



**US Army Corps
of Engineers®**
Engineer Research and
Development Center



Investigation of Materials for Charleroi Lock and Dam Monongahela River Reconstruction Project

Monica A. Ramsey and Cody M. Strack

May 2020



The U.S. Army Engineer Research and Development Center (ERDC) solves the nation's toughest engineering and environmental challenges. ERDC develops innovative solutions in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, the Department of Defense, civilian agencies, and our nation's public good. Find out more at www.erdclibrary.on.worldcat.org/discovery.

To search for other technical reports published by ERDC, visit the ERDC online library at <http://www.erdclibrary.on.worldcat.org/discovery>.

Investigation of Materials for Charleroi Lock and Dam Monongahela River Reconstruction Project

Monica A. Ramsey and Cody M. Strack

*Geotechnical and Structures Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199*

Final report

Approved for public release; distribution is unlimited.

Prepared for U.S. Army Corps of Engineers Pittsburgh District
Pittsburgh, PA 15222

Under MIPR W81ET491842462, Lower Monongahela River Navigation System
Feasibility Study

Abstract

The investigation described in this report was conducted for the U.S. Army Engineer District, Pittsburgh as part of a preliminary investigation of cementitious materials and concrete design pursuant to construction of Charleroi Lock and Dam Monongahela River Reconstruction Project. Local materials provided to the U.S. Army Engineer Research Development Center (ERDC) for testing included three different coarse aggregate gradations, two fine aggregate sources, a type II (MH) cement, four fly ash sources, a slag cement, a silica fume, a limestone powder, five admixtures, and two water sources. Aggregate tests consisted of sieve analysis, specific gravity, absorption, materials finer than No. 200, organic impurities, soundness, LA abrasion, clay lumps and friable particles, flat and elongated particles, lightweight particles, and petrography. All cementitious, admixtures, and water-source materials were tested for chemical and physical properties based on appropriate specifications. In addition, four mixture proportions developed by the ERDC for this project in 2005 were scaled to determine the early stiffening of mortar, freezing and thawing, and heat of hydration. This report presents the material characteristic results determined by laboratory testing in accordance with American Society for Testing and Materials procedures or regulating specification criteria.

DISCLAIMER: The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. All product names and trademarks cited are the property of their respective owners. The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

DESTROY THIS REPORT WHEN NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

Contents

Abstract.....	iii
Figures and Tables.....	vi
Preface	viii
1 Introduction	1
1.1 Background	1
1.2 Problem statement.....	1
1.3 Scope of work	1
2 Materials	3
3 Mixture Proportions.....	4
4 Aggregate Testing Analysis	5
4.1 Sieve analysis	5
4.2 Specific gravity and absorption	6
4.3 Materials finer than No. 200 sieve.....	6
4.4 Organic impurities	7
4.5 Soundness of aggregates	7
4.6 LA abrasion	8
4.7 Clay lumps and friable particles	8
4.8 Flat and elongated particles	9
4.9 Lightweight particles	9
5 Freezing and Thawing.....	11
5.1 Mixture proportions and test procedures	11
5.2 Calculations	13
5.3 Results	13
6 Petrography Analysis	16
6.1 Hanson aggregate	17
6.2 Shelly aggregate	18
6.3 Georgetown aggregate	19
7 Cementitious Analysis.....	21
7.1 Portland cement	21
7.2 Fly ash	23
7.3 Slag cement	25
7.4 Silica fume	26
7.5 Limestone powder	27
8 Early Stiffening of Mortar.....	29

9	Water Quality Test Results	31
10	Chemical Admixture Testing.....	32
10.1	Air entraining admixture (AEA).....	32
10.2	Retarding (RET) admixture.....	33
10.3	Water Reducing (WR) admixture	33
10.4	Anti-Washout (AW) admixture	34
10.5	High Range Water Reducing (HRWR) admixture	35
11	Heat of Hydration	37
12	Summary and Conclusions	40
	References.....	45
	Appendix A: Aggregate Test Results	48
	Appendix B: Freezing and Thawing Reports.....	55
	Appendix C: Petrography Data Tables and XRD Patterns.....	62
	Appendix D: Cementitious Material Reports.....	68
	Appendix E: Admixture Reports	75
	Appendix F: Water Quality Test Reports	80
	Unit Conversion Factors.....	91
	Report Documentation Page	

Figures and Tables

Figures

Figure 1. Durability factor and relative dynamic modulus with respect to number of freezing and thawing cycles.	15
Figure 2. Photomicrographs of different sieve sizes for Hanson aggregate.	17
Figure 3. Photomicrographs of different sieve sizes for Shelly sand aggregate.	18
Figure 4. Photomicrographs of different sieve sizes for Georgetown sand aggregate.	20
Figure 5. Visible settled solids in well water sample from left bank batch plant area.	31
Figure 6. Heat of hydration for mix 1, 5, 7, and 10 by fly ash at 7 and 28 days.	39
Figure C1. XRD pattern for Hanson with calculated weight percentages from whole pattern fitting.	63
Figure C2. XRD pattern for Shelly with calculated weight percentages from whole pattern fitting.	65
Figure C3. XRD pattern for Georgetown with calculated weight percentages from whole pattern fitting.	67

Tables

Table 1. Standard test methods used for materials tests.	2
Table 2. Materials for Charleroi L&D material testing.	3
Table 3. Concrete mixture designs for Charleroi L&D.	4
Table 4. Sieve analysis results of fine and coarse aggregates.	5
Table 5. Bulk specific gravity and absorption results of fine and coarse aggregates.	6
Table 6. Materials finer than No. 200 sieve results by percent.	7
Table 7. Organic impurities results of fine aggregates.	7
Table 8. Soundness of aggregates by cumulative percent loss.	8
Table 9. LA abrasion and impact results by percent of sample.	8
Table 10. Clay lumps and friable particles in aggregate results.	9
Table 11. Flat and elongated particle results by percent of sample.	9
Table 12. Lightweight particles in fine and coarse aggregates results.	10
Table 13. Concrete mixture proportions for freezing and thawing specimens.	11
Table 14. Freezing and thawing final results.	14
Table 15. Armstrong cement tested in accordance to ASTM C150.	22
Table 16. Fly ash results tested in accordance to ASTM C618.	23
Table 17. Argos-Essroc slag, grade 100 results tested in accordance to ASTM C989.	25

Table 18. Elkem grade 970D silica fume results tested in accordance to ASTM C1240.....	26
Table 19. Limestone powder analysis summary results.	28
Table 20. Early stiffening of Mix 1, 5, 7, and 10 tested in accordance to ASTM C359.	30
Table 21. Compressive strength results comparing control and AEA-92 concrete.....	32
Table 22. Water content, compressive strength, and time of setting results comparing control and Eucon RET-75 admixture in concrete.	33
Table 23. Water content, compressive strength, and time of setting results comparing control and Eucon WR admixture in concrete.	34
Table 24. Compressive strength and time of setting results of comparing control and Eucon AWA in concrete.....	35
Table 25. Water content, compressive strength, and time of setting results comparing control and Eucon 37 admixture in concrete.	36
Table 26. Batch quantities for heat of hydration in accordance to ASTM C1702.....	37
Table 27. Average heat of hydration results at 7 and 28 days.....	38
Table C1. Data table used in preparation of ASTM C-295 for the Hanson aggregate.	62
Table C2. Data table used in preparation of ASTM C-295 for the Shelley Sand aggregate.	64
Table C3. Data table used in preparation of ASTM C-295 for the Georgetown aggregate.	66

Preface

This study was conducted by U.S. Army Engineer Research and Development Center (ERDC) for the Corps of Engineers Pittsburgh District in Pittsburgh, PA, for Charleroi Lock Reconstruction project. The MIPR was W81ET491842462, Lower Monongahela River Navigation System Feasibility Study. The Pittsburgh District technical manager was Mr. Glenn W. Bush Jr.

The work was performed by the Concrete and Materials Branch (GMC) of the Engineering Systems and Materials Division (GM), U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory (ERDC-GSL). At the time of publication, Mr. Christopher M. Moore was Chief, GMC; Mr. Justin S. Strickler was Chief, GM; and Mr. R. Nicholas Boone, GZT, was the Technical Director for Force Projection and Maneuver Support. The Deputy Director of the ERDC GSL was Mr. Charles W. Ertle, and the Director was Mr. Bartley P. Durst.

COL Teresa A. Schlosser was the Commander of ERDC, and Dr. David W. Pittman was the Director.

1 Introduction

1.1 Background

The baseline design for the Charleroi Locks originated in 1991 from the Lower Monongahela River Navigation System Feasibility Study. The feasibility study evaluated the ability of Locks and Dams 2, 3, and 4 of the Monongahela River Navigation System to serve navigation interests through the year 2050. The conclusion of the study was to implement a “2 for 3” replacement known as “The Lower Mon Project.”

The Lower Mon Project consists of (a) replacement of the fixed-crest dam at Locks and Dam 2 with a gated dam to be renamed the Braddock Locks and Dam, (b) construction of twin 84-ft x 720-ft locks at Locks and Dam 4 to be renamed the Charleroi Locks and Dam, (c) removal of Locks and Dam 3 at Elizabeth; navigation dredging, and (d) relocation of adversely impacted public facilities. The combination of these features will allow for one 30.3-mile navigation pool between Braddock Locks and Dam and the Charleroi Locks and Dam.

1.2 Problem statement

The Charleroi Lock reconstruction began in 2002 with site development and has continued as funding has become available. The project uses government-designed concrete mixes developed in 2005 by the U.S. Army Engineer Waterways Experiment Station, later the Engineer Research and Development Center, in Vicksburg, MS, and produced at the left bank batch plant, a government-owned, contractor-operated batch plant located across the river from the lock chambers. However, original material reports were outdated, and there was no guarantee that the source materials were still capable of meeting project requirements. All cementitious and aggregate materials required retesting to appropriate specifications to ensure quality assurance for all proposed construction materials.

1.3 Scope of work

The objective of this study was to evaluate the properties of the materials proposed for use in the rehabilitation of the Charleroi Lock and Dam (L&D) Monongahela River in accordance to the standard test designations listed in Table 1.

Table 1. Standard test methods used for materials tests.

ASTM Designation	Description	Material
C 136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates	3 Coarse Aggregates 2 Fine Aggregates
C 127	Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate	3 Coarse Aggregates
C 128	Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate	2 Fine Aggregates
C 117	Standard Test Method for Materials Finer than (No. 200) Sieve	3 Coarse Aggregates 2 Fine Aggregates
C 40	Standard Test Method for Organic Impurities in Fine Aggregates for Concrete	2 Fine Aggregates
C 88	Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate	3 Coarse Aggregates 2 Fine Aggregates
C 131	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregates by Abrasion and Impact in the Los Angeles Machine	3 Coarse Aggregates
C 142	Standard Test Method for Clay Lumps and Friable Particles in Aggregates	3 Coarse Aggregates 2 Fine Aggregates
D 4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate	3 Coarse Aggregates
C 123	Standard Test Method for Lightweight Particles in Aggregate	3 Coarse Aggregates 2 Fine Aggregates
C 666	Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing	1 Coarse Aggregate 2 Fine Aggregates 1 Mixture Design
C 1271	Standard Test Method for X-ray Spectrometric Analysis of Lime and Limestone	1 Limestone Powder Source
D 546	Standard Test Method for Sieve Analysis of Mineral Filler for Asphalt Paving Mixtures	1 Limestone Powder Source
C 295	Standard Practices for Petrographic Examination of Aggregates for Concrete	3 Coarse Aggregates 2 Fine Aggregates
C 150	Standard Specification for Portland Cement	1 Type II(MH) Cement Source
C 359	Standard Test Method for Early Stiffening of Hydraulic Cement	4 Mixture Designs
C 618	Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete	4 Fly Ash Sources
C 989	Standard Specification for Slag Cement for Use in Concrete	1 Slag Source
C 1240	Standard Specification for Silica Fume	1 Silica Fume Source
C 1702	Standard Test Method for Measurement of Heat of Hydration Using Isothermal Conduction Calorimetry	4 Mixture Designs
C 494 C 260	Standard Specification for Chemical Admixtures For Concrete	5 Admixtures
CRD-C 400	Water for mixing and curing	2 Water Sources

2 Materials

Candidate project materials including cements, pozzolans, and aggregates were chosen by the Pittsburgh District. The source materials were marketed in the vicinity of the proposed project location. Table 2 identifies the materials included in this study. ERDC tested all materials in accordance to the ASTM requirements referenced in the table for validation.

Table 2. Materials for Charleroi L&D material testing.

Material	Manufacturer	Location	CMB #	Testing Validation
Type II(MH) Cement	Armstrong	Cabot, PA	150063	ASTM C150
Class F Fly Ash	Headwaters Resources, Ft. Martin	Maidsville, WV	150064	ASTM C618
	Headwaters Resources, W. H. Sammis	Stratton, OH	150065	
	Separation Technologies, Longview	Maidsville, WV	180005	
	Separation Technologies, Brandon Shores	Curtis Bay, MD	180018	
Slag Cement, Grade 100	Argos-Essroc-Lehigh	Middlebranch, OH	150066	ASTM C989
Limestone Powder	Graymont	Bellefonte, PA	150067	ASTM C1271 ASTM D546 ASTM D242
Silica Fume	Elkem Materials	Pittsburgh, PA	150068	ASTM C1240
¾-inch Coarse Aggregate	Hanson Quarry	Connellsville, PA	150070	ASTM C40 ASTM C88 ASTM C117 ASTM C127/128 ASTM C131 ASTM C136 ASTM C142 ASTM D4791 ASTM C123
1 ½-inch Coarse Aggregate			150071	
3-inch Coarse Aggregate			150072	
Fine Aggregates	Georgetown	Georgetown, PA	150069	
	Shelly	Reedsville, OH	160004	
AEA-92 Admixture	Euclid	Cleveland, OH	150073	ASTM C494
Retarder 75 Admixture			150074	
WR Admixture			150075	
AW Admixture			150076	
HRWR Admixture, 37			150077	
Municipal Water	-	Charleroi Municipal Water Authority	150088	CRD-C 400
Well Water	-	Left Bank Batch Plant	150089	CRD-C 400

3 Mixture Proportions

The composition of the concrete mixture proportions developed by ERDC for the Pittsburgh District in 2005 named Mix 1, Mix 5, Mix 7, and Mix 10 are detailed in Table 3. Certain test methods presented in this report including the early stiffening of mortar, freezing and thawing, and heat of hydration testing scaled batch proportions based on these mixture proportions.

Table 3. Concrete mixture designs for Charleroi L&D.

