MassDOT's Journey to Concrete Specification Modernization:

A National Concrete Consortium Success Story

September 9, 2025

massDOT
Massachusetts Department of Transportation
Highway Division

NCC
NATIONAL CONCRETE CONSORTIUM

MASSACHUSETTENSIS SIGILLUM REIPUBLICÆ

Presenter

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2016 – The Beginning of the Journey

A National Concrete Consortium Success Story

Where to start?

- **American Concrete Institute (ACI)**
  - Collection of Concrete Codes, Specifications, and Practices
- **Portland Cement Association (PCA)**
  - Design and Control of Concrete Mixtures
- **American Association of State Highway and Transportation Officials (AASHTO)**
  - AASHTO PP 84 (2016) Developing Performance Engineered Concrete Pavement Mixtures
- **National Concrete Consortium (NC^2)**
  - Spring 2017 Salt Lake City, UT
  - Spring 2019 Denver, CO
  - Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual (2019)

What concepts were learned?

- **Constituent Materials**
  - Update cementitious materials, aggregate, and chemical admixtures
  - Add mixing water and fibers
- **Mix Design Formulation**
  - Remove minimum total cementitious contents, slump targets, silica fume content for high performance concrete, and other prescriptive measures. Let the Producer determine these targets!
  - Update air content targets and w/cm targets
  - Add combined aggregate system and paste system requirements

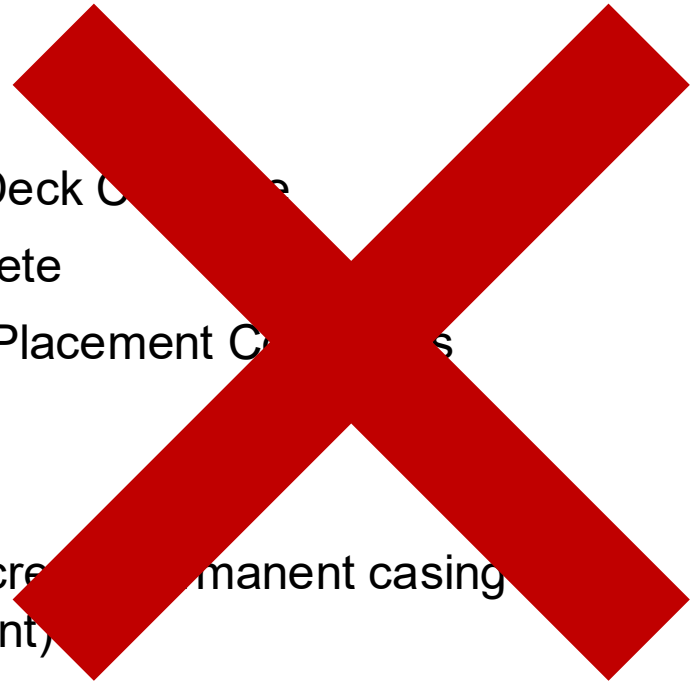
What concepts were learned?

Concrete Strength (28-Day)	Coarse Aggregate Size	Minimum Cement Content (lbs/yd³)
2,500 psi	1½ in.	42
		0
3,000 psi	1½ i	470
	¾ i	520
		-
3,500 psi	in.	
	¾ in.	565
	⅜ in.	610

Concrete Strength (28-Day)	Coarse Aggregate Size	Minimum Cement Content (lbs/yd³)
4,000 psi	1½ in.	56
		0
5,000 psi	1½ i	660
	¾ i	705
		-

What concepts were learned?

Concrete Type	Slump (inches)
Mass Concrete	2 ± ½ in.
Exposed Bridge Deck C e	2.5 ± ½ in.
Reinforced Concrete	3 ± 1 in.
Very Constricted Placement C s	4 ± 1 in.
Pump Concrete	4 ± 1 in.
Tremie Concrete	6 ± 1 in.
Drilled Shaft Concre manent casing uncased placement)	5 ± 1 in.



What concepts were learned?

Coarse Aggregate Size	Entrained Air Content (%) ±1.5
1½ inch	5.0%
¾ inch	6.0%
⅜ inch	7.0%

Notes:

- Severe Exposure: Concrete exposed to seve onments (e.g., bridge decks, freeze-thaw) should be 4,000 psi with 7.0% ±1.5% entra
- Drilled Shafts: Concrete for drilled shaft es **1.5%** entrained air
- All concrete must include a water-red admixture

What concepts were learned?

Additive Type	Specification	Notes
Air-Entraining Admixtures	AASHTO M 154M /	Required for proper air entrainment.
Retarders	AASHTO M 194	Used to delay setting time.
Water Reducers	AASHTO M 194 / M 194	All concrete must include a water-reducing admixture.
Calcium Nitrite Corrosion Inhibitor	AASHTO M 194M /	Must be 30 ± 2% calcium nitrite by weight; dosage: 3 gal/yd³ of concrete to raise chloride corrosion threshold to 9.9 lb/yd³ at rebar level.

These are all t… admixtures avail…

What about ASTM C1582?

What concepts were learned?

