



EDC-7 Innovation : Enhancing Performance with Internally Cured Concrete (EPIC²)

HIGH PERFORMANCE INTERNALLY CURED CONCRETE (HPIC)

NJSTIC Meeting

April 30th, 2025 Samer Rabie, Project Manager, DPM Team D Jess Mendenhall, PE, Structural Engineer, Structural Engineering Services

AGENDA





DEFINE THE PROBLEM & OBJECTIVE

INTRODUCE INTERNAL CURING

DISCUSS THE IMPLEMENTATION PLAN

NEXT STEPS & GOALS







"Identify and rapidly deploy proven yet underutilized innovations...

shorten the project delivery process, enhance roadway safety, reduce traffic congestion, or integrate automation."





- EDC I (2011-2012) : PREFABRICATED BRIDGE ELEMENTS & SYSTEMS (PBES)
- EDC 2 (2013-2014) : ACCELERATED BRIDGE CONSTRUCTION
- EDC 3 & 4 (2015-2018) : ULTRA HIGH PERFORMANCE CONCRETE (UHPC) FOR PBES
- EDC 6 (2021-2022) : UHPC FOR BRIDGE PRESERVATION & REPAIR

Core Innovation Area

Infrastructure Preservation

• EDC 7 (2023-2024): ENHANCING PERFORMANCE WITH INTERNALLY CURED CONCRETE (EPIC²)





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HIGH PERFORMANCE CONCRETE (HPC)



HPC Section 903.05 :

- Low w/cm ratio : 0.40
- Large amount of Pozzalonic or SCM's (fly ash, slag, silica fume)
- Improved durability properties

<u>However,</u>

- Increased susceptibility of cracking
- Undermined durability improvements
- Most HPC Bridge Decks experience shrinkage cracking
- Sealing of the cracking recommended



Curing Section 507.03.02.J :

- Within 30 min of texturing, apply wet burlap and white polyethylene sheeting for at least 14 days.
- Reduces Shrinkage, Cracking & Water movement.

HPC BRIDGE DECK TRANSVERSE CRACKING





New Jersey Department of Transportation 1035 Parkway Avenue, PO Box 600, Trenton, New Jersey 08625-0600

Baseline Document Change Announcement

ANNOUNCEMENT: BDC21S-05

SUBJECT:

DATE: January 06, 2023

Concrete Deck Repair

- Revision to the 2019 Standard Specifications for Road and Bridge Construction, Subpart 507.02.01 and Subsection 507.04, & addition of Subpart 507.03.08

Subpart 507.02.01 and Subsection 507.04 have been revised & new Subpart 507.03.08 has been added to the 2019 Standard Specifications for Road and Bridge Construction in order to allow the RE to direct if and where to apply BRIDGE DECK AND BRIDGE APPROACH SEALING.

	QTY	UNITS UNIT PRIC				BTOTAL	MA	RK UP	SU	B TOTAL
MATERIAL										
FURNISH SIKAGARD -705L (2 COATS APPROX. 11,000SF/CT) - 5 GAL PAIL	20	EA	\$	375.00	\$	7,500.00	\$ 1	,875.00	\$	9,375.00
FURNISH PUMP SPRAYERS	2	EA	\$	180.00	\$	360.00	\$	90.00	\$	450.00
LABOR (6 MAN CREW, 10 HR SHIFTS) 2 SHIFTS TO PREP, 2 SHIFT TO APPLY										
LABOR FOREMAN	40	HR	\$	127.36	\$	5,094.40	\$	-	\$	5,094.40
LABORER	200	HR	\$	124.79	\$	24,958.00	\$	-	\$	24,958.00
EQUIPMENT PER SHIFT										
FOREMAN TRUCK	40	HR	\$	24.26	\$	970.40	\$	-	\$	970.40
LIGHT TOWER	40	HR	\$	14.82	\$	592.80	\$	1.07	\$	592.80
GENERATOR	40	HR	\$	8.80	\$	352.00	\$	-	\$	352.00
COMPRESSOR	40	HR	\$	16.68	\$	667.20	\$	-	\$	667.20
PRESSURE WASHER	40	HR	\$	5.79	\$	231.60	\$	-	\$	231.60
TMA	40	HR	\$	41.27	\$	1,650.80	\$	-	\$	1,650.80
BOX TRUCK	40	HR	\$	27.42	\$	1,096.80	\$	-	\$	1,096.80
ARROW BOARD	40	HR	\$	2.43	\$	97.20	\$	-	\$	97.20
GRAND TOTAL									\$	45,536.20



TYPES OF SHRINKAGE CRACKS

Туре	What is happening	When	What is driving this	Mitigation strategies
Plastic	Water leaving the concrete <u>before setting</u>	First few hours	Bleeding & evaporation rate	Use fibers, curing membranes, foggers, etc
Drying	Water leaving the concrete after setting	Weeks and months	Relative humidity of the environment	External curing, aggregate choice, minimize water, shrinkage reducing admixtures, reinforcement, expansive cements
Thermal	Concrete temperature changing	First few days and on-going	Environmental temperatures swings and high heat of hydration	Minimize heat of hydration, low thermal expansion aggregates
Autogenous (Chemical)	Water consumed by hydration of cementitious materials <u>after setting</u>	First few days	Self-desiccation of cementitious materials (insignificant when w/c>0.42)	Minimize self desiccation and rate of hydration (lower cement content), reinforcement, and <u>INTERNAL</u> <u>CURING</u>

Source: WJE



PROBLEM

Early-age Cracking (within 60 days) in HPC Bridge Decks and the resulting Reduction in Service Life.

OBJECTIVE

Reduce Autogenous Shrinkage and the resulting Transverse Cracking in new HPC Bridge Decks.



ENHANCING PERFORMANCE WITH INTERNALLY CURED CONCRETE (EPIC²)

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More than 30 years of extensive studies have shown that internal curing addresses:

- Durability: targets and mitigates the source of shrinkage cracking particularly in lower w/cm concretes, resulting in lower permeability concretes to improve durability
- Versatility: can be used anywhere traditional concrete is used.
- Cost Savings: higher-durability and reducing the need to rehabilitate or replace critical elements such as bridge decks during the design life of the bridge, resulting in lifecycle cost savings.
- Embodied Carbon Reduction: opportunities for increased utilization of natural, waste, or recycled SCMs without reduced performance or increased risk of cracking.

INTERNAL CURING



- Internal curing is simply curing where the water is provided from inside.
- The main difference between HPC and HPIC is Replacing <u>some</u> conventional fine aggregate (sand) with pre-wetted lightweight fine aggregate (LWFA).
- Water absorbed :
 - Does not contribute to the w/cm ratio
 - Remains in the LWFA during mixing and until set.
- Results in better dispersion of curing water throughout the concrete depth.



INTERNAL CURING



- At the time of set, capillary stresses draw the water out of the LFWA and cures the concrete section.
- Supplemental to, not replacement for, external curing.
- Increases the hydration of the cement and reaction of SCMs.
- Utilizing the cementitious materials more efficiently and reduces the porosity.