Material	Batch Quantities			
	Mix 1	Mix 5	Mix 7	Mix 10
	Typical Shaft Tremie Concrete	Interior Mass Concrete	Exterior Mass Concrete	General Purpose Concrete
Cement (lb/yd)	167	191	253	495
Class F Fly Ash (lb/yd)	158	75	139	165
GGBFS (lb/yd)	367	87	69	0
Silica Fume (lb/yd)	29	0	0	0
Limestone Powder (lb/yd)	155	0	0	0
$\frac{3}{4}$ -in. Coarse Aggregate (lb/yd)	1,323	739	1,129	1,720
$1\frac{1}{2}$ -in. Coarse Aggregate (lb/yd)	0	747	935	0
3-in. Coarse Aggregate (lb/yd)	0	1,000	0	0
Fine Aggregate (lb/yd)	1,409	958	1,141	1,239
Potable Water (lb/yd)	303	183	213	258
Air Entraining Admixture (fl oz/yd)	0	8	16	7
Water Reducing Admixture (fl oz/yd)	0	0	0	0
High Range Water Reducing Admixture (fl oz/yd)	138.1	0	0	12
Retarding Admixture (fl oz/yd)	30.1	7	7	7
Anti-Washout Admixture (fl oz/yd)	97.2	0	0	0

4 Aggregate Testing Analysis

Two sources of natural sand and three gradations of limestone coarse aggregates were tested in accordance with ASTM procedures presented in this section. Aggregate quality requirements were based on the Charleroi construction specifications (USACE Pittsburgh District 2015). Further aggregate report details can be found in Appendix A.

4.1 Sieve analysis

The gradation results for aggregates tested in accordance to ASTM C136 (ASTM 2016c) are presented in Table 4.

Table 4. Sieve analysis results of fine and coarse aggregates.

Nominal Size (Sieves with Square Openings)	Gradations of aggregates by cumulative % passing									
	Hanson Quarry 3-inch Aggregate		Hanson Quarry 1½-inch Aggregate		Hanson Quarry ¾-inch Aggregate		Georgetown Natural Sand		Shelley Natural Sand	
	Test Results	Charleroi Spec. Limits	Test Results	Charleroi Spec. Limits	Test Results	Charleroi Spec. Limits	Test Results	Charleroi Spec. Limits	Test Results	Charleroi Spec. Limits
4-in.	100	100	-	-	-	-	-	-	-	-
3-in.	92	90-100	-	-	-	-	-	-	-	-
2½-in.	66	-	-	-	-	-	-	-	-	-
2-in.	20	20-55	100	100	-	-	-	-	-	-
1½-in.	1	0-10	83	90-100	-	-	-	-	-	-
1-in.	0	0-5	16	20-45	100	100	-	-	-	-
¾-in.	0	-	3	0-10	97	90-100	-	-	-	-
½-in.	-	-	-	-	46	-	-	-	-	-
3/8-in.	-	-	0	0-5	17	20-55	100	100	100	100
No. 4	-	-	-	-	4	0-10	98	95-100	99	95-100
No. 8	-	-	-	-	1	0-5	86	80-95	88	80-95
No. 16	-	-	-	-	-	-	74	60-80	77	60-80
No. 30	-	-	-	-	-	-	55	35-60	57	35-60
No. 40	-	-	-	-	-	-	33	-	30	-
No. 50	-	-	-	-	-	-	14	15-30	12	15-30
No. 100	-	-	-	-	-	-	2	5-10	2	5-10
No. 200	-	-	-	-	-	-	0	0-3	0	0-3

The coarse and fine aggregates met all grading requirements with the following exceptions:

- The Georgetown natural sand resulted in 14% passing the #50 sieve (15-30% criteria) and 2% passing the #100 sieve (5-10% criteria).
- The Shelly natural sand resulted in 12% passing the #50 sieve (15-30% criteria) and 2% passing the #100 sieve (5-10% criteria).
- The 1½-in. Hanson aggregate resulted in 83% passing the 1½-in. sieve (90 to 100% criteria) and 16% passing the 1-in. sieve (20 to 55% criteria).
- The ¾-in. Hanson aggregate resulted in 17% passing the ¾-in. sieve (20 to 55% criteria).

4.2 Specific gravity and absorption

The bulk specific gravity at the saturated, surface-dry condition and absorption for the coarse and fine aggregates were tested in accordance with ASTM C127 (ASTM 2015a) and C128 (ASTM 2015b), respectively. Specific gravity and absorption results are provided in Table 5. All aggregates met the limiting criteria of specific gravity (minimum 2.55 for fine aggregates and 2.63 for coarse aggregates) and absorption (maximum 2% for fine aggregates and 3% coarse aggregates) as defined in project specifications.

Table 5. Bulk specific gravity and absorption results of fine and coarse aggregates.

Property	Hanson 3-in.	Hanson 1½-in.	Hanson ¾-in.	Georgetown Sand	Shelley Sand
Bulk specific gravity (SSD)	2.69	2.68	2.67	2.62	2.60
Absorption, %	0.42	0.44	0.61	1.4	1.7

4.3 Materials finer than No. 200 sieve

The amount of material finer than a No. 200 sieve by washing was determined in accordance to ASTM C117 (ASTM 2017a). Procedure A (water only) was used to disperse clay and other particles from the aggregates during the test. The results of the percentage of the material finer than the No. 200 sieve contained in the fine aggregate are provided in Table 6. The limiting criteria based on project specifications is 3% maximum for fine aggregates and 1% maximum for coarse aggregates. The Hanson 1½- and 3-in. coarse aggregates exceeded this criteria with 1.05% and 1.01%, respectively.

Table 6. Materials finer than No. 200 sieve results by percent.

Aggregate	Percent finer than No. 200 sieve
Hanson ¾-in. Aggregate	0.73
Hanson 1½-in. Aggregate	1.05
Hanson 3-in. Aggregate	1.05
Shelley Sand	0.6
Georgetown Sand	0.9

4.4 Organic impurities

Fine aggregates were tested in accordance with ASTM C40 (ASTM 2016b) to quantify if injurious amounts of organic impurities are present in the aggregate sample. This test procedure exposes material to a sodium hydroxide solution (NaOH) that releases color, which is then compared to five glass color standards. The five color standards correlate to an organic plate No. 1-5 with 3 being the standard. If a sample is darker than the standard color, i.e. No. 3, the fine aggregate is considered to possibly contain injurious organic impurities. The organic plate No. results shown in Table 7 indicate that both sands do not contain organic impurities at a concentration great enough to warrant further testing at this time.

Table 7. Organic impurities results of fine aggregates.

Aggregate	Organic Plate No.
Shelly Sand	2
Georgetown Sand	2

4.5 Soundness of aggregates

The preliminary estimate of the soundness of aggregates proposed for project usage were tested in accordance to ASTM C88 (ASTM 2018b). Aggregates were immersed in a magnesium sulfate solution to simulate severe weathering conditions. The maximum allowable limits for soundness suggested in ASTM C33 (ASTM 2016a) is 18% for all weathering conditions. Cumulative percent loss results given in Table 8 reveal all aggregates fall below this criteria.

Table 8. Soundness of aggregates by cumulative percent loss.

Aggregate	Cumulative percent loss
Hanson ¾-in. Aggregate	1.2
Hanson 1½-in. Aggregate	5.3
Hanson 3-in. Aggregate	0.5
Shelley Sand	10.6
Georgetown Sand	8.2

4.6 LA abrasion

The resistance to degradation of small-size coarse aggregates by abrasion was tested in accordance to ASTM C131 (ASTM 2014a). This method uses a Los Angeles (LA) machine to expose aggregates to a combination of actions including abrasion, impact, and grinding in a rotating steel drum that contains a specified number of steel spheres. The drum rotates at a constant rate while the shelf inside the drum picks up the sample and steel spheres and drops them. Five hundred revolutions of the testing machine were used. Loss by abrasion and impact is reported by percent of the sample mass in Table 9. All aggregates met the abrasion project specification requirement of less than 40% loss.

Table 9. LA abrasion and impact results by percent of sample.

Small-Size Coarse Aggregate	Loss (%)
Hanson ¾-in. Aggregate	22.1
Hanson 1½-in. Aggregate	22.5
Hanson 3-in. Aggregate	11.6

4.7 Clay lumps and friable particles

The approximate determination of clay lumps and friable particles in potential project aggregates were in accordance to ASTM C142 (ASTM 2017c). The percent clay lumps and friable particles reported in Table 10 are less than the limiting criteria (1.2% for fine aggregate and 2% for coarse aggregate) given in the project specifications.

Table 10. Clay lumps and friable particles in aggregate results.

Aggregate	Clay Lumps and Friable Particles (%)
Hanson ¾-in. Aggregate	0.1
Hanson 1½-in. Aggregate	0.1
Hanson 3-in. Aggregate	0.1
Shelley Sand	0.3
Georgetown Sand	0.1

4.8 Flat and elongated particles

The percentage of flat particles, elongated particles, or flat and elongated particles in coarse aggregates were tested in accordance to ASTM D4791 (ASTM 2010). The original procedure presented in the standard Method A was used for non-Superpave applications. Individual particles of aggregates of specific sieve sizes were measured with a caliper device set at a 3:1 ratio to determine the ratios of width to thickness, length to width, and length to thickness. The flat and elongated particle results by percent of sample provided in Table 11 are less than the 12% maximum limiting criteria defined in the project specification.

Table 11. Flat and elongated particle results by percent of sample.

Aggregate	Percent of Sample
Hanson ¾-in. Aggregate	0.0
Hanson 1½-in. Aggregate	8.0
Hanson 3-in. Aggregate	9.8

4.9 Lightweight particles

The amount of lightweight material in fine and coarse aggregates were tested in accordance with ASTM C123 (ASTM 2017b). Zinc bromide (2.4 specific gravity) was used to determine chert and shale content and zinc chloride (2.0 specific gravity) was used to separate particles that may be classified as coal or lignite. The maximum allowable chert and shale content defined in project specifications is 10% for fine aggregates and 5% for coarse aggregates. The maximum allowable coal and lignite particles is 1% for fine aggregates and 0.5% for coarse aggregates. The percentage of lightweight particles results are given in Table 12. All

aggregates met the limiting criteria with the exception of the 1.2% coal and lignite content in the Georgetown sand.

Table 12. Lightweight particles in fine and coarse aggregates results.

Lightweight Particle	Heavy Liquid	Aggregate				
		Shelley Sand	Georgetown Sand	Hanson $\frac{3}{4}$ -inch	Hanson 1½-in. Aggregate	Hanson 3-in. Aggregate
Chert and Shale	Zinc Bromide (2.4 Specific Gravity)	1.1	1.2	1.5	0.4	0
Coal and Lignite	Zinc Chloride (2.0 Specific Gravity)	0.7	1.2	0	0	0

5 Freezing and Thawing

The freezing and thawing durability of one project coarse aggregate (Hanson), two project natural sand fine aggregates (Shelly and Georgetown), and one project mixture design (Mix 7) were determined in accordance to Procedure A of ASTM C666 (ASTM 2015d). In this method, specimens were frozen in water and cycled between 4 and -18°C in 2-hr intervals until the specimens reached 300 cycles of freezing and thawing. Further report details can be found in Appendix B.

5.1 Mixture proportions and test procedures

Freezing and thawing test specimens were prepared from the mixture proportion of materials detailed in Table 13.

Table 13. Concrete mixture proportions for freezing and thawing specimens.

			Weight at SSD, (lb/yd ³)			
Mixture Constituent	Source	CMB ID	Hanson	Shelly	Georgetown	Mix 7
Type II(MH) Cement	Armstrong	150063	563	563	563	253
Class F Fly Ash	Headwaters Resources, Sammis Power Plant	150065	-	-	-	139
Slag Cement	Argos-Essroc	150066	-	-	-	69
Coarse Aggregate	Hanson	150070	1,874	-	-	2,064
	Calera (Control)	140040	-	1,937	1,935	-
Fine Aggregate	Arkadelphia (Control)	160142	1,158	-	-	-
	Shelly	160004	-	1,163	-	-
	Georgetown	150069	-	-	1,160	1,141
Admixture	Eucon AEA 92	150073	1.8 (fl oz)	2.7 (fl oz)	1.7 (fl oz)	1.4 (fl oz)
	Eucon 75 Retarder	150074	-	-	-	0.7 (fl oz)
Water	Vicksburg, MS Municipal		276	265	270	-
	Charleroi, PN Municipal		-	-	-	213

The specimens for the Hanson, Shelley, and Georgetown project aggregates were fabricated by the ERDC under laboratory conditions. The exterior mass concrete specimen beams for Mix 7 were prepared in the field by the USACE Pittsburgh District and shipped to the ERDC laboratory for testing.

Mixes conducted by ERDC were performed in a drum type mechanical mixer. First, half of the mixing water was mixed with coarse aggregate and air entraining admixture for 30 sec. The sand was then added and mixed for 15 sec. Finally, the cement and remaining mixing water was added and mixed in accordance to the standard ASTM C192 (ASTM 2016d) mixing sequence. The freshly mixed concrete was tested for the air content and slump were tested according to ASTM C143 (ASTM 2015c) and C231 (ASTM 2017d) respectively. The dosage of the air entraining agent was adjusted to obtain an air content of $6 \pm 1/2$ percent and a slump of $2-1/2 \pm 1/2$ in. Triplicate 3-in. x 4-in. x 16-in. beam specimens were fabricated using steel molds. After casting, the specimen were stored in their molds covered with plastic sheets at 23°C, 100% RH environmental conditions for 24 hr. The specimens were then demolded and cured in the same environmental conditions for 14 days before being subjected to the freeze-thaw cycle testing.

Test specimens were then placed in rectangular steel cans and surrounded by water. Freezing and thawing was accomplished by alternately circulating cold and warm antifreeze solutions around the steel cans. Each freezing and thawing cycle was carried out in approximately 2-hr intervals. The specimen chamber was cycled between 4 and -18°C in 2 hr, so that 12 complete freezing-and-thawing cycles were executed in 24 hr. Specimens were removed from the freezing and thawing apparatus approximately every 3 days, and resonant frequency and mass determinations were made until the test specimen reached 300 cycles of freezing and thawing.

5.2 Calculations

The relative dynamic modulus of elasticity, P_c , is defined by the following equation.

$$P_c = \frac{(n_1)^2}{(n)^2} \times 100$$

where

P_c = relative dynamic modulus of elasticity after c cycles of freezing and thawing, percent

n = fundamental transverse frequency at 0 cycles of freezing and thawing

n_1 = fundamental transverse frequency after c cycles of freezing and thawing

The durability factor, DF, is defined by the following equation.

$$DF = \frac{P \times N}{M}$$

where

DF = durability factor of the test specimen

P = relative dynamic modulus of elasticity at N cycles, percent

N = number of cycles at which P reaches the specified minimum value for discontinuing the test or the specified number of cycles at which the exposure is to be terminated, whichever is less

M = specified number of cycles at which the exposure is to be terminated. For the tests conducted on these specimen, the M was continued only up to 300 cycles

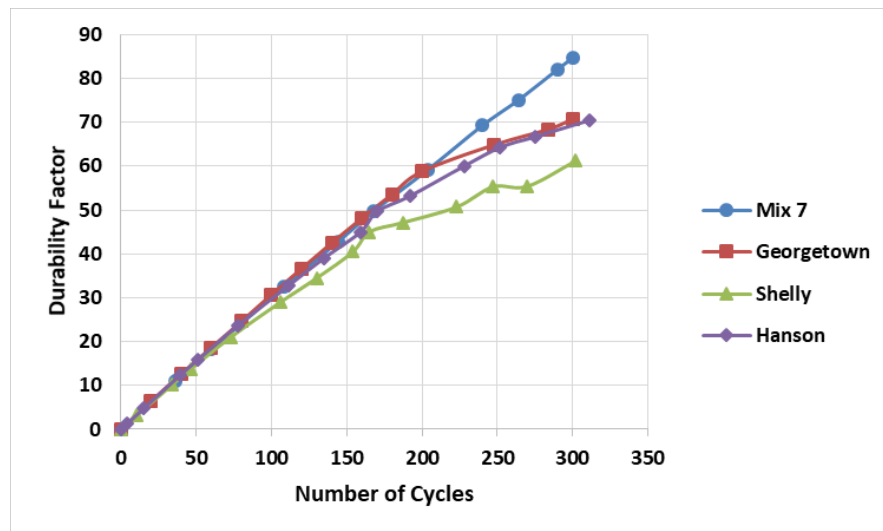
5.3 Results

The average weight change, relative dynamic modulus, and durability factor at the final freeze-thaw cycle duration are summarized in Table 14 and illustrated in Figure 1. The durability factors ranged from a minimum of 61 to a maximum of 85. Overall, the relative dynamic modulus of elasticity stayed above 60% for all test specimen throughout the 300 cycles of freezing and thawing.

