



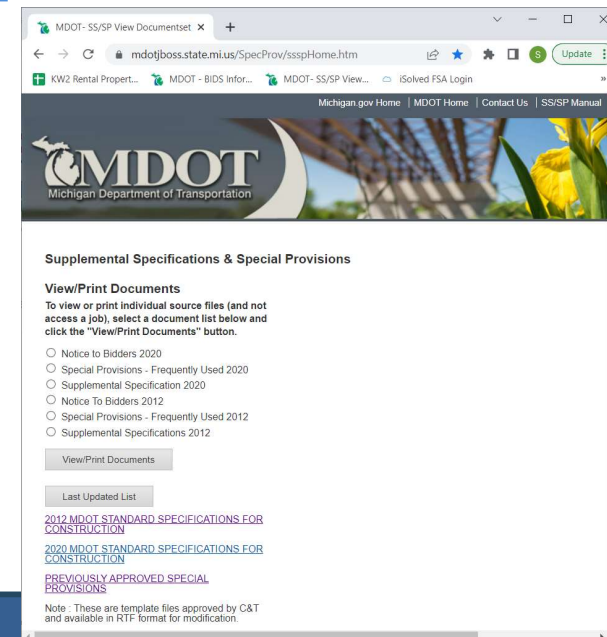
MDOT Concrete Mix Design: Proportioning, Approvals, etc.

Steve Waalkes, P.E., Director of Engineering – W. Mich.

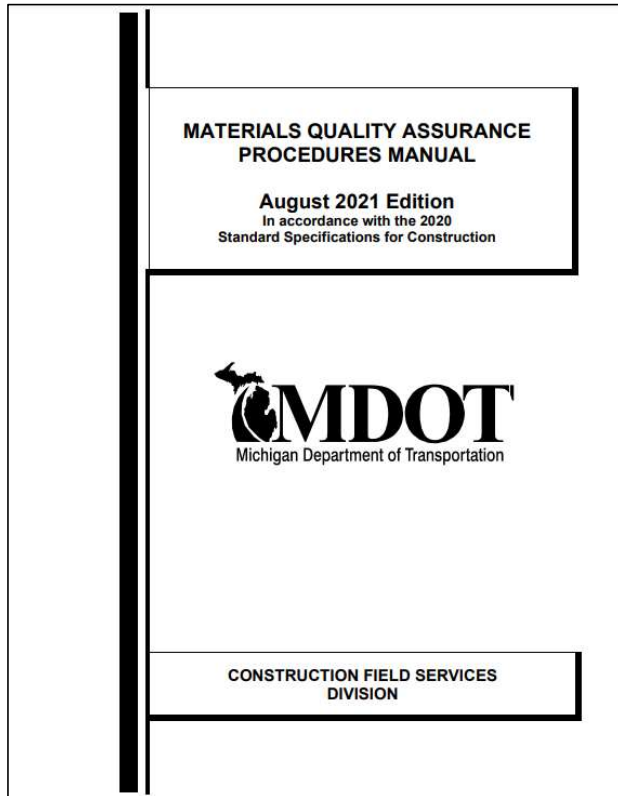
Michigan Concrete Association

Where are MDOT specs located?

- Standard Specifications for Construction and Frequently Used Special Provisions (2020)
 - <https://mdotjboss.state.mi.us/SpecProv/ssspHome.htm>
- Previously approved special provisions
- Various other project-specific special provisions



Approved Materials



- Materials Quality Assurance Procedures Manual
 - A contract document
 - Current revision in place at the time of contractor's bid is binding for the project
 - Quarterly updates
 - Available on MDOT website
 - Just Google "MDOT Materials Quality Assurance Procedures Manual"

Approved Materials – Cement, Slag Cement

- Approved manufacturers of portland cement – ASTM C150 and/or ASTM C595 (MDOT 901)
- Prior to addition to approved list,
 - MDOT reviews historical mill reports for ASTM compliance
 - Verifies physical properties of lab samples
- Ongoing,
 - Biannual mill report submitted and reviewed
 - Random samples may be taken in the field for QA verification
- Type III cement is permitted only for precast / prestressed (not for ready-mix or paving)

APPROVED MANUFACTURERS		
Spec. # and Material Name	Approved Manufacturers	Approved Distribution Facilities (not manufacturer specific)
901 Cement	Argos USA, LLC - Martinsburg, WV Ash Grove - Mississauga, Ontario, Canada; Joliette, Quebec, Canada Buzzi Unicem USA - Chattanooga, TN; Festus MO; Greencastle, IN Central Plains Cement - Sugar Creek, MO Continental Cement Company - Hannibal, MO Fairborn Cement Company - Fairborn, OH Holcim (US), Inc. - Alpena, MI; Paulding, OH; and Bloomsdale, MO Illinois Cement Company - LaSalle, IL Kosmos Cement Company - Louisville, KY LeHigh Cement Company, LLC - Logansport and Mitchell, IN; Union Bridge, Maryland; Picton, Ontario, Canada McInnis Cement - Port Daniel-Gascons, Quebec, Canada St. Mary's Cement, Inc. (US) - Detroit and Charlevoix, MI; Bowmanville and St. Mary's, Ontario, Canada	Ash Grove - Detroit, and Dundee, MI; Duluth, MN Buzzi Unicem USA - Elmira and Grandville, MI; Elkhart, IN; Joliet, IL Holcim (US), Inc. – Detroit, Essexville, Muskegon, St. Joseph and Zilwaukee, MI; Chicago, Lemont and Summit, IL; Toledo, OH; Green Bay, WI St. Mary's Cement, Inc. (US) – Cleveland 1, Cleveland 2, Marysville and Toledo, OH; Ferrysburg, MI;
901.06 Slag Cement	Ash Grove - Detroit, MI; Mississauga, Ontario, Canada Holcim (US), Inc. - South Chicago, IL Skyway Cement Company, LLC - Chicago, IL St. Mary's Cement, Inc. (US) - Detroit, MI; Milwaukee, WI	Ash Grove - Dundee, MI Holcim (US), Inc. – Detroit, Essexville, Muskegon, St. Joseph and Zilwaukee, MI; Chicago, Lemont and Summit, IL; Toledo, OH; Green Bay, WI St. Mary's Cement, Inc. (US) – Cleveland 1, Cleveland 2 and Marysville, OH; Ferrysburg, MI

Approved Materials – SCM's

- Required amount: 25%-40% total replacement of portland in high performance mixtures
 - Could be lower in certain situations (mass concrete placements)
- Approved Manufacturers of supplemental cementitious materials (MDOT 901)
- Prior to addition to list,
 - MDOT reviews historical mill reports for compliance
 - Fly ash – C618, Class C and F
 - Slag cement – C989, Grade 100, minimum
 - Verifies physical properties of lab samples
- Ongoing,
 - Monthly mill report submitted and reviewed – fly ash only
 - Random samples may be taken in the field for QA verification

Spec. # and Material Name	Approved Manufacturers	Approved Distribution Facilities (not manufacturer specific)
901.07 Pozzolanic Admixtures (Fly Ash) for Concrete	Ash Grove - Bell River, St. Clair, MI Boral Resources - Avon Power Plant, Avon Lake, OH; Erickson Power Plant, Lansing, MI; Sammis Power Station, Stratton, OH; Monroe Power Plant, Monroe, Michigan; Schahfer Station, Unit 15, Unit 17 & Unit 18, Wheatfield, IN; Labadie Power Station, Labadie, MO; Rush Island Power Station, Festus, MO; Coal Creek Steam Generating Plant, Underwood, ND Charah, Inc. - Zimmer Power Station, Moscow, OH; Miami Fort Unit 7 & 8, North Bend, OH Holcim (US), Inc. - Will Co. Plant, Romeoville, IL; Elm Road Generating Station, Oak Creek, IL; Columbia, Portage, WI; Edgewater Sta. Unit 5, Sheboygan, WI; Pleasant Prairie, Kenosha, WI; Weston #3, Wausau, WI; Separation Technologies, LLC - Clifty Creek Power Station, Madison, IN; Longview Power Plant, Maidsville, WV Waste Mgmt./FlyAsh Direct - Zimmer Power Plant, Moscow, OH; Miami Fort Unit 7 & 8, North Bend, OH; Avon Lake Unit 9, Cleveland, OH; Joppa Generating Station, Joppa, IL	Ash Grove - Dundee, MI

Approved Materials – Aggregates

- Prequalified aggregate sources – (Section 902)

- Yearly inspection of labs
- History of a well controlled process
- History of specification compliance
- Reduced MDOT QA acceptance of source
 - 1 test per 10,000 tons of material produced

- Non-Prequalified aggregate sources

- No history of specification or process control
- Normal MDOT QA acceptance of source
 - 1 test per 1000 tons of material produced

Effective for projects referencing the 2020 Standard Specifications for Construction

