What to Do Before Mix Design?

Brian D. Prowell, Ph.D., P.E.

What to do before you begin

- Read the specifications!
- Characterize aggregates and recycle
  - Stockpile gradations
  - Bulk specific gravity
  - Consensus aggregate properties
- What is plant breakdown?
- Think about construction aspects of what mix will be used for

Which stockpile gradations do you use?

- Quarries?
- Long-term historical average?
- Recent running average?
- Stockpile sample(s)?
- Communicate with quarry?

Ten Year Average?

COARSE CONCRETE AGGREGATE PROPERTIES – 20 TO 5 MM MARTIN MARIETTA AT AULDS COVE, NOVA SCOTIA														
SIEVE ANALYSIS (TEST METHOD: CSA A23.2-2A, ASTM C 136)	Percent Passing													
	Oct 1999	Nov 2000	Dec 2001	Nov 2002	Oct 2003	Dec 2004	Dec 2005	Oct 2006	Oct 2007	Oct 2008	Oct 2009	Oct 2010	Average	CSA Specification
28	100	100	100	100	100	100	100	100	100	100	100	100	**100**	100
20	98	98	97	98	98	97	94	95	96	97	92	95	**96**	85 to 100
14	67	66	69	68	73	64	63	65	67	63	52	64	**65**	50 to 90
10	41	41	42	40	40	39	36	34	41	31	26	33	**37**	25 to 60
5	7	6	7	7	8	7	4	4	7	2	3	4	**6**	0 to 10
2.5	3	2	2	2	3	2	1	1	2	1	1	2	**2**	0 to 5
0.080	0.4	0.2	0.4	0.4	0.5	0.4	0.2	0.2	0.5	0.7	0.3	0.8	**0.4**	Maximum 1.0
TEST METHOD: CSA A23.2-12A, ASTM C 127														
Apparent Relative Density	2.68	2.66	2.68	2.68	2.72	2.68	2.65	2.70	2.65	2.68	2.67	2.67	**2.68**	
Bulk Relative Density	2.64	2.60	2.61	2.62	2.68	2.65	2.60	2.67	2.62	2.64	2.63	2.64	**2.63**	
Bulk Relative Density (SSD)	2.65	2.62	2.64	2.64	2.69	2.66	2.62	2.68	2.63	2.66	2.65	2.65	**2.65**	
Absorption, %	0.68	0.88	0.89	0.82	0.55	0.41	0.62	0.46	0.47	0.62	0.56	0.51	**0.63**	
TEST METHOD CSA A23.2-16A, ASTM C 131														
Los Angeles Abrasion, % Loss at 500 Revolutions (Type B Charge)	13.2	13.8	15.7	11.3	13.2	13.5	18.1	13.8	18.5	16.7	19.3	18.9	**15.5**	Maximum 35
TEST METHOD CSA A23.2-24A														
Unconfined Freeze Thaw, % Loss	1.0	1.9	1.3	2.0	0.5	0.6	2.1	0.4	0.8	0.8	0.3	0.3	**1.0**	Maximum 6
TEST METHOD CSA A23.2-29A														
Micro Deval, % Loss	3.3	3.3	3.4	4.3	5.1	3.5	3.0	2.8	2.9	3.6	3.0	3.3	**3.5**	Maximum 17
TEST METHOD CSA A23.2-9A, ASTM C 88														
Soundness in $MgSO_4$ Weighted Average Loss, %	0.4	0.8	0.2	1.4	0.5	0.3	0.1	0.1	0.3	0.4	0.2	0.1	**0.4**	Maximum 12
TEST METHOD NSTPW, ASTM C 295 (SCRATCH HARDNESS)														
Petrographic Number	115	117	101	105	116	103	109	112	111	107	103	102	**108**	
TEST METHOD CSA A23.2-3A, ASTM C 142														
Clay Lumps, %	0	0	0	0	0	0	0	0	0	0	0	0	**0**	Maximum 0.25
TEST METHOD CSA A23.2-4A, ASTM C 123														
Low Density Granular Material, %	0	0	0	0	0	0	0	0	0	0	0	0	**0**	Maximum 0.5
TEST METHOD CSA A23.2-13A, ASTM D 4791														
Flat and Elongated Particles, % (4:1)	0 flat 0 elongated 2.8 flat & elongated	0 flat 0 elongated 1.0 flat & elongated	0 flat 0 elongated 2.1 flat & elongated	0 flat 0 elongated 4.0 flat & elongated	0 flat 0 elongated 1.4 flat & elongated	0 flat 0 elongated 1.6 flat & elongated	0 flat 0 elongated 2.7 flat & elongated	0 flat 0 elongated 5.7 flat & elongated	0 flat 0 elongated 0 flat & elongated	0 flat 0 elongated 0 flat & elongated	0 flat 0 elongated 2.0 flat & elongated	0 flat 0 elongated 2.7 flat & elongated	0 flat 0 elongated 2.2 flat & elongated	