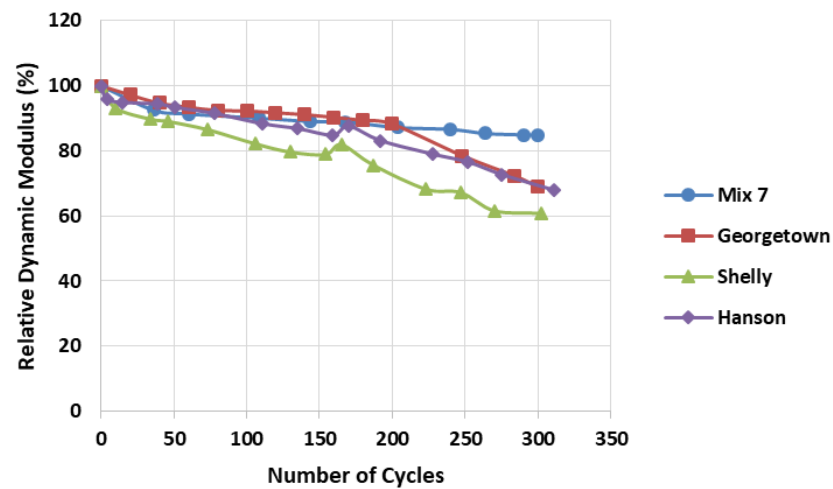
Table 14. Freezing and thawing final results.

Mixture ID	# Cycles	Mass Loss (%)	Relative Dynamic Modulus (%)	Durability Factor
Hanson	311	2.49	68	70
Shelly	302	2.44	61	61
Georgetown	300	1.39	69	69
Mix 7	300	1.06	85	85

Figure 1. Durability factor and relative dynamic modulus with respect to number of freezing and thawing cycles.



(a) Durability factor with respect to number of cycles.



(b) Relative dynamic modulus of elasticity with respect to number of cycles.

6 Petrography Analysis

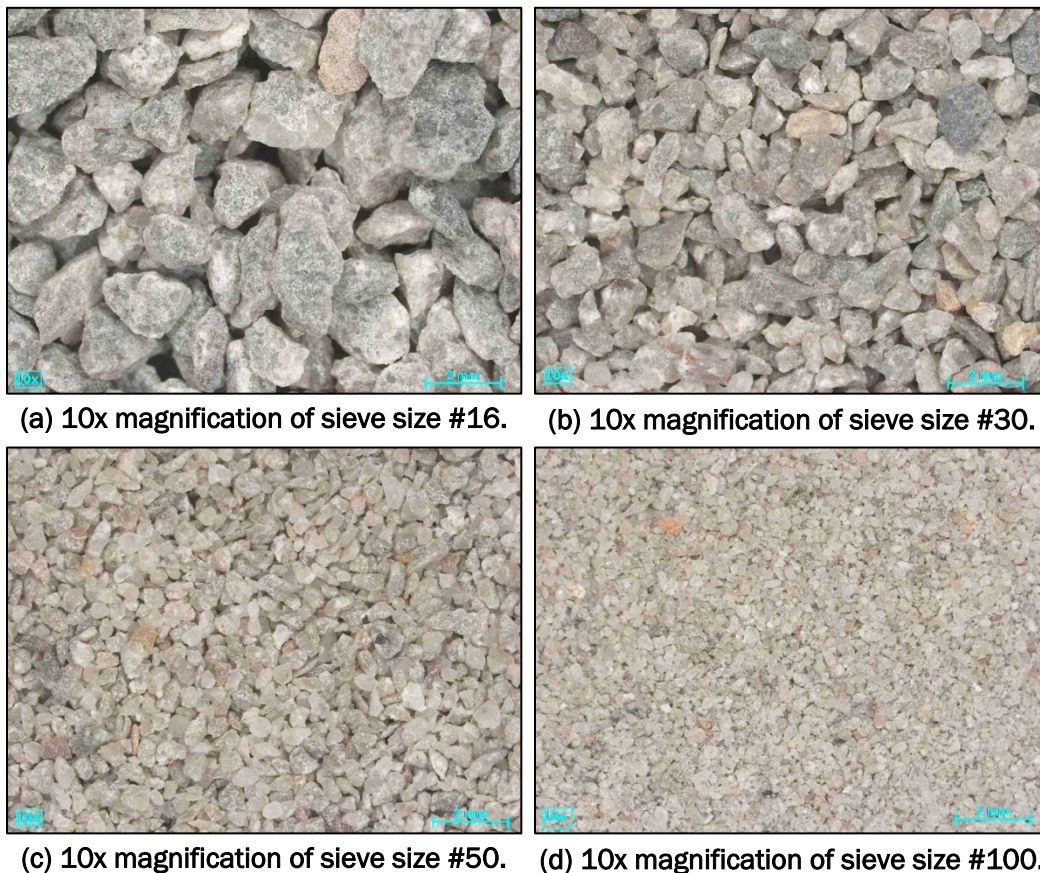
Petrographic examination of three aggregates was performed according to the method described in ASTM C295 (ASTM 2017e) “Standard Practices for Petrographic Examination of Aggregates for Concrete.” Along with the petrographic examination, X-ray diffraction was performed on the samples to identify the mineralogical composition of the received aggregate. The three samples were Georgetown, Hanson, and Shelly aggregates. They were ascribed CMB ID numbers of 150069, 150070, and 160004, respectively. Data associated with these aggregates are presented in Appendix C.

Each sieve size was examined with a petrographic microscope and photographed under a stereo-microscope. The ASTM requires 150 counts per sieve size; 300 particles were counted in this study to account for mineralogical variation. Samples were grouped into categories based on mineralogy and extent of weathering. The mineralogy of the sample was determined using X-ray diffraction (XRD) analysis. In preparation for XRD analysis, a portion of the sample was ground in a Pulverisette (Fritsch Co., Idar-Oberstein, Germany) and passed through a 45- μm (No. 325) sieve. Random orientation powder mounts of bulk samples were analyzed using XRD to determine the mineral constituents present in each sample. XRD patterns were gathered from an X-Pert Pro Multipurpose Powder Diffractometer system that used standard techniques for phase identification (Malvern Panalytical Inc.). The run conditions included Co-K α radiation and scanning from 2 to 70 $^{\circ}2\theta$ at a step size of 0.02 $^{\circ}2\theta$ and an accelerating voltage of 45 kV and 40 mA with collection of the diffraction patterns accomplished using the PC-based Windows version of X-Pert Pro Data Collector, and analysis of the patterns using the Jade2010 program (Materials Data Inc.)

6.1 Hanson aggregate

The Hanson aggregate (Figure 2) was composed almost entirely of crushed siliceous limestone. The grains were noticeably crystalline with euhedral faces. Some grains exhibited an orangey stain. Inclusions of other minerals such as muscovite were present, yet rare. The aggregate did not appear to be heavily affected by weathering; the particles were crystalline and dense.

Figure 2. Photomicrographs of different sieve sizes for Hanson aggregate.

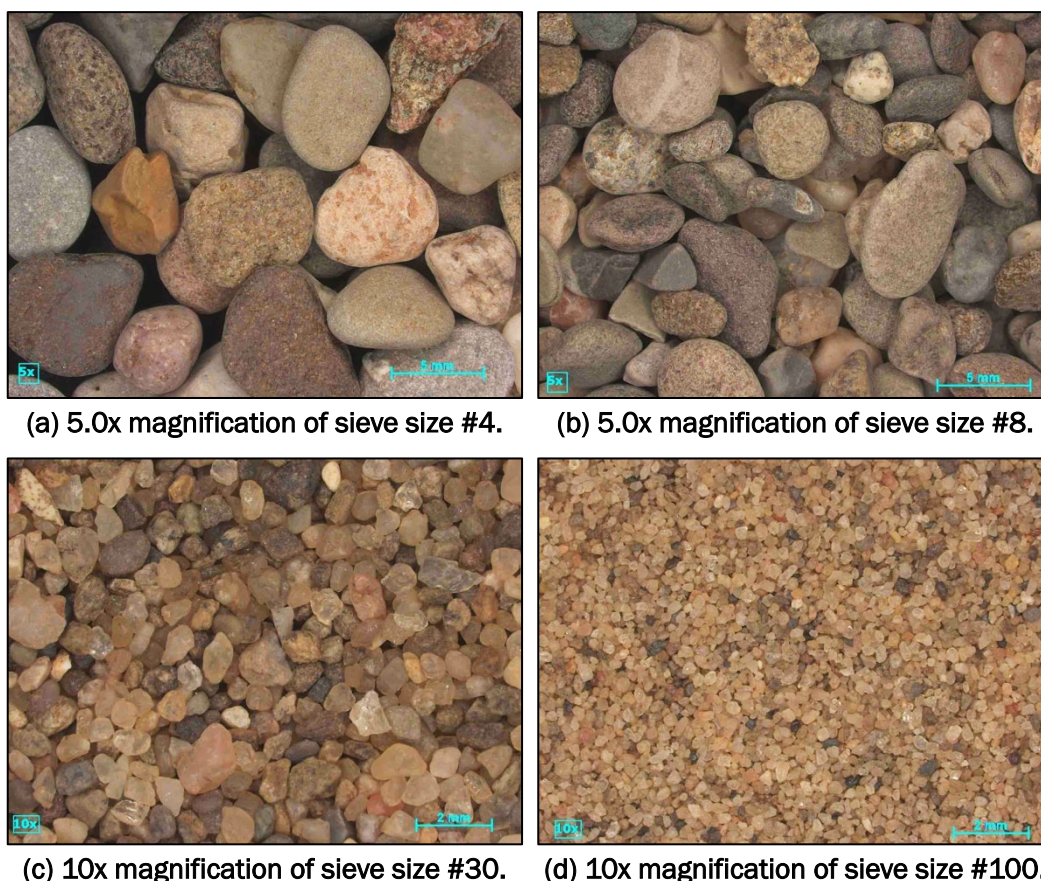


The X-ray diffraction pattern obtained for this sample was used to identify and confirm the mineral constituents present in the aggregate. Calcite (CaCO_3) (55.7 percent), Quartz (SiO_2) (37.7%), micas Biotite ($\text{K}(\text{Mg,Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (5.1%), and Muscovite ($\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (1.5%) were present.

6.2 Shelly aggregate

The Shelly aggregate (Figure 3) was dominated by three separate lithologies, i.e., monomineralic quartz (A), sandstone/granite (B), and limestone (C). The quartz portion varied in shape ranging from angular to round. Its color was also variable exhibiting orangey and purple hues in the crystals indicating some impurity in the quartz. Lithology B ranged from quartz-rich sandstone to variations of granite evident by feldspars being present. The microcrystalline nature of these rocks made distinguishing their exact rock type difficult at the applied magnifications. It exhibited a sub-round to round shape. Lithology C was a limestone, often weathered as indicated by dissolution textures.

Figure 3. Photomicrographs of different sieve sizes for Shelly sand aggregate.



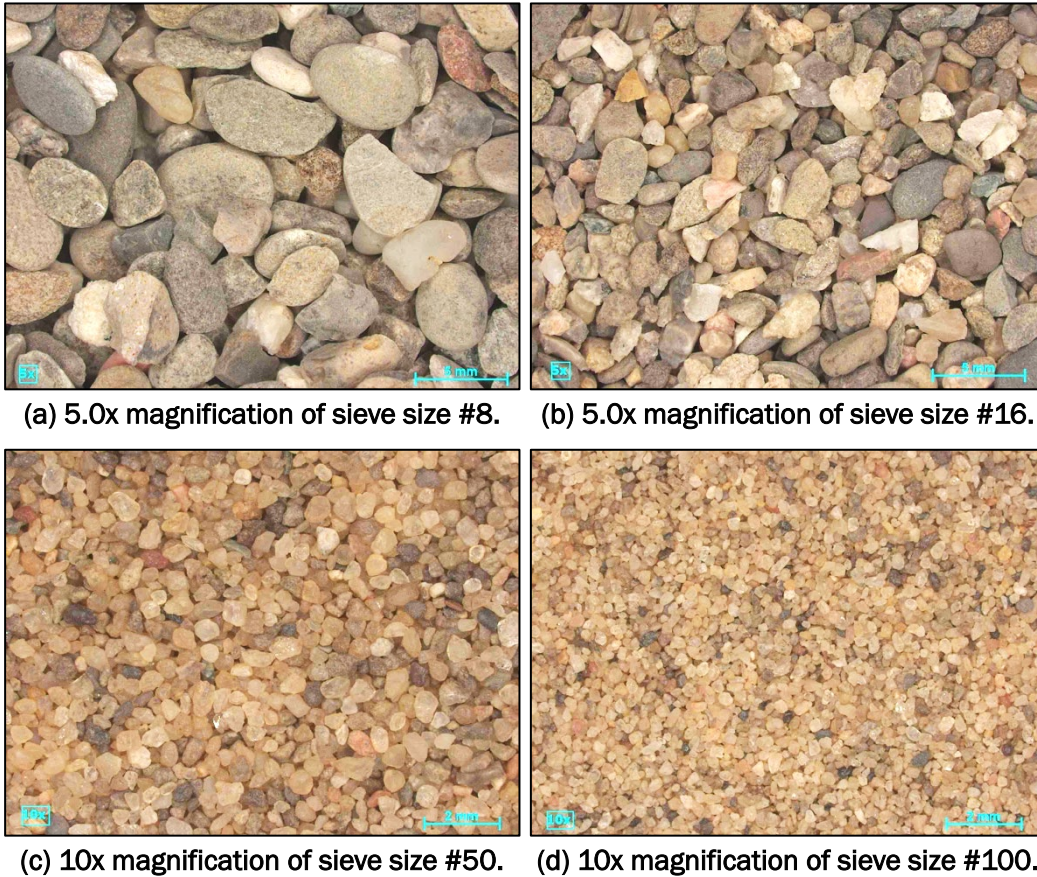
The X-ray diffraction pattern obtained for this sample was used to identify and confirm the mineral constituents present in the aggregate, i.e., Quartz (SiO_2) (69.0%), Albite ($\text{Na(AlSi}_3\text{O}_8)$) (14.0%), Graphite (C) (6.2%), Calcite (CaCO_3) (4.4%), micas Biotite

(K(Mg,Fe)₃(AlSi₃O₁₀)(F,OH)₂) (5.8%), and Muscovite (KAl₂(AlSi₃O₁₀)(F,OH)₂)) (0.7%).