MDOT Michigan Department of Transportation		Material Type	All material classifications must adhere to gradations and physical property specifications found in the 2020 Michigan Standard Specifications for Construction Section 902 for valid acceptance testing																Date	Date							
MDOT Prequalified Aggregate Supplier	Source Name		AS1 #	MDOT makes no representation as to the quality of the materials listed																*Date unavailable							
Prequalification allows reduced acceptance testing for state or federally funded projects based off the Suppliers Quality Control Plan, and is only applicable when this material is supplied directly to the project or concrete plant from the Supplier listed below.			Coarse Aggregate	Open Graded Aggregate	Open Graded Aggregate	Free Aggregates	Granular Materials											Added to Program	Entry last updated								
			3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18	3/4" 1.18		
A. Lindberg & Sons	Lindberg #3	52-009	SG																								
A. Lindberg & Sons	480 Roma	52-109	QU	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
A. Lindberg & Sons	480 Black	52-110	QU	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Aggregate Industries	Sweet #2	03-065	SG																								
Aggregate Industries	Wayland (Wilson)	03-088	SG																								
Aggregate Industries	Sutton Creek	13-091	SG																								
Aggregate Industries	Edwardburg (Niles)	14-026	SG																								
Aggregate Industries	Chelsea (Klump Bros.)	38-046	SG																								
Aggregate Industries	Kalamazoo West	39-078	SG																								
Aggregate Industries	Dundas (Hickam)	52-006	QU	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Aggregate Resources	Guincy	12-037	SG																								
Aggregate Resources	Ravine Road/Vehlage	39-056	SG																								
Aggregate Resources	Melway/Hofford	39-064	SG																								
Aggregate Resources	Galesburg	39-069	SG																								
Aggregate Resources	6th Street	39-073	SG																								
Aggregate Resources	Keweenaw Creek	02-046	QU																								
Ashey Land Development Co	Muir Road	47-030	SG																								
Bay Aggregates, Inc	Bay Agg Crushed Concrete	09-001	CC																								
Blumfield Sand & Gravel	Blumfield Sand & Gravel	79-097	SG																								
Burling Sand & Gravel Products, Inc	Exing	05-040	SG																								
Cadillac Asphalt	Shelby Crushed Concrete Plant	50-004	CC																								
Carl Schlegel	Scott	19-004	SG																								
Carl Schlegel	Marlin	19-055	SG	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Carl Schlegel	Wood Road Crushed Concrete Plant	19-080	CC																								
Carl Schlegel	Island	19-085	SG																								
Carl Schlegel	Dabone Road	33-115	SG																								
Carl Schlegel	Dann	38-098	SG																								
Carl Schlegel	Mann	38-103	SG																								
Carr Brothers & Sons, Inc	Kirgeman	13-010	SG																								
Carr Brothers & Sons, Inc	Plarier	13-083	SG																								
Carr Brothers & Sons, Inc	Sevitt	13-092	SG																								
Carr Brothers & Sons, Inc	Rockwell	13-094	SG																								
Carr Brothers & Sons, Inc	Shelton	13-095	SG																								
Carr Brothers & Sons, Inc	Wade Pt	30-049	SG																								
Carr Brothers & Sons, Inc	Beck Road Pt	30-068	SG																								
Carr Brothers & Sons, Inc	Leads Pt	30-076	SG																								
Carr Brothers & Sons, Inc	Crappel Lake	38-021	SG																								
Carr Brothers & Sons, Inc	Sevitt	38-079	SG																								
Carr Brothers & Sons, Inc	Elm Row Road	38-086	SG																								

MDOT-AggregateQuality@michigan.gov Updated 3/25/2022 1 of 14



Approved Materials – Aggregates (cont.)

- Aggregate Quality
 - Coarse Agg. Freeze-Thaw
 - Maximum F-T dilation = 0.067 for most concrete applications
 - Maximum F-T dilation = 0.040 for all paving, high performance concrete
 - Specific gravity
 - F-T values are good for all products from that quarry/pit that are within -0.04 of the specific gravity of the product tested
- Aggregate Inspection Manual



PROCEDURES FOR AGGREGATE INSPECTION



2019
Construction Field Services Division
Aggregate Quality Unit



ASR Testing (Fine Aggregate only)

- ASTM C 1260
 - Expansion < 0.10% at 14 days
 - ASTM C 1293
 - Expansion < 0.040% at 1 year
 - Need to start test 1 year before product is desired to be used
 - Must be run on the class of aggregate to be used
 - ASTM C 1567
 - Must use replacement of portland cement with slag cement or fly ash
 - Expansion < 0.10% at 14 days
- Data good for two years

Approved Materials – Admixtures

- Admixtures (MDOT 903) – Qualified Products List (QPL) in Materials Source Guide
 - Accepted for use on MDOT projects based on the trade name, model number, etc., as listed.
 - Manufacturer secures independent lab testing using three locally available cements
 - Air entraining ASTM C260
 - Water reducers, retarders, accelerators ASTM C494
 - Yearly affidavit from manufacturer
 - Re-submit every 7 years
- Try to avoid “witches brew” or “chemical soup”
- Dosage rates listed are only manufacturer's recommendations

QUALIFIED PRODUCTS LIST (QPL)				
ADMIXTURES FOR CONCRETE				
Air Entraining - ASTM C 260; Chemical - ASTM C 494				
(See Notes Following Listing of Admixtures)				
Spec. # and Material Name	Manufacturer or Supplier and Trade Name	Type	Producer and Description	Recommended Dosage min. or range fl oz/cwt
903.01 Air Entraining Admixtures	EUCLID CHEMICAL CO. Eucon AEA 92	AE	Air-entraining	1.5
	Accelguard G3	E	Water-reducer accelerator (non-chloride)	16 - 90
903.02 Liquid Chemical Admixtures	Accelguard NCA	C	Accelerator (non-chloride)	15
	Eucon Air Mix 200	AE	Air-entraining	3
	EUCON Air MAC6	AE	Air-entraining	0.5 - 4
	EUCON MR	A	Water-reducer	4.5
		MR	Mid-range water-reducer	5.5
		F	High-range water-reducer	12
	EUCON MRX	MR	Mid-range water-reducer	3.5
		F	High-range water-reducer	7.5
	EUCON SE	A	Water-reducer	2.5
		D	Water-reducer retarder	4.5
	EUCON WR	A	Water-reducer	2.5 - 10
		D	Water-reducer retarder	2.5 - 10
	EUCON WR-91	A	Water-reducer	3
MR		Mid-range water-reducer	5	
D		Water-reducer retarder	6	
A		Water-reducer	3.5	
EUCON A+	A	Water-reducer	3.5	
	MR	Mid-range water-reducer	4.5	

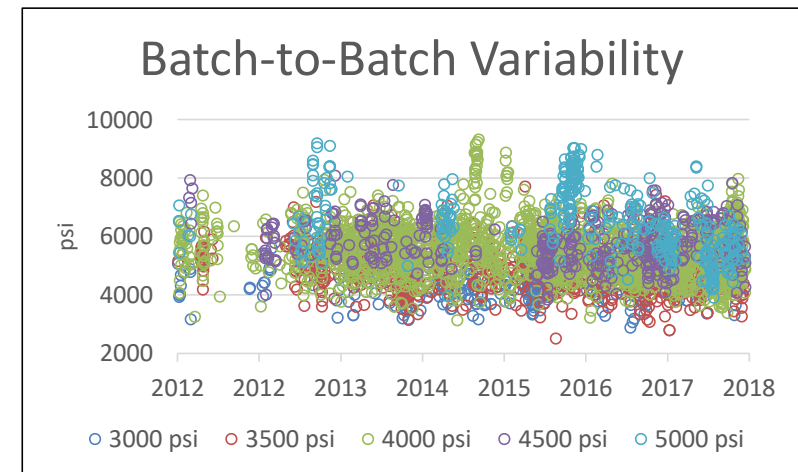
Where do Mixes Originate?

- Contractor provided mixes:
 - Based on ACI 211 procedure
 - The contractor is responsible for submitting the mix documentation to the MDOT project engineer
 - Developed by MCA Level 2 Concrete Technician
- Department (MDOT) provided mixes:
 - Structural patching, mortar, and grout
 - Project-specific mixes, per special provision
 - Bridge deck overlays
 - Latex modified
 - Silica fume



Developing the Mix

- Contractor provided mix designs and mixture proportions (Section 1003)
 - Supporting documentation
 - Methods of verification
 - Method 1 – Trial batches: same materials used on project
 - Method 2 – Same mix: recent experience with same ingredients
 - Method 3 – Similar mix: similar aggregates (of same geologic type), with same cement/additives
 - Method 4 – Annual verification: concrete plant verification, same materials
- All materials must meet MDOT specs



MDOT Grades of Concrete

Grade	3000	3500	3500HP	4000	4500	4500HP	P-NC
Old name	P2, S3	P1, S2, T	P1M, S2M	S1	D	DM	P-NC
Use	Shoulders, sidewalk	Pavement, bridge substructure, curb & gutter, driveways, Tremie *	HP conc pavt, HP bridge approaches, HP substructure	Foundations, piles	Bridge decks, railing	HP bridge decks, HP railing	Pavement patching (full-depth repairs)

* Tremie does not require aggregate optimization when pumped



MDOT Spec Book

- Section 1004, "Portland Cement Concrete Mixtures"
- For pavements:
 - 0 to 3 inch slump is typical
 - 0 to 6 inch slump if mix includes a mid-range water reducer
- Air content spec limits:
 - 5.5% to 8.5%

**Table 1004-1:
Concrete Mixtures**

		Concrete Grade							M	X
		3000	3500	3500HP ^{(a),(b)}	4000	4000HP ^{(a),(b)}	4500	4500HP ^{(a),(b)}		
Compressive strength (psi)	7 day	2200	2600	2600	3000	3000	3200	3200	Commercial-grade concrete containing 517 lb/cyd. Portland cement may be replaced with an SCM.	Unless otherwise specified, Grade X concrete contains 282 lb/cyd of cement.
	28 day	3000	3500	3500	4000	4000	4500	4500		
	70%	2100	2450	2450	2800	2800	3150	3150		
Flexural strength (psi)	7 day	500	550	550	600	600	625	625		
	28 day	600	650	650	700	700	750	750		
	70%	420	455	455	490	490	525	525		
Slump (inch)		(c)-(f)	(c)-(k)	(c)-(k)	(l)-(n)	(l)-(n)	(d)-(f)	(d)-(f)		
Cementitious material content (lb/cyd)		489-517	517-611 ^(o)	470-564 ^(o)	517-611	517-611	517-658	517-658		
Class of coarse aggregate									(p)-(r)	
Maximum w/cm ratio		0.45								
Air content range		5.5 - 8.5%								
Section reference		402, 403, 602, 803, 804, 806, 808, 810, 813, 814, 819	401, 602, 603, 705, 706, 712, 713, 718, 801, 802, 803, 810, 819	401, 602, 603, 706, 712, 713, 718, 801, 802, 803, 810, 819	705, 922	705, 922	706, 711, 712	706, 711, 712	N/A	N/A

