100	85 - 100
9.50	75 - 100	75 - 100	55 - 75
4.75	25 - 45	25 - 45	15 - 25
2.36	5 - 15	5 - 15	5 - 10
0.075	1.0 - 3.0	1.0 - 3.0	2.0 - 4.0

TABLE 650-2
OGAFC MIX DESIGN CRITERIA

Property	**Design Parameters**		
Asphalt Binder Grade	PG 64-22	PG 76-22	PG 76-22
Asphalt Binder, % Range	5.0 - 8.0	5.0 - 8.0	5.0 - 8.0
Mixing Temperature Range Established by Engineer	200 - 275°F	300 - 350°F	300 - 350°F
Draindown,%, AASHTO T 305	0.3 max.	0.3 max.	0.3 max.

650-4 PLANT EQUIPMENT

Use plant equipment in accordance with Article 610-5 and the requirements herein.

When fiber stabilizing additives are used as an ingredient of the mixture, use a separate feed system capable of accurately proportioning the required quantity into the mixture and in such a manner that uniform distribution will be obtained. Interlock the proportioning device with the aggregate feed or weigh system so as to maintain the correct proportions for all rates of production and batch sizes. Accurately control the proportion of fibers to within ± 10% of the amount required. Provide flow indicators or sensing devices for the fiber system that are interlocked with plant controls such that mixture production will be interrupted if introduction of the fiber fails.

When a batch type plant is used, add the fiber to the aggregate in the weigh hopper or as approved. Increase the batch dry mixing time by 8 to 12 seconds, or as directed, to assure the fibers are uniformly distributed before the injection of asphalt binder into the mixer.

When a continuous mix or dryer-drum type plant is used, add the fiber to the aggregate and uniformly disperse at the point of injection of asphalt binder. Add the fiber in such a manner that it will not become entrained in the exhaust system of the drier or plant.

650-5 CONSTRUCTION METHODS

Produce, transport to the site and place the OGAFC in accordance with Section 610, except as otherwise provided below.

Do not place OGAFC between October 31 and April 1 of the next year, unless otherwise approved. Place friction course, Type FC-1 mixes, only when the road surface temperature is 50°F or higher and the air temperature measured in the shade away from artificial heat is 50°F or higher. The minimum air and road surface temperature for placing Type FC-1 Modified and FC-2 Modified mixes will be 60°F.

Before starting production of the mix, stockpile all aggregates for a sufficient period of time to facilitate the drainage of free moisture.

Add the anti-strip additive to the asphalt binder in accordance with Article 620-3.

Clean the existing surface in an acceptable manner before placement of any asphalt material.

Remove all existing raised pavement markers as directed and repair any damaged areas caused by the removal. Use an approved dense graded mixture of similar type material for the repair.

Apply tack coat in accordance with Section 605 and the following

(A) Use Asphalt Binder, Grade PG 64-22 tack coat material or as approved.

(B) Uniformly apply the tack coat material at a rate of application 0.06 to 0.08 gal/sy, as directed.

Spread and finish the friction course as specified in Article 610-8. Roll the friction course as specified in Article 610-9.

Perform this work in accordance with and using equipment meeting Section 9.5 of the *HMA/QMS Manual.*

Use a Material Transfer Vehicle (MTV) when placing all types of OGAFC. Use a MTV meeting Section 9.5(E) of the *HMA/QMS Manual.*

Remove and replace any part of the finished friction course that shows non-uniform distribution of asphalt binder, aggregate or fiber at no additional cost to the Department.

Coordinate plant production, transportation and paving operations such that uniform continuity of operation is maintained. If spreading operations are interrupted, the Engineer may require that a transverse joint be constructed any time the mixture immediately behind the paver screed cools to less than 250ºF.

When OGAFC, Type FC-2 Modified mixture is specified, use OGAFC, Type FC-1 Modified on entrance and exit ramps, gore areas and at end of project construction joints. Adjust the thickness of placement as specified below.

For end of project joints, provide a transition area consisting of one load of mixture per lane, or as directed. Taper the mixture in thickness from 3/8" at the end of the project to the typical thickness (approximately 3/4") within the maximum distance of spread for one load of mixture. For ramps and gore areas, taper the mixture in thickness from that at the edge of the mainline, approximately 3/4" to 3/8" at the point of the ramp transverse joint. Construct the ramp transverse joint at a point specified by the plans or as directed.

650-6 QUALITY MANAGEMENT SYSTEM

Produce the OGAFC in accordance with Section 609.

650-7 MEASUREMENT AND PAYMENT

Open-Graded Asphalt Friction Course, Type FC-1, Type FC-1 Modified or *Type FC-2 Modified* will be measured and paid as the actual number of tons of friction course incorporated into the completed and accepted work. The friction course will be measured by being weighed in trucks on certified platform scales or other certified weighing devices.

Furnishing asphalt binder for the mix will be paid as provided in Article 620-4 for *Asphalt Binder for Plant Mix*. Adjustments in contract unit price due to asphalt binder price fluctuation will be made in accordance with Section 620.

No direct payment will be made for providing and using the materials transfer vehicle or any associated equipment, as the cost of providing same shall be included in the contract unit bid price per ton for the mix type to be placed.

Payment will be made under:

Pay Item	**Pay Unit**
Open-Graded Asphalt Friction Course, Type FC-1	Ton
Open-Graded Asphalt Friction Course, Type FC-1 Modified	Ton
Open-Graded Asphalt Friction Course, Type FC-2 Modified	Ton

SECTION 652
PERMEABLE ASPHALT DRAINAGE COURSE, TYPES P-78M AND P-57

652-1 DESCRIPTION

Perform the work covered by this section including, but not limited to, the construction of a plant mixed permeable asphalt drainage course (PADC) properly laid upon a prepared surface in accordance with these Specifications and in conformity with the lines, grades, thickness and typical sections shown on the plans; producing, weighing, transporting, placing and rolling the plant mix as specified in Section 610; furnishing the asphalt binder, anti-strip additive and all other materials for the plant mix; furnishing and applying tack coat as specified in Section 605; furnishing scales; providing QC as specified in Section 609 as modified for PADC; making any repairs or corrections to the friction course that may become necessary; and maintaining the friction course until final acceptance of the project.

652-2 MATERIALS

Refer to Division 10.

Item	Section
Anti-strip Additives	1012-1(G)
Asphalt Binder	1020-2
Coarse Aggregate	1012-1(B)
Fine Aggregate	1012-1(C)

The coarse aggregate shall meet Article 1012-1 except that that portion of the coarse aggregate retained on the No. 4 sieve shall contain at least 60% by weight of crushed pieces having 2 or more mechanically induced fractured faces.

652-3 COMPOSITION OF MIXTURE

(A) General

Formulate the PADC from a mixture of crushed aggregate, asphalt binder, anti-strip additive and other additives as required to produce a mix meeting Table 652-1.

Submit in writing a mix design (M&T 601 only) and proposed JMF targets for each required mix type and combination of aggregates to the Engineer for review and approval at least 10 days before start of asphalt mix production. The JMF will be established in accordance with Article 610-3. Establish the asphalt binder content at the midpoint of the range specified in Table 652-1 or as approved. Submit the mix design and proposed JMF targets on forms and in a format approved by the Department.

The formula for each mixture will indicate the blend percentage of each aggregate fraction to be used, a single percentage of combined aggregate passing each required sieve, the percentage and grade of asphalt binder (by weight of total mixture) to be incorporated into the mixture, the percentage of anti-strip additive to be added to the asphalt binder and the temperature at that the mixture is to be discharged from the plant.

Have on hand at the asphalt plant the approved mix design and JMF issued by the Department, before beginning the work.

The JMF for each mixture will remain in effect until modified in writing, provided the results of QMS tests performed on material currently being produced conform with specification requirements.

If a change in sources of aggregate materials needs to be made, a new mix design and JMF will be required before the new mixture is produced.

When unsatisfactory results or other conditions make it necessary, the Engineer may establish a new JMF.

(B) Mix Design

Design PADC mixtures conforming to the gradation requirements and other mix design criteria in Table 652-1 for the mix type specified.

Use the asphalt binder grade shown in Table 652-1 for the mix type specified or as approved.

Use an anti-strip additive in all PADC mixes. It may be hydrated lime or a chemical additive or both. Add chemical anti-strip additive at a rate of 0.5% by weight of asphalt binder. Add hydrated lime at a rate of 1.0% by weight of dry aggregate. Use an approved source and grade.

When requested, submit samples of mix components to the Materials & Tests Unit. Submit sample sizes as noted below or as requested. Provide the samples at least 20 days before the anticipated beginning placement of PADC mixture.

250 lb of each coarse aggregate
150 lb fine aggregate
2 gal. of asphalt binder
1 pint of anti-strip additive

Aggregate samples when combined according to the Contractor's proposed aggregate blend percentages shall be within the gradation range defined by the target values of Table 652-1 for each sieve or the samples will not be representative.

The mixing temperature at the asphalt plant will be established on the JMF.

TABLE 652-1
PERMEABLE ASPHALT DRAINAGE COURSE
GRADATION AND MIX DESIGN CRITERIA

Sieve Size (mm)	Total Percent Passing	
	Type P-78M	**Type P-57**
37.5	-	100
25.0	-	95 - 100
19.0	100	-
12.5	95 - 100	25 - 60
9.50	75 - 100	-
4.75	20 - 45	10 - 20
2.36	3 - 15	5 - 10
0.075	1.0 - 3.0	1.0 - 3.0
Asphalt Binder Content, %	2.5 - 3.5	2.0 - 3.0
Mixing Temperature at Plant (Established by the Engineer)	240 - 270°F	260 - 290°F

652-4 CONSTRUCTION METHODS

Produce, transport to the site and place the asphalt plant mix in accordance with Section 610, except as otherwise provided herein.

Incorporate the asphalt binder into the asphalt plant mix in accordance with Section 620. Add the anti-strip additive to the asphalt binder in accordance with Article 620-3.

A prime coat or tack coat will not be required.

When the PADC is placed in trench sections, the rolling equipment and rolling sequences required by Article 610-9 will not apply. Compact the PADC to a degree acceptable to the Engineer.

Following placement of the PADC mixture to the appropriate line, grade and thickness, begin rolling when the mat has cooled sufficiently to support the weight of an 8 to 12 ton steel-wheel tandem roller. Mat temperature at the time of initial rolling shall be approximately 175°F to 225°F. The number of roller passes will be 2 or 3, unless otherwise directed. Consolidate the drainage layer sufficiently with rolling so as to support the weight of equipment that will place the next layer of pavement. Do not compact the drainage layer to the extent that it is not free draining or that the aggregate is crushed.

No construction traffic will be allowed to travel on any PADC layer. Only equipment necessary to place the next layer of pavement will be allowed on the drainage layer.

Do not place PADC that will not be covered with the next layer of pavement during the same calendar year or within 15 days of placement if the PADC is placed in January or February.

652-5 QUALITY MANAGEMENT SYSTEM FOR ASPHALT PAVEMENTS

Produce the PADC in accordance with the Section 609.

652-6 MEASUREMENT AND PAYMENT

Permeable Asphalt Drainage Course, Type ____ will be paid as the actual number of tons of drainage course incorporated into the completed and accepted work. The drainage course will be measured by being weighed in trucks on certified platform scales or other certified weighing devices.

Asphalt Binder for Plant Mix will paid in accordance with Article 620-4.

Payment will be made under:

Pay Item	Pay Unit
Permeable Asphalt Drainage Course, Type P-78M	Ton
Permeable Asphalt Drainage Course, Type P-57	Ton

SECTION 654
ASPHALT PLANT MIX, PAVEMENT REPAIR

654-1 DESCRIPTION

Perform the work covered by this section including, but not limited to, repairing of existing pavement with asphalt plant mix in order to provide a safe, passable and convenient condition for traffic, or to replace pavement removed in order to remove or to place pipe lines.

Perform the work by cutting the existing pavement to a neat vertical joint and uniform line; removing and disposing of pavement, base and subgrade material as approved or directed; coating the area to be repaired with a tack coat; furnishing, placing and compacting asphalt plant mix; and replacing of the removed material with asphalt plant mix.

Make the repairs in accordance with the plans, or as approved or directed.

654-2 MATERIALS

Where a pavement repair detail is not shown in the plans, use an approved asphalt plant mix.

Where a pavement repair detail is shown in the plans, the type of plant mix shall be in accordance with the pavement repair detail except where the Specifications permit the substitution of another type of plant mix or where approved.

In areas where the existing pavement is not to be resurfaced, the Contractor will not be allowed to substitute a different type of surface course from that shown on the pavement repair detail.

654-3 CONSTRUCTION METHODS

(A) General

Perform repair of existing pavement as approved or directed. Coordinate the work with all other work and operations necessary to maintain traffic.

(B) Pipe Removal or Installation

Where traffic is to be maintained, perform the removal or installation of pipe in sections so that half the width of the roadway will be available to traffic. Immediately upon completion of the entire pipeline removal or installation, repair the pavement.

654-4 MEASUREMENT AND PAYMENT

Asphalt Plant Mix, Pavement Repair will be paid as the actual number of tons of asphalt plant mix, complete in place, used to make completed and accepted repairs, except for those repairs made necessary by the contractor's negligence. The asphalt plant mixed material will be measured by being weighed in trucks on certified platform scales or other certified weighing devices.