6.3 Georgetown aggregate

The Georgetown aggregate (Figure 4) consisted of three main lithologies, i.e., monomineralic quartz (A), sandstone/granite (B), and limestone (C). The quartz ranged from angular to round with variations in luster from opaque to translucent. An orangey coating was present on some grains. Inclusions and heterogeneities were present but rare. Lithology B consisted of microcrystalline quartz among other minerals, thus distinguishing between sandstone and granite was difficult. The crystals were often cemented together. Grains were round to sub-round and oxidized evident by the orangey coating. The limestone was heavily weathered, evident by the dissolution textures and porosity seen in the grains. Some of the grains had macroscopic fossils.

Figure 4. Photomicrographs of different sieve sizes for Georgetown sand aggregate.



The X-ray diffraction pattern obtained for this sample was used to identify and confirm the mineral constituents present in the aggregate, i.e., Quartz (SiO_2) (70.1%), Albite ($\text{Na(AlSi}_3\text{O}_8)$) (16.0%), Calcite (CaCO_3) (5.6%), micas Biotite ($\text{K(Mg, Fe)}_3(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (5.2%), and Muscovite ($\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (3.2%).

7 Cementitious Analysis

Potential cementitious project materials were provided to the ERDC for compliance testing in accordance to the Charleroi L&D specifications. This section provides result summaries of each cementitious material tested. Additional test reports can be found in Appendix D.

7.1 Portland cement

A type II (MH) cement produced by Armstrong in Cabot, PA, was tested in accordance to ASTM C150 (ASTM 2018c). The chemical analysis included a calculation of the equivalent alkalies content to determine low-alkali (LA) cement criteria. The heat of hydration (HH) and false set (FS) optional physical requirements as specified in table 4 of ASTM C150 were also tested. A summary of the chemical and physical properties are given in Table 15. The Armstrong cement met all ASTM C150 specification requirements for a Type II (MH) cement and was in compliance with the LA, FS, and HH criteria required by the Charleroi L&D specifications.

Table 15. Armstrong cement tested in accordance to ASTM C150.

Chemical Analysis	Test Results	Spec Limits
SiO ₂ , %	20.48	-
Al ₂ O ₃ , %	4.59	6.0% max
Fe ₂ O ₃ , %	6.3	^A 6.0% max
CaO, %	62.7	-
MgO, %	1.24	6.0% max
SO ₃ , %	2	3.0% max
Na ₂ O, %	0.13	-
K ₂ O, %	0.66	-
Equivalent Alkalies-total as Na ₂ O, %	0.56	^B 0.60% max
Loss on ignition, %	0.45	3.0% max
Tricalcium silicate (C ₃ S)	54	-
Dicalcium silicate (C ₂ S)	18	-
Tricalcium aluminate (C ₃ A)	2	8
Tetracalcium aluminoferrite (C ₃ AF)	19	-
Sum of C ₃ S +4.75C ₃ A	63.5	100
Physical Analysis	Test Results	Spec Limits
Air content (%)	7.9	12% max
Surface area (m ² /kg)	329	260 min
Autoclave expansion (%)	0.02	0.80% max
Initial set by Vicat (minutes)	155	45 min
Final set by Vicat (minutes)	290	375 max
Compressive strength, 3 day (psi)	1,525	^C 1,020 psi min
Compressive strength, 7 day (psi)	1,920	^C 1,740 psi min
Compressive strength, 28 day (psi)	4,175	^D 3,190 psi min
Heat of Hydration, 3 days (J/g)	185	^D 255 J/G max
Heat of Hydration, 7 days (J/g)	240	-
Heat of Hydration, 28 days (J/g)	330	-
False set (%)	80	50% min

^A Does not apply when heat of hydration limit in Table 4 is specified^B Limit in Table 2 for low-alkali cement^C Required only when optional heat of hydration in Table 4 is specified^D As specified in Table 4 optional physical requirements

7.2 Fly ash

Class F fly ashes from four sources were tested in accordance to ASTM C618 (ASTM 2017h) “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.” Two fly ashes produced by Headwaters Resources (Sammis plant located in Stratton, OH, and Fort Martin plant located in Maidsville, WV) were initially submitted for evaluation. However, both plants closed almost simultaneously in the fall of 2017. Two other sources of fly ash produced by Separation Technologies (Longview Plant in Maidsville, WV, and Brandon Shores Plant in Curtis Bay, MD) were then submitted for compliance testing. Chemical and physical analysis results of the four fly ashes are detailed in Table 16.

Table 16. Fly ash results tested in accordance to ASTM C618.

Chemical Analysis					
Component	Sammis Fly Ash	Ft. Martin Fly Ash	Longview Fly Ash	Brandon Shores Fly Ash	Spec Limits
SiO ₂ , %	44.2	52.6	50.81	45.95	-
Al ₂ O ₃ , %	20.2	22.5	21.75	22.42	-
Fe ₂ O ₃ , %	24.2	13.5	15.64	21.49	-
Sum, %	88.6	88.6	88.2	89.86	70.0% min
Na ₂ O, %	2.87	2.49	0.62	0.45	-
K ₂ O, %	2.05	2	2.36	1.85	-
CaO, %	0	1.1	3.37	2.64	-
MgO, %	0.9	0.9	1.07	0.79	-
SO ₃ , %	0.6	0.3	0.92	0.82	5.0% max
Loss on Ignition, %	2.99	3.1	1.9	2	6.0% max
Moisture Content, %	0.11	0.13	0.13	0.3	3.0% max
Physical Analysis					
Property	Sammis Fly Ash	Ft. Martin Fly Ash	Longview Fly Ash	Brandon Shores Fly Ash	Spec Limits
Strength Activity % 7 day	71	64	68	77	^A 75% min
Strength Activity % 28 day	72	65	78	76	^A 75% min
Water Requirement, %	100	100	99	98	105% max
Specific Gravity	2.6	2.52	2.34	2.41	5% max
Soundness, %	0.001	0.001	-0.03	-0.06	0.8% max
Fineness, %	25.92	23.85	38.6	19.12	34% max
Increase of drying shrinkage at 28 days	0.05	0.001	0.01	0.01	-
Uniformity Requirement, amount of Vinsol	0.2	0.2	0.16	0.15	-

^A Meeting the 7 day or 28 day strength activity index will indicate specification compliance. Armstrong Type II (MH) project cement was used for reference cement for strength activity index tests.

Only the Brandon Shores fly ash met all physical requirements of ASTM C618. The Sammis fly ash fell below the 75% minimum strength activity requirement at 7 and 28 days with results of 71% and 72%, respectively. Similarly the Fort Martin fly produced a strength activity index of 64% at 7 days and 65% at 28 days. The Longview fly ash failed at 7 days with 68% strength activity index and also exceeded the 34% fineness allowed on a #325 sieve with 38.6% retained.

Table 2 of ASTM C618 notes the strength activity index with portland cement is not to be considered a measure of the compressive strength of concrete containing the fly ash. The mass of fly ash specified for the test to determine the strength activity index with portland cement is not considered to be the proportion recommended for the concrete to be used in the work. The optimum amount of fly ash for any specific project is determined by the required properties of the concrete and other constituents of the concrete and is to be established by testing. Strength activity index with portland cement is a measure of reactivity with a given cement and is subject to variation depending on the source of both the fly ash and the cement. Meeting the 7-day or 28-day strength activity index will indicate specification compliance. It is at the District's discretion to accept or reject each fly ash source.

7.3 Slag cement

Slag cement grade 100 produced by the Argos-Essroc-Lehigh source located in Middlebranch, OH, was tested in accordance to ASTM C989 (ASTM 2018d) “Standard Specification for Slag Cement for Use in Concrete and Mortars.” A summary of the chemical and physical properties given in Table 17 indicate this slag satisfied the ASTM C989 specification requirements.

Table 17. Argos-Essroc slag, grade 100 results tested in accordance to ASTM C989.

Chemical Analysis	Test Results	Spec Limits
Sulfide Sulfur, S %	2.02	2.5% max
Sulfate Sulfur, (as SO ₃) %	0.04	4% max
Aluminum Oxide, (as Al ₂ O ₃) %	10.15	-
Chloride Content of Slag	0.05	-
Na ₂ O, %	0.27	-
K ₂ O, %	0.47	-
Equivalent Alkalis-total as Na ₂ O, %	0.57	
Physical Analysis	Test Results	Spec Limits
Compressive strength, (psi) 7 day, ¹ Reference	1,880	-
Compressive strength, (psi) 28 day, ¹ Reference	3,956	-
Compressive strength, (psi) 7 day, Slag/Cement	1,583	-
Compressive strength, (psi) 28 day, Slag/Cement	3,802	-
Strength Activity Index, (%) 7 day	88	70% min
Strength Activity Index, (%) 28 day	96	90% min
Surface area, m ² /kg	626	260 min
Specific Gravity, ASTM C188	2.81	-
Fineness, % Retained on #325	2.8	20% max
Air content, %	4.2	12% max

Notes:

¹Armstrong Type II project cement was used for reference cement for strength activity index tests.

7.4 Silica fume

Microsilica grade 970D produced by Norkem Chemicals Inc. and provided by Elkem Materials was tested in accordance to ASTM C1240 (ASTM 2015e), “Standard Specification for Silica Fume Used in Cementitious Mixtures.” A summary of the chemical and physical properties given in Table 18 indicate this silica fume satisfied the ASTM C1240 specification requirements.

Table 18. Elkem grade 970D silica fume results tested in accordance to ASTM C1240.

Chemical Analysis	Test Results	Spec. Limits
SiO ₂ , %	95.16	85%, min
Al ₂ O ₃ , %	0.24	-
Fe ₂ O ₃ , %	0.52	-
Sum, %	95.92	-
Na ₂ O, %	0.3	-
K ₂ O, %	0.49	-
MgO, %	0.25	-
SO ₃ , %	0.01	-
Loss on ignition, %	2.61	6%, max
Moisture %	0.61	3%, max
Physical Analysis	Test Results	Spec. Limits
Control Mixture ¹ : Compressive strength, 7 day (psi)	1,990	-
Test Mixture ² : Compressive strength, 7 day (psi)	3,280	-
Strength Activity Index,(%) 7 day	165	105%, min
Water Requirement	³	100-115%
Specific Gravity	2.32	-
Uniformity Requirement, amount of Vinsol	0.04 g	-
Effectiveness in Controlling ASR at 14 days	95%	80%, min

^{1, 2} Armstrong Type II project cement was used for reference cement for strength activity index tests.

³ Following the standard ASTM C1240 method, 2 mL of HRWRA required with test mixture to produce flow limits using 242 mL of water.

7.5 Limestone powder

The Graymont limestone powder produced by the facility in Bellefonte, PA, was tested in accordance to ASTM C1271 (ASTM 2012) “Standard Test Method for X-ray Spectrometric Analysis of Lime and Limestone,” ASTM D546 (ASTM 2017g) “Standard Test Method for Sieve Analysis of Mineral Filler for Asphalt Paving Mixtures,” and ASTM D242 “Standard Specification for Mineral Filler for Bituminous Paving Mixtures” (ASTM 2014b). The chemical and sieve analysis results are detailed in Table 19. The material is composed primarily of calcium carbonate (CaCO_3) and considered non-plastic Silty Sand (SM), Gray when tested by ASTM D4318 procedures. The mineral filler met the grading limits established in ASTM D242.

Table 19. Limestone powder analysis summary results.

ASTM C1271 X-ray Spectrometric Analysis of Limestone									
Chemical Analysis					Test Results				
SiO ₂ , %					0.95				
Al ₂ O ₃ , %					0.38				
Fe ₂ O ₃ , %					0.15				
CaO, %					54.18				
Na ₂ O, %					0.04				
K ₂ O, %					0.09				
MgO, %					0.71				
Loss on ignition (950°C), %					43.29				
Ca as CaCO ₃ , %					96.69				
Mg as MgCO ₃ , %					1.49				
Calculated Carbonates as CO ₂					43.29				
L.O.I. / CO ₂ Balance					1				
Mg as CaMg(CO ₃) ₂ , %					3.26				
Residual Ca as CaCO ₃ , %					94.92				
ASTM D546 Sieve Analysis of Mineral Filler for Bituminous Paving Mixtures									
Sieve Size	Run 1		Cumulative Percent		Run 2		Cumulative Percent		
	Mass Retained (g)	% Retained	% Retained	% Passing	Mass Retained (g)	% Retained	% Retained	% Passing	Avg. % Passing
No. 16	0.00	0.00	0.00	100	0.00	0.00	0.00	100	100
No. 30	0.52	0.51	0.51	99.49	0.60	0.53	0.53	99.47	99.48
No. 50	0.50	0.49	1.00	99.00	0.58	0.51	1.04	98.96	98.98
No. 100	1.93	1.89	2.89	97.11	2.08	1.83	2.87	97.13	97.12
No. 200	22.00	21.56	24.45	75.55	24.16	21.25	24.12	75.88	75.72
Minus No.200	77.09	75.55	100		86.28	75.88	100		
Original Sample	102	100			113.70	100			
<u>Remarks:</u> Limestone powder material is considered non-plastic silty sand (SM), gray when tested by ASTM D4318 (2017g).									
ASTM D242 Mineral Filler For Bituminous Paving Mixtures									
<u>Sieve No.</u>			<u>Average Test Result</u>			<u>ASTM D242 Graded Limits</u>			
No. 16			100			100			
No. 30			99.48			97 to 100			
No. 50			98.98			95 to 100			
No. 200			75.72			70 to 100			

8 Early Stiffening of Mortar

The early development of stiffness in the working characteristics of the hydraulic-cement mortar designs of mix 1, 5, 7, and 10 were tested in accordance to ASTM C359 (ASTM 2013). The four fly ash sources were evaluated independently with each mix design for a total of 16 tests. Mortars were prepared using specified quantities of cementitious materials scaled from the mixture designs with adequate mixing water to produce an initial penetration of 46 ± 3 mm using a modified Vicat apparatus. Measurements of penetration were made at stipulated intervals after the beginning of the mixing procedure. Upon completion of the first series of penetration measurements, the mortar was remixed followed by a final penetration measurement. A tabulation of the penetration measurements and the amount of mixing water used in the 16 tests is detailed in Table 20. The early stiffening rate of the 16 mortars ranged from a minimum of 5.3 mm/min to a maximum of 7.2 mm/min and the overall recovery ranged from a minimum of 96% to a maximum of 100%. This indicates a low potential of early stiffening of the hydraulic mortars.