- **Performance Testing**
  - Remove 90-day ASTM C1202 Rapid Chloride Ion Penetration Test
  - Add AASHTO T 19 Aggregate Void Content, AASHTO T 121 Unit Weight, and 28-day AASHTO T 358 Chloride Ion Penetration Resistance testing
  - Add limits (allowable tolerances) unit weight, slump, and air content targets

Implementation of learned concepts

- **Present learned concepts to Producers**
- **Develop standard automated Excel workbook for Producers to report their mix design formulations**
  - RMS 043 Cement Concrete Mix Design Sheet.xlsm
- **Create web-based submission portal (SharePoint) for Producers to submit required items**
- **Require Producers to submit the RMS 043 Cement Concrete Mix Design Sheet.xlsm for review and approval**
- **Maintain an open dialogue with Producers**

Implementation of Concepts Learned

massDOT Massachusetts Department of Transportation Highway Division
Rev. 03/31/2025

2025 CEMENT CONCRETE MIX DESIGN SHEET

RMS 043

PLANT INFORMATION		MAILING ADDRESS			MIX DESIGN SHEET IDENTIFICATION
PLANT NAME	LOCATION	STREET NO. & ADDRESS	CITY/TOWN	EMAIL ADDRESS	CONTRACT / SHEET IDENTIFICATION NO.
BOSTON SAND AND GRAVEL	BOSTON, MA	100 N Washington Street 2nd Floor	Boston, MA 02114	jcarreira@bostonsand.com	24-02-12-06-48-18

CONSTITUENT MATERIALS

	AGGREGATE						UW_{DR}	VC	PERCENT PASSING BY MASS (%)												
ID	SOURCE	LOCATION	NMAS	DESCRIPTION	SPEC.	SG	(PCF)	(%)	2 IN.	1 1/2 IN	1 IN.	3/4 IN.	1/2 IN.	3/8 IN.	#4	#8	#16	#30	#50	#100	#200	FM
FINE	OSSIPEE AGGREGATES	OSSIPEE, NH	FINE	NORMAL WEIGHT	M 6	2.61	104.9	35.5	100.0	100.0	100.0	100.0	100.0	100.0	98.1	91.1	77.3	51.0	20.3	5.5	1.5	2.57
CA1	HOLCIM	SWAMPSCOTT, MA	3/4 IN.	NORMAL WEIGHT - 67	M 80	2.87	105.0	41.3	100.0	100.0	100.0	93.8	46.9	28.0	7.9	2.1	1.0	1.0	1.0	1.0	1.0	6.64
CA2	HOLCIM	SWAMPSCOTT, MA	3/8 IN.	NORMAL WEIGHT - 8	M 80	2.87	102.0	43.0	100.0	100.0	100.0	100.0	100.0	98.9	24.8	1.3	1.0	1.0	1.0	1.0	1.0	5.71
CA3																						

CEMENT; SUPPLEMENTARY CEMENTITIOUS MATERIALS; PACKAGED; FIBERS							CHEMICAL ADMIXTURES						
ID	SOURCE	LOCATION / PRODUCT	TYPE	DESCRIPTION	SPEC.	SG	ID	SOURCE	PRODUCT	TYPE	DESCRIPTION	SPEC.	V_S (%)
CEM	CIMENT QUEBEC	ST BASILE, QC (I / II)	I / II	GENERAL / MOD. SULFATE	M 85	3.15	AD1	GCP APPLIED TECHNOLOGIES	DAREX II AEA	AEA	AIR ENTRAINING	M 154	9.90
SCM1	CIMENT QUEBEC	MADISON, IN	FA-F	LOW CALCIUM (F)	M 295	2.46	AD2	CHRYSO INC	CHRYSO QUAD 842	F	HIGH RANGE WATER REDUCING	M 194	17.05
SCM2	HOLCIM	BALTIMORE,								D	ATER REDUCING AND RETARDI	M 194	41.30
SCM3										CLSM	CLSM ENHANCING	TDS	100.00
PKG													
FIBER													

Design Targets for Production Testing

MIX DESIGN FORMULATION

MIX DESIGN ID	PRODUCER ID	MIX DESIGN TYPE	f'_c (PSI)	NMA (IN.)	S (IN.)	AC (%)	W/CM RATIO	PC (%)	AGGREGATE (LBS.) FINE	CA1	CA2	CA3	CEMENTITIOUS; PACKAGED; FIBER (LBS.) CEM	SCM1	SCM2	SCM3	PKG	FIBER	WATER (GAL.) W_T	W_{ADMIX}	ADMIXTURES (FL. OZ.) AD1	AD2	AD3	AD4	AD5	AD6	YIELD (CF)	UW (PCF)
01	343016	CC	3000	3/4	4.00	6.0	0.53	26.7	1315.0	1800.0			338.0	78.0	104.0				33.0	0.3	6.5	26.0	7.8				27.00	144.8
02	343014	CC	3000	3/4	4.00	6.0	0.53	26.5	1325.0	1800.0			312.0		208.0				33.0	0.2	2.3	26.0	7.8				27.00	145.2
03	244066	CC	4000	3/8	7.50	7.5	0.45	32.1	1194.0		1600.0		448.0	104.0	138.0				37.0	0.3	6.0	34.5	10.4				27.00	140.5
04	344066	CC	4000	3/4	5.50	6.0	0.43	29.6	1190.0	1800.0			423.0	97.0	130.0				33.5	0.3	5.3	32.5	9.8				27.00	145.2
05	344062	CC	4000	3/4	5.50	6.0	0.43	29.5	1191.0	1800.0			520.0	130.0					33.5	0.3	7.0	32.5	9.8				27.00	145.2
06	344064	CC	4000	3/4	5.50	6.0	0.43	29.2	1205.0	1800.0			423.0		227.0				33.5	0.3	4.2	32.5	9.8				27.00	145.8
07	345076	CC	5000	3/4	6.50	6.0	0.39	30.5	1192.0	1750.0			461.0	107.0	142.0				33.0	0.4	4.5	49.7	10.7				27.00	145.5
08	294296	UWC	4000	3/8	8.50	4.0	0.43	36.3	1164.0		1600.0		520.0	120.0	160.0				41.0	0.2	5.0		32.0				27.00	144.7
09	295296	UWC	5000	3/8	8.50	4.0	0.40	37.5	1112.0		1600.0		563.0	127.0	170.0				41.0	0.2	3.9		34.0				27.00	145.0
10	100502	CLSM MANUAL EXC	100	FINE	10.50	3.0	1.53	34.2	2756.0				50.0	250.0					55.0	0.0							27.00	130.2
11	100102	CLSM MECH EXC	200	FINE	10.50	3.0	1.34	35.6	2694.0				100.0	250.0					56.0	0.0							27.00	130.0
12	100152	CLSM NON-EXC	1000	FINE	10.50	3.0	1.18	36.8	2641.0				150.0	250.0					56.5	0.0							27.00	130.1
13	344034	ESC	4000																				9.2				27.00	144.3
14	110100	CLSM MANUAL EXC	100																					1.0			27.00	103.7
15	191552	CLSM NON-EXC	1000																								27.00	130.9
16	344296	UWC	4000																				16.3				28.99	147.3