Any requirements included in the contract that provide for adjustments in compensation due to variations in the price of asphalt cement will not be applicable to payment for the work covered by this section.

Payment will be made under:

Pay Item	Pay Unit
Asphalt Plant Mix, Pavement Repair	Ton

SECTION 657
SEAL EXISTING PAVEMENT CRACKS AND JOINTS

657-1 DESCRIPTION

The work consists of sealing existing longitudinal and transverse pavement cracks and joints with hot applied joint sealer at locations as directed by the Engineer. The Contractor will not be required to seal the existing edge joints.

657-2 MATERIALS

Refer to Division 10.

Item	Section

Hot Applied Joint Sealer	1028-2

657-3 CONSTRUCTION METHODS

Install the sealant so that it forms a complete watertight bond with a high degree of elasticity, with maximum flexibility and longevity under extreme temperature ranges.

Clean cracks and joints using a hot compressed air lance to blast out any vegetation, dirt, dampness and loose materials from the cracks and joints. Equip the air compressor with suitable traps and filters to remove moisture and oil from the compressed air. Use the hot air lance to dry and warm the adjacent pavement immediately before sealing. Direct flame dryers are not allowed.

Heat and apply the sealant material according to the manufacturer's recommendations. Use a portable melting kettle for heating the material that is equipped with indirect heating (air-jacketed flow) and is capable of constantly agitating the joint sealer to maintain a uniform temperature. Equip the kettle with either mechanically operated paddles and/or a continuous circulating pump to maintain agitation. Use heating equipment capable of controlling the sealant material temperature within the manufacturer's recommended temperature range and that is thermostatically-control calibrated between 200°F to 600°F. Locate a thermometer on the kettle so the Engineer can safely check the temperature of the sealant material. Overheating of the sealant material will not be permitted.

Apply sealant in the prepared cracks and joints within the manufacturer's recommended temperature range, using a pressure screed shoe to completely fill the crack or joint, leaving a sealed 2" overband. Excessive overbanding or waste of sealant materials will not be tolerated. Immediately squeegee the crack seal material to minimize the height of the overband. All sealed cracks and joints shall have a minimum of 1/8" depth of sealant installed.

Do not apply the hot applied joint sealer when the surface temperature of the pavement is below 32°F. Follow manufacturer's recommendations.

After the crack or joint has been sealed, promptly remove any surplus sealer on the pavement. Do not permit traffic over the sealed cracks and joints without approval by the Engineer. When approved by the Engineer, place sand or other approved material over the crack or joint to prevent tracking.

657-4 MEASUREMENT AND PAYMENT

Sealing existing pavement cracks and joints will be measured and paid as the actual number of pounds of material that has satisfactorily been used to seal pavement cracks and joints in the designated highway. Any material spilled, used in excessive overbanding, wasted, misapplied or unsatisfactorily used in any way will be deducted in determining quantities for payment. The Engineer will determine the quantity, if any, to be deducted. The Engineer's decision on the quantity to be deducted will be final and binding.

Payment will be made under:

Pay Item	**Pay Unit**
Sealing Existing Pavement Cracks and Joints	Pound

SECTION 660
ASPHALT SURFACE TREATMENT

660-1 DESCRIPTION

Perform the work covered by this section including, but not limited to, furnishing, hauling, spreading and rolling the asphalt material and aggregate consisting of one or more applications of liquid asphalt material and one or more applications of aggregate cover coat material on a prepared surface; furnishing and spreading blotting sand; and maintaining and repairing the asphalt surface treatment.

660-2 MATERIALS

Refer to Division 10.

Use one of the following grades of asphalt:

Item	**Section**
Aggregates for Asphalt Surface Treatment	1012-2
Blotting Sand	1012-3
Emulsified Asphalt, Grade CRS-2	1020-3
Emulsified Asphalt, Grade CRS-2L	1020-3
Emulsified Asphalt, Grade CRS-2P	1020-3
Emulsified Asphalt, Grade CSS-1H	1020-3

Item	Section
Fine Aggregate	1014
Mineral Filler	1012-1(D)
Water	1024-4

Before any asphalt surface treatment is placed, obtain from the asphalt supplier and furnish to the Engineer a certification of compatibility of the asphalt with the aggregate proposed for use.

660-3 WEATHER AND SEASONAL LIMITATIONS

Do not place any asphalt surface treatment between October 15 and March 16, except for asphalt surface treatment that is to be overlaid immediately with asphalt plant mix.

Apply asphalt material only when the surface to be treated is dry and when the atmospheric temperature is above 50°F in the shade away from artificial heat.

When placing asphalt surface treatment that is to be immediately overlaid with asphalt plant mix, the seasonal and temperature limitations of Article 610-4 shall apply.

Do not apply asphalt material when the weather is foggy or rainy.

660-4 SURFACE PREPARATION

Clean the surface to be treated of all dust, dirt, clay, grass, sod and any other deleterious matter before application of the asphalt surface treatment.

660-5 ACCEPTANCE OF ASPHALT MATERIALS

The acceptance of asphalt materials will be in accordance with Section 1020-1.

660-6 APPLICATION EQUIPMENT

Use asphalt application equipment that meets Article 600-5.

Apply aggregate by the use of a self-propelled, pneumatic-tire aggregate spreader capable of maintaining a specified rate with a uniform application for the width of asphalt material being covered. Tailgate spreaders will not be permitted. Areas that are inaccessible to the aggregate spreader may be covered by hand spreading or other acceptable methods.

660-7 APPLICATION OF ASPHALT MATERIALS

The grades, rates of application and the temperature that the asphalt material is to be applied shall be within the limits shown in Table 660-1.

Base the required rates of application on the volume of material at the application temperature.

TABLE 660-1
MATERIAL APPLICATION RATES AND TEMPERATURES

Type of Coat	Grade of Asphalt	Asphalt Rate Gal/SY Total	Application Temp. °F	Aggregate Size	Aggregate Rate Lb/SY Total
Mat	CRS-2 or CRS-2P	0.35 - 0.45	150 - 175	No. 6M[A,C]	30 - 35
	CRS-2 or CRS-2P	0.30 - 0.35	150 - 175	No. 67	35 - 45
	CRS-2 or CRS-2P	0.45 - 0.50	150 - 175	No. 5 [B,C]	45 - 50
	CRS-2 or CRS-2P	0.30 - 0.40	150 - 175	No. 78M[A,C]	15 - 20
Straight Seal	CRS-2 or CRS-2P	0.35 - 0.40	150 - 175	No. 78M	16 - 22
	CRS-2 or CRS-2P	0.35 - 0.40	150 - 175	Lightweight	9 - 12
Split Seal	CRS-2 or CRS-2P	0.5 - 0.60	150 - 175	No.78M	30 - 35
	CRS-2 or CRS-2P	0.45 - 0.60	150 - 175	Lightweight	18 - 20
Triple Seal	CRS-2 or CRS-2P	0.60 - 0.75	150 - 175	No. 78M	45 - 51
	CRS-2 or CRS-2P	0.60 - 0.75	150 - 175	Lightweight	27 - 29
Sand Seal	CRS-2 or CRS-2P	0.22 - 0.30	150 - 175	Blotting Sand	12 - 15

A. Use No. 6M or No. 78M aggregate for retreatment before an overlay on existing pavement.
B. Use No. 5 aggregate for initial treatment on new construction.
C. Article 660-9 includes more details regarding variations of the types of coats.

660-8 APPLICATION OF AGGREGATES

The size of the aggregate shall be as shown in Table 660-1 for the mat coat or the type of seal coat to be constructed. The rate of application for mat and seal aggregates shall be within the limits shown in Table 660-1. When directed, weigh a sufficient number of truck loads of aggregate before spreading to verify that the rate of application is within the required limits and use ASTM D5624 to determine rate of application.

660-9 CONSTRUCTION METHODS

(A) Asphalt Mat Coat

The surface on which the mat coat is to be applied shall be approved by the Engineer before the mat coat liquid asphalt is applied.

Place a string line guide for application equipment unless otherwise permitted. Place the mat coat in full-lane widths, unless otherwise permitted.

Immediately follow the application of mat liquid asphalt with the spreading of the aggregate. No more than 5 minutes can elapse from the time the liquid asphalt is applied and the rolling is completed when using CRS-2. No more than 4 minutes can elapse from the time the liquid asphalt is applied and the rolling is completed when using CRS-2P or CRS-2L.

Test mat coat aggregate, have approved and drained of free moisture before use. Spread the aggregate uniformly at the required rate and correct all non-uniform areas before rolling.

Roll immediately after the aggregate is uniformly spread. Rolling consists of at least 3 complete coverages with two 5 to 8 ton steel-wheel rollers. Continue rolling until the aggregate is thoroughly keyed into the mat liquid asphalt. Do not allow crushing of the aggregate or picking up of the material by the rollers. A combination steel-wheel and pneumatic-tire roller will not be permitted. Use 2 individual steel-wheel rollers. The 3 coverages shall be completed within 5 minutes of the spraying of the mat liquid asphalt.

At the beginning of each mat liquid asphalt application, spread a paper over the end of the previously completed mat coat and begin the asphalt application on the paper. After application, remove and dispose of the paper.

After the aggregate is thoroughly seated, broom all excess aggregate off of the surface of the mat coat as directed. Traffic may be permitted on the mat coat immediately after the rolling and brooming is complete.

Correct defects or damage to the mat coat before the application of seal coat or plant mix overlay. The seal coat or plant mix may be applied the same day the mat coat is placed provided the mat coat has been satisfactorily applied and rolled.

(B) Asphalt Seal Coat

Use the type of seal coat as required by the contract. Test seal coat aggregates, obtain approval and drain of free moisture before use.

Adjust the aggregate rates to provide a sufficient quantity of cover material to be spread over the surface of the seal coat preventing traffic damage, where it is necessary to permit traffic on sections of a completed seal coat.

Perform rolling of each layer immediately after the aggregate has been uniformly spread. Rolling will consist of at least 3 complete coverages with 2 pneumatic-tire rollers followed by at least one complete coverage with a 5 to 8 ton steel-wheel roller. These coverages shall be completed within 5 minutes of the asphalt emulsion being placed when using CRS-2. When CRS-2P or 2L is used all roller coverages shall be completed within 4 minutes of the asphalt emulsion being placed. Do not allow crushing of the aggregate or picking up of the material by the rollers. The use of a combination steel-wheel and pneumatic-tire roller will be permitted instead of the 5 to 8 ton steel-wheel roller.

The requirements of Subarticle 660-9(A) will apply to the width of seal coat construction, application of liquid asphalt and aggregate and the construction of joints. When directed, broom excess aggregate material from the surface of the seal coat and apply blotting sand in accordance with Section 818.

The construction of the various types of seal coats will be in accordance with the following additional requirements:

(1) Straight Seal

Apply liquid asphalt material to the existing surface followed immediately by an application of granite or lightweight aggregate using Table 660-1 and requirements in the contract. Uniformly spread the full required amount of aggregate in one application and correct all non-uniform areas before rolling.

Immediately after the aggregate has been uniformly spread, perform rolling as previously described.

(2) Split Seal

Apply liquid asphalt material to the existing surface followed immediately by an application of granite or lightweight aggregate using Table 660-1 and requirements in the contract ensuring each is uniformly placed over the existing surface and rolled as previously described.

Immediately after the first application of seal aggregate has been made uniform and rolled, apply the second application of the required amount of liquid asphalt material and seal coat aggregate or blotting material as defined in Article 1012-3 and roll as previously described.

(3) Triple Seal

Follow the procedure outlined in Subarticle 660-9(B)(2) with the exception that only granite or lightweight aggregate can be used on the second application. Apply liquid asphalt material and granite aggregate, lightweight aggregate or blotting material as defined in Article 1012-3 as a third layer and roll as previously described.

Instead of the No. 78M or lightweight stone, blotting material as defined in Article 1012-3 may be used for the top aggregate layer with an application rate of approximately 6 to 12 lb/sy.

(4) Slurry Seal

(a) Mix Requirements

Submit to the Engineer a mix design and results of the wear loss by the wet track abrasion test (WTAT) as prepared by an approved testing laboratory. The WTAT will be performed in accordance with ASTM D3910. The wear loss by the Wet Track Abrasion Test shall not be greater than 100 g/sf. Apply the wear loss to the asphalt content limits designated on the JMF.

Place a test strip for approval by the Engineer before beginning the work. Once the consistency of the mix has been approved by the Engineer, maintain the total water content within 3% of the approved blend during the course of operation.

Submit a mix design for each type slurry. The gradation of the mix produced shall conform to the job mix range. The asphalt content (residual asphalt) shall not vary by more than 1.5% from the approved mix design.

TABLE 660-2
SLURRY SEAL GRADATION CRITERIA

Type	Percentage of Total by Weight Passing								Remarks
	3/8"	#4	#8	#16	#30	#50	#100	#200	
B	100	90-100	65-90	45-70	30-50	18-33	10-21	5-15	Design Asphalt Content,% #: 8.5-13
C	100	90-100	70-90	32-54	23-38	16-29	9-20	5-15	Design Asphalt Content,% #: 8.5-11.5

(b) Sampling Requirements

Samples for gradation will be taken from aggregate stockpiles designated by the Contractor for use. Take samples for asphalt content and total water content from the completed mixture. Samples of aggregate, filler and emulsion for wet track abrasion check test will be taken at the job site. The frequency of sampling and testing will be established by the Engineer based upon the Department's acceptance program and local conditions encountered.