It is not lightweight concrete!

INTERNAL CURING DEPLOYMENT



Deployed and institutionalized by more than 15 States or transportation agencies :

- Bridge Decks: ~150 bridge decks
 New York State, Indiana, Louisiana, North Carolina,
 Ohio, and Utah DOTs; Western Federal Lands
 Highway Division; and the Illinois State Toll Highway
 Authority.
- Pavements: Kansas and Texas DOTs and the North Texas Tollway Authority.
- Pavement Patches: City of West Lafayette, Indiana; Texas DOT; and Michigan municipalities.



INTERNAL CURING DEPLOYMENT



NYSDOT Experience :

- Experimental Features plan for FHWA: I2 projects, up to 20 decks using IC
- Increased durability and higher cracking resistance. (70% reduction in early age cracking).
- No increase in cost.
- Curing period reduced from 14 to 7 days for HPIC.
- Mandatory for continuous bridges & all NYC bridges.



New York State Peer Exchange - FHWA EDC-7 EPIC2 Albany, NY | May 29-30, 2024

NJDOT IMPLEMENTATION PLAN





NJDOT IMPLEMENTATION PLAN



Comparative Studies : Twin Bridges HPC vs HPIC



CANDIDATE BRIDGES/PROJECTS



Project Name	Scope	County	Region	Current Phase	FDS	Award
North Munn Ave, Bridge over Rt 280	LS Super. Repl.	Essex	North	Con.	2024	2024
CR 507 (Maple Ave), Bridge over Rt 208	LS Super. Repl.	Bergen	North	FD	2025	2025
Hanover Ave (CR650), Bridge over I-287	LS Deck Repl.	Morris	North	FD	2025	2026
Prince Rodgers Ave, Bridges over Rt 287	LS Deck Repl.	Somerset	Central	FD	2025	2026
Rt 202 Bridge over North Branch of Raritan River	FS Bridge Repl.	Somerset	Central	FD	2026	2026
Rt 45 Bridge over Woodbury Creek	FS Bridge Repl.	Gloucester	South	FD	2026	2026
Rt 23 SB Bridge over NYS&W Railroad	LS Deck Repl.	Passaic	North	FD	2026	2027
Rt 124 Bridges over Passaic River	LS Deck Repl.	Morris	North	FD	2026	2028
Change Bridge Rd (CR 621), Bridge over Rt 80	LS Deck Repl.	Morris	North	CD	2027	2029
Blue Heron Rd Bridge over Rt 15	LS Deck Repl.	Sussex	North	CD	2028	2029



PROJECT IMPLEMENTATION

- Specifications (Special Provisions)
- Contract Pay Items
- Local concrete supplier coordination
- Design
- Contract Plans



SPECIAL PROVISIONS

- Section 500 (Construction)
- Section 900 (Materials)
- Performance Specification
 - Contractor Mix Design
 - Verification Materials Testing
- Light-weight aggregate
- Test slab and trial batching
- Guide Specification developed

Table 903.05.04-2 Ac	Fest lettern to C	northerth
Percent Air Entrainment	OI II alls	0.0=1.5 (No. 37/07 Aggregate) 7.0 = 1.5 (No. 8 Aggregate)
Slump (inches) ^{1,2}	AASHTO T 119	3±1
Surface Resistivity @ 56 days ^{3,4,5} (kΩ-cm, minimum)	AASHTO T 358	19
Unit Weight ⁶ (pounds per cubic foot, minimum)	AASHTO T 121	135
Compressive Strength ^{3,7} @ 3, 7, 28, 56 days (pounds per square inch, minimum)	ASTM T22	4,400
1. 2 AT Content: increase both the top of the end of the top of the end of the top of the end of the end of the top of the end of the top of the end	Ind tolerance percentages on the order of the transfer of the 1.2 share of the transfer of the	ETE
The HPIC mix design shall have total normal-we uggregate (LWFA) that conforms to the requirem to calculated to provide a Ghient volume of in Aggregate design absorpti Standarto periods. Aggregate desorption need not be consid- ubstitution Gottan Road and the accordance GOTTRoad and a	ight fine aggregate volume s nents as specified in 901.06.0 In Specified in 901.06.0 In Specification accord and the substitution calcu Bridge Co	ubstituted with pre-wetted lightweigh 4. The quantity of LWFA substitution gases with ASTM C1761, Appendix 3 LIONS instead of 72-hr soaking lations. The maximum quantity of L' discrete the second second second second second the second second second second second second the second second second second second second second second second second second second second second second second second second seco
	to supershead ant polymer	or colloidal silica will not be accepte



MATERIALS – LIGHTWEIGHT AGGREGATE

- Expanded shales, clays, slates, slags
- High absorption capacity %
- Fine LWA (LWFA) preferred over Coarse LWA
 Concrete sands
- ASTM CI761



Source: Hydrocure ©



MATERIALS - NJDOT QPL

Producer	Address	Quarry/Pit Location	Size	%Abs	Bulk Sp. Gr.	SSD Sp. Gr.	App. Sp. Gr.	Unit Wt.	DRW
Carolina Stalite Co.	217 Klumac Rd. P.O. Box 1037 Salisbury, NC 28144	Gold Hill,NC	lt. wt. agg. for internal curing HPC	9.8	1.745	1.912	2.095	60	65
Norlite Corp.	628 South Saratoga Street Cohoes,NY 12047	Cohoes,NY	lt. wt. agg. for internal curing HPC	23.2	1.587	1.831	2.100	53	59
Northeast Solite	PO Box 437 Mount Marion,NY 12456	Saugerties,NY	lt. wt. agg. for internal curing HPC	12.0	2.172	1.936	1.734	62	68



LW AGGREGATE STOCKPILE MANAGEMENT

- Pre-soak with sprinkler or soaker (24-48 hrs)
 - Aggregate absorbs water
- Drain-down period (12-16 hrs):
 - Reduce surface moisture.
 - ➢ Mix & increase uniformity.
- At concrete production facility



Source: FHWA



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LW AGGREGATE - MOISTURE TESTING

- Paper-towel method (ASTM CI761 / NYSDOT)
- Centrifuge Method (INDOT/Purdue Univ.)
- Performed by regional Materials personnel.
- Confirm minimum absorption % met.
- Determine excess free-moisture:
 - Batch adjustments







HPIC MIX DESIGN

- Mix <u>conversion</u>
- Convert existing HPC mix to internally cured
- Substitute ~30-50% of total fine aggregate (volume) with LWFA.
- LWFA substitution volume dependent on aggregate absorption/desorption properties.