HP = high performance

- | | |
|---|--|
| <ul style="list-style-type: none"> (a) HP mixtures require optimized gradation meeting subsection 1004.03.C. (b) HP mixtures require 25 to 40% replacement of portland cement with an SCM. (c) 0- to 3-inch slump for mixtures for pavements. (d) 0- to 3-inch slump without admixtures or with Type A or D admixture. (e) 0- to 6-inch slump after the addition of Type MR admixture. (f) 0- to 7-inch slump after the addition of Type F or G admixture. (g) 3- to 7-inch slump for tremie applications without admixture or with Type A or D admixture. (h) 3- to 7-inch slump for tremie applications after the addition of Type MR admixture. (i) 3- to 8-inch slump for tremie applications after the addition of Type F or G admixture. (j) 6- to 8-inch slump for dry placed drilled shafts. (k) 7- to 9-inch slump for wet placed drilled shafts. | <ul style="list-style-type: none"> (l) 3- to 5-inch slump without admixtures or with Type A or D admixture. (m) 3- to 6-inch slump after the addition of Type MR admixture. (n) 3- to 7-inch slump after the addition of Type F or G admixture. (o) For concrete pavement repair mixtures, use 658 lb/cyd of cement when the weather is forecast to be above 50°F or 752 lb/cyd when the weather is forecast to be 50°F or below. (p) Use aggregates only from geologically natural sources for pavement, shoulder, miscellaneous pavement (including ramps), concrete pavement overlay, bridge approach slab, structural concrete, drilled shaft, bridge railing, and bridge sidewalk applications. (q) Unless otherwise required, use Coarse Aggregate 6AA or 17A for exposed structural concrete in bridges, retaining walls, and pump stations. (r) The flexural and compressive strengths are not part of the specifications but are listed for informational purposes only and are the minimum strengths anticipated for the mix proportions specified for the various grades of concrete when cured under standard conditions. |
|---|--|

MDOT Form 1976 (JMF Form)

- Develop JMF (mix proportions) according to ACI 211
- Aggregate bulk density
 - >65% coarse agg content
- JMF valid for 2 years


Michigan Department of Transportation 1976 (02/16)		JOB MIX FORMULA (JMF) CONCRETE FIELD COMMUNICATION		Clear Form
This form applies only to the project listed below and is not transferable to other projects DISTRIBUTION: ORIGINAL - Project Engineer COPIES - Contractor, Lansing CES, Region, Inspector				
CONTROL SECTION	JOB NUMBER	PROJECT LOCATION	PROJECT ENGINEER	
CONCRETE SUPPLIER		PLANT LOCATION		PLANT NUMBER
GRADE OF CONCRETE	PSI REQUIREMENT	MIX DESIGN NUMBER	INTENDED USE (S)	CONTRACTOR QC PLAN Y <input type="checkbox"/> SUBMITTED? (MDOT use only) N <input type="checkbox"/>
PRIME / SUBCONTRACTOR(S)				
STANDARD SPEC DATE	QC/QA SPECIAL PROVISION DATE	DATE EFFECTIVE	AGG. CORRECTION	
MATERIAL DESIGN SOURCES AND PROPERTIES				
COARSE AGGREGATE		INTERMEDIATE AGGREGATE		FINE AGGREGATE
Aggregate Type	_____	Aggregate Type	_____	Source Name
Source Name	_____	Source Name	_____	MDOT Source No.
MDOT Source No.	_____	MDOT Source No.	_____	MDOT Series Class
MDOT Series Class	_____	MDOT Services Class	_____	Specific Gravity (Bulk Dry)
Specific Gravity (Bulk Dry)	_____	Specific Gravity (Bulk Dry)	_____	Specific Gravity (Bulk SSD) optional
Specific Gravity (Bulk SSD) optional	_____	Specific Gravity (Bulk SSD) optional	_____	Absorption
Absorption	_____	Absorption	_____	Unit Weight (Dry Rodded) DR or
Unit Weight (Dry Rodded) DR or	_____	Unit Weight (Dry Rodded) DR or	_____	Unit Weight (Dry Loose) DL
Unit Weight (Dry Loose) DL	_____	Unit Weight (Dry Loose) DL	_____	Percent Crushed
Percent Crushed	_____	Percent Crushed	_____	MDOT Freeze-Thaw (F-T) Cycles
MDOT Freeze-Thaw (F-T) Cycles	_____	MDOT Freeze-Thaw (F-T) Cycles	_____	Specific Gravity (Bulk Dry) of F-T
Specific Gravity (Bulk Dry) of F-T	_____	Specific Gravity (Bulk Dry) of F-T	_____	Sample*
Sample*	_____	Sample*	_____	Date of MDOT Freeze-Thaw Report
Date of MDOT Freeze-Thaw Report	_____	Date of MDOT Freeze-Thaw Report	_____	
*If the bulk dry specific gravity is more than 0.04 less than the bulk dry specific gravity of the most recently tested freeze-thaw sample, the aggregate will be considered to have changed characteristics and be required to have a new freeze-thaw test conducted prior to the use on Department projects.				
CEMENTITIOUS		ADMIXTURES		
Cement Source / Plant	_____	Air Entrainment	_____	
Cement Type	_____	Water Reducer	_____	
Cement Specific Gravity	_____	Water Reducer	_____	
Fly Ash Source (distributor & plant)	_____	Water Reducer	_____	
Fly Ash Class	_____	Accelerator	_____	
Fly Ash Specific Gravity	_____	Other	_____	
Slag Cement Source	_____	(Indicate Source & Product name with socket code)	_____	
Slag Cement Grade	_____	TYPE OF MIX	WINTER/SUMMER	
Slag Cement Specific Gravity	_____		_____	
Other	_____		_____	
MIX PROPORTIONS				
Volume of Coarse Aggregate (DR)	_____	Design Slump	_____	
Coarse Aggregate Weight (Dry)	_____	Design Air %	_____	
Intermediate Aggregate Weight (Dry)	_____	Specified Air %	_____	
Fine Aggregate Weight (Dry)	_____	PSI minimum required	_____	
Portland Cement Weight	_____	Total Cementitious	_____	
Fly Ash Weight	_____	Yield cuft.	_____	
Fly Ash Percent of Cementitious	_____		_____	
Slag Cement Weight	_____		_____	
Slag Cement Percent of Cementitious	_____		_____	
Total Water Weight	_____	I certify that all applicable standard test methods have been followed verifying the mix design and JMF		
Net Water Weight	_____			
WC (as designed)	_____	Signature _____		
Air Entrainer (dosage)	_____	MCA Level / Expiration Date _____		
Water Reducer (dosage)	_____	Date _____		
Other (dosage)	_____			



Reviewing the Mix

- Contractor submits mix documentation (Form 1976)
 - 10 days prior to anticipated date of placement
- Problems with submitted mix
 - Incomplete packages will be returned without review
- Checklist?

Concrete Mix Design Approval Checklist



Cementitious materials:

- ❑ From facility or manufacturer on MDOT Approved Manufacturers List?
www.michigan.gov/mdot/
[click "doing business"](#) (on left)
[click "Construction and Technology"](#)
[click "Manuals & Guides"](#) (down the page)
[click "Materials Source Guide"](#)
- ❑ Cementitious materials content minimized (≤ 564 ~~lb/cyd~~ ^{lb/cyd} ≤ 6-sack; max. of 658 ~~lb/cyd~~ ^{lb/cyd}, i.e. ≤ 7-sack)?
- ❑ Fly ash content ≤ 25% of total cementitious content?
- ❑ Slag cement (GGBFs) content ≤ 40% of total cementitious content?
- ❑ Total SCM (slag + fly ash) content ≤ 50% of total cementitious content?
- ❑ w/cm ratio ≤ 0.50 for fixed form or hand pours; w/cm ratio ≤ 0.45 for slipform?

Aggregates:

- ❑ From certified pits? ([see](#) Approved Manufacturers in Materials Source Guide)
- ❑ Combined, the coarse and fine aggregates make up 60% to 75% of the total concrete volume?
- ❑ Proportion (by weight) of ~~coarse~~ ^{coarse}-to-fine aggregate is around 60/40; roughly 55% to 65% coarse, and 35% to 45% fine?
- ❑ Combined aggregate gradation ~~analyzed~~ ^{analyzed}; mix design in a good zone on workability chart?
- ❑ Fineness modulus of fine aggregate (sand) analyzed and in higher range (2.7 and above, 3.0 to 3.5 or higher works best)?