Six Month Average?

Product Quality Summary Report

Rougemont Quarry CA217
#34'S, #44'S, #67 & #78M Gradation Report

Period 03/13/2013 - 09/13/2013

Plant **E018-ROUGEMONT**

	Product	20034 Blended Screenings	20044 Washed Screenings	20067 67 CLIMB	20078 #78M
	Specification	Blended Screenings	Washed Screenings	NCDOT 67	
1" (25mm)				100	
3/4" (19mm)				94	100
1/2" (12.5mm)				51	100
3/8" (9.5mm)		100	100	30	93
#4 (4.75mm)		96	97	7	32
#8 (2.36mm)		80	79	2	7
#10 (2mm)		72	70		
#16 (1.18mm)		52	50		
#30 (0.6mm)		38	30		
#40 (0.425mm)		32	24		
#50 (0.3mm)		24	18		
#80 (0.18mm)		20	12		
#100 (0.15mm)		18	10		
#200 (75um)		11.3	5.8		
Pan		0.0	0.0	0.0	0.0
SE		42	70		
Wash Loss (#200/75um)				0.2	0.3

When does breakdown occur?

Sieve Size, mm	57's			67's			78's			8's		
	Quarry	Plant	Dif.	Quarry	Plant	Dif.	Quarry	Plant	Dif.	Quarry	Plant	Dif.
50.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0
37.5	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0
25.0	95.1	100.0	-4.9	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0
19.0	62.3	81.8	-19.5	92.2	96.0	-3.8	100.0	100.0	0.0	100.0	100.0	0.0
12.5	37.2	30.0	7.2	41.8	48.1	-6.3	94.1	93.0	1.1	100.0	100.0	0.0
9.5	19.2	17.8	1.4	22.3	33.6	-11.3	68.8	64.2	4.6	91.9	92.8	-0.9
4.75	1.6	4.0	-2.4	5.3	6.5	-1.2	10.3	8.2	2.1	27.1	24.6	2.5
2.36	0.7	2.2	-1.5	0.9	3.0	-2.1	1.0	1.9	-0.9	3.4	6.0	-2.6
1.18	0.6	1.8	-1.2	0.6	2.0	-1.4	0.6	1.2	-0.6	1.5	3.1	-1.6
0.60	0.6	1.7	-1.1	0.6	1.6	-1.0	0.6	1.1	-0.5	1.3	2.6	-1.3
0.30	0.5	1.6	-1.1	0.6	15.0	-14.4	0.5	1.0	-0.5	1.2	2.4	-1.2
0.150	0.5	1.5	-1.0	0.5	1.4	-0.9	0.5	0.9	-0.4	1.2	2.2	-1.0
0.075	0.5	1.4	-0.9	0.5	1.3	-0.8	0.5	0.8	-0.3	1.2	2.0	-0.8

AMS LLC

When does breakdown occur?