Combined Aggregate and Paste System

COMBINED AGGREGATE AND PASTE SYSTEM

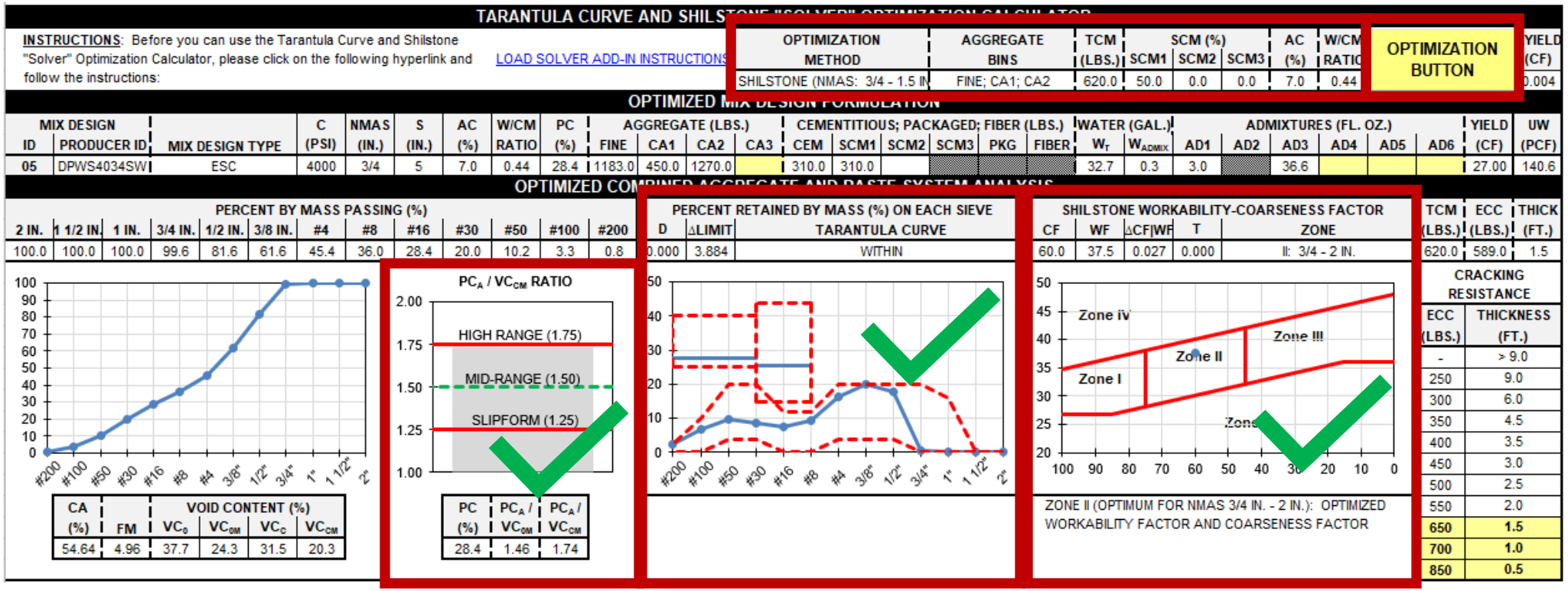
																		SCM (%)			TCM	ECC	THICK
																		SCM1	SCM2	SCM3	(LBS.)	(LBS.)	(FT.)
01	343016	100.0	100.0	100.0	96.3	68.0	56.7	43.8	37.5	31.4	20.9	8.7	2.8	1.2	OUTSIDE	IV: TOO FINE	38.9	25.1			1.41		15.0	20.0	0.0	520.0	481.0	2.5
02	343014	100.0	100.0	100.0	96.3	68.2	56.9	44.1	37.8	31.6	21.0	8.7	2.8	1.2	OUTSIDE	IV: TOO FINE	38.8	25.1			1.40		0.0	40.0	0.0	520.0	520.0	2.0
03	244066	100.0	100.0	100.0	96.3	68.4	57.2	44.4	38.2	31.9	21.3	8.8	2.8	1.2	OUTSIDE	IV: TOO FINE	38.8	24.6			1.48		15.1	20.0	0.0	690.0	638.0	1.5
04	344066	100.0	100.0	100.0	96.3	68.2	56.9	44.1	37.8	31.6	21.0	8.7	2.8	1.2	OUTSIDE	IV: TOO FINE	38.8	25.1			1.40		14.9	20.0	0.0	650.0	601.5	1.5
05	344062	100.0	100.0	100.0	96.3	68.0	56.7	43.8	37.5	31.4	20.9	8.7	2.8	1.2	OUTSIDE	IV: TOO FINE	38.9	25.1			1.41		20.0	0.0	0.0	650.0	585.0	1.5
06	344064	100.0	100.0	100.0	96.3	68.2	56.9	44.1	37.8	31.6	21.0	8.7	2.8	1.2	OUTSIDE	IV: TOO FINE	38.8	25.1			1.40		0.0	34.9	0.0	650.0	650.0	1.0
07	345076	100.0	100.0	100.0	96.3	68.4	57.2	44.4	38.2	31.9	21.3	8.8	2.8	1.2	OUTSIDE	IV: TOO FINE	38.8	24.6			1.48		15.1	20.0	0.0	710.0	656.5	1.0
08	294296	100.0	100.0	100.0	100.0	100.0	99.4	55.7	39.1	33.1	22.1	9.1	2.9	1.2	OUTSIDE	III: < 3/4 IN.	39.7	23.7			1.70		15.0	20.0	0.0	800.0	740.0	0.5
09	295296	100.0	100.0	100.0	100.0	100.0	99.4	54.9	38.1	32.3	21.5	8.9	2.8	1.2	OUTSIDE	III: < 3/4 IN.	39.8	23.3			1.78		14.8	19.8	0.0	860.0	796.5	0.5
10	100502	100.0	100.0	100.0	100.0	100.0	100.0	98.1	91.1	77.3	51.0	20.3	5.5	1.5	OUTSIDE	IV: TOO FINE	35.5	22.3			1.67		83.3	0.0	0.0	300.0	175.0	9.0
11	100102	100.0	100.0	100.0	100.0	100.0	100.0	98.1	91.1	77.3	51.0	20.3	5.5	1.5	OUTSIDE	IV: TOO FINE	35.5	21.8			1.77		71.4	0.0	0.0	350.0	225.0	9.0
12	100152	100.0	100.0	100.0	100.0	100.0	100.0	98.1	91.1	77.3	51.0	20.3	5.5	1.5	OUTSIDE	IV: TOO FINE	35.5	21.4			1.86		62.5	0.0	0.0	400.0	275.0	6.0
13	344034	100.0	100.0	100.0	97.2	76.2	67.5	46.7	37.8	31.7	21.1	8.8	2.8	1.2	OUTSIDE	II: 3/4 - 2 IN.	39.1	25.4			1.38		0.0	24.5	0.0	611.0	611.0	1.5
14	110100	100.0	100.0	100.0	100.0	100.0	100.0	98.1	91.1	77.3	51.0	20.3	5.5	1.5	OUTSIDE	IV: TOO FINE	35.5	19.3			2.37		0.0	0.0	0.0	100.0	100.0	9.0
15	191552	100.0	100.0	100.0	100.0	100.0	100.0	98.1	91.1	77.3	51.0	20.3	5.5	1.5	OUTSIDE	IV: TOO FINE	35.5	20.3			2.10		54.5	0.0	0.0	550.0	400.0	3.0
16	344296	100.0	100.0	100.0	96.5	69.8	59.0	46.8	40.5	33.9	22.5	9.3	2.9	1.2	OUTSIDE	IV: TOO FINE	38.7	25.4			1.35		25.1	24.9	0.0	650.0	568.5	1.5