(c) Equipment

Combine the mixing and spreading equipment in a single mobile operating unit. Attach a burlap drag 19" wide to the back of the unit for the purpose of smoothing the slurry seal. Equip the mobile unit with an approved feeder that will accurately meter or otherwise introduce a predetermined amount of material into the mixer simultaneously with the aggregate. Use the feeder whenever mineral filler is added to the mix. Equip the mobile unit with a water pressure system and fog type spray bar capable of completely fogging the surface to that slurry seal is to be applied. Use a mobile unit capable of an operative speed of at least 60 ft/min and that has sufficient storage capacity to mix and apply a minimum of 5 tons of slurry.

(i) Mixer

Use a continuous flow type mixer capable of delivering water and a predetermined proportion of aggregate and asphalt emulsion to a revolving multiblade mixer tank. Use a mixer that discharges the thoroughly mixed product on a continuous basis and in that the blades of the mixing unit are capable of thoroughly blending all ingredients.

(ii) Spreader

Use a spreader equipped with a flexible type squeegee positioned in contact with the pavement surface and designed to apply a uniform spread with a minimum loss of slurry.

(iii) Auxiliary Equipment

Provide hand squeegees, shovels and other hand equipment as necessary to perform work in areas that are inaccessible to the unit.

(d) Construction Methods

(i) Preparation of Surface

Thoroughly clean the surface upon which slurry seal is to be applied of all loose material, vegetation, silt spots and other objectionable materials immediately preceding application by either brooming or the use of compressed air.

(ii) Application

Wet aggregate immediately before mixing with the emulsion. The Engineer may direct that the surface of the pavement be fogged with water (approximately 0.05 gal/sy) immediately preceding the pass of the spreader. Provide a slurry mixture of a consistency such that it rolls in the spreader box in a continuous mass. Slurry that segregates in the spreader box, so that flowing of liquids (water and emulsion) is evident, is not acceptable and shall not be applied. The liquid portion of slurry mixture shall not flow from either the spreader box or the applied slurry. Evidence of such flow is sufficient cause for rejection of the applied material. Place the slurry on the road in full lane widths up to and including 12 ft. Use a mechanical device such as an auger to distribute the slurry mix in the spreader box.

Correct excess buildup of slurry on longitudinal and transverse joints.

Do not open treated areas to traffic until such time as the slurry seal has cured to the extent that it will no longer be damaged by traffic. The applied slurry mixture shall be uniform in texture and not flush under traffic. Correct any areas not satisfactory to the Engineer. Nothing contained herein is intended to relieve the Contractor from sharing in the responsibility and performance of the treatments, if a failure occurs before acceptance of the contract. Article 105-17 is amended accordingly.

Do not apply slurry seal surface course on surfaces containing ponding water and the minimum surface temperature shall be 50°F.

The Engineer may require the surface area to that the slurry has been applied by hand to be rolled using a pneumatic-tire type roller. Operate the roller at an approximate tire pressure of 50 psi and subject the paved area to a minimum of 2 coverages.

If oversize aggregate is encountered in the stockpile, immediately cease operation and remove the oversize aggregate by screening.

(iii) Thickness of Application

The average minimum thickness of application shall be at least 3/16" for Type B and at least 5/16" for Type C, unless otherwise specified.

In the event of a test failure on compatibility or WTAT (loss greater than 100 g/sf) for a sample of material being applied to the road, take corrective action before start-up of another day's run. If the sample taken following adjustment fails the compatibility or WTAT, cease application on the road. Maintain responsibility for furnishing additional compatibility or WTAT results and field application site(s). Resume application when the acceptability of seal is clearly demonstrated.

The disposition of rejected material will be subject to the approval of the Engineer.

(5) Sand Seal

Place the fully required amount of asphalt material in one application and immediately cover with the seal coat aggregate. Uniformly spread the fully required amount of aggregate in one application and correct all non-uniform areas before rolling.

Immediately after the aggregate has been uniformly spread, perform rolling.

When directed, broom excess aggregate material from the surface of the seal coat.

When the sand seal is to be constructed for temporary sealing purposes only and will not be used by traffic, other grades of asphalt material meeting Articles 1020-5 and 1020-6 may be used instead of the grade of asphalt required by Table 660-1 when approved.

(C) Asphalt Mat and Seal

Construct the mat coat in accordance with Subarticle 660-9(A) using the size aggregate required by the contract.

Construct the seal coat in accordance with Subarticle 660-9(B) using the type seal required by the contract.

(D) Cape Seal

Construct the cape seal by applying a seal coat followed by applying a slurry seal as defined in Subarticle 660-9(B).

660-10 MAINTENANCE AND PROTECTION

Maintain and protect the asphalt surface treatment until it is accepted by the Department. Make all necessary repairs in such a manner as to preserve the uniformity of the surface.

660-11 MEASUREMENT AND PAYMENT

Asphalt Surface Treatment, Mat Coat, No. __ Stone; Asphalt Surface Treatment, ____ Seal and *Asphalt Surface Treatment, Mat and Seal* will be measured and paid at the contract unit price per square yard. *Asphalt Surface Treatment, ____ Seal* includes *Straight Seal, Split Seal, Triple Seal, Slurry Seal, Sand Seal* and *Cape Seal.* Payment at the above prices will be made for replacing any satisfactorily completed asphalt surface treatment when such replacement has been made necessary by defects in subgrade or base constructed by others.

When the Engineer directs that the rate of application of asphalt material be decreased below the minimum rate shown in Table 660-1, no reduction in compensation will be made.

When the Engineer directs that the rate of application of asphalt material be increased above the maximum rate shown in Table 660-1, compensation to the Contractor will be made in the amount of 5 cents plus the verified cash cost to the Contractor at the point of delivery for each gallon of asphalt material, measured at application temperature, necessitated by the increase.

Blotting Sand will be paid in accordance with Article 818-4.

Asphalt Surface Treatment, Slurry Seal materials placed in stockpiles or on the road not meeting the required tolerances may be accepted at a reduced price if it is not considered detrimental to the life of the treatment by the Engineer in accordance with Article 105-3. The following price adjustment schedule will be used for *Asphalt Surface Treatment, Slurry Seal* when appropriate:

(A) One percent reduction in the bid price per square yard for each 1/10% the asphalt content is out of tolerance.

(B) One-quarter percent price adjustment in the bid price per square yard for each 1% that the aggregate gradation is out of the job mix range.

(C) One-half percent reduction in the bid price per square yard for each gram per square foot of wet-track abrasion test (WTAT) loss between 101 g and 200 g. Material having a loss greater than 200 g will not be accepted for payment.

(D) One percent reduction in the bid price per square yard for each 1% water in excess of the approved water content plus 3%.

Price adjustments under Subarticles 660-11(A) through 660-11(D) above shall apply concurrently; however, price adjustment will not apply in the event the material is rejected.

Furnishing and applying prime will be paid as provided in Article 600-9 for *Prime Coat.*

Payment will be made under:

Pay Item	Pay Unit
Asphalt Surface Treatment, Mat Coat, No. __ Stone	Square Yard
Asphalt Surface Treatment, ____ Seal	Square Yard
Asphalt Surface Treatment, Mat and Seal	Square Yard

SECTION 661
ULTRA-THIN BONDED WEARING COURSE

661-1 DESCRIPTION

Produce and place an Ultra-thin Bonded Wearing Course (UBWC), including an application of a warm Polymer-Modified Emulsion Membrane (PMEM) followed immediately with an UBWC hot mix asphalt overlay. Spray polymer-modified emulsion membrane immediately before applying hot mix asphalt.

Provide and conduct the QC and required testing for acceptance of the UBWC in accordance with the contract.

661-2 MATERIALS

Refer to Division 10.

Item	Section

Item	Section
Anti-strip Additives	1012-1(G)
Coarse Aggregate	1012-1(B)
Fine Aggregate	1012-1(C)
Mineral Filler	1012-1(D)
Polymer Modified Asphalt Binder	1020-2
Reclaimed Asphalt Shingles (RAS)	1012-1(E)

Use either PG 70-28 or PG 76-22 binder in the mix design. Conform to Section 620. Ensure that the asphalt binder is compatible with the PMEM and the existing pavement.

661-3 COMPOSITION OF MIX

Do not use crystalline limestone, crystalline-dolomitic limestone or marble for aggregates and do not use RAP. Use a mixture of coarse and fine aggregate, asphalt binder, mineral filler and other additives when required. Size, uniformly grade and combine in such proportions such that the resulting mixture meets the gradation and physical requirements of Tables 661-1 and 661-2. Use the mix design and optimum asphalt content for *Ultra-thin Bonded Wearing Course Mix Design Guidelines* on file with the Materials and Tests Unit and available upon request. RAS may be used in accordance with Subarticle 610-3(A).

Submit in writing a mix design and proposed JMF targets for each required mix type and combination of aggregates to the Engineer for review and approval at least 20 days before start of asphalt mix production. Submit the mix design and proposed JMF targets on forms and in a format approved by the Department and in accordance with applicable requirements of Article 610-3.

Establish the JMF target values within the mix design criteria specified in Table 661-2for the particular type mixture.

Have on hand at the asphalt plant, the approved mix design and JMF issued by the Department, before beginning the work.

The JMF for each mixture shall remain in effect until modified in writing by the Engineer, provided the results of QMS tests performed on material currently being produced conform with specification requirements. If a change in sources of aggregate materials needs to be made, a new mix design and JMF will be required before the new mixture is produced. When unsatisfactory results or other conditions make it necessary, the Engineer may establish a new JMF.

Determine and certify compatibility of all asphalt emulsion, asphalt binder and aggregate components.

TABLE 661-1
UBWC GRADATION CRITERIA

Sieves (mm)	% Passing by Weight
12.5	100
9.50	85 - 100
4.75	28 - 44
2.36	17 - 34
1.18	13 - 23
0.600	8 - 18
0.300	6 - 13
0.150	4 - 10
0.075	3.0 - 7.0

TABLE 661-2
UBWC MIX DESIGN CRITERIA

Property	Requirement
Asphalt Content, %	4.6 - 5.8
Draindown Test, AASHTO T 305	0.1% max
Moisture Sensitivity, AASHTO T 283[A]	85% min
Application Rate, lb/sy	70 lb/sy
Approximate Application Depth, in.	5/8"
Asphalt PG Grade, AASHTO M 320	PG 70-28 or PG 76-22

A. Specimens for T 283 testing are to be compacted using the Superpave gyratory compactor. The mixtures shall be compacted using 100 gyrations to achieve specimens approximately 95 mm in height. Use mixture and compaction temperatures recommended by the binder supplier.

661-4 CONSTRUCTION METHODS

(A) Equipment

Use asphalt mixing plants in accordance with Article 610-5. Furnish paving machine with the following capabilities:

(1) Self-priming paving machine capable of spraying the Polymer-Modified Emulsion Membrane, applying the hot asphalt concrete overlay and screeding the surface of the mat to the required profile and cross section in one pass at any rate between 30 and 92 ft/minute.

(2) Receiving hopper, feed conveyor, storage tank for Polymer-Modified Emulsion Membrane material, PMEM emulsion single variable-width spray bar and a variable width, heated, vibratory-tamping bar screed.

(3) Screed with the ability to be crowned at the center both positively and negatively and have vertically and horizontally adjustable extensions to accommodate the desired pavement profile and widths.

(4) Sprayer system capable of accurately and continuously monitoring the rate of spray and providing a uniform application across the entire width to be overlaid.

(5) Use pavers equipped with an electronic screed control that will automatically control the longitudinal profile and cross slope of the pavement. Control the longitudinal profile through the use of either a mobile grade reference(s), including mechanical, sonic and laser grade sensing and averaging devices, an erected string line(s) when specified, joint matching shoe(s), slope control devices or the approved methods or combination of methods. Unless otherwise specified, use a mobile grade reference system capable of averaging the existing grade or pavement profile over at least a 30 ft distance or by non-contacting laser or sonar type ski with at least 4 referencing stations mounted on the paver at a minimum length of 24 ft. Establish the position of the reference system such that the average profile grade is established at the approximate midpoint of the system. The transverse cross slope shall be controlled as directed by the Engineer.

Use an erected fixed stringline for both and longitudinal profile and cross slope control when required by the contract. When an erected fixed string line is required, furnish and erect the necessary guide line for the equipment. Support the stringline with grade stakes placed at maximum intervals of 25 ft for the finished pavement grade.

Use the 30 ft minimum length mobile grade reference system or the non-contacting laser or sonar type ski with at least 4 referencing stations mounted on the paver at a minimum length of 24 ft to control the longitudinal profile when placing the initial lanes and all adjacent lanes of all layers, including resurfacing and asphalt in-lays, unless other specified or approved. A joint matching device (short 6"shoes) may be used only when approved.

Use the automatic slope control system unless otherwise approved. The Engineer may waive the use of automatic slope controls in areas where the existing surface (subgrade, base, asphalt layer, etc.) exhibits the desired cross slope of the final surface. The Engineer may also waive the use of automatic slope controls in areas where the use of such equipment is impractical due to irregular shape or cross section (such as resurfacing). When the use of the automatic slope controls is waived, the Engineer may require the use of mobile grade references on either or both sides of the paver. Manual screed operation will be permitted in the construction of irregularly shaped and minor areas, subject to approval. Waiver of the use of automatic screed controls does not relieve the Contractor of achieving plan profile grades and cross slopes.