Other:

- ❑ Admixtures from Qualified Products List? ([see](#) Materials Source Guide)
- ❑ Admixture dosage within limits? ([check](#) QPL for specifics)
 - Air entrainment usually around 1.0 to 3.0 oz/cwt to achieve 5-8%
 - Type A water reducer usually up to 4.0 oz/cwt
 - Mid-range water reducer usually up to 8.0 oz/cwt
 - ~~high-range~~ ^{high-range} (superplasticizer) not usually recommended except for pumping or very low w/cm ratio
- ❑ Air content checked against yield calcs?
- ❑ Fibers in the mix?
 - Synthetic fiber dosage rate usually 1.5 ~~lb/cyd~~ ^{lb/cyd} (1 bag per ~~cyd~~ ^{cyd})

Optimized Aggregates

From
this:



To
this:



Goal of Optimized Aggregates

- Reduce permeability
 - Reduce paste
 - Less shrinkage
 - Potential cost savings related to less cementitious
- Better workability for pumping and finishing
 - Need saturated aggs. in the stockpile
- Greater durability
 - Better air system quality
 - Lower w-cm ratio
- Req'd for pumped concrete and HP mixes

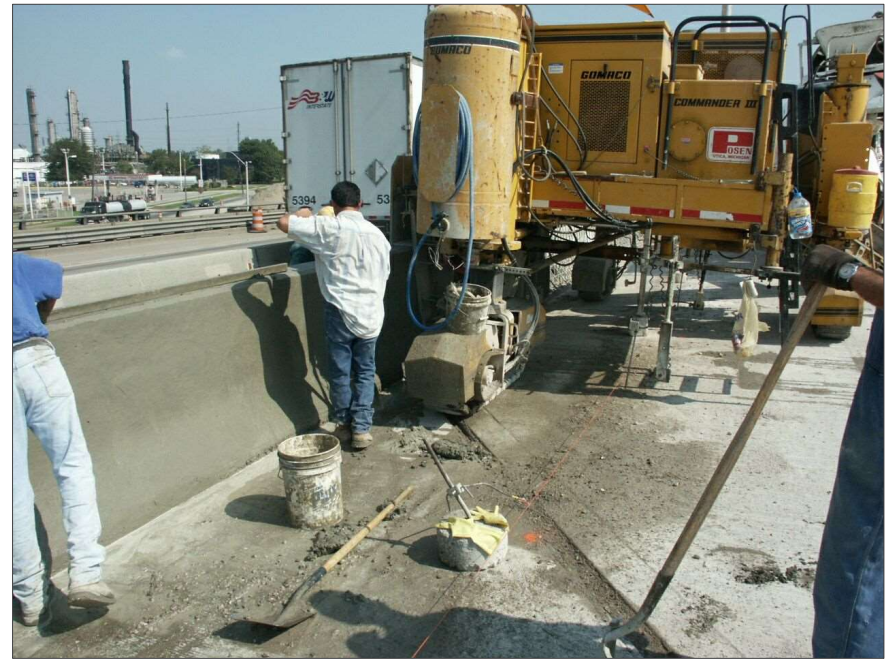


Improved Finishing

Less Handwork



Better Barrier Walls



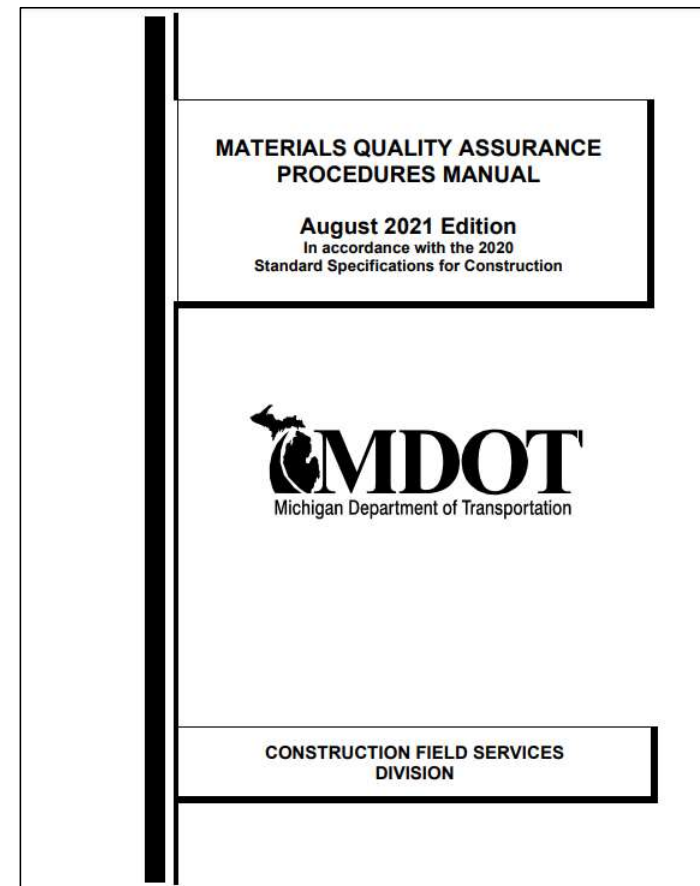
Workability



Harsh initial appearance, but very workable once vibrated

MQAP Section 3.09

- Does not specify MDOT gradation series for aggregates
 - CA – retained on ½ inch sieve or greater (0.040 F-T dilation)
 - IA – retained on No. 4 and passing ½ inch (0.067 F-T dilation)
 - FA – passing No. 4 sieve (ZNS sand)
- Physical Requirements for each aggregate are located in subsection 902.03.C of the 2020 Spec Book
- LBW (P200) 2% CA, 3% IA & FA
- Max of 5% material with F-T >0.040 retained above ½" sieve
- No more than 15% carbonate passing No. 4 sieve



MQAP Section 3.09

- Stockpile Management Plan
 - Process controls for shipping, handling, and storage (see next slides)
- Two different max aggregate sizes
 - Pavements > 6 inches = 2 inch max size
 - Pavements ≤ 6 inches = 1½ inch max size
 - All other applications = 1½ inch max size

Custom size material (not an MDOT standard gradation)

6AA / 6AAA size



Aggregate Stockpile Management

- Truck delivery
- How do we build a stockpile?
- Segregation minimization
- Moisture control
- Mini Stockpile – sampling for tests



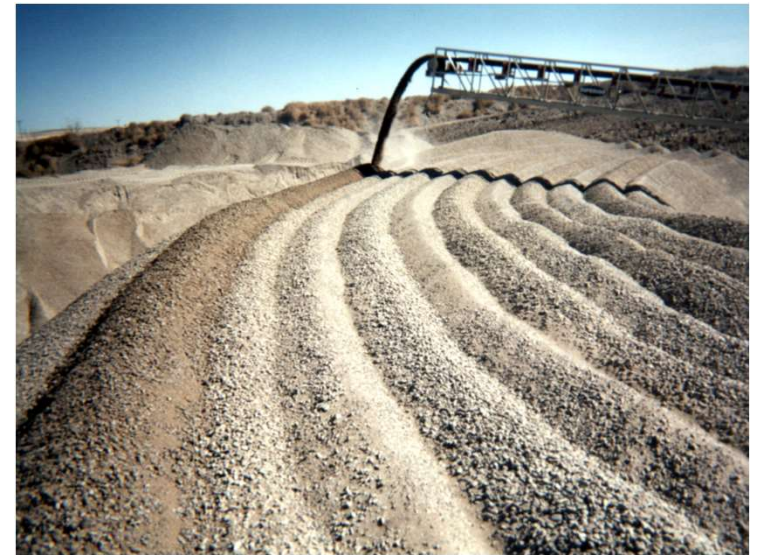
Aggregate Stockpile Management

- Maintain uniform gradation
 - Restore uniform gradation if necessary
- Minimize contamination
 - Place a pad or aggregate separation layer
 - Or don't utilize bottom layer of stockpile
- Maintain uniform moisture content
 - Keep moist



Basic Stockpiling Concepts

- Create stockpile in lifts
 - Complete each lift before beginning next
- Do not dump material over edge of stockpile
- Minimize free-fall heights
- Only stockpile amount of aggregate which is practical
- Minimize crushing by loader



Optimized Aggregate Gradation Acceptance Criteria

- One test per 5000 tons
- One test per 1000 tons –if not prequalified supplier material
- Use Mini -stockpile sampling protocol – MTM 107
- Use AASHTO method T 248 to
 - ❖ Reduce sample size by quartering –CA and IA
 - ❖ Miniature Stockpile sampling for FA



Combined Gradation

7								
8			6AA	26A	2NS		Combined	Percent
9		% Blend →	50.0%	10.0%	40.0%	0%	100%	Retained
10		Sieve Size	Percent Passing					
11	50 mm	2	100.0	100.0	100.0	0.0	100.0	0.0
12	37.5 mm	1 1/2	100.0	100.0	100.0	0.0	100.0	0.0
13	25 mm	1	98.6	100.0	100.0	0.0	99.3	0.7
14	19 mm	3/4	77.7	100.0	100.0	0.0	88.9	10.5
15	12.5 mm	1/2	41.6	99.5	100.0	0.0	70.8	18.1
16	9.5 mm	3/8	22.7	79.4	100.0	0.0	59.3	11.5
17	4.75 mm	#4	2.7	9.8	99.0	0.0	41.9	17.4
18	2.36 mm	#8	1.4	3.2	84.0	0.0	34.6	7.3
19	1.18 mm	#16	1.4	2.1	66.0	0.0	27.3	7.3
20	600 µm	#30	1.3	1.8	47.0	0.0	19.6	7.7
21	300 µm	#50	1.3	1.7	19.0	0.0	8.4	11.2
22	150 µm	#100	1.2	1.6	4.0	0.0	2.4	6.1
23	75 µm	#200	0.8	1.6	0.3	0.0	0.7	1.7
24								
25		Coarseness Factor		62.3			34.6	Workability
26								