Sheet ID No.	+	ID No.	=	Mix Design No.
24-02-12-06-48-18	+	01	=	24-02-12-06-48-18-01

Mr. James Carreira — *NAME*
Technical Director — *TITLE*
AUTHORIZED SIGNATURE
4/22/2025 — *DATE*

Implementation of Concepts Learned

Mix Design "Solver" Optimization



Implementation of Concepts Learned

massDOT Highway Division
Rev. 12/17/2024

CEMENT CONCRETE MIX DESIGN COMBINED AGGREGATE SYSTEM ANALYSIS

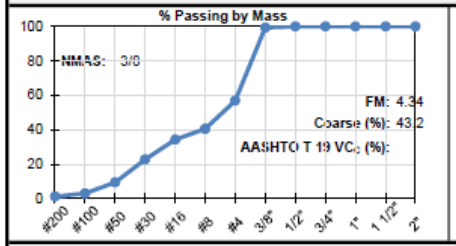
PLANT INFORMATION		MAILING ADDRESS			MIX SHEET IDENTIFICATION	
PLANT NAME	LOCATION	STREET NO. & ADDRESS	CITY/TOWN	EMAIL ADDRESS	CONTRACT	SHEET IDENTIFICATION NO.
BOSTON SAND AND GRAVEL	BOSTON, MA	100 N Washington Street 2nd Floor	Boston, MA 02114	jcarreira@bostonsand.com		24-02-12-08-04-32

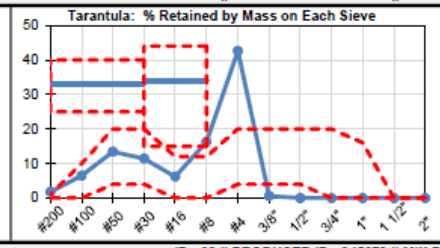
CONSTITUENT MATERIALS

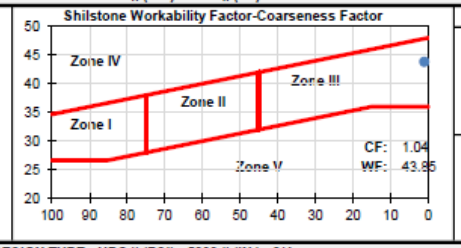
ID	MANUFACTURER	AGGREGATE SOURCES LOCATION	NMAS	DESCRIPTION	SPEC.	SG (DRY)	UW (PCF)	VC (%)	PERCENT PASSING BY MASS (%) 2 IN.	1 1/2 IN.	1 IN.	3/4 IN.	1/2 IN.	3/8 IN.	#4	#8	#16	#30	#50	#100	#200	FM
FINE	OSSIPEE AGGREGATES	OSSIPEE, NH	FINE	NORMAL WEIGHT	M 6	2.61	104.9	35.5	100.0	100.0	100.0	100.0	100.0	100.0	98.1	91.1	77.3	51.0	20.3	5.5	1.5	2.57
CA1	HOLCIM	SWAMPSCOTT, MA	3/4 IN.	NORMAL WEIGHT - 67	M 80	2.87	105.0	41.3	100.0	100.0	100.0	93.8	46.9	28.0	7.9	2.1	1.0	1.0	1.0	1.0	1.0	6.64
CA2	HOLCIM	SWAMPSCOTT, MA	3/8 IN.	NORMAL WEIGHT - 8	M 80	2.87	102.0	43.0	100.0	100.0	100.0	100.0	100.0	98.9	24.8	1.3	1.0	1.0	1.0	1.0	1.0	5.71
CA3																						