COMPORTIT TYT NAME PRODUCT// SUPPLIE MODESSATE SLATUPE COMPORTS RELATIVE RELATIVE COMPORTS ABSORTICE WEIGHT VICUME NAME NAME COMPORTS Topic 111 - Restade Camere - 2.00 - 570 2.00 1.2.5% 2.2.% 1.2.% 0.0.00%	MIX PROPORTIONS:	CONVERT	ED INTER	RNALLY CURED								
Const NC Top HI Busined General J. J.G. Top HI J. Sole J. Sole J. Sole	COMPONENT	TYPE		NAME	PRODUCER / SUPPLIER	AGGREGATE SIZE / GRADATION	RELATIVE DENSITY	ABSORPTION	WEIGHT (Ib)	VOLUME (ft ³)	% MIX WEIGHT	% MIX VOLUME
PCC1 Type III . Reside Center . 1.150 0.000 1.2 0.0 0.000 0.0 0.0 0.000 0.0 0.000 0.0 0.000 0.0 0.000 0.0 0.000 0.0 0.000 0.0 0.000 <t< td=""><td>Cement</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	Cement											
PRC2 None - - 0.000 - 0.000	PCC1	Type III			Riverside Cement		3.150		570	2.900	14.3%	10.7%
Space Construction Mate - 0 0.000	PCC2	None		-	-	-	0.000	-	0	0.000	0.0%	0.0%
Non- solution Site arrow (SSA 3) - - - 2200 - SSA 000 00000 00000<									Σ 570	2.90	14.3%	10.7%
Soriel	SCM 1	Silica Euro					2 200		25	0.192	0.6%	0.7%
SXX 3 Nore Other kurv Other kurv Other kurv Other kurv Store Sto	SCM 2	Slag	ie.	45 Slag (F1)	FarthCEM	-	2.200	-	130	0.726	3.3%	2.7%
Local Local Local Local Local Local Jos	SCM 3	None		45 5108 (01)	controction		0.000		100	0.000	0.0%	0.0%
$ \frac{500}{C4.2} + \frac{500}{5000} + \frac{500}{2} + \frac{500}{2}$	Somo	None					0.000		Σ 155	0.000	3.9%	3.4%
A.4 Stone - Gilbertar Rock #57 2.75 0.58 6.60 578 133.8 778 G.2 Stone - Gilbertar Rock #5 2.707 0.351 6.60 572 133 4938 133.8 778 G.2 Stone - Gilbertar Rock #6 2.707 0.351 600 507 123 4938 1248	Coarse Aggregate						SSD	SSD		0.01	0.070	0.470
$ \frac{1}{12} + \frac{1}{12}$	CA 1	Stone		-	Gilbraltar Rock	#57	2,795	0.5%	1320	7,568	33,1%	27.9%
Bits Automatic Concrete Sand Solar Solar <thsolar< th=""> Solar Solar<</thsolar<>	CA 2	Stone			Gilbraltar Rock	#8	2.770	0.5%	650	3,761	16.3%	13.9%
Image: constrained biological states in a serie of press of the states in a serie of the state in a serie of the state in a serie of the state in									Σ 1970	11.33	49.5%	41.8%
Kal (MV) Concrete Sand - Sahaa Sand - 2.857 0.48 501 3.04 1.254 1.134 Kater .	Fine Aggregate						SSD/WSD	SSD/WSD				
FA2(LW) Solite - - 1.745 1.4.4% 3.83 3.34 9.1% 1.23% Mate: R R44 6.83 6.83 5.9% 1.9% Mix Verser - - 1.000 - 2.25 3.76 5.9% 1.9% Alr.Content Arr.Emaining Same - - - 0 0.175 0.0% 6.53% Alr.Content Arr.Emaining Same Same - - 1.000 - 0.0 0.075 0.00% 6.53% ADM.1 Resident Parametrize Site Copp. - 1.000 - 0.459 0.000	FA 1 (NW)	Concrete Sa	and		Sahara Sand	-	2.637	0.4%	501	3.047	12.6%	11.2%
Water Image: Control Introduction of SUB Control Introduction of SUB Control Introduction State Subject Control Interview Subject Content Subject Control Interview Sub	FA 2 (LW)	Solite					1.745	14.4%	363	3.334	9.1%	12.3%
Variant Mix Warer ·									Σ 864	6.38	21.7%	23.6%
Mix Water - - - 1.000 - 2.25 3.76 5.94 1.93% Mix Context Ari Emrainment 6.5% - - - - 0 1.75 0.0% 6.5% Animater ARIE mainment 6.5% - - - 0 1.75 0.0% 6.5% ADM.1 Ari Entraining - Site Corp. - 1.000 - 0.189 0.030 0.00% 0.05% 6.5% ADM.3 HIWN Viscorette 210 Site Corp. - 1.000 - 0.189 0.030 0.00% 0	Water											
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ADM. 4 None .	ADM. 3	HRWR		Viscocrete 2100	Sika Corp.	-	1.000	-	1.890	0.030	0.05%	0.11%
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MINUSAN PROPERTIES: University of the state			_									
Plastic Unit Weight = 140 IIU/rt ³ [Theoretical unit weight of plastic concrete mixture] Sack Content (Cement) = 6 sack [# of \$4 to Cement sacks per (?) Sack Content (Cement) = 6 sack [# of \$4 to Cement sacks per (?) Content (Cement) = 6 sack [# of \$4 to Cement sacks per (?) WC = 0.41 - [Water-Cement titluos Materials ratios, prweight] Paste Volume Fraction = 0.53 - [Fraction of volume of practice, prevent, sacks, number to total bach volume] Mortar Volume fraction = 0.58 - [Fraction of volume of practice, prevent, sacks, number to total bach volume] Sock(ZMIT = 0.27 - [Ratio of Sacks Cement, Sack, prevelyme 100 total bach volume] Sock(ZMIT = 0.27 - [Ratio of Sacks Cement, Sack, prevelyme 100 total bach volume] Sock(ZMIT = 0.27 - [Ratio of Sacks Cement, prevelyme 100 total bach volume] Sock(ZMIT = 0.27 - [Ratio of Sacks Cement, prevelyme 100 total bach volume] Sock(ZMIT = 0.27 - [Ratio of Sacks Cement, prevelyme 100 total bach volume] Sock(ZMIT = 0.26	WIX DESIGN PROPERTIES:	CONVERTED IN	TERNALL	FCORED								
Volumetric User 225 10 [Weight of ement + 500a] Sack Content (rement + 500a) 8 sack [# of \$4 lb Cement sacks per CY] Gallons Water + 250a 8 [sack formet (ruliding SCMS]) Gallons Water + 250a 10 [Water-Cement ratio, by weight] W/Cl = 0.42 - [Water-Cement ratio, by weight] W/Cl = 0.23 - [Fraction of volume of notic (nement, SCMs, and water) to total batch volume] Mottra Volume Fraction = 0.28 - [Fraction of volume of notic (nement, SCMs, fine aggregate, water, and entrained air) to total batch volume] Std/CEMENT = 0.22 - [Ratio of Sand to total aggregate, by volume] Std/CEMENT = 0.22 - [Ratio of Sand to total aggregate, by volume] Std/Total Aggregate = 0.36 - [Ratio of Sand to total aggregate, by volume] Volumetric Distribution: Cement = 10.7% SSN = 364 Std/Total Aggregate = 0.36 - [Ratio of Sand to total aggregate, by volume] Volumetric Distribution: Cement = 10.7% SSN = 364 Conse Agg = 4.15% Fine Agg (WN) = 1.2% Co	Plastic Unit Weight =	140	lb/ft ³	(Theor	etical unit weight of plasti	c concrete mixture	9					