Sieve Size, mm	S 11's			Man Sand			Sand		
	Quarry	Plant	Dif.	Quarry	Plant	Dif.	Quarry	Plant	Dif.
12.5	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0
9.5	100.0	100.0	0.0	100.0	100.0	0.0	99.9	100.0	-0.1
4.75	90.0	88.5	1.5	99.7	99.1	0.6	98.7	98.0	0.7
2.36	54.3	53.8	0.5	80.5	79.8	0.7	91.0	89.0	2.0
1.18	36.5	34.2	2.3	54.1	46.3	7.8	82.4	80.0	2.4
0.60	24.7	23.3	1.4	35.3	27.8	7.5	63.8	62.0	1.8
0.30	16.6	16.1	0.5	19.8	16.2	3.6	13.4	11.0	2.4
0.15	11.6	11.6	0.0	8.6	9.5	-0.9	0.6	3.0	-2.4
0.075	8.9	9.5	-0.6	2.6	6.8	-4.2	0.3	0.3	0.0

AMS LLC

Where does breakdown occur?

- During loading and unloading,
- In transportation
  - Barge,
  - Rail,
  - Truck,
- Stockpiling,
- Going through plant!

Recommended Steps

- Communicate with quarry regarding expected changes – remember quarry serves multiple customers,
- Look at recent running average,
- Adjust, if quarry values, for expected breakdown based on historical data,
- Sample stockpile and run washed gradations,
- Base mix design on expected gradation quarry is to supply,
- Batch to match expected gradation.

Best Practice

- One of our clients develops targets and range with quarry,
- Gradation data shared between quarry and contractor
  - Quarry provides QC gradations
  - Asphalt plant provides sample gradations of new material
- Weekly meeting to discuss

Operations

- How are stockpiles built?
- How does loader work though pile?
- What is the minimum amount cold feed bin can consistently feed?
- What is the maximum amount you should feed through a single bin?

Aggregate Specific Gravity

- Apparent
- Effective
- Bulk

Aggregate Specific Gravity

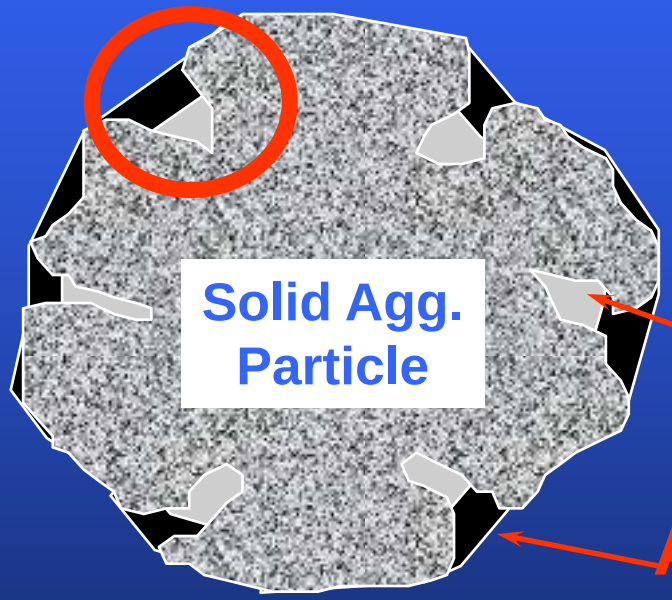
- Bulk specific gravity used to calculate voids in mineral aggregate – critical
- Apparent always largest, then effective, bulk gravity always smallest
- Gravity can change between ledges in a quarry or if material blended between two aggregate types
- Correction factor, between effective and bulk, established in design, used for production

Problem: Measuring G_{sb}

- Time consuming, approximately 2 days
- Coarse Agg. repeatable except with irregular shapes such as slag
- Fine Agg. Slump effected by:
  - grading
  - angularity
  - fines (- 0.075 mm)