COMBINED AGGREGATE SYSTEM ANALYSIS

ID: 01 || PRODUCER ID: 245679 || MIX DESIGN TYPE: HPC || (PSI): 5000 || (IN.): 3/8







Analysis

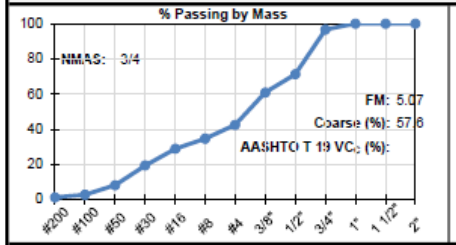
Tarantula

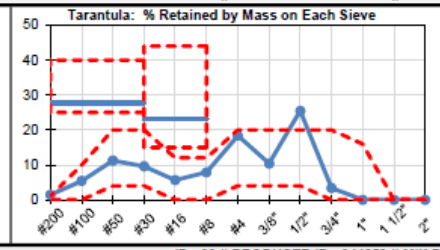
OUTSIDE: |1/2 IN.||3/8 IN.||#4||#8| EXCESSIVE COARSE AGGREGATE RESULTING IN DECREASED WORKABILITY AND INCREASED SEGREGATION AND EDGE SLUMPING. EXCESSIVE COARSE SAND RESULTING IN DECREASED FINISHABILITY.

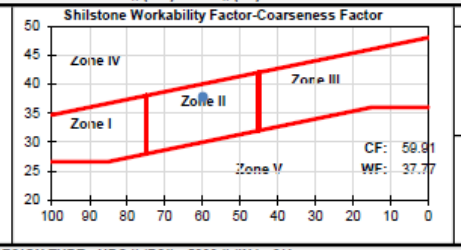
Shilstone Workability-Coarseness

ZONE III (OPTIMUM FOR NMAS < 3/4 IN.): OPTIMIZED WORKABILITY FACTOR AND COARSENESS FACTOR

ID: 02 || PRODUCER ID: 345679 || MIX DESIGN TYPE: HPC || (PSI): 5000 || (IN.): 3/4







Analysis

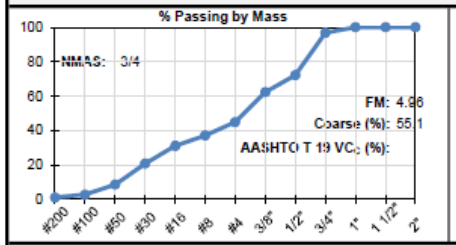
Tarantula

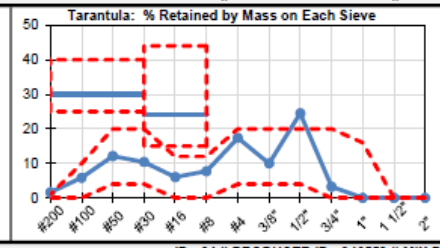
OUTSIDE: |1/2 IN.| EXCESSIVE COARSE AGGREGATE RESULTING IN DECREASED WORKABILITY AND INCREASED SEGREGATION AND EDGE SLUMPING.

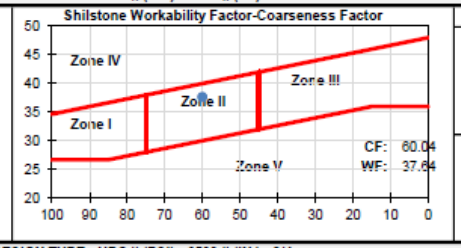
Shilstone Workability-Coarseness

ZONE II (OPTIMUM FOR NMAS 3/4 IN. - 2 IN.): OPTIMIZED WORKABILITY FACTOR AND COARSENESS FACTOR

ID: 03 || PRODUCER ID: 344259 || MIX DESIGN TYPE: HPC || (PSI): 5000 || (IN.): 3/4







Analysis

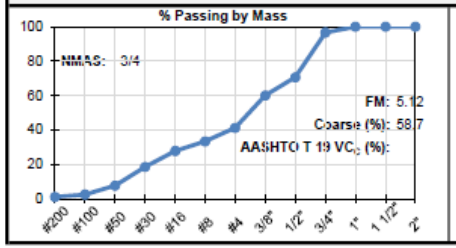
Tarantula

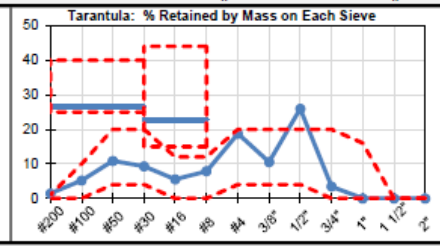
OUTSIDE: |1/2 IN.| EXCESSIVE COARSE AGGREGATE RESULTING IN DECREASED WORKABILITY AND INCREASED SEGREGATION AND EDGE SLUMPING.

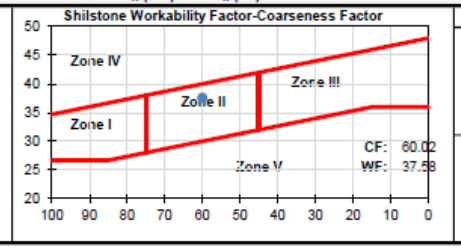
Shilstone Workability-Coarseness

ZONE II (OPTIMUM FOR NMAS 3/4 IN. - 2 IN.): OPTIMIZED WORKABILITY FACTOR AND COARSENESS FACTOR

ID: 04 || PRODUCER ID: 346559 || MIX DESIGN TYPE: HPC || (PSI): 6500 || (IN.): 3/4







Analysis

Tarantula

OUTSIDE: |1/2 IN.| EXCESSIVE COARSE AGGREGATE RESULTING IN DECREASED WORKABILITY AND INCREASED SEGREGATION AND EDGE SLUMPING.