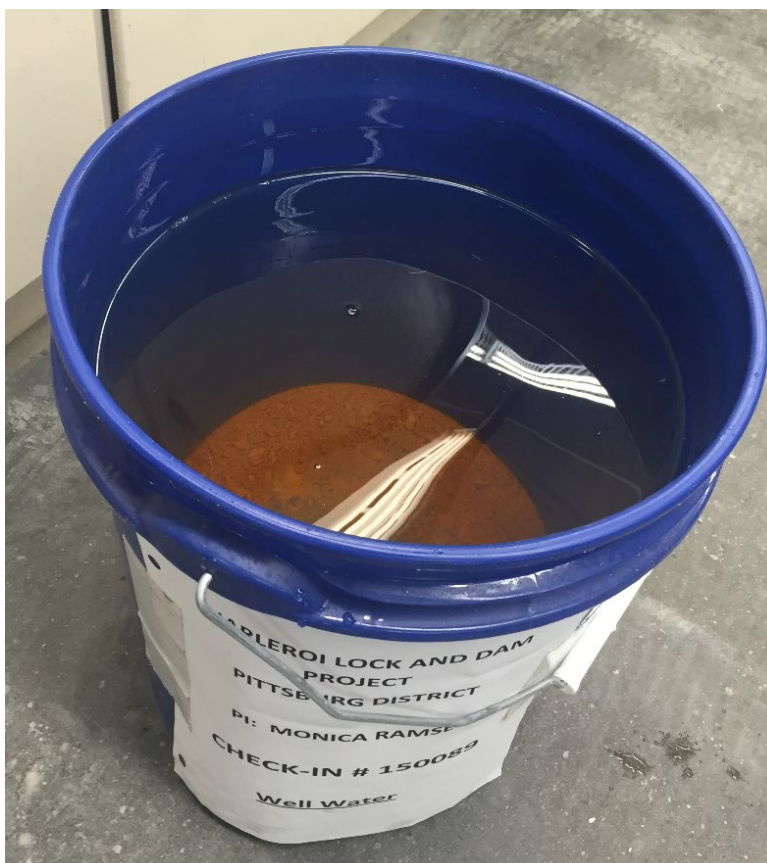
Table 20. Early stiffening of Mix 1, 5, 7, and 10 tested in accordance to ASTM C359.

Mix #	Fly Ash Source	Mixing Water (mL)	Initial pen. (mm)	5-min pen. (mm)	8-min pen. (mm)	11-min pen. (mm)	Remix pen. (mm)	Early Stiffening Amount (mm)	Early Stiffening Rate (mm/min)	Early Stiffening Recovery (%)
Mix 1	Sammis	185	49	10	5	3	49	46	7.3	100
	Ft. Martin	185	45	7	4	2	45	43	6.9	100
	Longview	183	46	11	6	3	44	43	6.7	96
	Brandon Shores	180	46	10	4	2	45	44	6.9	98
Mix 5	Sammis	175	46	18	5	3	45	43	6.3	98
	Ft. Martin	180	45	26	10	5	45	40	5.5	100
	Longview	175	48	20	6	4	46	44	6.4	96
	Brandon Shores	173	45	18	4	3	43	42	6.2	96
Mix 7	Sammis	180	47	20	6	4	46	43	6.3	98
	Ft. Martin	180	46	25	9	4	46	42	5.8	100
	Longview	175	45	18	6	4	44	41	6.1	98
	Brandon Shores	175	44	17	6	3	43	41	6.1	98
Mix 10	Sammis	170	46	31	11	6	46	40	5.3	100
	Ft. Martin	170	46	30	12	6	46	40	5.3	100
	Longview	166	45	28	9	5	43	40	5.4	96
	Brandon Shores	165	45	28	10	5	44	40	5.4	98

9 Water Quality Test Results

Municipal water from the Charleroi water authority (sample ID 150088) and well water from the left bank batch plant area (sample ID 150089) were tested for water quality in accordance to CRD-C 400 (U.S. Army Corps of Engineers 1963). Both filtered and unfiltered water quality samples were tested for iron by EPA Method 300.0, sulfate and chloride anions by EPA 6000/7000 series method, and hydrogen-ion concentration by EPA method 150.1. Detailed test results are provided Appendix F. Both filtered samples and the unfiltered municipal water met the criteria requirements for analytes tested. The unfiltered well water failed the limiting criteria for iron and chloride ions in the water. The well had not been circulating at the time the water sample was provided, and settled solids were observed as illustrated in Figure 5. It is notable to mention the unfiltered well water was never used as batch water for the project.

Figure 5. Visible settled solids in well water sample from left bank batch plant area.



10 Chemical Admixture Testing

Test results on five chemical admixtures produced by the Euclid Chemical Company are presented in this section. The manufacturer's reports are provided in Appendix E. Project source materials were used in the proportioning of the concrete mixtures as prescribed in ASTM C494 (ASTM 2017f).

10.1 Air entraining admixture (AEA)

Eucon AEA-92 formulated by the Euclid Chemical Company was the air entraining agent proposed for the Charleroi L&D concrete mixtures. The admixture is a liquid solution of synthetic organic chemicals compatible with concrete mixes containing calcium chloride, water reducing admixtures, retarding admixtures, or high-range water reducers.

Abbreviated testing was performed in accordance to ASTM C494 (ASTM 2017f) and ASTM C260 (ASTM 2016e). Results of the resistance to freezing and thawing performance requirement using this admixture was presented earlier. The same concrete mixture proportions used for the freezing and thawing testing of the Hanson coarse aggregate and other project materials was the control concrete for other physical tests. Compressive strength specimens were fabricated in accordance to ASTM C192 (ASTM 2016d) and tested in accordance to ASTM C39 (ASTM 2018a) procedures using triplicate 4 × 8 in. specimens at each test age. Strength results presented in Table 21 indicate the Eucon AEA-92 meets the requirement for a level of performance comparable to the control concrete.

Table 21. Compressive strength results comparing control and AEA-92 concrete.

Physical Analysis	Test Results	ASTM C260 Spec Limits
Compressive strength, (psi) 3 day, Control	3,750	
Compressive strength, (psi) 7 day, Control	4,300	-
Compressive strength, (psi) 28 day, Control	5,780	-
Compressive strength, (psi) 3 day, Eucon AEA-92	3,680	-
Compressive strength, (psi) 7 day, Eucon AEA-92	4,130	-
Compressive strength, (psi) 28 day, Eucon AEA-92	5,550	-
Percent of Control, 3 days	98	90% min
Percent of Control, 7 days	96	90% min
Percent of Control, 28 day	96	90% min

10.2 Retarding (RET) admixture

Eucon RET-75 formulated by the Euclid Chemical Company was the concrete water-reducing, set-retarding admixture proposed for the Charleroi L&D concrete mixtures. The admixture is a synthetically produced liquid water-reducing and set-retarding agent for concrete. It does not contain calcium chloride or other potential corroding materials and may be used in the presence of aluminum or zinc metals. Abbreviated testing was performed in accordance to ASTM C494, Type B using a dosage of 5 oz per 100 lb of the RET-75 admixture. Water content, time of setting, and compressive strength results are provided in Table 22.

Table 22. Water content, compressive strength, and time of setting results comparing control and Eucon RET-75 admixture in concrete.

Physical Analysis	Control	RET-75 Admixture	% of Control	ASTM C494 Spec Limits
Water Content (gal/yd ³)	27.8	25.6	92	-
Compressive strength, (psi) 3 day ASTM C39	3,750	4,090	109	90% (min)
Compressive strength, (psi) 7 day ASTM C39	4,300	4,920	114	90% (min)
Compressive strength, (psi) 28 day ASTM C39	5,780	6,780	117	90% (min)
Time of setting (minutes), Initial ASTM C403	240	290	50 min. later than control	At least 60 min. later and not more than 210 min later from control
Time of setting (minutes), Final ASTM C403	320	375	55 min. later than control	Not more than 210 min later from control

10.3 Water Reducing (WR) admixture

Eucon WR formulated by the Euclid Chemical Company was the water reducing admixture proposed for the Charleroi L&D concrete mixtures. The admixture is marketed as an aqueous solution of refined lignosulfonate that is free of any added chloride ions. It provides a more plastic and cohesive mix in the fresh concrete and better durability, reduced shrinkage, and less permeability in the hardened concrete. Abbreviated testing was performed in accordance to ASTM C494, Type A

using a dosage of 4 fl-oz/cwt of cementitious materials. Water content, time of setting, and compressive strength results are provided in Table 23.

Table 23. Water content, compressive strength, and time of setting results comparing control and Eucon WR admixture in concrete.

Physical Analysis	Control	Eucon WR Admixture	% of Control	ASTM C494 Spec Limits
Water Content (gal/yd ³)	27.8	25.12	90	95% (max)
Compressive strength, (psi) 3 day ASTM C39	3,750	4,650	124	110% (min)
Compressive strength, (psi) 7 day ASTM C39	4,300	5,110	118	110% (min)
Compressive strength, (psi) 28 day ASTM C39	5,780	6,940	120	110% (min)
Time of setting (minutes), Initial ASTM C403	240	250	10 min later	Not more than 60 min earlier nor 90 min later than control
Time of setting (minutes), Final ASTM C403	320	330	10 min later	Not more than 60 min earlier nor 90 min later than control

10.4 Anti-Washout (AW) admixture

Eucon AWA formulated by the Euclid Chemical Company was the anti-washout (AW) admixture proposed for the Charleroi L&D concrete mixtures. The admixture is marketed as a ready-to-use liquid designed to reduce the loss of cement and fine aggregate during the placement of underwater concrete. It greatly reduces or eliminates concrete bleed water and improves slump retention. Abbreviated testing was performed in accordance to ASTM C494 for Types S using a dosage of 25 fl-oz per 100 lb of cementitious materials. Water content, time of setting, and compressive strength results are provided in Table 24.

Table 24. Compressive strength and time of setting results of comparing control and Eucon AWA in concrete.

Physical Analysis	Control	Eucon AWA Admixture	% of Control	ASTM C494 Spec Limits
Compressive strength, (psi) 3 day ASTM C39	3,750	3,300	88	90% (min)
Compressive strength, (psi) 7 day ASTM C39	4,300	3,870	90	90% (min)
Compressive strength, (psi) 28 day ASTM C39	5,780	5,260	91	90% (min)
Time of setting (minutes), Initial ASTM C403	240	320	80 min later	Not more than 60 min earlier nor 90 min later than control
Time of setting (minutes), Final ASTM C403	320	410	90 min later	Not more than 60 min earlier nor 90 min later than control

10.5 High Range Water Reducing (HRWR) admixture

Eucon 37 formulated by the Euclid Chemical Company was the high range water reducing (HRWR) admixture proposed for the Charleroi L&D concrete mixtures. The admixture is formulated to retain plastic consistency for 30-60 min after dosing depending on the initial slumps, dosage rates, and ambient temperature. It produces low water content and low water/cement ratio concrete allowing higher strengths. Abbreviated testing was performed in accordance to ASTM C494 criteria for a Type F admixture using a dosage of 16 fl-oz per 100 lb of cementitious materials. Water content, time of setting, and compressive strength results are provided in Table 25.

Table 25. Water content, compressive strength, and time of setting results comparing control and Eucon 37 admixture in concrete.

Physical Analysis	Control	Eucon 37 Admixture	% of Control	ASTM C494 Spec Limits
Water Content (gal/yd ³)	27.8	22.9	82	88% (max)
Compressive strength, (psi) 3 day ASTM C39	3,750	5,250	140	125% (min)
Compressive strength, (psi) 7 day ASTM C39	4,300	5,375	125	115% (min)
Compressive strength, (psi) 28 day ASTM C39	5,780	7,110	123	110% (min)
Time of setting (minutes), Initial ASTM C403	240	310	70 min later	Not more than 60 min earlier nor 90 min later than control
Time of setting (minutes), Final ASTM C403	320	395	75 min later	Not more than 60 min earlier nor 90 min later than control

11 Heat of Hydration

Heat of hydration (HOH) testing for mix designs 1, 5, 7, and 10 provided by the Pittsburgh District were scaled to test in accordance to ASTM C1702 (ASTM 2017i), “Standard Test Method for Measurement of Heat of Hydration of Hydraulic Cementitious Materials Using Isothermal Conduction Calorimetry.” This was done to create a heat of hydration signature for each mixture made with all available local materials and provide baseline information for future construction projects.

The four fly ash sources were tested independently in each mix design for a total of 16 tests to compare the efficacy to mitigate the heat generation. Table 26 provides a summary of the actual HOH mixture proportions tested.

Table 26. Batch quantities for heat of hydration in accordance to ASTM C1702.

Material	Mixture ID			
	Mix 1	Mix 5	Mix 7	Mix 10
	Mass (g)			
Cement	115.8	270.5	274.4	375
Class F Fly Ash	109.6	106.2	150.8	125
GGBFS	254.5	123.2	74.8	-
Silica Fume	20.1	-	-	-
Limestone Powder	107.5	-	-	-
Admixture	Volume (mL)			
AEA	0	0.739	1.131	0.346
WRA	0	0	0	0
HRWRA	6.244	0	0	0.593
RET	1.361	0.646	0.495	0.346
AWA	4.395	0	0	0
Water	Volume (mL)			
Deionized	195.5	258.5	230.0	235.0

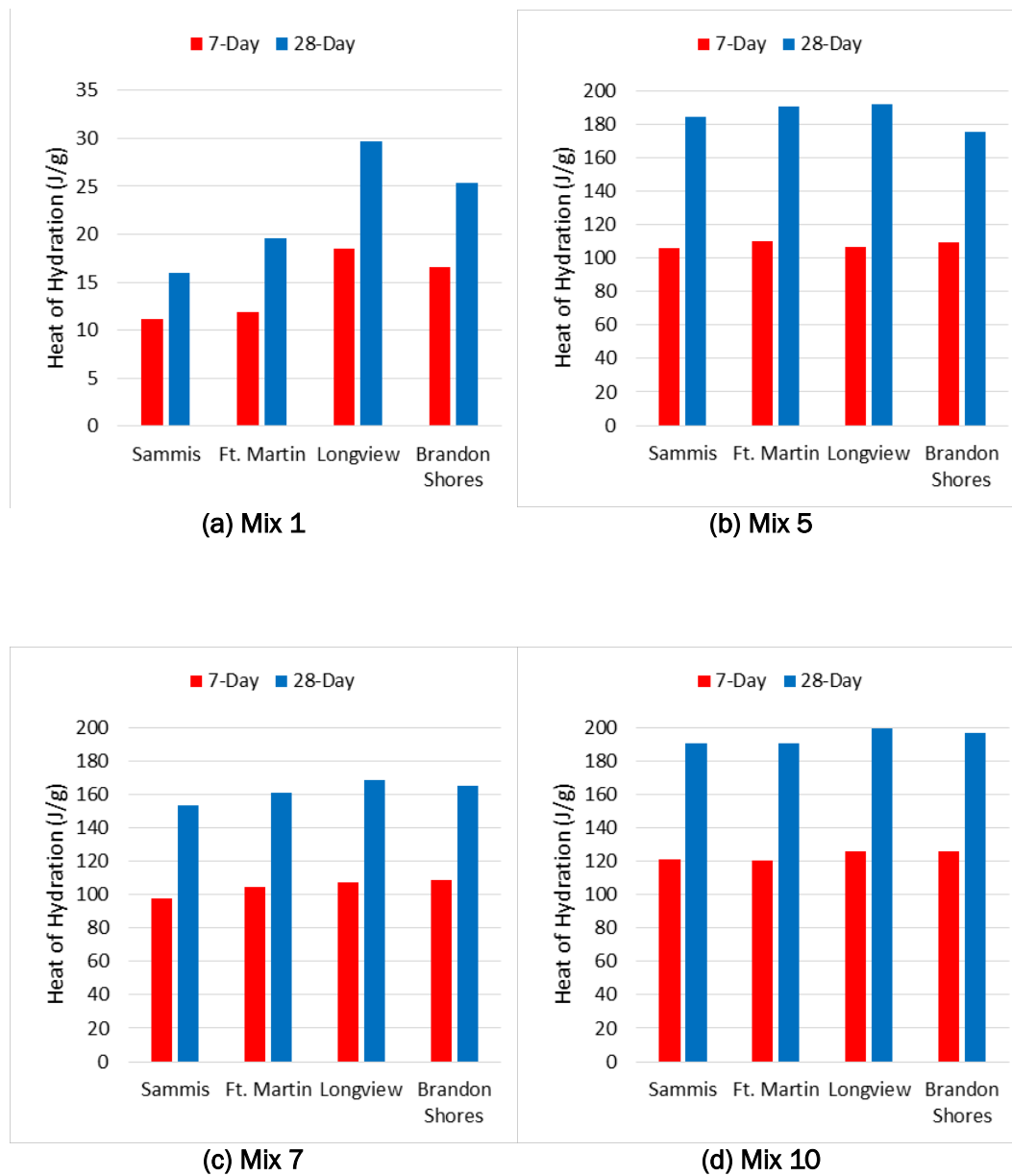
Each sample mixture was tested in duplicate runs for up to 28 days in accordance with ASTM C1702 (Method B, external mixing) using a TAMAIR isothermal conduction calorimetry manufactured by TA instruments.