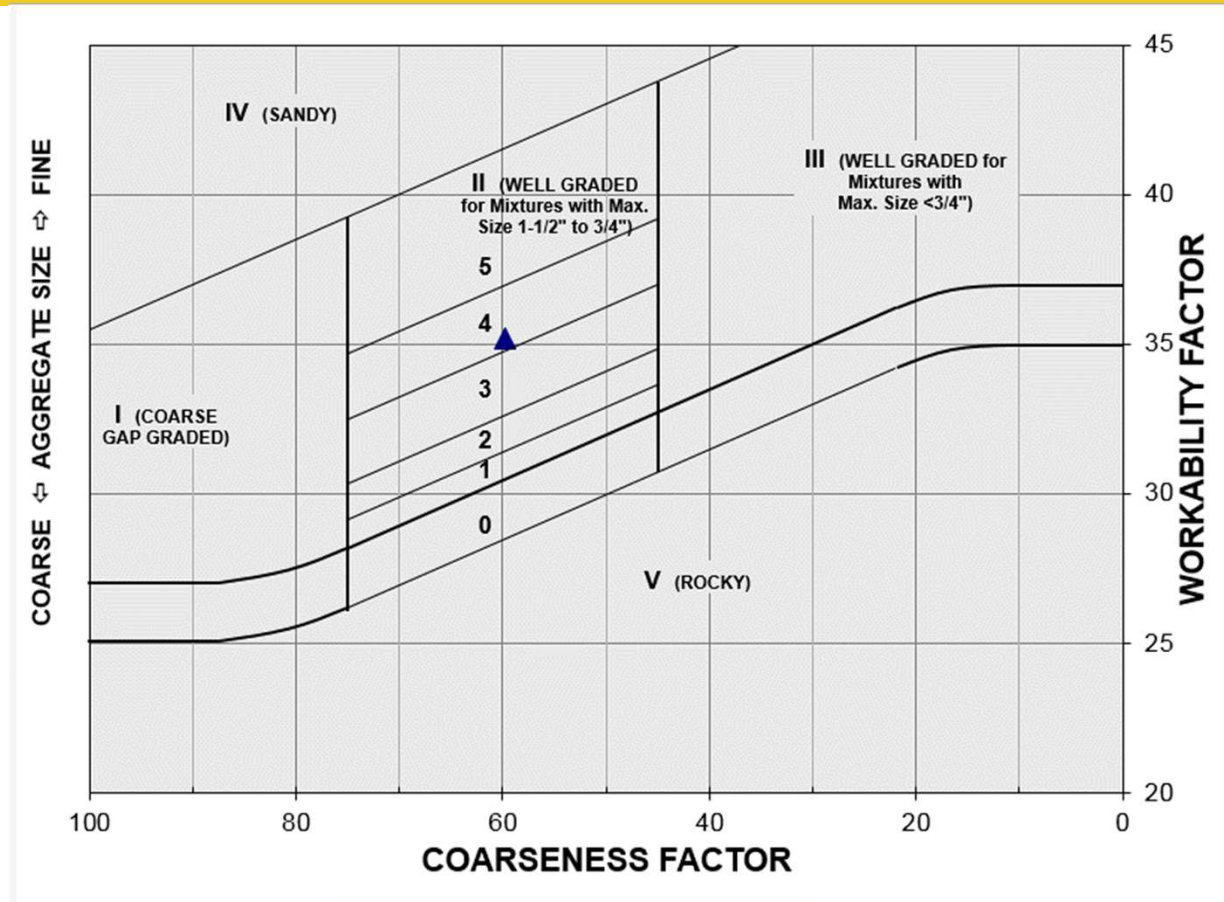
NOTE: Submittal must also include individual gradations of each of the three (or more) aggregates.

Coarseness vs. Workability Chart

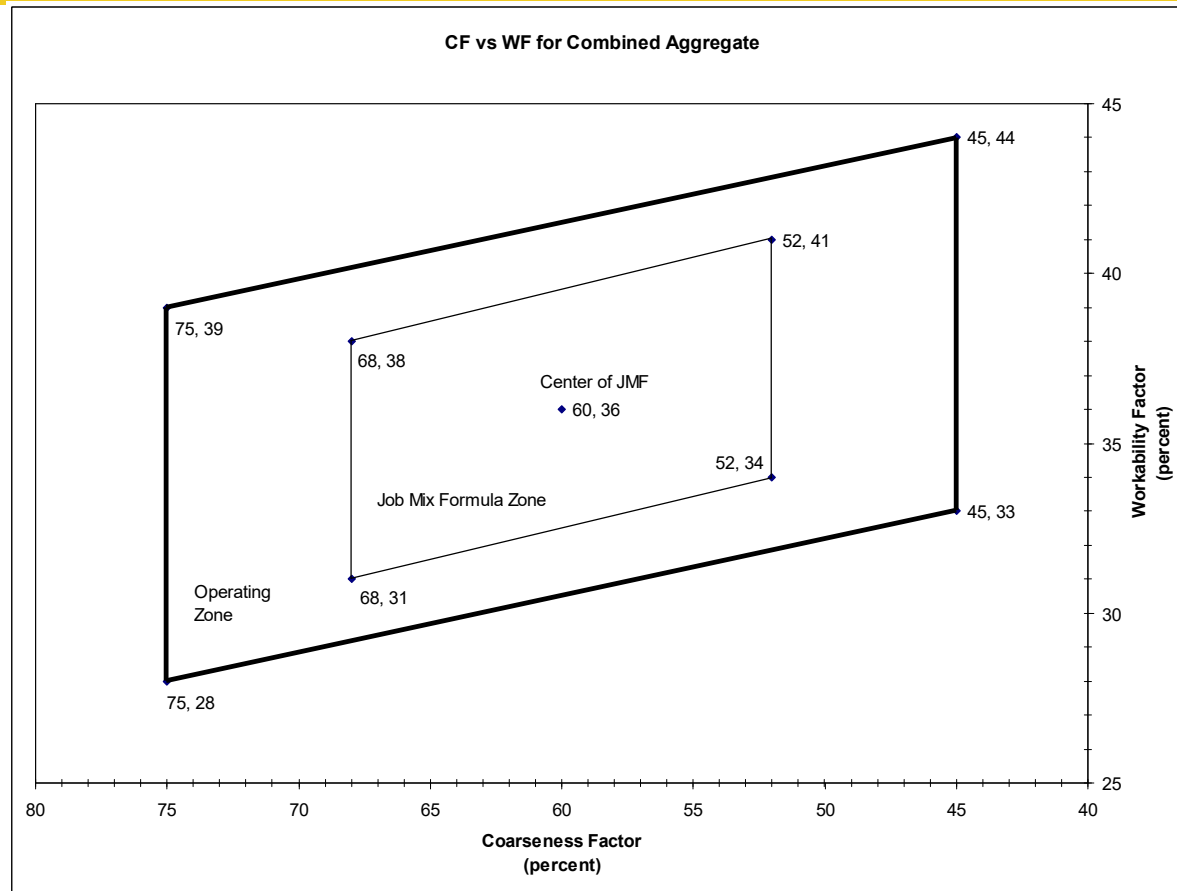
- $CF = \frac{[\text{combined \% retained above } 3/8 \text{ inch sieve}]}{[\text{combined \% retained above No.8 sieve}]} \times 100$