Shilstone Workability-Coarseness

ZONE II (OPTIMUM FOR NMAS 3/4 IN. - 2 IN.): OPTIMIZED WORKABILITY FACTOR AND COARSENESS FACTOR

Implementation of Concepts Learned

massDOT Massachusetts Department of Transportation Highway Division

Rev. 02/01/2025

CEMENT CONCRETE MIX DESIGN AIR VOID AND PASTE SYSTEM ANALYSIS

PLANT INFORMATION		MAILING ADDRESS			MIX SHEET IDENTIFICATION	
PLANT NAME	LOCATION	STREET NO. & ADDRESS	CITY/TOWN	EMAIL ADDRESS	CONTRACT	SHEET IDENTIFICATION NO.
BOSTON SAND AND GRAVEL	BOSTON, MA	100 N Washington Street 2nd Floor	Boston, MA 02114	jcarreira@bostonsand.com		24-02-12-08-04-32

DESIGN PARAMETERS FOR ENHANCED WORKABILITY AND DURABILITY

ID NO.	PRODUCER ID	MIX DESIGN TYPE	C (PSI)	NMAS (IN.)	S (IN.)	AC (%)	W / CM	PC (%)	PC_A (%)	VC_{CM} (%)	PC_E (%)	PC_A / VC_{CM}	SCM1 (%)	SCM2 (%)	SCM3 (%)	UW (PCF)	YIELD (CF)	TCM (LBS.)	ECC (LBS.)	THICK (FT.)
01	245679	HPC	5000	3/8	6 1/2	6.5	0.39	29.9	36.4	25.1			15.1	19.4	0.0	144.4	27.0	690.0	645.2	1.5
02	345679	HPC	5000	3/4	6 1/2	6.5	0.39	29.7	36.2	24.9			15.0	20.0	0.0	145.2	27.0	685.0	640.6	1.5
03	344259	HPC	5000	3/4	7 1/2	6.5	0.40	25.4	31.9	26.4			20.1	0.0	0.0	147.1	27.0	582.0	530.9	2.0
04	346559	HPC	6500	3/4	7 1/2	5.5	0.37	30.0	35.5	25.2			14.6	22.4	0.0	147.6	27.0	720.0	674.8	1.0

DEF and Thermal Cracking Resistance [1]

Smallest Dimension of Concrete Member (ft.)	Maximum Equivalent Cement Content (lbs.)
> 9.0	[2]
> 6.0; ≤ 9.0	250
> 4.5; ≤ 6.0	300
> 3.5; ≤ 4.5	350
3.5	400
3.0	450
2.5	500
2.0	550
1.5	650
1.0	700
0.5	850

[1] Heat Reduction Factors for Equivalent Cement Content: Portland Cement = 1.0; Silica Fume = 1.2; Metakaolin = 1.2; Slag (≤ 45%) = 1.0; Slag (> 45% and ≤ 65%) = 0.9; Slag (> 65% and ≤ 80%) = 0.8; Fly Ash (Class C) = 0.8; Fly Ash (Class F) = 0.5

[2] Heat of hydration analysis and thermal control plan

01	245679	HPC	5000	3/8	6 1/2	6.5	0.39	29.9	36.4	25.1			15.1	19.4	0.0	144.4	27.0	690.0	645.2	1.5

Freezing, Thawing, and De-Icing Resistance

Class	Severity	Condition	Maximum W/CM Ratio: Reinforced	Maximum W/CM Ratio: Non-Reinforced	Minimum Air Content (%): NMAS (In.)	Minimum Air Content (%): Reinforced < 5000 psi	Minimum Air Content (%): Reinforced ≥ 5000 psi	Minimum Air Content (%): Non-Reinforced
F1	Moderate	Exposed to freezing and thawing cycles; Not exposed to accumulation of snow, ice, and de-icing chemicals; Limited exposure to water.	0.55	0.55	3/8	6.0	5.0	7.0
					1/2	5.5	4.5	7.0
					3/4	5.0	4.0	6.5
					1	4.5	3.5	6.5
					1 1/2	4.5	3.5	6.0
F2	Severe	Exposed to freezing and thawing cycles and accumulation of snow and ice; Not exposed to de-icing chemicals; Frequent exposure to water; Direct contact with soil.	0.45	0.45	3/8	SAME MIMIMUM AIR CONTENT REQUIREMENTS AS CLASS F3		
					1/2			
					3/4			
					1			
					1 1/2			
F3	Very Severe	Exposed to freezing and thawing cycles and accumulation of snow, ice, and de-icing chemicals; Frequent exposure to water.	0.40	0.45	3/8	7.5	6.5	7.5
					1/2	7.0	6.0	7.0
					3/4	6.0	5.0	7.0
					1	6.0	5.0	6.5
					1 1/2	5.0	4.5	6.5

Corrosion Resistance of Steel Reinforcement [1]

Class	Severity	Condition	Maximum W/CM Ratio
C2	Severe	Exposed to moisture and external sources of chlorides including de-icing chemicals, salt, brackish water, and seawater	0.40
PS	All	All prestressed concrete structures exposed to any condition	

[1] High performance concrete shall also be formulated with 384 fl. oz. / cy (3.0 gal. / cy) of corrosion inhibiting admixture.