HOH results at 7 and 28 days are summarized in Table 27 and illustrated in Figure 6. Mix 1 showed the overall lowest heat generation while Mix 10 showed the overall highest heat generation. The lowest HOH was 11.1 J/g and 16.0 J/g at 7 and 28 days, respectively, produced by the Sammis fly ash in Mix 1. The highest HOH was 126.0 J/g and 199.8 J/g produced by the Longview fly ash in Mix 10. Results indicate there is not a significant difference in the four fly ashes tested within each unique mixture design.

Table 27. Average heat of hydration results at 7 and 28 days.

Mixture ID	7 days (J/g)	28 days (J/g)
Armstrong Type II Cement	241.2	330.1
Mix 1: Sammis Fly Ash	11.1	16.0
Mix 1: Ft. Martin Fly Ash	11.9	19.6
Mix 1: Longview Fly Ash	18.5	29.7
Mix 1: Brandon Shores Fly Ash	16.6	25.4
Mix 5: Sammis Fly Ash	106.2	184.7
Mix 5: Ft. Martin Fly Ash	110.2	190.6
Mix 5: Longview Fly Ash	106.8	191.7
Mix 5: Brandon Shores Fly Ash	109.4	175.4
Mix 7: Sammis Fly Ash	97.8	153.3
Mix 7: Ft. Martin Fly Ash	104.4	160.9
Mix 7: Longview Fly Ash	107.7	168.8
Mix 7: Brandon Shores Fly Ash	108.6	165.4
Mix 10: Sammis Fly Ash	120.8	190.4
Mix 10: Ft. Martin Fly Ash	120.4	190.9
Mix 10: Longview Fly Ash	126.03	199.8
Mix 10: Brandon Shores Fly Ash	125.6	196.6

Figure 6. Heat of hydration for mix 1, 5, 7, and 10 by fly ash at 7 and 28 days.



12 Summary and Conclusions

The purpose of this investigation was to test potential construction materials provided by the USACE Pittsburgh District for the Charleroi Lock and Dam Monongahela River Reconstruction Project. Materials included three different coarse aggregate gradations, two fine aggregate sources, a type II (MH) cement, four class F fly ash sources, a slag cement, a silica fume, a limestone powder, five admixtures, and two water sources. Relevant conclusions from laboratory testing are summarized below. However, the suitability of each material and final acceptance will be at the District's discretion.

Aggregate testing

A total of nine ASTM procedures were conducted for the three proposed project aggregate sources (Hanson, Georgetown, and Shelley). Unless otherwise stated, aggregate quality requirements were based on the Charleroi construction specifications (USACE Pittsburgh District 2015). Test specific results indicate the following:

- Sieve analysis (ASTM C136)
The coarse and fine aggregates met all grading requirements with the following exceptions:
 - Georgetown sand: 14% passing the #50 (15-30% criteria) and 2% passing the #100 (5-10% criteria)
 - Shelly sand: 12% passing the #50 (15-30% criteria) and 2% passing the #100 (5-10% criteria)
 - Hanson 1½-inch aggregate: 83% passing the 1½-inch (90 to 100% criteria) and 16% passing the 1-inch (20 to 55% criteria)
 - Hanson ¾-inch aggregate: 17% passing the ¾-inch (20 to 55% criteria)
- Specific Gravity and Absorption (ASTM C127/128)
All aggregates met criteria specified for specific gravity and absorption.
- Materials Less than No. 200 Sieve (ASTM C117)
All aggregates fell below the 1% maximum allowance for materials finer than No. 200 sieve with the exceptions of the 1½-inch Hanson aggregate(1.05%) and 3-inch Hanson aggregate (1.01%).

- Organic Impurities (ASTM C40)
The organic plate results indicated both sands do not contain organic impurities at a concentration great enough to warrant further testing at this time.
- Soundness of Aggregates (ASTM C88)
All aggregates met the magnesium sulfate soundness requirement given in ASTM C88 of less than 18% cumulative mass loss at 5 cycles.
- LA Abrasion (ASTM C131)
All aggregates met the abrasion requirement of less than 40% loss.
- Clay Lumps and Friable Particles (ASTM C142)
All aggregates met the quality requirements for clay lumps and friable particles (1.2% maximum for fine aggregate; 2% maximum for coarse aggregate).
- Flat and Elongated Particles (ASTM D4791)
The flat and elongated particle results are less than the 12% maximum limiting criteria defined in the project specification.
- Lightweight Particles (ASTM C123)
All aggregates fell below the maximum percentage of chert and shale lightweight particles when tested with zinc bromide (2.4 specific gravity). All aggregates fell below the 1.0% maximum percentage of lightweight particles when tested with zinc chloride (2.0 specific gravity) with the exception of 1.2% in the Georgetown sand.

Freezing and thawing testing

The freezing and thawing durability of one project coarse aggregate (Hanson), two project natural sand fine aggregates (Shelly and Georgetown), and one project mixture design (Mix 7) were determined in accordance to Procedure A of ASTM C666. The relative dynamic modulus ranged from a minimum of 61% to a maximum of 85%, which is above the 60% requirement throughout the 300 freezing and thawing cycles for all specimens tested.

Petrography testing

Petrographic examination of the Hanson, Georgetown, and Shelly aggregates performed in accordance to ASTM C295 used X-ray diffraction patterns to identify and confirm the following mineral constituents:

- Hanson Aggregate
Calcite (CaCO_3) (55.7%), Quartz (SiO_2) (37.7%), micas Biotite

- ($\text{K}(\text{Mg,Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (5.1%), and Muscovite ($\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (1.5%).
- Shelly Aggregate
Quartz (SiO_2) (69.0%), Albite ($\text{Na}(\text{AlSi}_3\text{O}_8)$) (14.0%), Graphite (C) (6.2%), Calcite (CaCO_3) (4.4%), micas Biotite ($\text{K}(\text{Mg,Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (5.8%), and Muscovite ($\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (0.7%).
 - Georgetown Aggregate
Quartz (SiO_2) (70.1%), Albite ($\text{Na}(\text{AlSi}_3\text{O}_8)$) (16.0%), Calcite (CaCO_3) (5.6%), micas Biotite ($\text{K}(\text{Mg, Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (5.2%), and Muscovite ($\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{F,OH})_2$) (3.2%).

Cementitious testing

- Cement
The Armstrong cement produced by the Cabot, PA, mill met all ASTM C150 specification requirements for a Type II moderate heat (MH) cement and was in compliance with the low-alkali (LA), false set (FS), and heat of hydration (HH) criteria required by the Charleroi L&D specifications.
- Fly Ash
Four class F fly ashes were tested in accordance to ASTM C618. The Brandon Shores class F fly ash from Curtis Bay, MD, met all specification requirements. The Longview fly ash from Maidsville, WV, exceeded the 34% fineness allowed on a #325 sieve with 38.6% retained. The Longview fly ash as well as the Sammis fly ash from Stratton, OH, and the Fort Martin fly ash from Maidsville fell below the 75% strength activity index as suggested in ASTM C618. However, this test is a measure of reactivity with a given cement and is subject to variation depending on the source of fly ash and cement. The mass of the fly ash and cement specified for the strength activity index is not considered to be the proportion recommended for the concrete to be used in the work and acceptance is based on the District's determination.
- Slag Cement
The grade 100 slag cement produced by Argos-Essroc sources located in Middlebranch, OH, satisfied all ASTM C989 specification requirements.

- **Silica Fume**
The microsilica grade 970D provided by Elkem Materials Inc. located in Pittsburgh, PA, conforms to all ASTM C1240 requirements.
- **Limestone Powder**
The Graymont limestone powder produced by the facility in Bellefonte, PA, is primarily composed of calcium carbonate (CaCO_3). When tested in accordance to ASTM D546, 75.72% of the material passed the No. 200 sieve opening. The material met the physical grading requirements of ASTM D242.

Early stiffening of mortar

The early development of stiffness in the working characteristics of the hydraulic-cement mortar designs of mix 1, 5, 7, and 10 were tested in accordance to ASTM C359. The four fly ash sources were evaluated independently with each mix design for a total of 16 tests. The early stiffening rate of the mortars ranged from a minimum of 5.3 mm/min to a maximum of 7.2 mm/min and the overall recovery ranged from a minimum of 96% to a maximum of 100%. This indicates a low potential of early stiffening of the hydraulic mortars.

Water quality testing

Municipal water from the Charleroi water authority and well water from the left bank batch plant area were tested for water quality in accordance to CRD-C 400. The well had not been circulating at the time the water sample was provided to the laboratory for testing. Both filtered and unfiltered municipal water samples met the criteria for iron, sulfate and chloride anions, and hydrogen-ion concentration. The unfiltered well water failed the limiting criteria for iron and chloride ions in the water. It is notable to mention that although the well water was included in the material tests, the unfiltered well water was never used as batch water in the Charleroi L&D project.

Chemical admixtures

Based on abbreviated ASTM C494 testing for five chemical admixtures produced by the Euclid Chemical Company the following conclusions are made:

- Eucon AEA-92 met the compressive strength requirement in for a level of performance comparable to that of the reference concrete.

- Eucon Retarder 75 met all water content, time of setting, and compressive strength physical requirements for a Type B admixture with the exception the initial time of setting. The test sample was only 50 min later than the control mixture and the allowable deviation is at least 60 min later.
- Eucon WR met all water content, time of setting, and compressive strength physical requirements for a Type A admixture.
- Eucon AWA met all compressive strength and time of setting physical requirements for a Type S admixture.
- Eucon 37 met all water content, time of setting, and compressive strength physical requirements for a Type F admixture with the exception of the final time of setting. The test sample was 95 min later than the control mixture and the allowable deviation is no more than 90 min later.

Heat of hydration

The heat of hydration of the hydraulic-cement mortar designs of mix 1, 5, 7, and 10 were tested up to 28 days in accordance to ASTM C1702. The four fly ash sources were evaluated independently with each mix design for a total of 16 tests. Mix 1 resulted the overall lowest heat generation while Mix 10 showed the overall highest heat generation. The lowest HOH was 11.1 J/g and 16.0 J/g at 7 and 28 days, respectively, produced by the Sammis fly ash in Mix 1. The highest HOH was 126.0 J/g and 199.8 J/g produced by the Longview fly ash in Mix 10. Results indicate there is not a significant difference in the four fly ashes tested within each unique mixture design.

References

- American Society for Testing and Materials (ASTM). 2010. *Standard test method for flat particles, elongated particles, or flat and elongated particles in coarse aggregate*. Designation: D 4791-10. West Conshohocken, PA: ASTM International.
- _____. 2012. *Standard test method for X-ray spectrometric analysis of lime and limestone*. Designation: C 1271-12. West Conshohocken, PA: ASTM International.
- _____. 2013. *Standard test method for early stiffening of hydraulic cement (mortar method)*. Designation: C 359-13. West Conshohocken, PA: ASTM International.
- _____. 2014a. *Standard test method for resistance to degradation of small-size coarse aggregates by abrasion and impact in the Los Angeles Machine*. Designation: C 131-14. West Conshohocken, PA: ASTM International.
- _____. 2014b. *Standard test method for mineral filler for bituminous paving mixtures*. Designation: D 1242-14. West Conshohocken, PA: ASTM International.
- _____. 2015a. *Standard test method for relative density (specific gravity) and absorption of coarse aggregate*. Designation: C 127-15. West Conshohocken, PA: ASTM International.
- _____. 2015b. *Standard test method for relative density (specific gravity) and absorption of fine aggregate*. Designation: C 128-15. West Conshohocken, PA: ASTM International.
- _____. 2015c. *Standard test method for slump of hydraulic cement concrete*. Designation: C 143-15. West Conshohocken, PA: ASTM International.
- _____. 2015d. *Standard test method for resistance of concrete to rapid freezing and thawing*. Designation: C 666-15. West Conshohocken, PA: ASTM International.
- _____. 2015e. *Standard specification for silica fume used in cementitious mixtures*. Designation: C 1240-15. West Conshohocken, PA: ASTM International.
- _____. 2016a. *Standard test method for concrete aggregates*. Designation: C 33-16. West Conshohocken, PA: ASTM International.
- _____. 2016b. *Standard test method for organic impurities in fine aggregates for concrete*. Designation: C 40-16. West Conshohocken, PA: ASTM International.
- _____. 2016c. *Standard test method for sieve analysis of fine and coarse aggregates*. Designation: C 136-14. West Conshohocken, PA: ASTM International.
- _____. 2016d. *Standard test method for making and curing concrete test specimens in the laboratory*. Designation: C 192-16. West Conshohocken, PA: ASTM International.
- _____. 2016e. *Standard test method for air-entraining admixtures for concrete*. Designation: C 260-16. West Conshohocken, PA: ASTM International.