- $WF = \text{Combined \% Passing No.8 Sieve}$

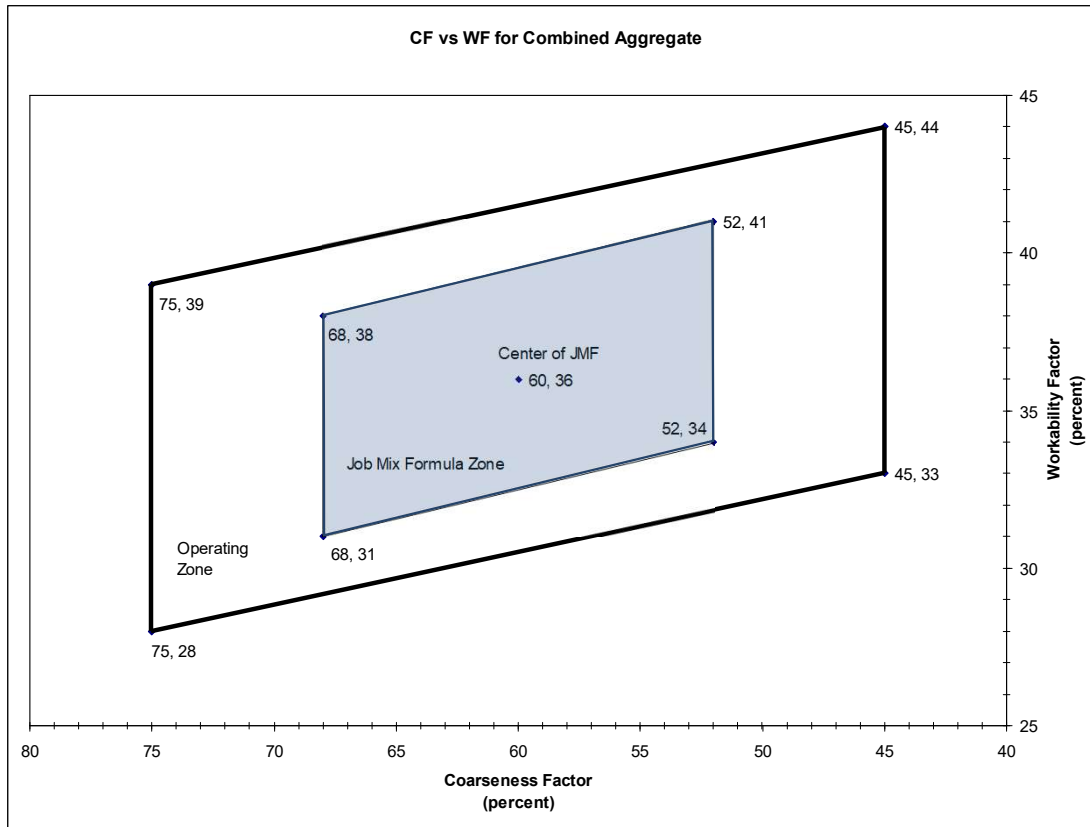
Coarseness vs. Workability Chart



MDOT Chart

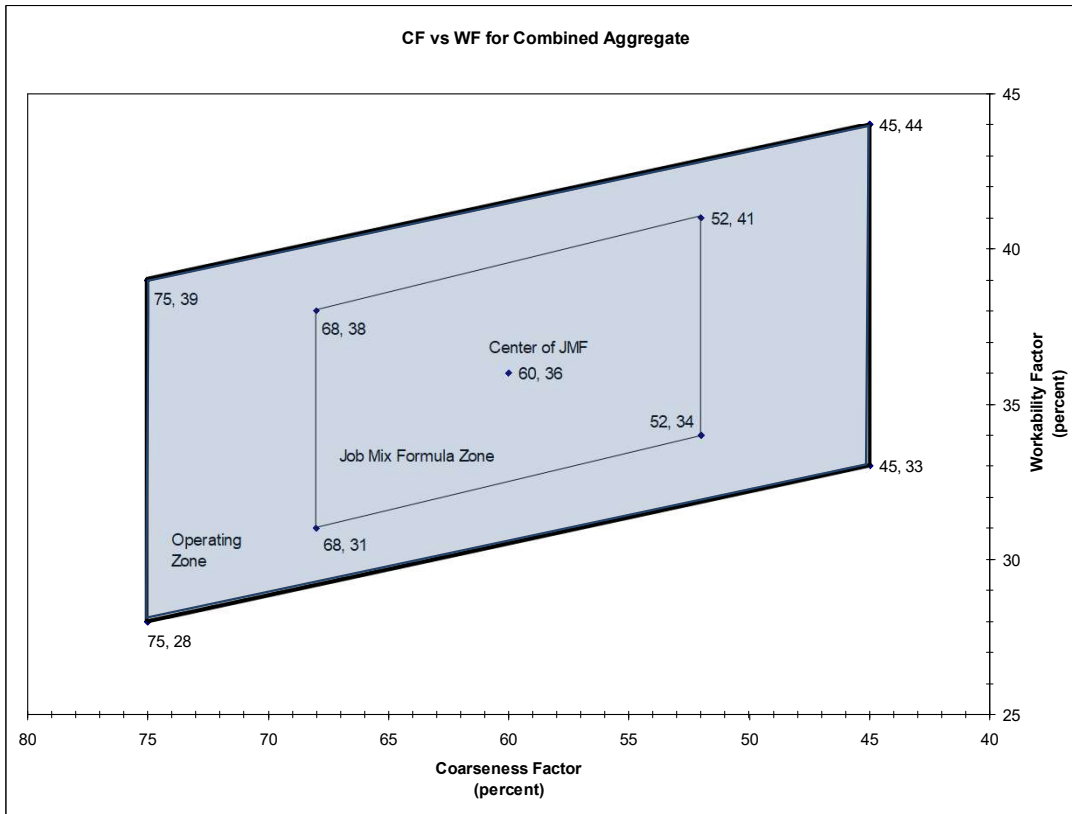


Zones in MDOT Chart



- ## Job Mix Formula (JMF) Zone
- Contractor's proposed optimized gradation for production, as submitted to the Engineer in the Initial Mix Design, must plot within this zone

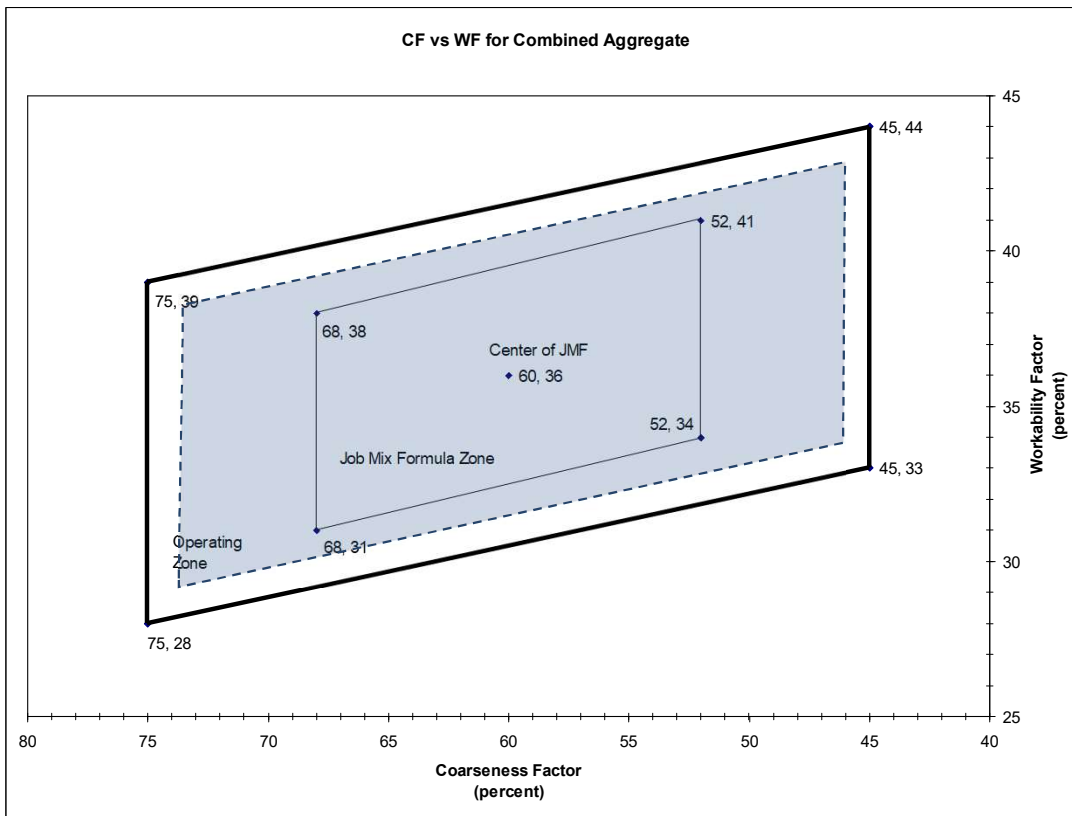
Zones in MDOT Chart



Operating Zone

- Contractor must ensure that the optimized gradation for production plots within this zone

Zones in MDOT Chart



Action Limits

- Contractor's proposed action limits; if production gradation plots outside this zone, steps taken to bring back within this zone. This is **NOT** a stop production criteria.

MDOT Spreadsheet

AutoSave Off MDOT-Optimized-Aggregate-Analysis_691451_7.xlsxm Search (Alt+Q) swaalkes@miconcrete.onmicrosoft.com

File Home Insert Page Layout Formulas Data Review View Help

Function Library: Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, More Functions

Defined Names: Name Manager, Define Name, Use in Formula, Create from Selection

Formula Auditing: Trace Precedents, Trace Dependents, Remove Arrows, Show Formulas, Error Checking, Evaluate Formula

Calculation: Watch Window, Calculation Options, Calculate Now, Calculate Sheet

D5: 2.55

Optimized Aggregate Gradation									
Aggregate Classification	Coarse Aggregate	Intermediate Aggregate	Fine Aggregate	Theoretical Combined Gradation %Passing	Theoretical Combined Gradation %Retained	Project Information			
Relative Percent	30.61	27.38	42.01					Control Section	41000
Actual Batch Weight (lbs) (SSD)	950.0	850.0	1350.0			Location	Kent	Date	8/21/22
Specific Gravity	2.55	2.55	2.64			Mix Design Type	3500HP	JMF Number	10347
Sieve Size	Percent Passing					Conc. Producer	ABC RediMix	Plant Location	South
						Pounds of Cement:		490	
						Comments			
2 inch	100	100	100	100.0	0.0				
1½ inch	91.7	100	100	97.5	2.5				
1 inch	40.8	100	100	81.9	15.6				
¾ inch	17.8	99.4	100	74.7	7.2				
½ inch	9.9	83.8	100	68.0	6.7				
⅜ inch	9.4	57.1	100	60.5	7.5				
No. 4	9.2	13.5	94.2	46.1	14.4				
No. 8	9.2	5.1	73.9	35.3	10.8				
No. 16	9.2	3.7	54.1	26.6	8.7				
No. 30	9.1	3.3	32.5	17.3	9.2				
No. 50	9.1	3.2	9.2	7.5	9.8				
No. 100	9.1	3	2	4.4	3.1				

Identify Aggregate with a Freeze/ Thaw Dilation > 0.040%	None	Key
Identify Aggregates from a Quarried Carbonate Source	Coarse/Intermediate	Enter Data

Calculations Combined Gradation CF vs. WF

Combined Gradation

Sieve Size	Retained (%)
1 inch	15.6
No. 8	14.4
No. 16	10.8
No. 30	9.8
No. 50	9.2

QC Testing Requirements for Optimized Aggregates

Ready-Mix Supplier:

- If aggregates from Prequalified Aggregate Supplier
 - Utilize aggregate source's current weekly gradation analysis
 - Must QA these QC results *weekly* to confirm
 - Adjust as necessary to re-optimized and/or move the plot back from Action Limits
- If not from Prequalified Supplier or gradations not supplied by aggregate sources
 - Requirements of On-Site batch plant apply (daily testing)

On-Site Batch Plant for Paving Project:

- Daily gradation testing each *day* of production; adjust as necessary

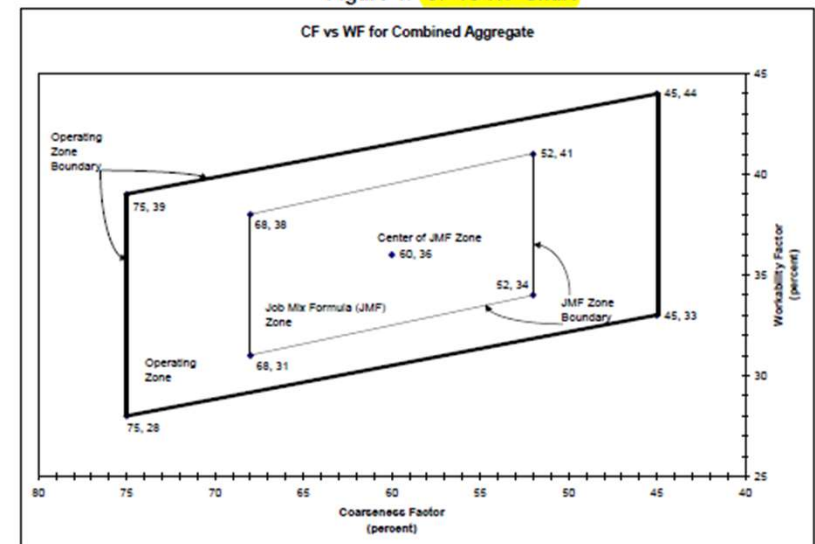


QA Testing Requirements for Optimized Aggregates

Acceptance (3.09.08)