Sulfate Reaction Resistance

Class	Severity	Condition: C1580 (% by mass)	Condition: D516 or D4130 (ppm)	Maximum W/CM Ratio	Cement or SCM Type
S1	Moderate	$0.10 < SO_4 < 0.20$	$150 < SO_4 < 1500$	0.50	Type MS and SCM
S2	Severe	$0.20 < SO_4 < 2.00$	$1500 < SO_4 < 10,000$	0.45	Type HS and SCM
S3	Very Severe	$SO_4 > 2.00$	$SO_4 > 10,000$	0.40	

Shrinkage and Cracking Resistance [1]

Concrete	Paste Content (PC) (%)
Pavement Concrete (Slip Formed)	≤ 25.0
Pavement Concrete (Fixed Formed)	≤ 28.0
High Performance Concrete	≤ 30.0
Exterior Slab Concrete	

[1] Not applicable to self-consolidating concrete or concrete with Type S-SRA shrinkage reducing admixtures at a dosage ≥ 128.0 oz./cy (or per Manufacturer's recommendations), Type S-CRA crack reducing admixtures at a dosage per Manufacturer's recommendations, fibers that inhibit shrinkage (dosage per Manufacturer's recommendations) or test results within the shrinkage limits specified in standard specifications.

Workability [1]

Condition	PC_A/VC_{CM} Ratio
Decreased Workability from Excessive Aggregate Content and Limited Paste Content	< 1.25
Pavement Concrete	1.25 – 1.75
High Performance Concrete	
Exterior Slab Concrete	
Increased Segregation from Excessive Paste Content and Limited Aggregate Content	> 1.75

[1] Not applicable to self-consolidating concrete or concrete with Type S chemical admixtures that enhance the workability of the concrete.

Suggested PC_A/VC_{CM} Ratio Target Limits:

[1a] 1.25 = Slip form and other low workability applications

[1b] 1.50 = Chute, buggy, wheel barrow, conveyor belt, bucket

[1c] 1.75 = Pumping and other high workability applications

Durability and Environmental

Supplementary Cementitious Materials	SCM (%)
Fly Ash (Class C)	20 – 50
Fly Ash (Class F)	15 – 30
Slag	20 – 50
Silica Fume	5 – 15
Metakaolin (Class N)	10 – 20
Calcined Clay or Shale (Class N)	20 – 35
Ground-Glass Pozzolan	[1]
High Reactivity Pozzolan	[1]
Total Fly Ash and Silica Fume	≤ 35
Total SCM	≤ 50

[1] Per Manufacturer's recommendations.

Durability and Environmental

Cement with Supplementary Cementitious Materials	SCM (%)
Blended Hydraulic Cement	[1]
Rapid Hardening Hydraulic Cement	[1]
Performance Based Hydraulic Cement	[1] [2]

[1] Target shall meet the requirements specified in the previous Durability and Environmental table.

[2] Target requirements are not applicable to pozzolanic performance based hydraulic cement.

2025 – Completion of Modern Concrete Specifications

A National Concrete Consortium Success Story

M4: Cement Concrete and Related Materials

Section	Title
M4.00.0	General
M4.01.0	Constituent Materials and Mix Design Formulations of Cement Concrete
M4.02.0	Concrete Produced by Stationary and Truck Mixed Methods
M4.03.0	Concrete Produced by Volumetric Mixers
M4.04.0	Cementitious, Grout, Mortar, and Concrete Bagged Products
M4.05.0	Brick, Block, and Drycast Segmental Retaining Wall Units
M4.06.0	Cement Concrete

Section	Title
M4.07.0	Elastomeric Concrete
M4.08.0	Controlled Low-Strength Materials
M4.09.0	Precast, Prestressed, and Prefabricated Concrete
M4.10.0	Epoxy Resin Adhesive Products
M4.11.0	Evaporation Reducing Materials
M4.12.0	Curing Materials
M4.13.0	Protective Sealing Compounds

M4.01.1: Cementitious Materials

Specification	Material
AASHTO M 85	Portland Cement
AASHTO M 240	Blended Hydraulic Cement
ASTM C1600	Rapid Hardening Hydraulic Cement
ASTM C1157	Performance-Based Hydraulic Cement
ASTM C1948	Alkali-Activated Cementitious Materials

Specification	Material
AASHTO M 295	Coal Ash
AASHTO M 302	Slag
AASHTO M 307	Silica Fume
ASTM C1945	Natural Pozzolans
AASHTO M 321	High Reactivity Pozzolans
ASTM C1866	Ground-Glass Pozzolans
ASTM C1697	Blended Supplementary Cementitious Materials

M4.01.4: Chemical Admixtures

Specification	Type	Description
AASHTO M 194	A	Water Reducing
AASHTO M 194	B	Retarding
AASHTO M 194	C	Accelerating
AASHTO M 194	D	Water Reducing and Retarding
AASHTO M 194	E	Water Reducing and Accelerating
AASHTO M 194	F	High Range Water Reducing
AASHTO M 194	G	High Range Water Reducing and Retarding
AASHTO M 194	AF	Mid-Range Water Reducing
AASHTO M 154	AEA	Air-Entraining

M4.01.4: Chemical Admixtures

Specification	Type	Description
AASHTO M 194	S-AWA	Anti-Washout
AASHTO M 194	S-CNA	Carbon Nanotube
AASHTO M 194	S-CRA	Crack Reducing
AASHTO M 194	S-PRAN	Permeability Reducing (Non-Hydrostatic)
AASHTO M 194	S-PRAH	Permeability Reducing (Hydrostatic)
AASHTO M 194	S-RCA	Rheology Controlling
AASHTO M 194	S-SEA	Strength Enhancing
AASHTO M 194	S-SCA	Shrinkage Compensating
AASHTO M 194	S-SRA	Shrinkage Reducing
AASHTO M 194	S-VMA	Viscosity Modifying
AASHTO M 194	S-WRA	Workability Retaining