Sec Content (Cernent) = 6 sack [2 of \$4 lo Cernent sacks per CY], Content (Cernent + SAM) = 8 sack [2 of \$4 lo Cernent sacks per CY], W/C= 0.41 - [Wtetr-Cernent Tailo, by weight] W/C= 0.32 - [Wtetr-Cernent Tailo, by weight] W/C= 0.32 - [Freation of volume of protect (SAMs, fine aggregate, water, and entrained air) to total batch volume] Morar Volume fraction = 0.38 - [Freation of volume of protect (Cernent, SCAMs, fine aggregate, water, and entrained air) to total batch volume] SCA/CMUHT = 0.27 - [Ratio of SCMs Content, SWeight] Sand / Total Aggregate = 0.38 - [Freation of volume of protect (Cernent, SCAMs, fine aggregate, water, and entrained air) to total batch volume] SCM/CMUHT = 0.27 - [Ratio of SCMs Content, SCAMs, fine aggregate, water, and entrained air) to total batch volume] SCM/CMUHT = 0.27 - [Ratio of SCMs Content, SWeight] Sand / Total Aggregate = 0.38 - [Ratio of SCMs Content, SCAMs, fine aggregate, water, and entrained air) to total batch volume] SCM = 0.78 Water = 10.78 SCM = 0.78 Water = 10.78 SCM = 0.78 Water = 10.78 SCM = 0.78 Water = 10.78 SCM = 0.78 Water = 0.28 Fine Agg (WN) = 0.128 Fine Agg (WN) = 0.126 Fine Agg (WN) = 0.28 m Water = 0.29 Fine Agg (WN) = 0.28 m Fine Agg (WN)	otal Weight Cementitious =	725	Ib	(Weigh	it of cement + SCMs]							
Content (Lement + SUM) = 8 statu [for Val Deternition and water ratio, by weight] Galinos Water = 2.2.2 gal [Galinos mix water ratio, by weight] Wick = 0.23 - [Water-Cement ratio, by weight] Paste Volume fraction = 0.28 - [Fraction of volume of more (cement, SUMs, and water) to total batch volume] Motar Volume fraction = 0.28 - [Fraction of volume of more (cement, SUMs, fine agregate, water, and entried and its to total batch volume] Motar Volume fraction = 0.28 - [Fraction of volume of more (cement, SUMs, fine agregate, water, and entried and its to total batch volume] Stat/CEMENT = 0.27 - [Ratio of Sands to Cement, by weight] Stand / Total Agregate = 0.36 - [Ratio of Sands to total agregate, by volume] Volumetric Distribution: Cement = 10.7% Sand Conventional HPC State = 3.5% Conventional HPC - - - Mix Proportions - Volumetric Distribution Conventional HPC - - - Galinos State = 3.5% - - - - - Conner Age: (WW) = 1.3% - <t< td=""><td>Sack Content (Cement) =</td><td>6</td><td>sack</td><td>[# of 94</td><td>Ib Cement sacks per CY]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	Sack Content (Cement) =	6	sack	[# of 94	Ib Cement sacks per CY]							
Calling Water = 24.4 g8 [Isaling mix water required] W/C = 0.41 - [Water-Cement Tailo, by weight] Work = 0.32 - [If rection of volume of more (cement, SDMs, and water) to total batch volume] Mora Volume firaction = 0.36 - [If rection of volume of more (cement, SDMs, and water) to total batch volume] Social/KDW1 = 0.37 - [Ratio of SDMs to Cement, SDMs, fine aggregate, water, and entrained air) to total batch volume] Sand / Total Aggregate = 0.36 - [Ratio of SDMs to Cement, SDMs, fine aggregate, by volume] Wolker = 10.7% - [Ratio of SDMs to Cement, by weight] Conventional HPC Conventional HPC Conventional HPC Conventional HPC Fine Agg. (W) = 11.2% Fine Agg. (W) = 11.2% Fine Agg. (W) = 11.3% 11.3% Water = 13.9% 0.7% 0.7% 0.6% + 6.3% Fine Agg. (W) = 12.6% 13.9% 0.7% 0.6% + 6.3% Fine Agg. (W) = 12.6% 13.9% 0.7% 0.6% + 6.3% 0.6% + 6.3% Fine Agg. (W) = 12.6% 13.9% 0.6% + 6.3% 0.6% + 6.3%	ck Content (Cement + SCM) =	8	sack	[# of 94	I b Cement sacks per CY, ir	actuding SCMS1						
WOR 0.4 - [Water-Cementition Study Streight] Paste Volume fraction = 0.28 - [Fraction of volume of most (cement, SSMs, and water) to total batch volume] Montar Volume fraction = 0.28 - [Fraction of volume of most (cement, SSMs, and water) to total batch volume] Study (ZMENT) 0.27 - [Ratio of SSMs to Cement, by weight] Study (ZMENT) 0.27 - [Ratio of SSMs to Cement, by weight] Study (ZMENT) 0.36 - [Ratio of SSMs to Cement, by weight] Cament = 0.36 - [Ratio of SSMs to Cement, by weight] Cament = 10.7% SSMs SSMs SSMs SSMs Study = 3.4% Conventional HPC Conventional HPC SSMs Value = 13.5% SSMs SSMs SSMs SSMs SSMs SSMs Study = 13.5% Coarse Age = 4.8% Fine Age (WW) = 13.5% Coarse Age = 4.3% Sine = 3.5% Coarse Age = 4.3% Fine Age (WW) = 2.6% Coarse Age = 9.3% Water = 13.5% Coarse Age = 9.3%	Gallons water =	28.2	gai	[Galloi								
Peste Volume fraction = 0.23 · · · [raction of volume of pasts (careers, 55M, as unested) to total latch volume] Morat Volume fraction = 0.23 · · · [raction of volume of pasts (careers, 55M, so unested) to total latch volume] Sand/CateBit = 0.27 · · · [Ratio of S2M is 0 Cement, by weight] Sand / Total Aggregate = 0.36 · · (Ratio of sand to total aggregate, by volume) Volumetric Distribution: Cement = 107% SCM = 3.4% SCM = 3.4% SCM = 3.4% SCM = 1.28% Water = 1.39% Arr = 6.55% Weight Distribution: Conventional HPC Fine Agg (WW) = 11.2% Fine Agg (WW) = 11.2% Fine Agg (WW) = 11.2% Fine Agg (WW) = 11.2% Fine Agg (WW) = 1.2% Fine Agg (WW) = 2.3% Coarse Agg = 4.05% Fine Agg (WW) = 2.5% Water = 5.9%		0.41		DMater	ns mix water required]							
Mora Volume Iraction = 0.53 - : [Fraction of volume of moraty (cenent, SXAs, fine aggregate, water, and entrained air) to total batch volume] Sand / Total Aggregate = 0.36 - : [Fraction of volume of moraty (cenent, SXAs, fine aggregate, water, and entrained air) to total batch volume] (Ratio of SXAs to Genent, by weight) Ratio of sand to total aggregate, by volume]	W/CM =	0.41	1	[Water	ns mix water required] -Cement ratio, by weight] -Cementitious Materials ri	ations by weight]						
SAV/CEMENT = 0.27 · igatio of SOAs to Cement, by weight] Sand / Total Aggregate = 0.36 · igatio of SoAs to Cement, by weight] (Ratio of sand to total aggregate, by volume)	W/CM =	0.41 0.32 0.28	-	[Water [Water [Fraction	ns mix water required] -Cement ratio, by weight] -Cementitious Materials ri	atios, by weight]	ater) to total ba	tch volume]				