Effective Specific Gravity

Surface Voids



$$G_{se} = \frac{\text{Mass, dry}}{\text{Effective Volume}}$$

Vol. of water-perm. voids not filled with asphalt

Absorbed asphalt

Effective volume = volume of solid aggregate particle + volume of surface voids not filled with asphalt

Shape Matters

- Specifications include:
  - Flat and elongated particles
  - Fine aggregate angularity
- Shape, particularly coarse aggregate shape, effects how aggregates pack together and aggregate breakdown
  - Cubical aggregates pack together better = lower VMA
  - Less breakdown with cubical aggregates

Deleterious Material

Deleterious Material

What about binder?

- Mixing and compaction temperatures will effect volumetric properties with Marshall designs
- Polymer modified PG 76-22 more critical – manufacturer's recommendation
- Be careful if new MSCR binder specifications implemented

AASHTO MP19

Table 1—Performance-Graded Asphalt Binder Specification[a]

Performance Grade	PG 46			PG 52							PG 58				
	34	40	46	10	16	22	28	34	40	46	16	22	28	34	40
Average 7-day max pavement design temp, °C[a]	<46			<52							<58				
Min pavement design temp, °C[a]	>-34	>-40	>-46	>-10	>-16	>-22	>-28	>-34	>-40	>-46	>-16	>-22	>-28	>-34	>-40
Original Binder															
Flash point temp, T 48, min °C	230														
Viscosity, T 316:[c] max 3 Pa•s, test temp, °C	135														
Dynamic shear, T 315:[d] G*/sinδ, min 1.00 kPa[e] test temp @ 10 rad/s, °C	46			52							58				
Rolling Thin-Film Oven Residue (T 240)															
Mass change, max, percent[f]	1.00														
MSCR, TP 70: Standard Traffic "S" Grade $J_{nr3.2}$, max 4.0 kPa^{-1} J_{nrdiff}, max 75% test temp, °C	46			52							58				
MSCR, TP 70: Heavy Traffic "H" Grade $J_{nr3.2}$, max 2.0 kPa^{-1} J_{nrdiff}, max 75% test temp, °C	46			52							58				
MSCR, TP 70: Very Heavy Traffic "V" Grade $J_{nr3.2}$, max 1.0 kPa^{-1} J_{nrdiff}, max 75% test temp, °C	46			52							58				
MSCR, TP 70: Extremely Heavy Traffic "E" Grade $J_{nr3.2}$, max 0.5 kPa^{-1} J_{nrdiff}, max 75% test temp, °C	46			52							58				
Pressurized Aging Vessel Residue (R 28)															
PAV aging temp, °C[g]	80			90							100				
Dynamic shear, T 315: "S" Grade G* sinδ, max 5000 kPa test temp @ 10 rad/s, °C	10	7	4	25	22	19	16	13	10	7	25	22	19	16	13
Dynamic shear, T 315: "H," "V," "E" Grades G* sinδ, max 6000 kPa test temp @ 10 rad/s, °C	10	7	4	25	22	19	16	13	10	7	25	22	19	16	13
Creep stiffness, T 313:[d] S, max 300 MPa m-value, min 0.300 test temp @ 60 s, °C	-24	-30	-36	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30
Direct tension, T 314:[h] Failure strain, min 1.0% test temp @ 1.0 mm/min, °C	-24	-30	-36	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30

MP19 Grades

- Standard – S - < 10 million ESALS
- Heavy – H – 10-30 million ESALs or slow moving traffic
- Very Heavy – V - > 30 million ESALs or standing traffic
- Extremely Heavy – E - > 30 million ESALs and standing traffic

Tested at base climatic temperature, e.g. 64

Brian Prowell
Advanced Materials Services, LLC
2515 E. Glenn Ave., Suite 107
Auburn, AL 36830
(334) 246-4428
Brian@AMSLLC.US