In the case of malfunction of the automatic screed control equipment, the paver may be manually operated for the remainder of the workday provided this method of operation produces acceptable results. Do not resume work thereafter until the automatic system is functional.

The Engineer will waive the requirement for use of pavers for spreading and finishing where irregularities or obstacles make their use impractical. Spread, rake and lute the mixture by hand methods or other approved methods in these areas.

Operate the paver as continuously as possible. Pave intersections, auxiliary lanes and other irregular areas after the main line roadway has been paved, unless otherwise approved.

Compact the wearing course with a steel double drum asphalt roller(s) with a minimum weight of 10 tons. Maintain rollers in reliable operating condition and equip with functioning water system and scrapers to prevent adhesion of the fresh mix onto the roller drums. Supply adequate roller units and compact promptly following the placement of the material.

Request approval of equipment before the start of any work. Maintain all equipment and tools in satisfactory working condition at all times.

(B) Surface Preparation

Perform the following items before the commencement of paving operations.

(1) Protect and cover manhole covers, drains, grates catch basins and other such utility structures with plastic or building felt before paving and reference for location and adjustment after paving.

(2) Remove thermoplastic traffic markings symbols, characters or other markings greater than 1/4" in thickness on the existing pavement.

(3) Clean and completely fill pavement cracks and joints greater than 1/4" wide. Do not overband the existing cracks and joints. Apply sealant per manufacturer's recommendation.

(4) Fill surface irregularities greater than 1" deep with a material approved by the Engineer.

(5) Thoroughly clean the entire pavement surface, giving specific attention to accumulated mud and debris. Pressurized water and/or vacuum systems may be required to ensure a clean surface.

(C) Application of Ultra-thin Bonded Wearing Course

Produce, transport to the site and place the UBWC in accordance with Section 610, except as otherwise provided below.

Use only one asphalt binder PG grade for the entire project, unless the Engineer gives written approval.

Do not place ultra-thin bonded wearing course between October 31 and April 1, when the pavement surface temperature is less than 50°F or on a wet pavement. In addition, when PG 76-22 binder is used in the JMF, place the wearing course only when the road pavement surface temperature is 60°F or higher and the air temperature in the shade away from artificial heat is 60°F or higher.

Apply the ultra-thin bonded wearing course mixture at the rate per square yard as shown in Table 661-2 for the mix type shown in the plans.

Spray the polymer-modified emulsion membrane at a temperature of 140°F to 180°F. Provide a uniform application across the entire width. Determine the rate of application (typically 0.15 to 0.25 gal/sy) by the mix design and current pavement condition for the specified project. Ensure the rate of application is approved by the Engineer before beginning work.

Do not allow wheels or other parts of the paving machine to touch the polymer-modified emulsion membrane before the hot mix asphalt concrete wearing course is applied.

Place the hot asphalt concrete wearing course over the full width of the polymer-modified emulsion membrane. Apply the hot mix asphalt concrete at a temperature of 300°F to 330°F and within a maximum of 3 seconds immediately after the application of the membrane.

Before opening to traffic, allow the pavement to sufficiently cool after the rolling operation to resist damage to the pavement.

(D) Compaction

Compact the wearing course with at least 2 passes of a steel double drum asphalt roller before the material temperature has fallen below 185°F. Do not allow the rollers to remain stationary on the freshly placed asphalt concrete. Compact immediately following the placement of ultra-thin bonded wearing course. A release agent (added to the water system) may be required to prevent adhesion of the fresh mix to the roller drum and wheels. Compact in the static mode.

661-5 QUALITY MANAGEMENT SYSTEM FOR ASPHALT PAVEMENTS

Produce the ultra-thin hot mix asphalt in accordance with Section 609.

661-6 MEASUREMENT AND PAYMENT

Ultra-thin Bonded Wearing Course will be measured and paid by the actual number of tons of mixture incorporated into the completed and accepted work. The hot mix asphalt pavement will be measured by being weighed in trucks on certified platform scales or other certified weighing devices.

Application of Ultra-thin Hot Mix Asphalt will be measured and paid at the contract unit price per square yard. In measuring this quantity, the length will be the actual length constructed, measured along the surface. The width will be the width required by the contract or directed by the Engineer.

Polymer Modified Asphalt Binder for Plant Mix will be paid in accordance with Article 620-4. Asphalt binder price adjustments when applicable will be based on Grade PG 64-22, regardless of the grade used.

Where PG 76-22 is being used in the production of ultra-thin, the grade of asphalt binder to be paid will be PG 70-28, unless otherwise approved.

The above prices and payments will be full compensation for all work covered by this section including, but not limited to, furnishing all materials, producing, weighing, transporting, placing and compacting the polymer modified asphalt emulsion; maintaining the ultra-thin bonded wearing course until final acceptance of the project; performing QC as

specified in the contract; and making any repairs or corrections to the surface of the pavement or adjacent landscape that may become necessary.

Payment will be made under:

Pay Item	Pay Unit
Ultra-thin Bonded Wearing Course, UBWC	Ton
Application of Ultrathin Hot Mix Asphalt	Square Yard

SECTION 663
HOT IN-PLACE RECYCLED ASPHALT CONCRETE

663-1 DESCRIPTION

This work shall consist of hot in-place recycling of the existing asphalt concrete surface by heating and softening the existing asphalt pavement with indirect heat, loosening the heated pavement by hot milling to the depth specified in the plans, adding a plant produced hot mix asphalt admixture, if required, applying a rejuvenating agent, thoroughly remixing the material in a pugmill, leveling, relaying and compaction of the hot in-place recycled asphalt mixture. Use a continuous, single train, single pass, multi-step process to accomplish this work.

Provide and conduct the QC and required testing for acceptance of the hot in-place recycled mixture in accordance with the contract.

663-2 MATERIALS

(A) Hot Mix Asphalt Admixture

Determine the type and amount of plant produced hot mix asphalt (HMA) admixture to be added to the recycled mixture, subject to the approval of the Engineer. The HMA admixture shall be a plant mixture of asphalt binder and aggregate(s) meeting Division 10 as shown below. The aggregate in the admixture may be a single standard size aggregate or a combination of aggregate sizes as needed. Provide enough binder content for the admixture such that the aggregate particles are fully coated. Provide a gradation and binder content for the admixture such that when blended with the other mix components, the hot in-place recycled mix properties shall meet the mix design criteria for the applicable mix type specified in the plans, unless otherwise approved by the Engineer.

Refer to Division 10.

Item	Section
Anti-strip Additives	1012-1(G)
Asphalt Binder	1020-2
Coarse Aggregate	1012-1(B)
Fine Aggregate	1012-1(C)

(B) Asphalt Rejuvenating Agent

Use an asphalt rejuvenating agent in accordance with Table 663-1.

TABLE 663-1
ASPHALT REJUVENATING AGENT PROPERTIES

Property	Minimum	Maximum
Viscosity, 77°F, SFS, ASTM D244	20 SFS	125 SFS
Sieve, %, ASTM D244	-	0.10%
Storage Stability, 24 hr, %, ASTM D244	-	1%
Residue from distillation, %[A]	60%	-
Oil Distillate, Volume %	-	5
Tests on Residue and Rolling Thin-Film Oven Tests:[B]		
Penetration @ 77°F, 5 sec.	300	-
Torsional Recovery 39.7°F, %	20%	-

A. ASTM D244 except that the maximum temperature shall be 350°F held for 20 minutes.
B. The residue from distillation shall be subject to the standard rolling thin film oven test.

663-3 COMPOSITION OF MIXTURE

(A) General Mix Design

Prepare and submit a proposed hot in-place recycled mix design and JMF to the Engineer at least 20 days before beginning work in accordance with Article 610-3 except as modified herein. Submit a proposed mix design for the admixture if an admixture is required.

Sample the existing pavement by coring, or other methods approved by the Engineer, to determine representative characteristics and properties of the existing pavement for use in mix design preparation. Take at least one sample every 2,000 lf of each lane. Provide samples for QA testing when requested by the Engineer. Take all QA test samples in the presence of the Engineer and at locations approved by the Engineer.

Perform and document a mix design in accordance with the Department's policies and procedures. Contact the Asphalt Design Engineer at the Materials and Tests Unit for copies of these procedures, if needed. Establish the proposed hot in-place recycled mix design such that the hot in-place recycled mix properties are within the design criteria for the type mix specified, unless otherwise approved by the Engineer. Submit the mix designs on forms and in the format approved by the Department. Once the proposed mix designs are approved, the Engineer will provide approved JMFs.

In addition to applicable mix design data required in Subarticle 610-3(A), the data shall include, but not be limited to, the proposed percent admixture, if needed, admixture components, gradation, binder grade, binder content, percent anti-strip additive in admixture, percent existing pavement (RAP), gradation and binder content of existing pavement, percent rejuvenating agent, penetration of recovered binder from total mix and all mix design properties and calculations.

(B) Mix Design Criteria

The finished asphalt pavement shall be a uniform mixture composed of the existing in-place asphalt pavement, asphalt rejuvenating agent and new hot mix asphalt admixture, if required. The hot in-place recycled asphalt mix shall meet Article 610-3 for the mix type specified, excluding the maximum percentage of allowable RAP and as modified herein.

The proposed hot in-place recycled mix design shall be established such that the hot in-place recycled mix properties will meet applicable gradation and mix design requirements of Table 610-2 and Table 610-3 for the mix type specified, except as modified herein, unless otherwise approved by the Engineer.

Add an asphalt rejuvenating agent at a rate that yields a completed mixture with the penetration value as specified in Table 663-1, unless otherwise approved by the Engineer.

(C) Job Mix Formula (JMF)

If the proposed mix design is approved, the Engineer will provide a JMF for the hot in-place recycled asphalt mix. The JMF will be established within the design criteria in Tables 610-2 and 610-3, unless otherwise approved by the Engineer.

If the hot in-place recycled mix design is approved, the Engineer will provide a JMF for the admixture if admixture is required. Produce the completed admixture in accordance with the JMF requirements for gradation and binder content in the contract.

Samples of the completed recycled mixture may be taken by the Department on a random basis to determine if the PG grading on the recovered asphalt binder is in accordance with AASHTO M 320 for the grade specified. If the grading is determined to be a value other than required for the specified mix type, the Engineer may require the Contractor to adjust the grade and the percentage of additional asphalt binder, asphalt rejuvenator and the blend of reclaimed material and admixture to bring the PG grade to the specified value for the required mix type in accordance with Table 610-3.

663-4 EQUIPMENT

(A) General

Equipment used to recycle the existing asphalt surface shall be designed and built for this specific purpose. The equipment shall be capable of a single pass, multi-step operation that includes multi-step heating, milling, introducing rejuvenating agent, introducing hot mix asphalt admixture, if required, mixing the new material with the reclaimed material in a separate on-board chamber, redistributing the recycled material, leveling and compacting the mixture.

(B) Pre-heating Units

Supply pavement pre-heaters capable of uniformly heating the asphalt pavement to a temperature high enough to remove excess moisture, to allow milling of the existing pavement material to the designated plan depth without excessive fracturing of aggregate particles, without charring the existing asphalt and without producing undesirable pollutants. Equip the heating mechanism so that the heat application is completely under an enclosed or shielded hood. Protect adjacent landscape from heat damage and repair any damage that may occur. The unit shall be adjustable in width. Ensure that the heaters overlap the completed adjacent lane by at least 6" to create a hot bond at the longitudinal joint.

(C) Milling/Blending Unit

Supply a self-propelled processing unit containing the following:

(1) A recycling machine equipped with additional heaters conforming to the same requirements as the pre-heaters.

(2) A unit capable of uniformly loosening the existing asphalt pavement to the depth specified. Care shall be taken to ensure that milling or pavement reclaiming does not degrade the aggregates but only loosens the heated existing pavement.

(3) A controlled system for adding and uniformly blending a rejuvenating agent at a predetermined rate with the reclaimed mix during the remixing and leveling operation. The metering equipment shall be capable of measuring in gallons. The application rate in gallons, for the added material, shall be synchronized with the machine ground speed to provide a uniform application. The actual rate used may be adjusted as determined.

(4) A blending unit consisting of a twin shafted pugmill capable of uniformly adding new hot mix asphalt admixture, if required, at a rate established by the mix design. The unit shall be capable of thoroughly mixing the loosened asphalt pavement, asphalt rejuvenating agent and new hot mix asphalt admixture, if required, at the pugmill to produce a uniform mixture.

(5) A unit capable of auguring the heated and loosened material into a windrow at the center of the machine before entry into the blending unit.

(6) A paving machine meeting Article 610-8, except as modified herein, shall be used to redistribute the remixed material over the width being processed and finished to produce a uniform cross section and surface. The paving machine shall be capable of screeding the full width of the remixed material. Provide and use automatic screed controls in accordance with Subarticle 661-4(A), unless otherwise approved by the Engineer.

(7) The recycling train shall be capable of maintaining an average production rate of at least one lane mile per day.

(8) The reheating and remixing units shall meet all State and local air quality emission standards for mobile sources.

(D) Compaction Equipment

Use rollers meeting Article 610-9 and capable of achieving the specified density and surface requirements.