Sand / Total Aggregate * 0.5 Itatio of sand to total aggregate, byvolume) Volumetric Distribution: Mix Proportions - Volumetric Distribution Ceneret * 10.7% SOL* 3.4% Coarse Agg = 41.8% Fine Agg (IW) * 12.3% Weight Distribution: 0 Ceneret * 13.9% Air * 6.5% Weight Distribution: Coarse Agg = 43.5% Coarse Agg = 49.5% Fine Agg (IW) * 12.6% Fine Agg (IW) * 9.3% Water * 5.9%	W/CM = Paste Volume Fraction = Mortar Volume Fraction =	0.41 0.32 0.28 0.58	- - -	(Water (Water (Fractio	ns mix water required] -Cement ratio, by weight] -Cementitious Materials ra on of volume of paste (cem on of volume of mortar (cei	atios, by weight) ient, SCMs, and wa ment, SCMs, fine a	ater) to total ba	itch volume] r. and entrained a	ir) to total	batch volume	-1	
Volumetric Distribution: Mix Proportions - Volumetric Distribution Cement = 10.7% 50% = 3.6% Coarse Age = 41.8% Fine Age (W) = 11.2% Fine Age (W) = 11.2% Water = 13.9% Water = 13.9% Mix Proportions - Volumetric Distribution Connent = 10.3% Connent = 10.7% Stote = 3.9% Coarse Age = 40.5% Fine Age (WW) = 23.6% Coarse Age = 40.5% Fine Age (WW) = 9.3% Water = 5.9%	W/CM = Paste Volume Fraction = Mortar Volume Fraction = SCM/CEMENT =	0.41 0.32 0.28 0.58 0.27	- - -	[Water [Water [Fractio [Fractio [Ratio]	ns mix water required) -Cement ratio, by weight) -Cementitious Materials rr on of volume of paste (cen on of volume of mortar (cen of SCMs to Cement, by weight	atios, by weight] ient, SCMs, and wa ment, SCMs, fine a zht]	ater) to total ba ggregate, wate	tch volume] r, and entrained a	iir) to total	patch volume	:]	
Volumetric Distribution: Cement = 107% SCM = 3.4% Consertional HPC Consertional HPC Mix Proportions - Weight Distribution Conventional HPC Mixer = 55% Weight Distribution: Conventional HPC Conventional HPC Mixer = 55% Weight Distribution: Conventional HPC Conventional HPC Mixer = 55% Weight Distribution: Conventional HPC Conventional HPC Mixer = 55% Weight Distribution: Conventional HPC Conventional HPC Mixer = 55% Water = 59% Conventional HPC Conventional HPC <td>W/CM = W/CM = Paste Volume Fraction = Mortar Volume Fraction = SCM/CEMENT = Sand / Total Aggregate =</td> <td>0.41 0.32 0.28 0.58 0.27 0.36</td> <td>- - - - -</td> <td>[Water [Water [Fractio [Fractio [Ratio [Ratio</td> <td>ns mix water required) -Cement ratio, by weight] -Cementitious Materials rr on of volume of paste (cem on of volume of mortar (cer of SCMs to Cement, by weig of sand to total aggregate,</td> <td>atios, by weight) sent, SCMs, and wa ment, SCMs, fine a ght] by volume]</td> <td>ater) to total ba ggregate, wate</td> <td>itch volume] r, and entrained a</td> <td>iir) to total</td> <td>patch volume</td> <td>*]</td> <td></td>	W/CM = W/CM = Paste Volume Fraction = Mortar Volume Fraction = SCM/CEMENT = Sand / Total Aggregate =	0.41 0.32 0.28 0.58 0.27 0.36	- - - - -	[Water [Water [Fractio [Fractio [Ratio [Ratio	ns mix water required) -Cement ratio, by weight] -Cementitious Materials rr on of volume of paste (cem on of volume of mortar (cer of SCMs to Cement, by weig of sand to total aggregate,	atios, by weight) sent, SCMs, and wa ment, SCMs, fine a ght] by volume]	ater) to total ba ggregate, wate	itch volume] r, and entrained a	iir) to total	patch volume	*]	
Total Number Mix Proportions Mix Proporti	W/CM = Paste Volume Fraction = Mortar Volume Fraction = SCM/CEMENT = Sand / Total Aggregate =	0.41 0.32 0.28 0.58 0.27 0.36	• • • •	[Water [Water [Fractic [Ratio [Ratio	is mix water required) -Cement ratio, by weight] -Cementitious Materials ro on of volume of paste (cem on of volume of mortar (cei of SCMs to Cement, by weig of sand to total aggregate,	atios, by weight] ient, SCMs, and wa ment, SCMs, fine a ght] by volume]	ater) to total ba ggregate, wate	atch volume] r, and entrained a	ir) to total	batch volume	e]	
Lement 10.7% Coarse Age - 41.8% Fine Age (IW) - 12.3% Water - 13% Arr - 6.5% Weight Distribution: Cement - 14.3% State - 3.9% Coarse Age - 49.5% Fine Age (IW) - 9.1% Water - 5.9% Coarse Age - 49.5% Fine Age (IW) - 23.6% Coarse Age - 41.8% Coarse Age - 49.5% Fine Age (IW) - 23.6% Coarse Age - 41.8% Coarse Age - 43.8% Coarse Age - 49.5% Fine Age (IW) - 23.6% Coarse Age - 41.8% Coarse Age - 43.5% Coarse	W/CM = Paste Volume Fraction = Mortar Volume Fraction = SCM/CEMENT = Sand / Total Aggregate =	0.41 0.32 0.28 0.58 0.27 0.36		Water (Water (Fracti (Fracti (Ratio (Ratio	is mix water required) -Cement ratio, by weightl -Cementitious Materials ra on of volume of paste (cerr on of volume of mortar (cet of SCMs to Cement, by weight of sand to total aggregate, chians - Volument-i- Di-	atios, by weight] ent, SCMs, and wa nent, SCMs, fine a ght] by volume]	ater) to total ba ggregate, wate	atch volume] r, and entrained a	iir) to total	patch volume	e]	
Coarse Agg = 41.8% Fine Agg (W) = 11.2% Fine Agg (W) = 11.2% Water = 13.9% Arr = 6.5% Weight Distribution Comment = 14.3% Coarse Agg = 40.5% Fine Agg (W) = 9.3% Water = 5.9% Coarse Agg = 40.5% Fine Agg (W) = 23.6% Coarse Agg = 40.5% Fine Agg (W) = 23.6% Fine Agg (W) = 23.6%	W/CM = Paste Volume Fraction = Morter Volume Fraction = SCM/CEMENT = Sand / Total Aggregate = <u>Volumetric Distribu</u>	0.41 0.32 0.28 0.58 0.27 0.36		Water (Water (Fractii (Fractii (Ratio (Ratio Mix Propo	is mix water required) -Cementitious Materials ri on of volume of paste (cem on of volume of mortar (cei of SCMs to Cement, by weight) of sand to total aggregate, 	atios, by weight) ient, SCMs, and wa ment, SCMs, fine a ght] by volume] itribution	ater) to total be ggregate, wate	atch volume] r, and entrained a <u>Mix Pro</u>	ir) to total	Weight Di	:] stribution	1