Specification	Type	Description
ASTM C1882	M-AWA	Anti-Washout
ASTM C1582	M-CIA	Corrosion Inhibiting
TDS	M-CSA	Colloidal Silica
TDS	M-BA	Bonding
ASTM C979	M-CA	Coloring
ASTM C1622	M-CWA	Cold Weather
ASTM C869	M-FA	Foaming

M4.01.6: Mix Design Formulation

- Global Warming Potential
- SCM Content for Enhanced Durability and Sustainability
- Equivalent Cement Content for DEF and Thermal Cracking Resistance
- Alkali Silica Reaction Resistance
- Sulfate Reaction Resistance
- Corrosion Resistance of Steel Reinforcement
- Shrinkage Resistance
- Water, Freezing, Thawing, and De-icing Resistance
- Combined Aggregate System
- Paste Content and Mix Design Void Content

M4.06.0: Cement Concrete

Specification	Type	Description
M4.06.1	CC	Conventional Concrete
M4.06.2	HPC	High Performance Concrete
M4.06.3	HESC	High Early Strength Concrete
M4.06.4	RHC	Rapid Hardening Concrete
M4.06.5	LWC	Lightweight Concrete
M4.06.6	SCC	Self-Consolidating Concrete

Specification	Type	Description
M4.06.7	ESC	Exterior Slab Concrete
M4.06.8	PC	Pavement Concrete
M4.06.9	MPC	Mass Placement Concrete
M4.06.10	FRC	Fiber Reinforced Concrete
M4.06.11	UHPC	Ultra-High Performance Concrete
M4.06.12	SHOT	Shotcrete
M4.06.13	UWC	Underwater Concrete
M4.06.14	DC	Drycast Concrete

M4.06.8: Pavement Concrete

Verification Testing Requirements for Aggregate Properties

Test Method	Quality Characteristic		Min.	Max.
AASHTO T 161	Deterioration Cracking (D-Cracking) Resistance	Durability Factor	90	–
		Mass Loss (%)	–	6.0
AASHTO T 19	Composite Void Content of Combined Aggregate System (%)		Informational	

M4.06.8: Pavement Concrete

Verification Testing Requirements for Fresh Concrete

Test Method	Quality Characteristic		Min.	Max.
AASHTO M 157	Batching Quantities of Constituent Materials		M4.02.3	
AASHTO T 121	Unit Weight (lb/ft^3)		Target -3.0	Target +3.0
AASHTO T 119	Slump (in.)	< 4 in.	Target -1.0	Target +1.0
		4 – 8 in.	Target -1.5	Target +1.5
	Segregation Resistance, Consolidation, and Cohesion		Pass	
AASHTO T 152	Air Content (%)		Target -1.5	Target +1.5
AASHTO T 309	Concrete Temperature (°F)		50	90
AASHTO T 396	Edge Slump (in.)		–	0.25
	Condition of Surface Category		–	2
	Surface Voids (%)		–	30
AASHTO T 395	System Air Metric (SAM) Number (psi) for Freezing and Thawing Resistance		–	0.20

M4.06.8: Pavement Concrete

Verification Testing Requirements for Hardened Concrete

Test Method	Quality Characteristic			Min.	Max.
AASHTO T 22	Compressive Strength (psi)		3 Days	Informational	
			7 Days	Informational	
			28 Days	5000	–
			56 Days	Informational	
Select One Method for Chloride Ion Penetration Resistance	AASHTO T 358	Apparent Surface Resistivity (kΩ-cm)	7 Days	Informational	
			28 Days	21	–
			56 Days	Informational	
	AASHTO T 402	Bulk Resistivity (Ω-m)	7 Days	Informational	
			28 Days	104.0	–
			56 Days	Informational	

M4.06.8: Pavement Concrete

Verification Testing Requirements for Hardened Concrete (Continued)

Test Method	Quality Characteristic			Min.	Max.
Select One Method for Alkali Silica Reaction Resistance	ASTM C1260	100% Cement Expansion (%)	14 Days	–	0.10
	ASTM C1567	SCM Mitigation Expansion (%)	14 Days	–	0.10
	AASHTO T 380	100% Cement Expansion (%)	56 Days	–	0.030
		SCM Mitigation Expansion (%)	56 Days	–	0.019
	AASHTO TP 142	100% Cement Expansion (%)	45 Days	–	0.039
		SCM Mitigation Expansion (%)	75 Days	–	0.039
			90 Days	–	0.039
		Mix Design Expansion (%)	120 Days	–	0.039
	AASHTO TP 144	Reactivity Index	21 Days	Non-reactive	

M4.06.8: Pavement Concrete

Verification Testing Requirements for Hardened Concrete (Continued)

Test Method	Quality Characteristic		Min.	Max.
AASHTO T 336	Coefficient of Thermal Expansion (με/°F)		Target -0.5	Target +0.5
AASHTO T 97	Flexural Strength (psi)	3 Days	Informational	
		7 Days	Informational	
		28 Days	650	–
		56 Days	Informational	
Select One Method for Freezing and Thawing Resistance	AASHTO T 161	Durability Factor	90	–
		Mass Loss (%)	–	6.0
	ASTM C457	Air-Void Spacing Factor (in.)	–	0.008
AASHTO T 365	Calcium Oxychloride Content (g CA_{OXY} / g Paste) for De-icing Resistance		–	0.14
ASTM C1585	Degree of Saturation for 30 Year Service Life		–	0.85

M4.06.8: Pavement Concrete

AMERICAN ENGINEERING TESTING

	Specification
Sample ID	
SSD Mass	
OD Mass	
Vacuumed	
Immersed	
ρ (Ω.m)	
F_{app}	
S_{nick} (%)	
S_2 (%)	
S (%) 30 y	≤ 85%
S (%) 50 y	≤ 85%

Notes:
1. All test specimens were fa
2. The test results represent
3. ϕ was considered 1.3, for
4. 30 and 50 years of service

massDOT Massachusetts Department of Transportation Highway Division

Thank You!

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