663-5 CONSTRUCTION METHODS

Hot in-place recycled mixtures shall not be produced or placed during rainy weather or when the air temperature measured in the shade away from artificial heat at the location of the paving operations is less than 50°F. Do not place surface course material that is to be the final layer of pavement between December 15 and March 16 of the next year.

Before heating and remixing operations, the pavement shall be cleaned of all loose material. Power brooms shall be used and supplemented when necessary by hand brooming or other cleaning operations, as required, to bring the surface to a clean, suitable condition free of deleterious material.

The pavement surface shall be evenly heated, loosened and remixed to the lines, grades and depths shown on the plans. Heating shall be controlled to ensure uniform heat penetration without overheating, cooking or sooting of the asphalt pavement. The milled material shall be picked up, mixed with an asphalt rejuvenator and asphalt admixture, if needed, in a pugmill and then distributed and leveled by a conventional paving machine. The temperature of the milled material shall not be more than 325°F when measured immediately behind the milling unit. The temperature of the remixed material shall not be less than 235°F directly behind the screed.

The heating operation shall extend at least 4" beyond the width of remixing on both sides. When a pass is made adjacent to a previously placed mat, the longitudinal joint shall extend at least 2" into the previously placed mat.

The layer thickness of the hot in-place recycled specified in the Plans or Contract Proposal shall be the compacted in-place thickness of the rejuvenated recycled mixture layer including any admixture. The depth of milling of the existing surface shall be such that the depth as specified on the plans is within ± 1/4", unless otherwise approved by the Engineer.

The asphalt rejuvenator shall be applied uniformly to the mixed material before remixing in the pugmill. The rate of application of rejuvenator will be as specified on the JMF approved by the Engineer based upon the Contractor’s proposed mix design.

The remixed asphalt pavement shall be compacted immediately after it has been spread and leveled, while it is still in a workable condition.

Density control may be by either core samples or nuclear density control in accordance with the Department's procedures. Density for hot in-place recycled mixes shall meet Table 610-6 for the specified mix type. The maximum

specific gravity tested in accordance with AASHTO T 209 will be determined by procedures specified in the Department's *HMA/QMS Manual*.

The compacted surface of the completed and accepted pavement structure shall meet Article 610-12.

The Contractor shall take precautions needed to protect the adjacent landscape from heat damage. Damaged landscape shall be repaired or replaced.

663-6 MEASUREMENT AND PAYMENT

Hot In-Place Recycled Asphalt Concrete, Type ____ will be measured and paid by the square yard in the completed and accepted work.

Emulsified Asphalt Rejuvenating Agent to be paid will be measured by the metered quantity in gallons used in all completed and accepted work and will be paid at the contract price per gallon.

Hot Mix Asphalt Admixture, when required, will be measured by being weighed in trucks on a certified weighing device and documented on load tickets and will be paid at the contract unit price per ton.

Asphalt binder in accepted work will be measured and paid in accordance with Section 620.

The above prices and payments will be full compensation for all work covered by this section including, but not limited to, furnishing all materials, producing, weighing, transporting, placing and compacting the recycled pavement; maintaining the finished course until final acceptance of the project; performing QC as specified in the contract; and making any repairs or corrections to the surface of the pavement or adjacent landscape that may become necessary.

Payment will be made under:

Pay Item	**Pay Unit**
Hot In-Place Recycled Asphalt Concrete, Type ____	Square Yard
Emulsified Asphalt Rejuvenating Agent	Gallon
Hot Mix Asphalt Admixture	Ton

SECTION 665
MILLED RUMBLE STRIPS ON ASPHALT CONCRETE SHOULDERS

665-1 DESCRIPTION

Construct rumble strips on asphalt concrete shoulders in accordance with the plans and as directed by the Engineer. Work includes, but is not limited to, furnishing all labor, equipment and all incidentals necessary to complete the work satisfactorily and disposing of milled material.

665-2 EQUIPMENT

Provide equipment consisting of a rotary-type cutting head with an outside diameter of no more than 24" and at least 16" long. Provide a cutting head that has the cutting tips arranged to provide a relatively smooth cut. Provide a cutting head on its own independent suspension from that of the power unit to allow the tool to self align with the slope of the shoulder or any irregularities in the shoulder surface.

Provide a cutting tool equipped with guides to provide consistent alignment of each cut in relation to the roadway and to provide uniformity and consistency throughout the project.

665-3 CONSTRUCTION METHODS

Demonstrate the ability to achieve desired surface inside each depression without tearing or snagging the asphalt before beginning the work.

Provide rumble strips that have finished dimensions of 7" ± 1/2" wide in the direction of travel and are at least 16" long measured perpendicular to the direction of travel. Provide rumble strips having depressions with a concave circular shape with a minimum 1/2" depth at center (no more than an allowable depth 5/8"). Place rumble strips in relation to the roadway according to the patterns shown in the plans.

Material resulting from the operation becomes the property of the Contractor. Remove and dispose of this material in accordance with Section 802.

At the end of each working day remove all equipment to a location where it does not present a traffic hazard, clean pavement and reopen work area to traffic.

665-4 MEASUREMENT AND PAYMENT

Milled Rumble Strips (Asphalt Concrete) will be measured and paid at the contract unit price per linear foot for the actual number of linear feet of shoulder, measured longitudinally along the surface of each shoulder, where rumble strips have been constructed.

Payment will be made under:

Pay Item	**Pay Unit**
Milled Rumble Strips (Asphalt Concrete)	Linear Foot

Problems

Superpave Mix Design Certification Class

Work Problem #1

Calculate the RAP Aggregate Gsb given the following information:

Gse RAP Agg. =	**2.676**
% Absorption RAP Agg. =	**0.1**
Gb (specific gravity of RAP AC) =	**1.02**

Superpave Mix Design Certification Class

Work Problem 1, New method

Calculate the RAP Aggregate Gsb given the following information:

Gse RAP Agg. =	2.676
% Absorption RAP Agg. =	0.1
Gb (specific gravity of RAP AC) =	1.02

Gsb = Gse / (((Pba x Gse) / (100 x Gb)) + 1)
Gsb = 2.676 / (((0.1 x 2.676) / (100 x 1.02)) + 1)
Gsb = 2.676 / ((0.2676 / 102)+ 1)
Gsb = 2.676 / (0.00262 + 1)
Gsb = 2.676 / 1.00262
Gsb = 2.669

Superpave Mix Design Certification Class

Work Problem #2

1. Calculate the Blend percentages so that they fit into the Control Points for a S-9.5B mix

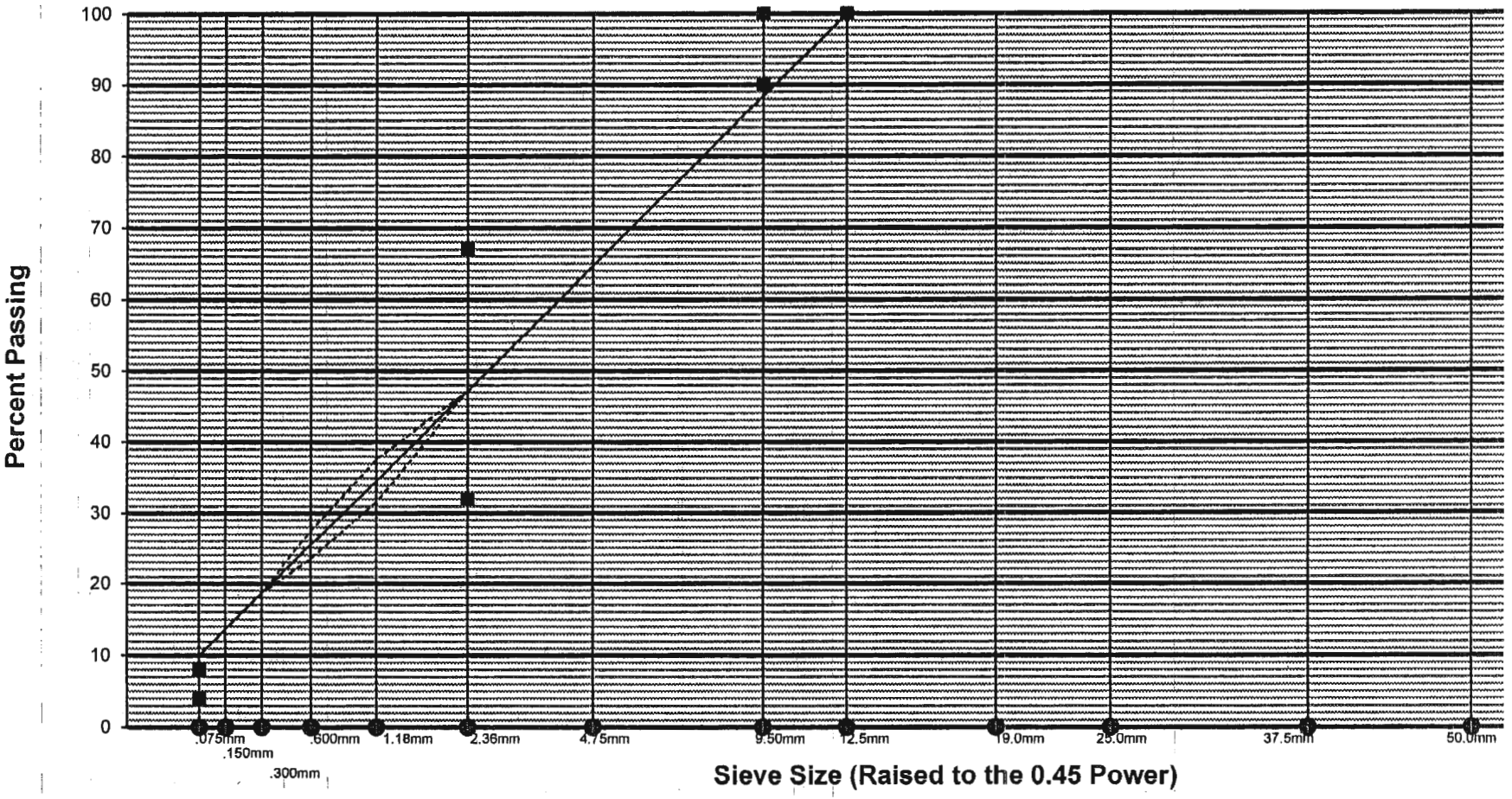
2. Calculate the cumulative aggregate specific gravities for Gsb and Gsa

Material	#78m	W. Scrngs	D. Scrngs	N.Sand	Fines	Blend	Control
Percent	28	32	24	15	1	100	Points
25.0mm	100.0	100.0	100.0	100.0	100.0		
19.0mm	100.0	100.0	100.0	100.0	100.0		
12.5mm	100.0	100.0	100.0	100.0	100.0		100
9.5mm	91.0	100.0	100.0	100.0	100.0		90 - 100
4.75m	28.0	99.0	100.0	100.0	100.0		< 90
2.36mm	4.0	88.0	86.0	100.0	100.0		32 - 67
1.18mm	1.0	54.0	58.0	98.0	100.0		
0.600mm	1.0	36.0	42.0	73.0	100.0		
0.300mm	1.0	13.0	26.0	34.0	100.0		
0.150mm	1.0	8.0	16.0	12.0	98.0		
0.075mm	0.5	4.0	11.0	6.9	94.5		4 - 8
Gsb	2.740	2.700	2.678	2.565	2.800		
Gsa	2.781	2.799	2.786	2.620	2.800		