View View <th< td=""><td>W/CM = Paste Volume Fraction = Mortar Volume Fraction = SCM/CEMENT = Sand / Total Aggregate = <u>Volumetric Distribu</u> Cement =</td><td>0.41 0.32 0.28 0.58 0.27 0.36 Ition:</td><td>: : :</td><td>Water (Water (Fractii (Ratio (Ratio Mix Propo</td><td>s mix water required) -Cement ratio, by weight) -Cement ratio, by weight) -Cementitious Materials n on of volume of poste (cem of SCMs to Cement, by weig of sand to total aggregate, </td><td>atios, by weight] tent, SCMs, and wa ment, SCMs, fine a ght] by volume] tribution</td><td>ater) to total be ggregate, wate</td><td>atch volume] r, and entrained a <u>Mix Pro</u>;</td><td>iir) to total portions - <u>Conven</u></td><td>Weight Di</td><td>e] stribution</td><td>1</td></th<>	W/CM = Paste Volume Fraction = Mortar Volume Fraction = SCM/CEMENT = Sand / Total Aggregate = <u>Volumetric Distribu</u> Cement =	0.41 0.32 0.28 0.58 0.27 0.36 Ition:	: : :	Water (Water (Fractii (Ratio (Ratio Mix Propo	s mix water required) -Cement ratio, by weight) -Cement ratio, by weight) -Cementitious Materials n on of volume of poste (cem of SCMs to Cement, by weig of sand to total aggregate, 	atios, by weight] tent, SCMs, and wa ment, SCMs, fine a ght] by volume] tribution	ater) to total be ggregate, wate	atch volume] r, and entrained a <u>Mix Pro</u> ;	iir) to total portions - <u>Conven</u>	Weight Di	e] stribution	1
Fine Ag: (UW) = 12.3% Water = 13.9% Mire 6.5% Weight Distribution: Connert = 14.3% SCM = 3.9% Coarse Ag: = 40.5% Fine Ag: (UW) = 2.5% Fine Ag: (UW) = 2.5% Coarse Ag: = 40.5% Fine Ag: (UW) = 2.5% Coarse Ag: = 41.5% Coarse Ag: = 42.5%	W/CM = Paste Volume Fraction = Monter Volume Fraction = SCM/CEMENT = Sand / Total Aggregate = <u>Volumetric Distribu</u> Cement = SCM = Course Ame -	0.41 0.32 0.28 0.58 0.27 0.36 ution: 10.7% 3.4% 41.8%		Water Water (Fractii (Fractii (Ratio (Ratio	s mix water required) -Cement ratio, by weight) -Cementitious Materials ra- on of volume of paste (cem on of volume of mortar (cen of SCMs to Cement, by weig of sand to total aggregate rtions - Volumetric Dis <u>Conventional HPC</u>	atios, by weight] lent, SCMs, and wa nent, SCMs, fine a htt] by volume] :tribution	ater) to total ba	r, and entrained a Mix Pro	ir) to total	Weight Di tional HPC	e] stribution	1
Water = 13.9% All = 65% Comment = 13.9% Distribution: 21.0% = 2.0% Comment = 14.3% Comm	W/CM = Paste Volume Fraction = Monter Volume Fraction = SCM/CENENT = Sand / Total Aggregate = Volumetric Distribut Cement = SCM = SCM = Eine Age (NM) =	0.41 0.32 0.28 0.58 0.27 0.36 ution: 10.7% 3.4% 41.8% 11.2%		[Water [Water [Fracti [Fracti [Ratio [Ratio	is mix water required) -Cement ratio, by weight) -Cementitious Materials in of volume of paste (cen on of volume of paste (cen of SKMs to Cement, by weight) of sand to total aggregate, of sand to total aggregate, rtions - Volumetric Dis Conventional HPC	atios, by weight] ient, SCMs, and wa ment, SCMs, fine a fit] by volume] tribution	ster) to total ba	stch volume] r, and entrained a <u>Mix Pro</u> Fine Agg. (LW)	ir) to total portions - <u>Conven</u> = 5.9%	Weight Di	e] stribution	<u>1</u>
Alr = 6.5% Weight Distribution: 20.7% Cement = 16.3% SOL4 = 3.9% Coarse Age = 40.5% Fine Age (UW) = 2.6% Coarse Age = 40.5% Fine Age (UW) = 2.6% Coarse Age = 4.5%	W/CM = Works Volume Fraction = SCM/CEMENT = Sand / Total Aggregate = Volumetric Distribut Cement = SCM = SCM = Fine Agg. (WV) = Fine Agg. (WV) =	0.41 0.32 0.28 0.58 0.27 0.36 ution: 10.7% 3.4% 41.8% 11.2%		(Water (Vater (Fracti (Fracti (Ratio (Ratio	s mix water required) -Cement ratio, by weight) -Cement tratio, by weight) -Cement tratio, by weight and routime of paste (cer on of volume of paste (cer of SCMs to Cement, by weight) of sand to total aggregate. 	atios, by weight] itent, SCMs, and wa ment, SCMs, fine a ght] by volume] stribution	ster) to total be ggregate, wate	r, and entrained a Mix Pro Fine Agg. (LW)	ir) to total portions - <u>Conven</u> = 5.94	oatch volume Weight Di tional HPC	e] stribution	1
Weight Distribution: 14.3% Cement = 14.3% 3.9% Coarse Age = 49.5% Fine Age (IVV) = 12.6% Fine Age (IVV) = 12.6% Fine Age (IVV) = 2.6% Viater = 5.3% Coarse Age = 41.6%	W(CA = Paste Volume Fraction = Schl/CEMENT = Schl/CEMENT = Sand / Total Agregate = Volumetric Distribu Cement = SCM = Coarse Age = Fine Age (IW) = Fine Age (IW) =	0.41 0.32 0.28 0.58 0.27 0.36 0.36 0.36 0.36 0.36 0.36 0.36 0.36		jWate (Wate (Fracti (Ratio Mix Propo	Smik water required) -Cement ratio, by weight) -Cementitious Materials in of volume of paste (cem on of volume of paste (cem of SMs to Cement, by weight) of sand to total aggregate, of sand to total aggregate, retions - Volumetric Dis Conventional HPC Water 658 Cements	stios, by weight] ent, SCMs, and wa ment, SCMs, fine a http: by volume] trribution	ster) to total ba	atch volume] r, and entrained a <u>Mix Pro</u> , Fine Agg. (LW)	ir) to total cortions - <u>Conven</u> = 5.9%	Weight Di	e] stribution	1
Weight Distribution: 13% Cemert = 143% 3% SCM = 3.9% 26.4% Coarse Agg = 49.5% Fine Agg (IW) = 12.6% Fine Agg (IW) = 9.3% Water = 5.9%	W/CA = W/CA = Morat volume fraction = SCM/CEMENT = Sand / Total Aggregate = Volumetric Distribu Coment = SCM = Coment = SCM = Coment e SCM = SCM =	0.41 0.32 0.28 0.58 0.27 0.36		[Water Water Fracti Ratio Ratio	15 mix water required] -Cement ratio, by weight] -Cement ratio, by weight] -Cement ratio, by astel (cer on of volume of pastel (cer on of volume of pastel (cer of sand to total aggregate, def to total aggregate, rations - Volumetric Dit Conventional HPC Water 6.5% Cement - 10.7%	atios, by weight] ient, SCMs, and w: ment, SCMs, fine a ght] by volume] tribution	ster) to total ba ggregate, wate	atch volume] r, and entrained a <u>Mix Pro</u> Fine Agg. (LW)	ir) to total	Weight Di tional HPC	e] stribution	1