-
- _____. 2016f. *Standard test method for time of setting of concrete mixtures by penetration resistance*. Designation: C 403-14. West Conshohocken, PA: ASTM International.
- _____. 2017a. *Standard test method for materials finer than (No. 200) sieve*. Designation: C 117-17. West Conshohocken, PA: ASTM International.
- _____. 2017b. *Standard test method for lightweight particles in aggregate*. Designation: C 123-17. West Conshohocken, PA: ASTM International.
- _____. 2017c. *Standard test method for clay lumps and friable particles in aggregates*. Designation: C 142-17. West Conshohocken, PA: ASTM International.
- _____. 2017d. *Standard test method for air content of freshly mixed concrete by the pressure method*. Designation: C 231-17. West Conshohocken, PA: ASTM International.
- _____. 2017e. *Standard practices for petrographic examination of aggregates for concrete*. Designation: C 295-17. West Conshohocken, PA: ASTM International.
- _____. 2017f. *Standard specification for chemical admixtures for concrete*. Designation: C494-17. West Conshohocken, PA: ASTM International.
- _____. 2017g. *Standard test method for sieve analysis of mineral filler for asphalt paving mixtures*. Designation: D 546-17. West Conshohocken, PA: ASTM International.
- _____. 2017h. *Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete*. Designation: C 618-17. West Conshohocken, PA: ASTM International.
- _____. 2017i. *Standard test method for measurement of heat of hydration of hydraulic cementitious materials using isothermal conduction calorimetry*. Designation: C 1702-17. West Conshohocken, PA: ASTM International.
- _____. 2018a. *Standard test method for compressive strength of cylindrical concrete specimens*. Designation: C 39-18. West Conshohocken, PA: ASTM International.
- _____. 2018b. *Standard test method for soundness of aggregates by use of sodium sulfate or magnesium sulfate*. Designation: C 88-18. West Conshohocken, PA: ASTM International.
- _____. 2018c. *Standard specification for portland cement*. Designation: C 150-18. West Conshohocken, PA: ASTM International.
- _____. 2018d. *Standard specification for slag cement for use in concrete and mortars*. Designation: C 989-18. West Conshohocken, PA: ASTM International.
- U.S. Army Corps of Engineers. 1963. *Requirements for water for use in mixing or curing concrete*. CRD-C 400-63. Washington, DC: USACE.

USACE Pittsburgh District. 2015. *Construction contract and specifications Volume 4 of 4 – Division 03 thru Division 16. Charleroi locks, contract 1; Charleroi locks and dams; Monongahela River, PA.* RFP W911WN-04-R-0003. Pittsburgh, PA: U.S. Army Corps of Engineers.

Appendix A: Aggregate Test Results

Hanson 3-in. Aggregate

Summary of Aggregate Tests Report									
Material Description: 3-inch limestone aggregate				Performing Organization:		Geotechnical and Structures Lab			
Source: Hanson Aggregates						Concrete and Materials Branch			
Location: Connellsville, PA				Tested by:		R. Hardy			
CMB Log in #: 150072				Reviewed by:		J. Burroughs/M. Ramsey			
Sponsoring Organization: USACE Pittsburgh District, Lower Mon Area Office									
Project: Chaferoi Lock and Dam Monongahela River Reconstruction Project									
ASTM C 136: Sieve Analysis:									
Sieve Size	Run 1		Cumulative Percent		Run 2		Cumulative Percent		% Passing
	Mass Ret, g	% Ret	Ret	Pass	Mass Ret, g	% Ret	Ret	Pass	
3 in	6010.6	7.57%	7.57%	92.43%	-	-	-	-	92%
2 1/2 in	20593.0	25.93%	33.50%	66.50%	-	-	-	-	66%
2 in	37104.0	46.72%	80.23%	19.77%	-	-	-	-	20%
1 1/2 in	14515.0	18.28%	98.50%	1.50%	-	-	-	-	1%
1 in	839.2	1.06%	99.56%	0.44%	-	-	-	-	0%
3/4 in	157.9	0.20%	99.76%	0.24%	-	-	-	-	0%
1/2 in	0.0	0.00%	99.76%	0.24%	-	-	-	-	0%
3/8 in	0.0	0.00%	99.76%	0.24%	-	-	-	-	0%
No. 4	0.0	0.00%	99.76%	0.24%	-	-	-	-	0%
No. 8	0.0	0.00%	99.76%	0.24%	-	-	-	-	0%
Pan	190.3	0.24%	100.00%		-	-	-	-	0%
Total	79409.9	100.00%							0%
ASTM C 117: Minus 75um (No. 200)									
OD Mass, g	20196.4	Mass Aft, g	19982.5	Mass Loss, g	212.9	% Loss:		1.05%	
ASTM C 127: Bulk Specific Gravity & Absorption:									
						Run 1	Run 2	Avg	
SSD Mass in Air, g						19039.8	21068.6		
SSD Mass in Water, g						11945.1	13282.1		
Displaced Water, g						7094.5	7794.5		
Water Temp C						23.5	23.5		
Relative Density (Bulk Specific Gravity)(SSD)						2.684	2.701	2.69	
Oven Dry Mass, g						18992.1	20932.1		
Moisture Loss, g						47.5	124.5		
Absorption						0.25%	0.59%	0.42%	
ASTM C 88 Magnesium Sulfate Soundness (5 cycles):									
Gradation > 5%	OD Mass, g	Mass Aft, g	Mass Loss, g	% Loss	Wt'd %	No. PCS	No. Flaked		
3 in	7.57%	6048.0	6039.3	8.7	0.00	0.0%			
2 1/2 in	25.93%	6362.1	6356.6	5.5	0.00	0.0%			
2 in	46.72%	2908.2	2906.3	1.9	0.00	0.0%			
1 1/2 in	18.28%	1966.1	1919.2	46.9	0.02	0.4%	12	3	
1 in	1.06%	1966.1	1919.2	46.9	0.02	0.0%			
3/4 in	0.20%	1966.1	1919.2	46.9	0.02	0.0%			
1/2 in	0.00%	1966.1	1919.2	46.9	0.02	0.0%			
3/8 in	0.00%	1966.1	1919.2	46.9	0.02	0.0%			
No. 4	0.00%	1966.1	1919.2	46.9	0.02	0.0%			
Total	99.76%				0.5%			0.5%	
ASTM C 123 Light Weight Particles and Pieces in Aggregate									
ASTM C 123: Lightweight Pieces:				Zinc Bromide 2.40 sp.gr.		No mat'l. lighter than 2.00 sp.gr.			
OD Mass, g	9843.9	Ret Mass, g	9843.9	Mass Loss, g	0	% Loss:		0.00%	
ASTM C 131 or C 535 Los Angeles Abrasion Resistance (500 rev.)									
Grading:	1	OD Mass, g	7537.5	Ret Mass, g	6666.2	% Loss:		11.56%	
ASTM C 142: Clay Lumps & Friable Particles:									
Gradation > 5%	OD Mass, g	Mass Aft, g	Mass Loss, g	% Loss	Wt'd %				
3 in	7.57%	5265.5	5259.8	5.7	0.00	0.0%			
2 1/2 in	25.93%	5373.9	5370.1	3.8	0.00	0.0%			
2 in	46.72%	5154.6	5150.9	3.7	0.00	0.0%			
1 1/2 in	18.28%	3173.1	3170.1	3.0	0.00	0.0%			
1 in	1.06%	3173.1	3170.1	3.0	0.00	0.0%			
3/4 in	0.20%	3173.1	3170.1	3.0	0.00	0.0%			
1/2 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
3/8 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
No. 4	0.00%	1.0	1.0	0.0	0.00	0.0%			
Total	99.76%				0.1%			0.1%	
ASTM D 4791 Flat or Elongated Particles:									
3:1 Ratio	Gradation > 10%	Pcs Before	Flat Pcs	Elong Pcs	F&E Pcs	% F, E&FE	Wt'd %		
3 in	7.57%	100	1	0	2	0.03	0.2%		
2 1/2 in	25.93%	103	3	0	9	0.12	3.0%		
2 in	46.72%	102	5	0	6	0.11	5.0%		
1 1/2 in	18.28%	106	2	0	7	0.08	1.6%		
1 in	1.06%	100	0	0	0	0.00	0.0%		
3/4 in	0.20%	100	0	0	0	0.00	0.0%		
1/2 in	0.00%	100	0	0	0	0.00	0.0%		
3/8 in	0.00%	100	0	0	0	0.00	0.0%		
No. 4	0.00%	100	0	0	0	0.00	0.0%		
Total	99.76%					9.8%		9.8%	

Hanson 1½-in. Aggregate

Summary of Aggregate Tests Report									
Material Description: 1 1/2-inch aggregate				Performing Organization:		Geotechnical and Structures Lab			
Source: Hanson Aggregates				Concrete and Materials Branch					
Location: Connells ville, PA				Tested by: R. Hardy					
CMB Log in #: 150071				Reviewed by: J. Burroughs/M. Ramsey					
Sponsoring Organization: USACE Pittsburgh District, Lower Mon Area Office									
Project: Charlevoix Lock and Dam Monongahela River Reconstruction Project									
ASTM C 136: Sieve Analysis:									
Sieve Size	Run 1		Cumulative Percent		Run 2		Cumulative Percent		Avg % Passing
	Mass Ret, g	% Ret.	Ret.	Pass	Mass Ret, g	% Ret.	Ret.	Pass	
3 in	0.0	0.00%	0.00%	100.00%	0.0	0.00%	0.00%	100.00%	100%
2 1/2 in	0.0	0.00%	0.00%	100.00%	0.0	0.00%	0.00%	100.00%	100%
2 in	0.0	0.00%	0.00%	100.00%	0.0	0.00%	0.00%	100.00%	100%
1 1/2 in	2985.3	19.55%	19.55%	80.45%	2177.2	13.89%	13.89%	86.11%	83%
1 in	9979.0	65.33%	84.88%	15.12%	10704.8	68.31%	82.21%	17.79%	16%
3/4 in	1841.1	12.05%	96.93%	3.07%	2268.0	14.47%	96.68%	3.32%	3%
1/2 in	398.0	2.61%	99.54%	0.46%	440.0	2.81%	99.49%	0.51%	0%
3/8 in	22.7	0.15%	99.69%	0.31%	32.0	0.20%	99.69%	0.31%	0%
Pan	47.9	0.31%	100.00%	0.00%	47.9	0.31%	100.00%	0.00%	0%
Total	15274.0	100.00%			15669.8	100.00%			
ASTM C 117: Minus 75um (No. 200)									
OD Mass, g	19605.7	Mass Aftg	19399.0	Mass Loss, g	206.7	% Loss:		1.05%	
ASTM C 127: Bulk Specific Gravity & Absorption:									
						Run 1	Run 2	Avg	
SSD Mass in Air, g						5321.2	5605.2		
SSD Mass in Water, g						3330.8	3514.8		
Displaced Water, g						1990.4	2090.4		
Water Temp C						23.5	23.5		
Relative Density (Bulk Specific Gravity) (SSD)						2.673	2.681	2.68	
Oven Dry Mass, g						5303.3	5575.5		
Moisture Loss, g						17.9	29.7		
Absorption						0.34%	0.53%	0.44%	
ASTM C 88 Magnesium Sulfate Soundness (5 cycles):									
05/01/15 1.5" rock									
Gradation > 5%	OD Mass, g	Mass Aft, g	Mass Loss, g	% Loss	Wt'd %	No. PCS	No. Flaked		
2 1/2 in	0.00%	1.0	1.0	0.0	0.00				
2 in	0.89%	4738.9	4708.8	30.1	0.01				
1 1/2 in	35.87%	4738.9	4708.8	30.1	0.01	34	4		
1 in	51.25%	983.1	981.2	1.9	0.00				
3/4 in	9.46%	473.3	272.0	201.3	0.43				
1/2 in	2.04%	473.3	272.0	201.3	0.43				
3/8 in	0.12%	473.3	272.0	201.3	0.43				
No. 4	0.11%	473.3	272.0	201.3	0.43				
No. 8	0.02%	473.3	272.0	201.3	0.43				
Total	99.75%				5.3%			5.3%	
ASTM C 123 Light Weight Particles and Pieces in Aggregate									
Bromide 2.40 sp.gr.		No mat'l. lighter than 2.00 sp.gr.							
OD Mass, g	6382.5	Ret Mass, g	6354.6	Mass Loss, g	27.9	% Loss:		0.44%	
ASTM C 131 or C 535 Los Angeles Abrasion Resistance (500 rev.)									
Grading:	A	OD Mass, g	5058.2	Ret Mass, g	3921.4	% Loss:		22.47%	
ASTM C 142: Clay Lumps & Friable Particles:									
Gradation > 5%	OD Mass, g	Mass Aft, g	Mass Loss, g	% Loss	Wt'd %				
2 1/2 in	0.00%	1.0	1.0	0.0	0.00				
2 in	0.89%	3173.1	3170.1	3.0	0.00				
1 1/2 in	35.87%	3173.1	3170.1	3.0	0.00				
1 in	51.25%	3009.4	3006.5	2.9	0.00				
3/4 in	9.46%	3523.7	3520.3	3.4	0.00				
1/2 in	2.04%	3523.7	3520.3	3.4	0.00				
3/8 in	0.12%	3523.7	3520.3	3.4	0.00				
No. 4	0.11%	3523.7	3520.3	3.4	0.00				
Total	99.63%				0.1%			0.1%	
ASTM D 4791 Flat or Elongated Particles:									
3:1 Ratio									
Gradation > 10%	Pcs Before	Flat Pcs	Elong Pcs	F&E Pcs	% F,E&FE	Wt'd %			
2 1/2 in	0.00%	100	0	0	0.00	0.0%			
2 in	0.89%	100	0	0	0.00	0.0%			
1 1/2 in	35.87%	114	2	0	8	3.1%			
1 in	51.25%	105	1	1	8	4.9%			
3/4 in	9.46%	100	0	0	0	0.0%			
1/2 in	2.04%	100	0	0	0	0.0%			
3/8 in	0.12%	100	0	0	0	0.0%			
No. 4	0.11%	100	0	0	0	0.0%			
Total	99.73%					8.0%	8.0%		