3. Plot the blend on the 0.45 Power Chart

Mix Type S 9.5 B

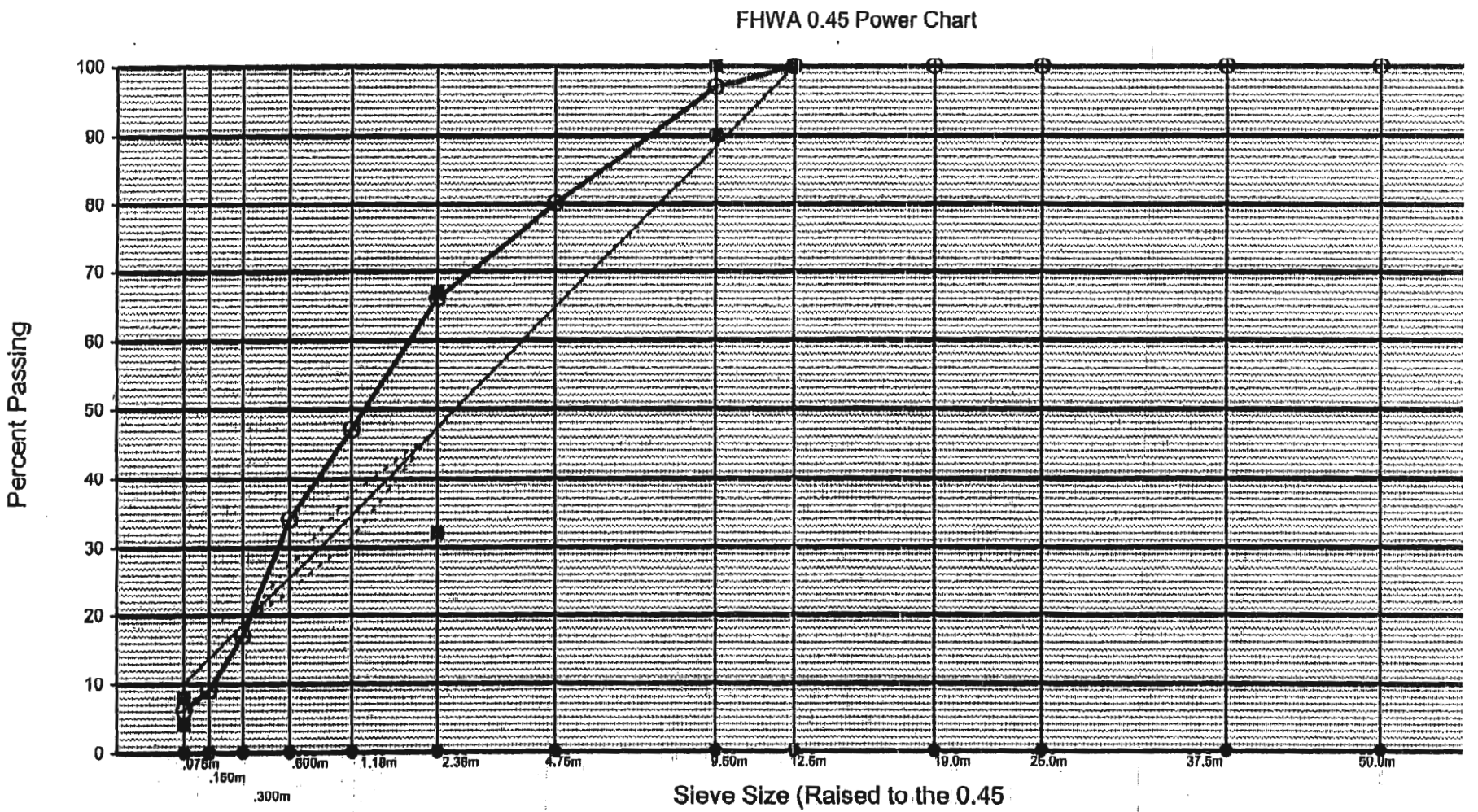
FHWA 0.45 Power Chart



Work Problem #2

Material	78m	W Scrngs	Dry Scrngs	N.Sand	Fines	Blend	Control
Percent	28	32	24	15	1	100	Points
25.0mm	100.0	100.0	100.0	100.0	100.0	100.0	
19.0mm	100.0	100.0	100.0	100.0	100.0	100.0	
12.5mm	100.0	100.0	100.0	100.0	100.0	100.0	100
9.5mm	91.0	100.0	100.0	100.0	100.0	97	90 - 100
4.75m	28.0	99.0	100.0	100.0	100.0	80	< 90
2.36mm	4.0	88.0	86.0	100.0	100.0	66	32 - 67
1.18mm	1.0	54.0	58.0	98.0	100.0	47	
0.600mm	1.0	36.0	42.0	73.0	100.0	34	
0.300mm	1.0	13.0	26.0	34.0	100.0	17	
0.150mm	1.0	8.0	16.0	12.0	98.0	9	
0.075mm	0.5	4.0	11.0	6.9	94.5	6.0	4 - 8
Gsb	2.740	2.700	2.678	2.565	2.800	2.687	
Gsa	2.781	2.799	2.786	2.620	2.800	2.764	

Mix Type S 9.5 B



Superpave Mix Design Certification Class

Work Problem #3

1. Calculate the stone factors (round to 2 decimal places) for the following materials. They are from the same source.

Material	#467	#57
Percent	*20*	*25*
37.5 mm	100.0	100.0
25.0mm	100.0	100.0
19.0mm	80.0	92.0
12.5mm	38.0	38.0
9.5mm	14.0	17.0
4.75m	7.0	3.0
2.36mm	2.0	1.0
1.18mm	1.0	1.0
0.600mm	1.0	1.0
0.300mm	1.0	1.0
0.150mm	1.0	1.0
0.075mm	0.9	1.0
Gsb	2.673	2.651
Gsa	2.713	2.699

Stone Factors	Sieve Size
	37.5
	25.0
	19.0
	12.5
	9.5
	4.75
	2.36
	-2.36

(Sum of the stone factors)

Weight(s)

(Sum of the weights)

2. Calculate the weight of each sieve size for a 4700 gram total aggregate weight.

Work Problem #3

1. Calculate the stone factors (round to 2 decimal places) for the following materials. They are from the same source.

Material	#467	#57
Percent	*20*	*25*
37.5 mm	100.0	100.0
25.0mm	100.0	100.0
19.0mm	80.0	92.0
12.5mm	38.0	38.0
9.5mm	14.0	17.0
4.75m	7.0	3.0
2.36mm	2.0	1.0
1.18mm	1.0	1.0
0.600mm	1.0	1.0
0.300mm	1.0	1.0
0.150mm	1.0	1.0
0.075mm	0.9	1.0
Gsb	2.673	2.651
Gsa	2.713	2.699

Stone Factors	Sieve Size
0.00	37.5
0.00	25.0
6.00	19.0
21.90	12.5
10.05	9.5
4.90	4.75
1.50	2.36
0.65	-2.36
45.00	

(Sum of the stone factors)

Weight, g
282
1029.3
472.4
230.3
70.5
30.6
2115.1

(Sum of the weights)

2. Calculate the weight of each sieve size for a 4700 gram total aggregate weight.

Superpave Mix Design Certification Class

Work Problem #4

Gb = 1.03

GRADATION OF MATERIALS USED

MATERIAL	78m	W Scrngs	D Scrgs	Sand			BgHsFines		BLEND	CONTROL
PERCENT (MD)	28.0	24.0	32.0	15.0			1.0		100.0	POINTS
PERCENT (JMF)	28.0	25.0	32.0	15.0			0.0		100.0	
Sieves(mm) 50.0	100.0	100.0	100.0	100.0			100.0		100	
37.5	100.0	100.0	100.0	100.0			100.0		100	
25.0	100.0	100.0	100.0	100.0			100.0		100	
19.0	100.0	100.0	100.0	100.0			100.0		100	
12.5	100.0	100.0	100.0	100.0			100.0		100	100
9.5	91.0	100.0	100.0	100.0			100.0		97	90 - 100
4.75	28.0	99.0	100.0	100.0			100.0		80	< 90
2.36	4.0	88.0	86.0	100.0			100.0		66	32 - 67
1.18	1.0	54.0	58.0	98.0			100.0		47	
0.600	1.0	36.0	42.0	73.0			100.0		34	
0.300	1.0	13.0	26.0	34.0			100.0		17	
0.150	1.0	8.0	16.0	12.0			98.0		9	
0.075	0.5	4.0	11.0	6.9			94.5		6.0	4.0 - 8.0
Ign.Furn. Corr.Factor										
Agg. Bulk Dry S.G.	2.740	2.700	2.678	2.565			2.800		2.686	
							Agg. Effective S.G.:			
Agg. Apparent S.G	2.781	2.799	2.786	2.620			2.800		2.764	

Mix Properties at N design

	Opt. Pb				
% Asphalt Binder-Total Mix		5.0	5.5	6.0	6.5
Gmb @ Ndes (or Nmax)		2.375	2.400	2.421	2.434
Max. Specific Gravity(Gmm)		2.512	2.493	2.475	2.457
% Voids-Total Mix (VTM)					
% Solids-Total Mix					
% Effective Binder Content (Pbe)					
Dust to Pbe Ratio ($P_{0.075}$/Pbe)					
By Volume of Effective Pb					
% Solids by Vol. of Agg. Only					
% Voids in Mineral Agg. (VMA)					
% Voids Fillied w/Binder (VFA)					
% Gmm @ Nini 8			-		
% Gmm @ Ndes 100					
% Gmm @ Nmax 160			-		

% RAP / % Virgin:	0/100
Pb in RAP:	
Pb from RAP:	0.0
Pb Absorption:	
% ASH:	
TSR % Retained :	
Ignition Furn. Calibr.:	
Pb (Design):	
Rice Specific Gravity:	
Lab Specific Gravity:	
Percent Air Voids:	
Percent VMA:	
Percent VFA:	
DUST/AC Ratio:	
% Gmm @ Nini	
% Gmm @ Nmax.	

COMMENTS:

DESIGNED BY:

APPROVAL:

Sand Equivalent:	80.6
C. Agg. Angularity:	100/100
F. Agg. Angularity:	46.3
Flat & Elongated:	3.7

Pb ADDED:	
Pb from RAP:	
Pb TOTAL:	

Work Problem #4
Gb = 1.03

$$Gse = \frac{100 - 5.5}{(100 \div 2.493) - (5.5 \div 1.03)} = 2.718$$

GRADATION OF MATERIALS USED

MATERIAL	78m	W Scrngs	D Scrgs	Sand			BgHsFines		BLEND	CONTROL
PERCENT (MD)	28.0	24.0	32.0	15.0			1.0		100.0	POINTS
PERCENT (JMF)	28.0	25.0	32.0	15.0			0.0		100.0	
Sieves(mm) 50.0	100.0	100.0	100.0	100.0			100.0		100	
37.5	100.0	100.0	100.0	100.0			100.0		100	
25.0	100.0	100.0	100.0	100.0			100.0		100	
19.0	100.0	100.0	100.0	100.0			100.0		100	
12.5	100.0	100.0	100.0	100.0			100.0		100	100
9.5	91.0	100.0	100.0	100.0			100.0		97	90 - 100
4.75	28.0	99.0	100.0	100.0			100.0		80	< 90
2.36	4.0	88.0	86.0	100.0			100.0		66	32 - 67
1.18	1.0	54.0	58.0	98.0			100.0		47	
0.600	1.0	36.0	42.0	73.0			100.0		34	
0.300	1.0	13.0	26.0	34.0			100.0		17	
0.150	1.0	8.0	16.0	12.0			98.0		9	
0.075	0.5	4.0	11.0	6.9			94.5		6.0	4.0 - 8.0
Ign.Furn. Corr.Factor										
Agg. Bulk Dry S.G.	2.740	2.700	2.678	2.565			2.800		2.686	
							Agg. Effective S.G.:		2.718	
Agg. Apparent S.G.	2.781	2.799	2.786	2.620			2.800		2.764	

Mix Properties at N design

		Opt. Pb					
% Asphalt Binder-Total Mix			5.0	5.5	6.0	6.5	
Gmb @ Ndes (or Nmax)			2.375	2.400	2.421	2.434	
Max. Specific Gravity(Gmm)			2.512	2.493	2.475	2.457	
% Voids-Total Mix (VTM)				3.7			
% Solids-Total Mix				96.3			
% Effective Binder Content (Pbe)				5.0			
Dust to Pbe Ratio ($P_{0.075}$/Pbe)				1.2			
By Volume of Effective Pb				11.7			
% Solids by Vol. of Agg. Only				84.6			
% Voids in Mineral Agg. (VMA)				15.6			
% Voids Fillied w/Binder (VFA)				76.3			
% Gmm @ Nini	8			-			
% Gmm @ Ndes	100						
% Gmm @ Nmax	160			-			

% RAP / % Virgin:	0/100
Pb in RAP:	
Pb from RAP:	0.0
Pb Absorption:	0.5
% ASH:	
TSR % Retained :	
Ignition Furn. Calibr.:	
Pb (Design):	
Rice Specific Gravity:	
Lab Specific Gravity:	
Percent Air Voids:	
Percent VMA:	
Percent VFA:	
DUST/AC Ratio:	
% Gmm @ Nini	
% Gmm @ Nmax.	
Pb ADDED:	
Pb from RAP:	
Pb TOTAL:	

COMMENTS:

DESIGNED BY:

APPROVAL:

Sand Equivalent:	80.6
C. Agg. Angularity:	100/100
F. Agg. Angularity:	46.3
Flat & Elongated:	3.7

/sed 10-16-99

M&T 612 (QMS-2)

NCDOT
TENSILE STRENGTH RATIO (TSR) TEST WORKSHEET
Gyratory Compactive Method
Work Problem #5

Date Mix Produced:	Mix Type: I19.0C	JMF No.:
Contractor: NCDOT	Plant Location:	Plant Cert. No.:
Additive Supplier:	Additive Grade:	Additive Dosage:
Date Compacted:	No. Gyrations:	Date Test Completed:

SPECIMEN NUMBER			1	2	3	4	5	6	7	8
DIAMETER(mm)		(a)	150.000	150.000	150.000	150.000	150.000	150.000	150.000	150.000
THICKNESS(mm)		(b)	97.100	95.700	96.300	96.400	96.200	96.000	95.800	96.300
DRY MASS IN AIR		(c)	3862.1	3849.7	3862.6	3863.6	3855.8	3856.1	3858.2	3865.9
SSD MASS IN AIR		(d)	3875.7	3858.3	3873.2	3876.6	3869.5	3874.1	3870.6	3879.9
MASS IN WATER		(e)	2212.3	2215.0	2213.7	2230.5	2224.1	2223.1	2221.0	2222.2
VOLUME	*(d-e)*	(f)			1659.5	1646.1			1649.6	1657.7
BULK SP. GR.	*(c ÷ f)*	(g)			2.328	2.347			2.339	2.332
MAX. SP.GR.	*(From Actual Rice Test)*	(h)	2.510	2.510	2.510	2.510	2.510	2.510	2.510	2.510
% AIR VOIDS	*(100 X (h - g) ÷ h)*	(i)			7.3	6.5	6.6	6.9	6.8	7.1
VOLUME AIR VOIDS	*(I X f) ÷ 100*	(j)			120.6	106.8	109.2	114.7	112.5	117.5
PEAK LOAD (Newton's)		(k)	16000	14000	18400	13000				
DRY TS(kPa)	*(2000 X k) ÷ (a X b X 3.1416)*	(l)					**********	**********	**********	**********
CALC. SSD AT 70% SAT.	*(0.70 X j) + c*								3936.9	3948.2
CALC. SSD AT 80% SAT.	*(0.80 X j) + c*								3948.2	3959.9