- Acceptance of the combined aggregate gradation will be based on the ability of the combined aggregate gradation to plot within the Operating Zone Boundary
- Loss by Wash \leq Spec Requirement
- Frequency of testing based on tonnage used (usually coarse agg. tons is trigger; all three sampled at same time)

Figure 1: CF vs WF Chart




Mix Design Submittal Info - Example

Summary page

JMF Form 1976

Strength Report



July 11th, 2019

Major Cement Co. Div II Paving
15361 Dale Street
Detroit, MI 48219

Attn: MDOT 82121-204009 M-5 from East of the Rouge River to East of M-39

We submit herewith the following concrete mixture(s) for the above referenced project:

Mix Code Description
 P1-FW 3500 PSI MDOT Grade P1 Pavement - 3" Slump
 P1-FM 3500 PSI MDOT Grade P1 Pavement + MIR - 6" Slump
 P2-FM 3000 PSI MDOT Grade P2 Pavement + MIR - 6" Slump
 NSHF MDOOT Non Structural Flowable Fill

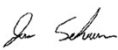
The above has been designed in accordance with MDOT 2012 Standard Specifications for Construction and/or the project specifications and in reference to ACI 318-08, Chapter 5 - (Concrete Quality), and ACI standard deviation/overdesign requirements. These materials will meet the noted criterion when handled, placed, cured and tested in accordance with current ASTM and ACI standards and recommended practices. Please refer to the attached concrete mix documents(s) for further detail.

In accordance with ACT 301-05, ASTM C94-05, we hereby request to receive concrete test results that pertain to this project from the testing laboratory of record for the purposes of quality assurance, the information can be forwarded to QC@mccoig.com.

Forward this submittal in its entirety to the proper individuals for approval and field reference. A written response on the status of this submittal is required and appreciated. If no response is received and a concrete order is placed for the above referenced project than that order shall be considered the approval of this submittal.

Please do not hesitate to contact the CSR if you have any questions or concerns regarding the submitted mixtures, or if we may be of additional service.

Respectfully submitted,



Jesse Schram
QC Technician
McCoig Materials, LLC

Michigan Department of Transportation
1976 (06/17)

JOB MIX FORMULA (JMF)
CONCRETE FIELD COMMUNICATION

This form applies only to the project listed below and is not transferable to other projects.

DISTRIBUTION: ORIGINAL - Project Engineer COPIES - Contractor, Lending CFS, Signer, Inspector

CONTRACT SECTION: 82121
JOB NUMBER: 204003
PROJECT LOCATION: M-5 from East of the Rouge River to East of M-39
PROJECT ENGINEER: (Blank)
CONTRACTOR: (Blank)

CONCRETE SUPPLIER: McCoig Materials
PLANT LOCATION: (Blank)
PLANT NUMBER: (Blank)

GRADE OF CONCRETE: P1
PSY REQUIREMENT: 3500
MIX DESIGN NUMBER: P1-FW
INTENDED USE (S): MDOOT P1 - 3" Slump
CONTRACTOR QC PLAN: V
SUBMIT TEST MDOOT Form 1976-1, 1.1

PRIME / SUBCONTRACTOR(S): Major Cement Co. / All Subcontractors

STANDARD SPEC DATE: 01/01/12
OGGA SPECIAL PROVISION DATE: 06/14/18
JMF EFFECTIVE DATE: 07/11/19
AGG. CORRECTION: 0.2%

MATERIAL DESIGN SOURCES AND PROPERTIES

COARSE AGGREGATE	INTERMEDIATE AGGREGATE	FINE AGGREGATE
Aggregate Type: Limestone	Aggregate Type: Limestone	Aggregate Type: StoneCo. Burnsville
Source Name: C&H	Source Name: C&H	Source Name: StoneCo. Burnsville
MOOT Source No.: 71-003	MOOT Source No.: 81-003	MOOT Source No.: 81-003
MOOT Service Class: SAA	MOOT Service Class: SAA	MOOT Service Class: SAA
Specific Gravity (Bulk Dry): 2.65	Specific Gravity (Bulk Dry): 2.65	Specific Gravity (Bulk Dry): 2.65
Specific Gravity (Bulk SSD) optional: 2.65	Specific Gravity (Bulk SSD) optional: 2.65	Specific Gravity (Bulk SSD) optional: 2.65
Absorption: 1.41%	Absorption: 1.41%	Absorption: 1.00%
Unit Weight (Dry Rocked) DR or Unit Weight (Dry Loose) DL: 92	Unit Weight (Dry Rocked) DR or Unit Weight (Dry Loose) DL: 92	Unit Weight (Dry Rocked) DR or Unit Weight (Dry Loose) DL: 92
Percent Cracked: 100%	Percent Cracked: 100%	Percent Cracked: 100%
MOOT Freeze-Thaw (F-T) Rating: 30,000	MOOT Freeze-Thaw (F-T) Rating: 30,000	MOOT Freeze-Thaw (F-T) Rating: 30,000
Specific Gravity (Bulk Dry) at F-T: 2.64	Specific Gravity (Bulk Dry) at F-T: 2.64	Specific Gravity (Bulk Dry) at F-T: 2.64
MOOT Freeze-Thaw Report: 08/2018	MOOT Freeze-Thaw Report: 08/2018	MOOT Freeze-Thaw Report: 08/2018

* If the bulk dry specific gravity is more than 0.04 less than the bulk dry specific gravity of the most recently tested freeze-thaw sample, the aggregate will be considered to have changed characteristics and be required to have a new freeze-thaw test conducted prior to the use on Department projects.

CEMENTITIOUS

Cement Source / Plant: Lafarge - Algona, MI
Cement Type: 151 (Type I/II)
Cement Specific Gravity: 3.15
Fly Ash Source (Supplier & plant): Boral - Monroe, MI
Fly Ash Class: C
Fly Ash Specific Gravity: 2.70
Slag Cement Source: -
Slag Cement Class: -
Slag Cement Specific Gravity: -
Other: -

ADMITTURES

Air Entrainment: BASF - Master Air AE 200-048-PR
Water Reducer: Chemours - Opti-90 - 100%LSR
Water Reducer: -
Accelerator: -
Other: -
Special Source & Product name will list here

MIX PROPORTIONS

Design Strength: 3500
Specified Slump: 3"-3"
Design Air %: 6.5%
Desired Air %: 6.5% - 8.5%
Filling minimum required: 3500
Total Cementitious: 550
Yield coeff: 27.8 +/- 0.3

I certify that all applicable standard test methods have been followed verifying the mix design and JMF.

Typed Name: Jesse Schram
Print Name: Jesse Schram
MC Co. (as designed): 45
Air Entrainment (measured): 1.0 actual
Water Reducer (measured): 3 - 5 actual
Other (measured): -

Date: 07/11/19

McCoig Materials

McCoig Laboratory
12100 Wayne road
Farmington, Michigan
Tel: 734-893-1215

STRENGTH PERFORMANCE REPORT

Mix: P1-FW - MDOOT P1 F25 WFA
Period: 11 May 2018 To 29 May 2019

Number of Tests	Specified Strength	3500	28 Day	Compressive Test
Average Strength	5180	Corrected CoV	0	ACI Running Average of 3 Criteria
Required Strength	4700	Standard Deviation	0	ACI Standard Deviation Criteria

Count	Air Content %	Concrete Temp (deg F)	Slump in	Strength (Day #)
Average	6.62	75	2.90	5180
STDEV	0.60	0	0.75	570
CoV%	8.8	11.6	25.3	11.1
Range Min	6.00	63	2.50	4500
Range Max	7.60	85	4.00	6110


Date	Sample	Air Content %	Concrete Temp (deg F)	Slump in	Strength (Day #)
5/29/2019	1203803	7.40	66	4.00	4500
6/17/2019	2176246	6.00	65	3.50	5230
6/15/2019	700	6.80	61	2.50	5410
6/12/2019	2172032	6.70	79	3.00	4920
6/5/2019	2171384	7.60	75	3.00	4670
6/11/2019	7166661	6.40	63	2.25	6110

Date: 6/15/2019 Page 1 of 1



Mix Design Submittal Info - Example

Admixtures Used



McCoig Materials
Phone 419-885-8828

Re: ALL MDCT PROJECTS

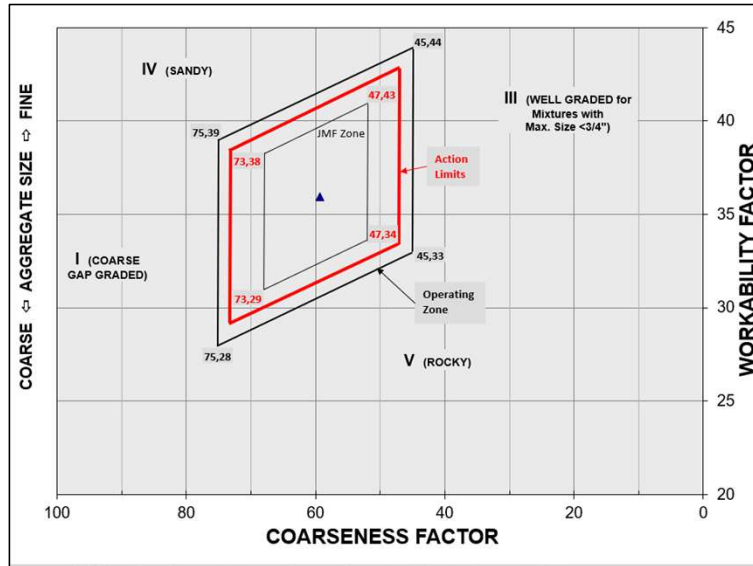
Administrative General Certification

Spec # and Material Name	Manufacturer	Product Name	McCoig Ticket Code
903.01 - Air Entraining Admix	BASF	MasterAir AE 200	0A8-RA
903.02 - Water Reducing Admix	Premiere	OptiFlo 50	0MRA-PR
903.02 - Water Reducing Admix	Premiere	OptiFlo MR	0MRLL-PR
903.04 - Concrete Accelerators	Premiere	NitroCast K	0NCAC-PR
903.02 - Water Reducing Retarding	Premiere	PreLong L	0STAL-PR


We certify that the above QPL materials indicated were provided and incorporated into the identified project.