Control 143% SM = 39% Control 42g. (NV) = 12.6% Fine Agg. (NV) = 2.6% Water = 5.9% Control 42g. (NV) = 2.6% Control 42g. = 49.5% Control 42g. = 49.5%	W/GA = Paste Volume Fraction = Mortar Volume Fraction = Sand / Total Aggregate = Outputter Data Coarse Agg Fine Agg. (WW) = Fine Agg. (WW) = Fine Agg. (WW) = Aggregate = Fine Agg. (WW) =	0.41 0.32 0.28 0.58 0.27 0.36 10.7% 3.4% 41.8% 11.2% 12.3% 13.9% 6.5%		[Wate [Vate [Fracti [Fracti [Ratio [Ratio	Smik water required) -Cement ratio, by weight) -Cement lious Materials in of volume of paste (cem on of volume of paste (cem of SMs to Cement, by weight) of sand to total aggregate, of sand to total aggregate, ritions - Volumetric Din Conventional HPC Water 6.5% Cement - 10.7%	atios, by weight] ient, SCMs, and w ment, SCMs, fine a ment, SCMs, fine a ment, SCMs, fine a ment, SCMs, and weight by volume]	ster) to total ba	atch volume] r, and entrained a <u>Mix Pro</u> Fine Agg. (LW)	ir) to total	Weight Di tional HPC	e] stribution	1SCM = 3.91
SCM 3.9% Coarse Agg. = 49.5% Fine Agg. (WW) = 22.6% Fine Agg. (WW) = 22.6% Coarse Agg. = 41.8% Water = 5.9%	W/(A4 = Paste Volume Fraction = Sch/(ZhEYT = Sand / Total Aggregate = Volumetric Distribut Cement = SCM = Conse Agg. = Fline Agg. (NW) = Fline Agg. (NW) = Fline Agg. (NW) = Alt = Water = Alt =	0.41 0.32 0.28 0.58 0.27 0.36 10.7% 3.4% 41.8% 11.2% 12.3% 13.9% 6.5% 0000		(Water LWater (Fractii (Ratio (Ratio Mix Propo	s mix water required) -Cement ratio, by weight] -Cement tatio, by weight] -Cement tatio, by aste (cer on of volume of paste (cer on of volume of paste (cer of sand to total aggregate, of sand to total aggregate, tritions - Volumetric Dis Conventional HPC	atios, by weight] itent, SCMs, and w: nent, SCMs, fine a pht] by volume] ttribution	ater) to total ba ggregate, wate	atch volume] r, and entrained a <u>Mix Pro</u> Fine Age. (LW)	ir) to total	Weight Di tional HPC Cement 14.3%	:] stribution	1SCM = 3.91
Coarse Age = 49.5% Fine Age (IW) = 1.26% Fine Age (IW) = 9.1% Water = 5.9%	W/GA = Paste Volume Fraction = SGM/CMENT = SGM/CMENT = Sand / Total Aggregate = Volumetric Distribu- Cement = SGM = Coarse Agg. = Fine Agg. (WW) = Fine Agg. (WW) = Fine Agg. (WW) = Ars = Weight Distribut Cement =	0.41 0.32 0.28 0.28 0.27 0.36		Uvater Uvater Fracti Fractio Ratio Mix Propo	Smik water required) -Cement ratio, by weight) -Cement ratio, by weight) -Cement ratio, by aster (cem on of volume of paster (cem of SCMs to Cement, by weight) of sand to total aggregate, of sand to total aggregate, etcome to total aggregate, conventional HPC Water e 5.5% Cement = 0.7%	atios, by weight] atios, by weight] tent, SCMs, and we ment, SCMs, fine a phi] by volume] tribution SCM = 3.4%	ater) to total baggregate, wate	stch volume) r, and entrained a <u>Mix Pro</u> Fine Agg. (LW)	ir) to total	Weight Di tional HPC Cement 14.3%	e] stribution	2SCM = 3.91
Fine Agg (WW) = 12.6% Fine Agg (WW) = 21.5% Water = 5.9% Coarse Agg = 41.5% Coarse Agg = 49.5%	W/G4 = Poste Volume Fraction = SCM/CMRNT = SCM/CMRNT = SCM/CMRNT = Connertic Distribut Connertic Distribut Conner & A Fine Age, (WW) = Fine Age, (WW) = Fine Age, (WW) = Air = Weight Distribut Cement = SCM =	0.41 0.32 0.28 0.58 0.27 0.36 10.7% 3.4% 41.8% 11.2% 12.3% 6.5% 6.5% ion: 14.3% 3.9%		Uvere Uvere (Fracti) (Fratio) (Ratio) Mix Propo	s mix water required) -cement ratio, by weight] -cement tatio, by weight] -cement tatio, by weight] -cement tation of the state of the state of solution of the state of the state of solution of the state of the state -conventional HPC	atios, by weight] tern, SCMs, and w enct, SCMs, fine a prof by volume]	ater) to total ba	itch volume) , , and entrained a <u>Mix Pro</u> Fine Agg. (UW)	ir) to total <u>cortions -</u> <u>Conven</u> = 5.9% = 26.4%	Weight Di Weight Di tional HPC Cement 14.3%	ej stribution	1SCM = 3.91
Fine Age (UM) = 9.1% Water = 5.9%	W/G4 = Paste Volume Fraction = SG//CMENT = SG//CMENT = Sand / Total Aggregate = Volumetric Distribut Coasse Agg. = Fine Agg.(W) = Fine Agg.(W) = Fine Agg.(W) = Agg.(W) = Moster = All = Coasse Agg. = SCM = Coasse Agg. =	0 41 0.12 0.22 0.28 0.58 0.57 0.36 0.27 0.23 0.23 0.27 0.23		(Water [Fracti [Fraction] [Fraction] [Fation] (Ration] Mix Propo	<pre>smik water required] -Cement ratio, by weight] -Cement ratio, by weight] -Cement ratio, by astel (cem on of volume of pastel (cem of SCMs to Cement, by weight) of sand to total aggregate, of sand to total aggregate, retions - Volumetric Dis Conventional HPC Voser s 55% Cement - 0.076 w) = 00000000000000000000000000000000000</pre>	atios, by weight) tern, SCMs, and we tern, SCMs, fine a http://wolumej trribution	ater) to total bi	Atch volume] r, and entrained e <u>Mix Pro</u> Fine Ag: (LW)	ir) to total	Weight Di tional HPC	e] stribution	2SCM = 3.91
Water = 5.9%	W/GA = Paste Volume Fraction = ScM/CMMN = Sand / Total Aggregate = Volumetric Distribut Cement = SCM = Coarse Agg = Fine Agg (LW) = Fine Agg (LW) = Fine Agg (LW) = Air = Weight Distribut Cement = ScM = Coarse Agg = Fine Agg (LW) =	0 41 0 42 0 22 0 28 0 27 0 36 0 27 0 36 0 38 0 27 0 36 0 38 0 38 0 42 0 38 4 1 28 4 1 28 4 1 28 4 1 28 4 1 28 5 55 6 555 0 001 1 4 39 5 3 955 4 9 555 1 2 655		Uvere Uvere (Fracti (Fracti) (Ratio) Mix Propo	- 226% Course Age - 2007	stlos, by weight] tent, SCMs, and we ent, SCMs, fine a nti by volume] tribution	ster) to total ba ggregate, wate	stch volume) r, and entrained a <u>Mix Pro</u> Fine Agg. (LW)	ir) to total portions - <u>Conven</u> = 5.9%	Weight Di tional HPC	e] stribution	2SCM = 3.91
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HPIC MIX CONVERSION (VOLUMETRIC DISTRIBUTION)