SATURATED	MINUTES @	"Hg							
ate and Time in:			Date and Time out:						
SD MASS	(m)					3935.4	3940.2	3941.1	3949.5
MASS IN WATER	(n)					2295.7	2301.7	2297.0	2302.9
VOLUME	*(m - n)*	(o)	**********	**********	**********	**********			1644.1	1646.6
VOL. ABS. H2O	*(m - c)*	(p)	**********	**********	**********	**********			82.9	83.6
% SATURATION	*100 X (p ÷ j)*		**********	**********	**********	**********			73.7	71.1

CONDITIONED 24 HOURS IN 140 DEGREE WATER

SSD MASS		(q)					3944.7	3960.2	3955.4	3963.6
MASS IN WATER		(r)					2315.7	2321.5	2316.5	2322.4
VOLUME	*(q - r)*	(s)	**********	**********	**********	**********			1638.9	1641.2
VOLUME ABS. H2O	*(q - c)*	(t)	**********	**********	**********	**********			97.2	97.7
% SATURATION	*100 X (t ÷ j)*		**********	**********	**********	**********			86.4	83.1
PEAK LOAD (Newton's)		(u)					15200	13200	12800	13200
WET TS(kPa)	*(2000 X u) ÷ (a X b X 3.1416)*	(v)	**********	**********	**********	**********				
INTERNAL SPECIMEN TEMPERATURE (°F .)			77.00	76.00	78.00	77.00	77.00	77.00	76.00	77.00

	Aver. VTM	Aver. Saturation	Aver. Temp	Median TS
Dry Subset	7.0			
Wet Subset	6.9			
TENSILE STRENGTH RATIO				
QA/QC COMPARATIVE TSR				

QA/QC Joint Test? Circle One: Yes No

TESTED BY:
CERT. NO.:
TESTED BY:
CERT. NO.:
LAB LOCATION:
LAB CERT NO.:

Visual Stripping: (Circle one)

None Minor Moderate Severe

Note: Attach proposed M&T 601 form when TSR specimens are being submitted to QA

Revised 10-16-99

M&T 612 (QMS-2)

NCDOT
TENSILE STRENGTH RATIO (TSR) TEST WORKSHEET
Gyratory Compactive Method
Work Problem #5

Date Mix Produced:	Mix Type: I19.0C	JMF No.:
Contractor:	Plant Location:	Plant Cert. No.:
Additive Supplier:	Additive Grade:	Additive Dosage:
Date Compacted:	No. Gyrations:	Date Test Completed:

SPECIMEN NUMBER			1	2	3	4	5	6	7	8
DIAMETER(mm)		(a)	150.000	150.000	150.000	150.000	150.000	150.000	150.000	150.000
THICKNESS(mm)		(b)	97.100	95.700	96.300	96.400	96.200	96.000	95.800	96.300
DRY MASS IN AIR		(c)	3862.1	3849.7	3862.6	3863.6	3855.8	3856.1	3858.2	3865.9
SSD MASS IN AIR		(d)	3875.7	3858.3	3873.2	3876.6	3869.5	3874.1	3870.6	3879.9
MASS IN WATER		(e)	2212.3	2215.0	2213.7	2230.5	2224.1	2223.1	2221.0	2222.2
VOLUME	*(d-e)*	(f)	1663.4	1643.3	1659.5	1646.1	1645.4	1651.0	1649.6	1657.7
BULK SP. GR.	*(c ÷ f)*	(g)	2.322	2.343	2.328	2.347	2.343	2.336	2.339	2.332
MAX. SP.GR.	*(From Actual Rice Test)*	(h)	2.510	2.510	2.510	2.510	2.510	2.510	2.510	2.510
% AIR VOIDS	*(100 X (h - g) ÷ h)*	(i)	7.5	6.7	7.3	6.5	6.6	6.9	6.8	7.1
VOLUME AIR VOIDS	*(i X f) ÷ 100*	(j)	124.7	110.1	120.6	106.8	109.2	114.7	112.5	117.5
PEAK LOAD (Newton's)		(k)	16000	14000	18400	13000				
DRY TS(kPa)	*(2000 X k) ÷ (a X b X 3.1416)*	(l)	699.3	620.9	810.9	572.3	**********	**********	**********	**********
CALC. SSD AT 70% SAT.	*(0.70 X j) + c*		3949.4	3926.8	3947.0	3938.4	3932.3	3936.4	3936.9	3948.2
CALC. SSD AT 80% SAT.	*(0.80 X j) + c*		3961.9	3937.8	3959.1	3949.1	3943.2	3947.9	3948.2	3959.9

SATURATED	MINUTES @	"Hg							
Date and Time in:			Date and Time out:						
SSD MASS		(m)					3935.4	3940.2	3941.1	3949.5
MASS IN WATER		(n)					2295.7	2301.7	2297.0	2302.9
VOLUME	*(m - n)*	(o)	**********	**********	**********	**********	1639.7	1638.5	1644.1	1646.6
VOL. ABS. H2O	*(m - c)*	(p)	**********	**********	**********	**********	79.6	84.1	82.9	83.6
% SATURATION	*100 X (p ÷ j)*		**********	**********	**********	**********	72.9	73.3	73.7	71.1

CONDITIONED 24 HOURS IN 140 DEGREE WATER

SSD MASS		(q)					3944.7	3960.2	3955.4	3963.6
MASS IN WATER		(r)					2315.7	2321.5	2316.5	2322.4
VOLUME	*(q - r)*	(s)	**********	**********	**********	**********	1629.0	1638.7	1638.9	1641.2
VOLUME ABS. H2O	*(q - c)*	(t)	**********	**********	**********	**********	88.9	104.1	97.2	97.7
% SATURATION	*100 X (t ÷ j)*		**********	**********	**********	**********	81.4	90.8	86.4	83.1
PEAK LOAD (Newton's)		(u)					15200	13200	12800	13200
WET TS(kPa)	*(2000 X u) ÷ (a X b X 3.1416)*	(v)	**********	**********	**********	**********	670.6	583.6	567.1	581.7
INTERNAL SPECIMEN TEMPERATURE (°F .)			77.00	76.00	78.00	77.00	77.00	77.00	76.00	77.00

	Aver. VTM	Aver. Saturation	Aver. Temp	Median TS
Dry Subset	7.0		77.0	660.1
Wet Subset	6.9	72.8	76.8	582.7
TENSILE STRENGTH RATIO				88
QA/QC COMPARATIVE TSR				

QA/QC Joint Test? Circle One — Yes / No

TESTED BY:
CERT. NO.:
TESTED BY:
CERT. NO.:
LAB LOCATION:
LAB CERT NO.:

Visual Stripping:(Circle one)

None Minor Moderate Severe

Note: Attach proposed M&T 601 form when TSR specimens are being submitted to QA

	VTM Average	
	Dry Sub	Wet Sub
1	7.5	
2	6.7	
3	7.3	
4	6.5	
5		6.6
6		6.9
7		6.8
8		7.1
	7.0	6.9

	Temp. Average	
	Dry Sub	Wet Sub
1	77.0	
2	76.0	
3	78.0	
4	77.0	
5		77.0
6		77.0
7		76.0
8		77.0
	77.0	76.8

Examples

Determining the Effective Specific Gravities
Gse Estimated and Gse Mix Design

In the beginning of the mix design process the estimated aggregate effective specific gravity is based on the trial aggregate blend gradation(s). The estimated Gse is found by using the bulk and apparent specific gravities of the aggregate blend(s) along with the following formula for normal aggregates:

$$Gse\ est. = Gsb + (0.8 \times (Gsa - Gsb))$$

Where: Gse est. = estimated effective gravity of the aggregate trial blend
Gsb = bulk dry specific gravity of the trial aggregate blend
Gsa = apparent specific gravity of the trial aggregate blend

For example, for trial blend no.1:
Gsb blend = 2.649
Gsa blend = 2.687

Then, Gse est. = ?

$$2.649 + (0.8 \times (2.687 - 2.649)) = 2.649 + (0.8 \times 0.038) = 2.649 + 0.030 = 2.679$$

Note: at this point you can use the estimated Gse for this blend to calculate an estimated maximum specific gravity for whatever percentage of binder that you choose.

After choosing the trial aggregate blend for the design, the optimum AC content is estimated, pills are batched up, and the maximum specific gravity (Gmm) at the second design increment is measured using either the rice or corelok test. It is used to find the mix design effective specific gravity.

For example, given:
Gmm = 2.490 (average of 2 rice tests run at the second design increment)
Pb = 4.5% (AC content at second design increment)
Gb = 1.03 (specific gravity of binder)

Then, Gse mix design = ?

$$\frac{100 - Pb}{\frac{100}{Gmm} - \frac{Pb}{Gb}} = \frac{100 - 4.5}{\frac{100}{2.490} - \frac{4.5}{1.03}} = \frac{95.5}{40.16 - 4.37} = \frac{95.5}{35.79} = 2.668$$

Check: Is the mix design Gse between Gsb blend and Gsa blend?
If yes, then ok. If no, then recheck the rice and aggregate specific gravity calculations and test procedures for errors.

Determining the Effective Specific Gravities
Gse Estimated and Gse Mix Design

In the beginning of the mix design process the estimated aggregate effective specific gravity is based on the trial aggregate blend gradation(s). The estimated Gse is found by using the bulk and apparent specific gravities of the trial aggregate blend(s) along with the following formula for normal aggregates:

$$Gse\ est. = Gsb + (0.8 \times (Gsa - Gsb))$$

Where: Gse est. = estimated effective gravity of the aggregate trial blend
Gsb = cumulative bulk dry specific gravity of the trial aggregate blend
Gsa = cumulative apparent specific gravity of the trial aggregate blend

For example, for trial blend no. 1:
Gsb blend = 2.649
Gsa blend = 2.687

Then, Gse est. = ?

Note: at this point you can use the estimated Gse for this blend to calculate an estimated maximum specific gravity for whatever percentage of binder that you choose.

After choosing the trial aggregate blend for the design, the optimum AC content is estimated, pills are batched up, and the maximum specific gravity (Gmm) at the second design increment is measured using either the rice or corelok test. It is used to find the mix design effective specific gravity.

For example, given:
Gmm = 2.490 (average of 2 rice tests run at the second design increment)
Pb = 4.5% (AC content at second design increment)
Gb = 1.03 (specific gravity of binder)

Then, Gse mix design = ?

(see the next page for the solution)

Drying to Constant Mass
Bulk Specific Gravity

For AASHTO T-166-12 Bulk Specific Gravity of Compacted HMA Using Saturated Surface Dry Specimens

3. Terminology
Section 3.1.2. constant mass—shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent when weighed at 2-h intervals when using oven drying, or by more than 0.05 percent when weighed after at least two drying cycles of the vacuum-drying apparatus required in ASTM D 7227/D 7227M. (Note: 0.05 percent is 0.05 ÷ 100, or 0.0005)

Method A

6. Procedure
Section 6.1. Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F). Samples saturated with water shall initially be dried overnight and then weighed at 2 hour drying intervals. Recently compacted lab samples that have not been exposed to moisture do not require drying. As an alternative to oven drying to constant mass, drying the sample according to ASTM D 7227/D 7227M may be used. When using ASTM D 7227/D 7227M to achieve constant mass, perform the drying procedure at least twice, with a mass determination after each drying cycle.