Respectfully submitted,
Kenneth C. Erving
QC / Testing Manager
McCoig Materials, LLC

Optimized Blend Chart



Sand Gradation



SPC Analysis Report

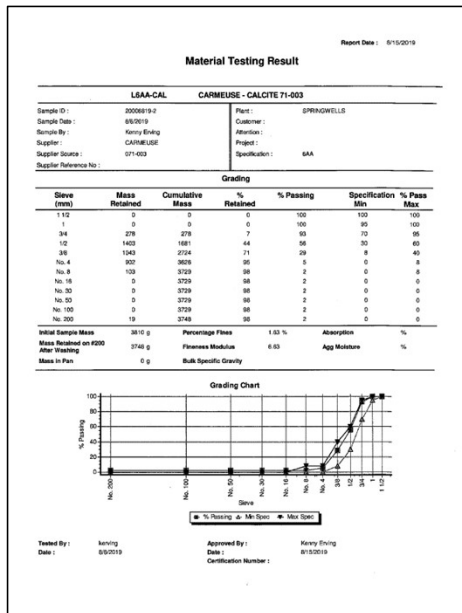
Plant: 141_01455-Burnsior
Product: 2272-2N9 Sand
Specification: MDOCT 2 NG Natural

	3/8" (9.5mm) (%)	#4 (4.75mm) (%)	#8 (2.36mm) (%)	#16 (1.18mm) (%)	#30 (0.6mm) (%)	#60 (0.3mm) (%)	#100 (0.15mm) (%)	#200 (75um) (%)	Pan (%)	Wash Loss (200/75um) (%)
Count	5	5	5	5	5	5	5	5	5	5
Min	100.0	95.0	85.0	62.2	41.1	13.3	2.4	0.99	0.00	0.9
Max	100.0	98.2	87.8	65.7	45.7	17.4	3.4	1.37	0.00	1.2
Range	0.0	0.7	2.0	3.5	4.6	4.1	1.0	0.38	0.00	0.3
Mean	100.0	95.9	86.9	63.6	43.4	15.7	3.0	1.18	0.00	1.1
St Dev	0.00	0.33	0.71	1.31	1.90	1.74	0.38	0.144	0.000	0.11
Lower Target										
Upper Target										
Lower Spec (LSL)	100	95	85	35	20	10	0	0		0
Upper Spec (USL)	100	100	95	75	55	30	10	3		3
Lower Limit (LCL)	100.0	94.6	84.9	59.8	38.5	10.1	1.7	0.85	0.00	0.7
Upper Limit (UCL)	100.0	96.9	86.9	67.3	46.3	21.4	4.3	1.71	0.00	1.5
Limit Mean (CL)	100.0	95.8	86.9	63.6	43.4	15.7	3.0	1.18	0.00	1.1
2-Sigma Lower	100.0	95.0	85.6	61.1	40.2	12.0	2.1	0.83	0.00	0.8
2-Sigma Upper	100.0	96.6	88.2	66.1	46.7	19.5	3.8	1.53	0.00	1.3
Cp		2.17	7.48	5.33	3.57	1.77	3.93	2.84		3.76
Cpk		0.69	4.04	3.05	2.36	1.01	2.35	2.23		2.66
		2.53	7.04	5.09	3.07	1.92	4.63	3.47		4.55
		0.80	3.80	2.81	2.03	1.09	2.77	2.74		3.21

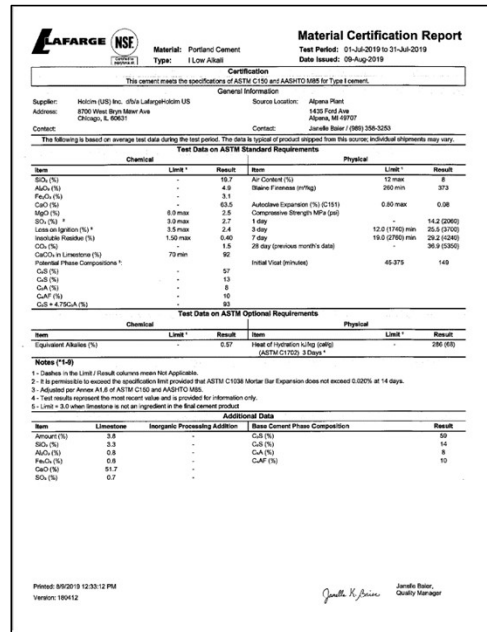
StonecomQC 06/11/2019 CRH America Materials (AMAT) Page: 2 of 3

Mix Design Submittal Info - Example

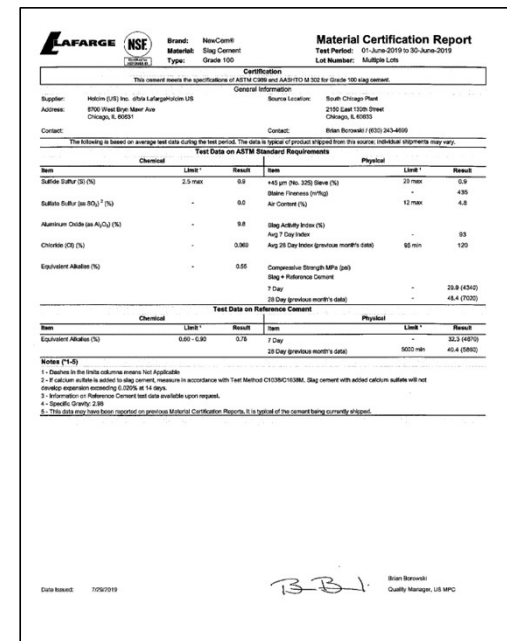
Coarse Gradation



Cement Mill Report



Slag Cement Mill Report




Mix Design Submittal Info - Example

Admixture Calibration

DISPENSER CALIBRATION

Premier Concrete Admixtures
 PO Box 277
 Romeo, MI 48154
 (800) 925-1618


 Date of Calibration: **Jan. 24, 2019**
 Certified By: **Mike McClellan**

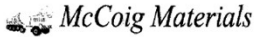
Requested by: **McCoig, Matthew**
 2010 Preston
 Eastland, MI 48229
 United States

Dispenser Model	Dispenser Product	Net/Std	Measured	Tol %
McCoig 7	Mason Ad 200	48	48	0%
McCoig 7	OptiFu 30	310	310	0%
McCoig 7	OptiFu 30R	260	260	0%
McCoig 7	ProLong 1	100	100	0%
McCoig 7	UltraFu 2000	100	100	0%
McCoig 7	NonCarK	225	225	0%

Certificate Signature

M. McClellan

Water Meter Calibration


Water Meter Accuracy Verification
55 Gallon Drum Calibration Sheet
90 Day Requirement for Volumetric Water Sampling Devices per MDOIT (sect 601.23 A. 1. a.)

Plant Information

Plant Name:	Azteca	Meter Type:	Flow
Plant Number:	3	Meter Brand name:	Badger
MDOIT Plant Number:	M-10	Plant Meter No.:	No. 1
Water Temperature:	60F	Meter Serial No.:	123456
Ambient Temperature:	60F	Meter Setting:	0.2645
		Pulse Count:	16 cc

Date Information

Calibration Date:	7/12/2019	Previous Calibration Date:	3/29/2019
Next Calibration Date:	10/12/2019		

Test 1

Metered Quantity	55 gallons	Measure Quantity	55 gallons
Meter Setting	0.2645	Adjusted Setting	Not Required

Test 2

Metered Quantity	55 gallons	Measure Quantity	55 gallons
Meter Setting	0.2645	Adjusted Setting	Not Required

Test 3

Metered Quantity	Not Required	Measure Quantity	Not Required
Meter Setting	Not Required	Adjusted Setting	Not Required

I certify the above information and test results are accurate, no adjustment to the meter was required at this time.

Test Performed By: Dustin Parker Test Witnessed By: Justin Morrison
 Signature: [Signature] Date: 2-2-19 Signature: [Signature] Date: 7/12/19

Stockpile Mgmt. Plan

McCoig Materials, LLC

**CONTRACTOR / PRODUCER AGGREGATE
STOCKPILE MANAGEMENT PLAN**

Submitted By:
McCoig Materials, LLC
12100 Wayne Road,
Romulus, MI 48174



Summary

- ACI 211 mix proportioning considers:
 - Strength
 - Slump
 - Air content
 - Durability
- MDOT JMF Form 1976 requires backup documentation
 - Approved sources
 - i's dotted, t's crossed
- Other considerations not in ACI 211:
 - Optimized aggregate gradations
 - Placeability / finishability
 - Air system quality
 - Admixture compatibility
 - Ultimate strengths

Questions?

swaalkes@miconcrete.net

616-633-9629

ddegraaf@miconcrete.net

517-862-5632

Thank you!!