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TRIAL BATCH & TEST SLAB

- Demonstrate contractor capabilities and provide experience to contractor & Department.
- Same stockpile management, batching,
 delivery and placement, and acceptance
 testing methods on test slab as
 production deck.
- Separate contract pay item.





PRODUCTION & CONSTRUCTABILITY

Batching:

LWFA stockpile management (soaking & moisture adjustments)

➤ additional material needs to be batched

Same placement/finishing methods as HPC:

Comparable workability and placement

➢ Pumpable

➤ Slump

External Curing:

Reduced duration from 14 to 7 days possible





CONSTRUCTION PROCESS FLOW-CHART





DESIGN



- Minimal effect on concrete design properties
- Minor improvement in compressive strength
- Minor reduction in unit weight & modulus
 - Consider deck weight, girder camber, stiffness effects on design



EFFECTS ON PROJECT



- Designer additional effort:
 - > Confirm design properties
 - Incorporate guide specifications
 - Coordinate with local concrete plants

Construction Phase:

- Additional HPIC construction costs:
 - > new mix design and verification testing (25k)
 - trial batch & test slab (25k)
 - > unit cost for production (per CY) (+20-40% unit cost increase)
- Schedule additional 'up-front' construction duration: mix verification testing, trial batch, test slab (~6 months)

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1	HPIC Mix Design Submittal:	112	Consecutiv	2																																			
	a Mix Design Calculations & Development	7																																					
	Procure Materials	7																																					
	verification Batching	3																																					
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d	i Scaling Resistance (ASTM C672) [28-day specimen cure]	60																																					
d.	ii Freeze-Thaw Durability (ASTM C666) [14-day specimen cure]	70																																					
d.	ii Surface Resistivity (AASHTO T358) [56-day specimen cure]	56					+++	+++																+++						\square							\square	ЩЦ	
d.i	v Compressive Strength (AASHTO T22) [56-day specimen cure]	56																																					
	e Department Reviews HPIC Mix Design Submittal	21																																					
2	HPIC Test Slab (Subsequent to Activity 1)																																						
	a Contractor Submits HPIC Test Slab Plan																																				\square		
	Department Reviews HPIC Test Slab Plan																																						
	c Procure Materials																																						
	Site Preparation	2	Business																					+++													\square	ЩЦ	
	e HPIC Trial Batching & Slab Casting	1	Business																																				
	f Curing	14	Consecutiv	2																																13	2		
	g Acceptance Testing						+++	+++																													\square	ЩЦ	
6	i Surface Resistivty [56-day specimen cure]	56	Consecutiv																																		\square		
g	ii Compressive Strength [56-day specimen cure]	56	Consecutiv																																		\square		
	. Department Reviews/Accepts Test Slab	10	Business																																				

HPIC Submittal, Mix Design, Verification Testing, & Test Slab Schedule



NORTH MUNN AVE. OVER I-280

- FIRST PILOT PROJECT
- STATUS:
 - ➢ MIX DESIGN COMPLETE ✓
 - ➢ VERIFICATION BATCHING COMPLETE ✓
 - VERIFICATION TESTING (SURFACE RESISTIVITY, COMPRESSIVE STRENGTH, FLEXURAL STRENGTH, SHRINKAGE) - COMPLETE
 - > VERIFICATION TESTING (SCALING, FREEZE-THAW) PENDING...
 - > TRIAL BATCH & TEST SLAB PENDING...
 - > PRODUCTION PENDING...



CHALLENGES



- Costs Initial vs Life Cycle
- Specifications Restrictions
- Concrete Plants:
 - Experience and willingness to produce IC mixes
 - Concerns with restrictive HPC acceptance testing
- Materials Availability / Supply Chain:
 - > Ample availability, but coordination required
- Economy of Scale & Standardization
- Awareness/Education



NEXT STEPS..



- CONCRETE PLANT OUTREACH PROGRAM SUMMER 2025
- HPIC WORKSHOPS SUMMER 2025
- CENTRIFUGETRAINING PROGRAM FALL 2025
- UPDATE SPECIFICATIONS
- ASSESS PILOT PROJECTS
- MONITOR PERFORMANCE





TEAM EFFORT

- FHWA
- NJDOT:

CONSTRUCTION & MATERIALS
 BRIDGE ENGINEERING
 PROJECT MANAGEMENT
 CAPITAL PROGRAM SUPPORT

- RUTGERS
- HNTB
- INITIAL INVESTIGATIONS TO CONSTRUCTION WITHIN 2 YEARS





QUESTIONS?