Example 1:
Given a sample weight (after the first 2 hour drying interval) equal to 1500.0 grams
Calculate: 1500.0 x 0.05 ÷ 100 = 0.75 grams
Then for constant mass the sample weight after the next second drying interval should be between: 1500.0 and 1499.25 grams (where 1500.0 – 0.75 = 1499.25)

Or, if the next weight after the second drying interval was 1499.3 grams then:
(1500.0 – 1499.3) ÷ 1500.0 x 100 = 0.05%, which <u>is</u> constant mass

However, if the next weight recorded after the second drying interval was 1499.0 instead of 1499.3 grams then: (1500.0 – 1499.0) ÷ 1500.0 x 100 = 0.07%, which is <u>not</u> constant mass because the change of 0.07% is greater than 0.05% as defined above

Drying to Constant Mass
Maximum Specific Gravity

For AASHTO T-209-12 Theoretical Maximum Specific Gravity and Density of HMA Paving Mixtures

9. Procedure
Section 9.2. Samples prepared in a laboratory shall be cured and dried in an oven at 135 ± 5°C (275 ± 9°F) for a minimum of 2 hours, or as appropriate to match the mix design procedure being used. Longer drying time may be necessary for the sample to achieve a constant mass (mass repeats within 0.1 percent). HMA which has not been prepared in a laboratory with oven dried aggregates shall be dried to a constant mass at a temperature of 105 ± 5°C (221 ± 9°F).
Note: 0.1 percent is 0.1 ÷ 100, or 0.001

Example 1:
Given a sample weight (after the first 2 hour drying interval) equal to 2020.0 grams
Calculate: 2020.0 x 0.1 ÷ 100 = 2.0 grams
Then for constant mass the sample weight after the next second drying interval should be between: 2020.0 and 2018.0 grams (where 2020.0 – 2.0 = 2018.0)

Or, if the next weight after the second drying interval was 2018.0 grams then:
(2020.0 – 2018.0) ÷ 2020.0 x 100 = 0.1%, which <u>is</u> constant mass

However, if the next weight recorded after the second drying interval was 2015.0 instead of 2018.0 grams, then: (2020.0 – 2015.0) ÷ 2020.0 x 100 = 0.25%, which is <u>not</u> constant mass because the change of 0.25% is greater than 0.1% as defined above

Batching for a 20% RAP Mix

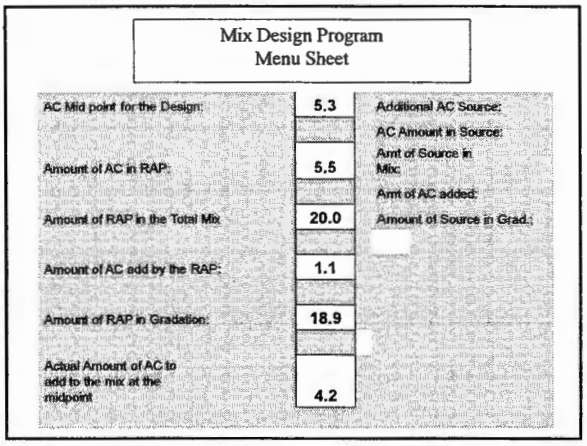
AMD Class

Mix Data

- Total AC in the Mix = 5.3%
  Determined by the mix design at 4% voids
- Starting Pill Weight = 4732.6 grams (determined from previous mix design experience)
- RAP Values
  - Amount of RAP in total mix = 20% (set by designer)
  - Amount of AC in the RAP = 5.5% from ignition furnace test Note: CF for RAP = 0.5%

Mix Data

- Percent (MD) From M&T 601- percent of each individual aggregate by weight of the total aggregate.
- The final blend must pass through control points of Superpave Aggregate Gradation Design Criteria Table 610-1.
- The percents are set by the mix designer
  - For 78M: 35.0%
  - For Washed Screenings: 23.0%
  - For Regular Screenings: 20.0%
  - For Bag-house Fines: 2.0%
  - For Rap: 20.0% by total weight of the mix (and in this case 20% by total weight of the aggregate as auto-calculated by mix design program and inserted onto the M&T 601 form)



From the Menu Sheet

1. The "AC Mid point for the Design" is set at 5.3%
2. The "Amount of AC in RAP" is given: 5.5%
3. The "Amount of RAP in the Total Mix" is set at 20%
4. The "Amount of AC added by the RAP" is auto calculated using values from bullet points 2 and 3: 5.5 x 0.20 = 1.1%
5. The "Amount of RAP in Gradation" is auto calculated using values from bullets 3 and 4: 20 – 1.1 = 18.9%
6. The "Actual Amount of AC to add to the mix at the midpoint" is calculated using values from bullets 1 and 4: 5.3 – 1.1 = 4.2%

M&T 601 Form - GRADATION OF MATERIALS USED

MATERIAL	78M	WS	RS				BHF	Rap	BLEND	CONTROL
PERCENT (MD)	35.0	23.0	20.0				2.0	20.0	100	POINTS
PERCENT (JMF)	35.0	23.0	22.0					20.0	100	
Sieves (mm)										
12.5	100.0	100.0	100.0				100.0	100.0	100	100.0
9.5	96.0	100.0	100.0				100.0	99.0	98	90.0 - 100.0
4.75	24.0	96.0	98.0				100.0	81.0	68	< 90.0
2.36	7.0	77.0	79.0				100.0	62.0	50	32.0 - 67.0
1.18	5.0	56.0	64.0				100.0	47.0	39	
0.600	4.0	38.0	42.0				100.0	35.0	28	
0.300	3.0	19.0	26.0				100.0	20.0	17	
0.150	2.0	8.0	16.0				100.0	12.0	10	
0.075	1.0	3.0	10.0				80.0	10.0	6.6	4.0 - 8.0

From M&T 601 Form
Gradations of Materials Used

- Percent (MD) for all virgin aggregates are set by the designer
- Percent (MD) for RAP is auto-calculated by the program as follows:

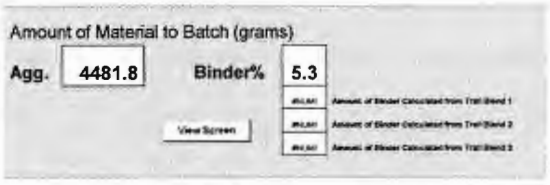
  %aggregate as percent of the total mix:

  100 – 5.3 = 94.7%

%RAP aggregate as percent of the aggregate in the mix:

18.9 ÷ 94.7 x 100 = 19.96 → 20.0%

From Batch1 Sheet



- The "Amount of Material to Batch (grams) Agg." is the total aggregate weight, generally 4500 to 4700 grams for aggregates with combined bulk specific gravities of 2.55 to 2.70, respectively
- In this case the target pill weight is 4732.6 grams, so calculate the aggregate batch weight:

4732.6 x ((100 – 5.3)÷ 100) = 4481.8 grams

From M&T 601 Form

Scroll down to the bottom of the form

Rap		Rap	Total		
Percent RAP in Mix		20.0	20.0	5.3	% ASHPALT CONTENT
Percent AC in RAP	5.5		1.1	4481.8	GRAMS (AGG. BATCH WEIGHT)
BINDER:	Charlotte				
GYRATIONS:	7/ 65/	PLANT & NO.:			
TRAFFIC LEVEL:	0.3 to 3.0	SPECIFICATION:			RS9.5B

- These values are not new

**Screenings can be scooped into the mix whereas 78M is separated bysizes first and then weighed into the mix*

TOTAL AGG. WEIGHT

THESE WEIGHTS ARE *INDIVIDUAL* WEIGHTS

4481.8

MATERIAL	78M Stone	Washed Scrgs.	Regular Scrgs.			Sieve
TOTAL MAT.	1568.6	1030.8	896.4			Sizes
Sieves (mm)						Sieves (mm)
12.5	Use stone factors here					12.5
9.5	62.7					9.5
4.75	1129.4	41.2	17.9			4.75
2.36	266.7	195.9	170.3			2.36
-2.36mm	109.8	793.7	708.2			-2.36mm

GRAMS of RAP

896.4

THIS TOTAL AMOUNT OF RAP HAS THE AC FIGURED IN ALSO.

BAGHOUSE FINES

89.6

GRAMS

AC CONTENT FOR THE BATCHS

% AC BY AGG. WT.			4.8	5.3	5.8	6.3
GRAMS PER BATCH			226.0	250.8	275.9	301.3
AC ADDED BY RAP			49.3	49.3	49.3	49.3
Additional AC Source:						
ADD AC TO MIX			176.7	201.5	226.6	252.0

ANTI-STRIP CONTENT FOR THE BATCHS

GRAMS PER BATCH			1.695	1.881	2.069	2.260

Aggregate Batch Weight Calculations

- Total weight of aggregate: 4481.8
- 35% of 78M
  0.35 x 4481.8 = 1568.6 ✓
- 23% of Washed screenings
  0.23 x 4481.8 = 1030.8 ✓
- 20% of Regular screenings
  0.20 x 4481.8 = 896.4 ✓
- 2% of Bag-house fines
  0.02 x 4481.8 = 89.6 ✓
- 20% of RAP aggregate
  0.20 x 4481.8 = 896.4 ✓

Aggregate Batch Weights

• 78M	1568.6	
• Washed Screenings:	1030.8	Weight of Virgin Aggregates
• Reg. Screenings:	896.4	↙
• Baghouse Fines:	89.6	3585.4
• RAP Aggregate:	896.4	
• Total Aggregate :	4481.8 ✓	

RAP AC Weight

- Given RAP aggregate weight: 896.4
- Given AC in RAP: 5.5%
- Calculate RAP AC weight:
  896.4 x (1 + 0.055) = 945.7
  945.7 – 896.4 = 49.3 ✓

Batch Weight of Virgin AC

- Given 5.3% AC by weight of the mix
- Given 1.1% RAP AC by weight of the mix
- %Virgin AC:
  5.3 – 1.1 = 4.2%
- Given 4732.6 total weight of the mix
- Weight of total AC:
  0.053 x 4732.6 = 250.8 ✓
- Total AC – RAP AC = Virgin AC
  250.8 – 49.3 = 201.5 ✓

Total Weight of Sample

- Virgin Aggregate: 3585.4
- RAP Aggregate: 896.4
- Virgin AC: 201.5
- RAP AC: 49.3
- Total Weight of Pill: 4732.6 ✓

RAP Batch Weight

- RAP Aggregate: 896.4
- RAP AC: 49.3
- Total RAP: 945.7 ← RAP Batch Weight

- RAP as percent of total mix:
  945.7 ÷ 4732.6 x 100 = 20.0% ✓
- RAP aggregate as percent of total aggregate:
  896.4 ÷ 4481.8 x 100 = 20.0% ✓

AC Batch Weight

- Virgin AC: 201.5 ← Virgin AC Batch Weight
- RAP AC: 49.3
- Total AC: 250.8

- AC by total weight of the mix:

250.8 ÷ 4732.6 x 100 = 5.3% ✓

Anti-strip Additive Batch Weight

- Anti-strip to be added separately at 0.75% by total weight of AC

  0.75 ÷ 100 x 250.8 = 1.881✓ → 1.9

Reclaimed Asphalt Pavement RAP

AMD Class

RAP in the Total Mix

- Given 24% RAP in the total mix and 5.3% AC in the RAP
- There is:

  0.24 x 5.3% = 1.27 → 1.3% RAP AC in the total mix

  24.0 – 1.3 = 22.7% RAP aggregate in the total mix

RAP Aggregate in the Total Aggregate

- Given 6.4% total AC in the mix

  100 – 6.4 = 93.6% aggregate in the total mix
- Find RAP aggregate in the total aggregate:

  22.7 ÷ 93.6 x 100 = 24.25 → 24.3%

Percent AC Contributed by RAP to the Total AC Content

- Given 1.3% RAP AC in the total mix
- Given 6.4% total AC in the total mix
- Find the Percent AC Contributed by the RAP:

  $1.3 \div 6.4 \times 100 = 20.31 \rightarrow 20.3\%$

Virgin AC Content

- Given 6.4% total AC in the mix
- Given 1.3% RAP AC in the total mix
- Find the Percent Virgin AC in the Mix:

  $6.4 - 1.3 = 5.1\%$

Reclaimed Asphalt Shingles RAS

AMD Class

RAS in the Total Mix

- Given 4.5% RAS in the total mix and 23.9% AC in the RAS
- There is:

  4.5% x 0.239 = 1.08 → 1.1% RAS AC in the total mix

  4.5 – 1.1 = 3.4% RAS aggregate in the total mix

RAS Aggregate in the Total Aggregate

- Given 5.5% total AC in the mix

  100 – 5.5 = 94.5% aggregate in the total mix
- Find RAS aggregate in the total aggregate:

  3.4 ÷ 94.5 x 100 = 3.59 → 3.6%

Percent AC Contributed by RAS to the Total AC Content

- Given 1.1% RAS AC in the total mix
- Given 5.5% total AC in the total mix
- Find the Percent AC Contributed by the RAS:

  1.1 ÷ 5.5 x 100 = 20.00 → 20.0%

Note: this is the maximum limit of %RAS binder contributed to the mix

Virgin AC Content

- Given 5.5% total AC in the mix
- Given 1.1% RAS AC in the total mix
- Find the Percent Virgin AC in the Mix:

  5.5 – 1.1 = 4.4%

Targeting Air Voids for TSR Specimens

Estimate the initial mass of the TSR specimens using one of the following formulas:

- For fine graded mixes: Mass = 1544.5 x Gmm
- For coarse graded mixes: Mass = 1536.1 x Gmm

Weigh up the trial samples using the initial mass (as calculated from above) as a guide. You can weigh up one sample at the initial estimated mass, one sample that is 15 to 20 grams heavier and one that is 15 to 20 grams lighter than the estimated initial mass. Compact the three trial specimens, run the bulk gravity tests, run a test to find the maximum specific gravity of the mix, then calculate the air void contents of the samples. Choose to use the sample mass that resulted in an air void content that is closest to the target of 7%. Then make the following adjustments if needed:

- To increase air voids to meet the target you should take out material
- To decrease air voids to meet the target you should add more material

Example calculation:

- For a fine graded mix with Gmm = 2.510
- Initial mass = 1544.5 x Gmm = 1544.5 x 2.510 = 3876.7 grams
- Va_t = 7.0% (target air voids)
- Va_m = 6.3% (Measured air voids for the compacted trial specimen)

$Mass_{adj} = (100 - Va_t) \div (100 - Va_m) \times$ Initial mass
$= (100 - 7.0) \div (100 - 6.3) \times 3876.7$
$= 93.0 \div 93.7 \times 3876.7$
$= 0.9925 \times 3876.7$
$= 3847.6$ grams

So to increase the voids by 0.7% to meet the target air content, you should subtract 28.9 grams of material from the original mass used for the trial specimen (3876.7 – 3847.6 = 29.1 grams) and compact the new specimens.

New Mass = 3847.6 grams