Hanson 3/4-in. Aggregate

Summary of Aggregate Tests Report									
Material Description: 3/4-inch limestone aggregate				Performing Organization: Geotechnical and Structures Lab					
Source: Hanson Aggregates				Concrete and Materials Branch					
Location: CMB Log in #: 150070				Tested by: R. Hardy					
Sponsoring Organization: USACE Pittsburgh District, Lower Mon Area Office				Reviewed by: J. Burroughs/M. Ramsey					
Project: Charleroi Lock and Dam Monongahela River Reconstruction Project									
ASTM C 136: Sieve Analysis:									
Sieve Size	Run 1		Cumulative Percent		Run 2		Cumulative Percent		Avg % Passing
	Mass Ret, g	% Ret.	Ret.	Pass	Mass Ret, g	% Ret.	Ret.	Pass	
3 in	0.0	0.00%	0.00%	100.00%	0.0	0.00%	0.00%	100.00%	100%
2 1/2 in	0.0	0.00%	0.00%	100.00%	0.0	0.00%	0.00%	100.00%	100%
2 in	0.0	0.00%	0.00%	100.00%	0.0	0.00%	0.00%	100.00%	100%
1 1/2 in	0.0	0.00%	0.00%	100.00%	0.0	0.00%	0.00%	100.00%	100%
1 in	0.0	0.00%	0.00%	100.00%	0.0	0.00%	0.00%	100.00%	100%
3/4 in	265.1	3.21%	3.21%	96.79%	255.1	3.07%	3.07%	96.93%	97%
1/2 in	4418.7	53.44%	56.65%	43.35%	4022.8	48.44%	51.51%	48.49%	46%
3/8 in	2306.2	27.89%	84.54%	15.46%	2544.6	30.64%	82.15%	17.85%	17%
No. 4	1017.2	12.30%	96.85%	3.15%	1076.2	12.96%	95.10%	4.90%	4%
No. 8	177.5	2.15%	98.99%	1.01%	285.8	3.44%	98.55%	1.45%	1%
Pan	83.1	1.01%	100.00%		120.8	1.45%	100.00%		
Total	8267.8	100.00%			8305.3				
ASTM C 117: Minus 75um (No. 200)									
OD Mass, g	9427.7	Mass Aft, g	9359.2	Mass Loss, g	68.5		% Loss:		0.73%
ASTM C 127: Bulk Specific Gravity & Absorption:									
						Run 1	Run 2	Avg	
SSD Mass in Air, g						3142.6	3529.7		
SSD Mass in Water, g						1965.1	2207.5		
Displaced Water, g						1177.5	1322.2		
Water Temp C						22.7	22.7		
Relative Density (Bulk Specific Gravity)(SSD)						2.669	2.670	2.67	
Oven Dry Mass, g						3123.4	3508.8		
Moisture Loss, g						19.2	20.9		
Absorption						0.61%	0.60%	0.61%	
ASTM C 88 Magnesium Sulfate Soundness (5 cycles):									
	Gradation > 5%	OD Mass, g	Mass Aft, g	Mass Loss, g	% Loss	Wt'ed %			
2 1/2 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
2 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
1 1/2 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
1 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
3/4 in	3.21%	674.4	668.0	6.4	0.01	0.0%			
1/2 in	53.44%	674.4	668.0	6.4	0.01	0.5%			
3/8 in	27.89%	1004.6	978.6	26.0	0.03	0.7%			
No. 4	12.30%	280.9	280.9	0.0	0.00	0.0%			
No. 8	2.15%	280.9	280.9	0.0	0.00	0.0%			
Total	98.99%					1.3%			1.3%
ASTM C 123 Light Weight Particles and Pieces in Aggregate									
Zinc Bromide 2.40 sp.gr.		No mat'l. lighter than 2.00 sp.gr.							
OD Mass, g	3004.0	Ret Mass, g	2959.7	Mass Loss, g	44.3	% Loss:	1.47%		1.5%
ASTM C131 or C535 LA Abrasion Resistance (500 rev)									
Grading:	B	OD Mass, g	5009.9	Ret Mass, g	3903.8	% Loss:	22.08%		22.1%
ASTM C 142: Clay Lumps & Friable Particles:									
	Gradation >5%	OD Mass, g	Mass Aft, g	Mass Loss, g	% Loss	Wt'ed %			
2 1/2 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
2 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
1 1/2 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
1 in	0.00%	1.0	1.0	0.0	0.00	0.0%			
3/4 in	3.21%	2037.7	2035.4	2.3	0.00	0.0%			
1/2 in	53.44%	2037.7	2035.4	2.3	0.00	0.1%			
3/8 in	27.89%	2001.1	1999.2	1.9	0.00	0.0%			
No. 4	12.30%	1007.0	1002.4	4.6	0.00	0.1%			
Total	96.85%					0.1%			0.1%
ASTM D 4791 Flat or Elongated Particles:									
3:1 Ratio	Gradation >10%	Pcs Before	Flat Pcs	Elong Pcs	F&E Pcs	% F,E&FE	Wt'ed %		
2 1/2 in	0.00%	100	0	0	0	0.00	0.0%		
2 in	0.00%	100	0	0	0	0.00	0.0%		
1 1/2 in	0.00%	100	0	0	0	0.00	0.0%		
1 in	0.00%	100	0	0	0	0.00	0.0%		
3/4 in	3.21%	100	0	0	0	0.00	0.0%		
1/2 in	53.44%	107	0	0	0	0.00	0.0%		
3/8 in	27.89%	120	0	0	0	0.00	0.0%		
No. 4	12.30%	102	0	0	0	0.00	0.0%		
Total	96.85%						0.0%		0.0%

Georgetown Sand Fine Aggregate

Summary of Aggregate Tests Report									
Material Description:			Fine Aggregate		Performing Organizaion:		Geotechnical and Structures Lab		
Source:			Georgetown Sand & Gravel				Concrete and Materials Branch		
Location:			Georgetown, PA		Tested by:		R. Hardy		
CMB Log in #:			150069		Reviewed by:		J. Burroughs/M. Ramsey		
Sponsoring Organization:			USACE Pittsburgh District, Lower Mon Area Office						
Project:			Charleroi Lock and Dam Monongahela River Reconstruction Project						
ASTM C 136 Sieve Analysis:									
Sieve Size	Run 1		Cumulative Percent		Run 2		Cumulative Percent		Avg % Passing
	Mass Ret, g	% Ret.	Ret.	Pass	Mass Ret, g	% Ret.	Ret.	Pass	
3/8 in.	0.00	0.00%	0.00%	100.00%	0.00	0.00%	0.00%	100.00%	100%
No. 4	10.60	2.19%	2.19%	97.81%	9.30	2.02%	2.02%	97.98%	98%
No. 8	53.90	11.11%	13.30%	86.70%	55.00	11.94%	13.96%	86.04%	86%
No. 16	63.00	12.99%	26.29%	73.71%	56.20	12.20%	26.17%	73.83%	74%
No. 30	89.80	18.52%	44.80%	55.20%	85.90	18.65%	44.82%	55.18%	55%
No. 40	106.80	22.02%	66.82%	33.18%	102.70	22.30%	67.12%	32.88%	33%
No. 50	95.30	19.65%	86.47%	13.53%	88.60	19.24%	86.36%	13.64%	14%
No. 100	54.00	11.13%	97.61%	2.39%	51.30	11.14%	97.50%	2.50%	2%
No. 200	10.40	2.14%	99.75%	0.25%	9.90	2.15%	99.65%	0.35%	0%
Pan	1.20	0.25%	100.00%		1.60	0.35%	100.00%		
Total	485.00	100.00%			460.50				
Fineness Modulus:			2.707				2.708		2.71
ASTM C 117 Minus 75um (No. 200)									
OD Mass, g	489.90	Mass Aft, g	485	Mass Loss, g	4.90	% Loss:	1.00%		Avg Loss
OD Mass, g	464.40	Mass Aft, g	460.7	Mass Loss, g	3.70	% Loss:	0.80%		0.9%
ASTM C 127: Bulk Specific Gravity & Absorption:									
							Run 1	Run 2	Avg
SSD Mass, g							503.80	507.90	
Mass Flask+Water, g							1261.80	1474.60	
Mass Flask+Water+Material, g							1573.50	1788.30	
Mass Displaced Water, g							192.10	194.20	
Water Temp C							22.7	22.7	
Relative Density (Bulk Specific Gravity)(SSD)							2.623	2.615	2.62
SSD Mass, g							503.80	507.90	
Oven Dry Mass, g							496.90	500.90	
Moisture Loss, g							690.00%	700.00%	
Absorption							1.39%	1.40%	1.39%
ASTM C 40 Organic Impurity Color Plate Number:									2
ASTM C 88 Magnesium Sulfate Soundness (5 cycles):									
Gradation > 5%		OD Mass, g	Mass Aft, g	% Loss	Wt'ed % Loss				
No. 4	2%	0.00	0.00						
No. 8	12%	100.40	88.40	12.0%	1.38%				
No. 16	13%	100.40	88.70	11.7%	1.47%				
No. 30	19%	100.60	87.80	12.7%	2.36%				
No. 50	19%	100.30	89.50	10.8%	2.09%				
No. 100	11%	100.00	92.10	7.9%	0.88%				
Total					8.18%				8.2%
ASTM C 123 Light Weight Particles and Pieces in Aggregate									
Zinc Bromide 2.40 sp.gr.									
OD Mass, g	477.1	Mass Aft, g	471.20					% Loss:	1.2%
Zinc Chloride 2.00 sp.gr.									
OD Mass, g	471.2	Mass Aft, g	465.40					% Loss:	1.2%
ASTM C 142 Clay Lumps & Friable Particles:									
OD Mass, g	270.1	Mass Aft, g	269.80	Loss, g	0.30			Loss, %	0.11%

Shelly Sand Fine Aggregate

Summary of Aggregate Tests Report									
Material Description: Fine Aggregate			Performing Organizaion: Geotechnical and Structures Lab Concrete and Materials Branch						
Source: Shelly Materials									
Location: Thornville, OH			Tested by: R. Hardy						
CMB Log in #: 160004			Reviewed by: J. Burroughs/M. Ramsey						
Sponsoring Organization: USACE Pittsburgh District, Lower Mon Area Office									
Project: Charleroi Lock and Dam Monongahela River Reconstruction Project									
ASTM C 136 Sieve Analysis:									
Sieve Size	Run 1		Cumulative Percent		Run 2		Cumulative Percent		Avg % Passing
	Mass Ret, g	% Ret.	Ret.	Pass	Mass Ret, g	% Ret.	Ret.	Pass	
3/8 in.	0.00	0.00%	0.00%	100.00%	0.00	0.00%	0.00%	100.00%	100%
No. 4	5.90	1.09%	1.09%	98.91%	6.10	1.11%	1.11%	98.89%	99%
No. 8	55.60	10.27%	11.36%	88.64%	57.90	10.56%	11.67%	88.33%	88%
No. 16	60.90	11.25%	22.61%	77.39%	59.10	10.78%	22.45%	77.55%	77%
No. 30	112.50	20.78%	43.39%	56.61%	112.60	20.53%	42.98%	57.02%	57%
No. 40	146.50	27.06%	70.45%	29.55%	150.40	27.43%	70.40%	29.60%	30%
No. 50	98.60	18.21%	88.66%	11.34%	98.30	17.92%	88.33%	11.67%	12%
No. 100	52.10	9.62%	98.28%	1.72%	53.70	9.79%	98.12%	1.88%	2%
No. 200	8.50	1.57%	99.85%	0.15%	8.80	1.60%	99.73%	0.27%	0%
Pan	0.80	0.15%	100.00%		1.50	0.27%	100.00%		
Total	541.40	100.00%			548.40	100.00%			
Fineness Modulus:			2.654				2.647		2.65
ASTM C 117 Minus 75um (No. 200)									
OD Mass, g	544.40	Mass Aft, g	541.4	Mass Loss, g	3.00	% Loss:	0.55%		Avg Loss
OD Mass, g	551.90	Mass Aft, g	548.4	Mass Loss, g	3.50	% Loss:	0.63%		0.6%
ASTM C 127: Bulk Specific Gravity & Absorption:									
							Run 1	Run 2	Avg
SSD Mass, g							508.60	505.10	
Mass Flask+Water, g							1263.50	1479.20	
Mass Flask+Water+Material, g							1576.30	1790.10	
Mass Displaced Water, g							195.80	194.20	
Water Temp C							21.8	21.8	
Relative Density (Bulk Specific Gravity)(SSD)							2.598	2.601	2.60
Oven Dry Mass, g							499.90	496.60	
Moisture Loss, g							8.70	8.50	
Absorption							1.74%	1.71%	1.7%
ASTM C 40 Organic Impurity Color Plate Number:									2
ASTM C 88 Magnesium Sulfate Soundness (5 cycles): New Solution 1.299 sp.gr.									
Gradation > 5%		OD Mass, g	Mass Aft, g	% Loss		Wt'ed % Loss			
No. 4	1%			11.1%		0.12%			
No. 8	10%	100.00	88.90	11.1%		1.16%			
No. 16	11%	100.00	86.80	13.2%		1.45%			
No. 30	21%	100.10	81.90	18.2%		3.76%			
Nos. 40 & 50	45%	100.10	90.70	9.4%		4.25%			
No. 100	10%								
Minus No. 100	2%								
Total	100%					10.62%	10.6%		
ASTM C 123 Light Weight Particles and Pieces in Aggregate									
Zinc Bromide 2.40 sp.gr.									
OD Mass, g	531.5	Mass Aft, g	525.60					% Loss:	1.11%
Zinc Chloride 2.00 sp.gr.									
OD Mass, g	535.3	Mass Aft, g	531.40					% Loss:	0.73%
ASTM C 142 Clay Lumps & Friable Particles:									
OD Mass, g	156.2	Mass Aft, g	155.80	Loss, g	0.40			Loss, %	0.26%

Limestone Powder

 US Army Corps of Engineers BUILDING STRONG.	Report on Test Specifications:		ASTM C1271 and C1301 for chemical properties and ASTM D546 and D4318 for physical properties of limestone powder.						
	Performing Organization:				Sponsoring Organization:				
	U.S Army Engineer Research and Development Center Geotechnical and Structures Laboratory (CEERD-GMC) 3909 Halls Ferry Road Vicksburg, MS 39180-6199				U.S. Army Corps of Engineers Pittsburgh District, Lower Mon Area Office 1811 Schoonmaker Ave., Monesson, PA 15062				
Material Description: Limestone Powder									
Manufacturer: Graymont Limestone									
Location: Pleasant Gap, PA									
CMB Serial #: 150067									
Project: Charleroi Lock and Dam Monongahela River Reconstruction Project									
Chemical Analysis				Test Results					
SiO ₂ , %				0.95					
Al ₂ O ₃ , %				0.38					
Fe ₂ O ₃ , %				0.15					
CaO, %				54.18					
Na ₂ O, %				0.04					
K ₂ O, %				0.09					
MgO, %				0.71					
C, %				0.17					
Loss on ignition (950°C), %				43.29					
<u>Calculated Compounds</u>									
Ca as CaCO ₃ , %				96.69					
Mg as MgCO ₃ , %				1.49					
Calculated Carbonates as CO ₂				43.29					
L.O.I. / CO ₂ Balance				1					
<u>Calculated Compounds- Mg as Dolomite</u>									
Mg as CaMg(CO ₃) ₂ , %				3.26					
Residual Ca as CaCO ₃ , %				94.92					
ASTM D 546 Sieve Analysis of Mineral Filler for Bituminous Paving Mixtures:									
Sieve Size	Run 1		Cumulative Percent		Run 2		Cumulative Percent		Avg. % Passing
	Mass Retained, g	% Retained	% Retained	% Passing	Mass Retained, g	% Retained	% Retained	% Passing	
No. 16	0.00	0.00%	0.00%	100.00%	0.00	0.00%	0.00%	100.00%	100.00%
No. 30	0.52	0.51%	0.51%	99.49%	0.60	0.53%	0.53%	99.47%	99.48%
No. 50	0.50	0.49%	1.00%	99.00%	0.58	0.51%	1.04%	98.96%	98.98%
No. 100	1.93	1.89%	2.89%	97.11%	2.08	1.83%	2.87%	97.13%	97.12%
No. 200	22.00	21.56%	24.45%	75.55%	24.16	21.25%	24.12%	75.88%	75.72%
Minus No.200	77.09	75.55%	100.00%		86.28	75.88%	100.00%		
Original Sample	102.04	100.00%			113.70	100.00%			
Remarks: Limestone powder material is considered non-plastic Silty Sand (SM), Gray when tested in accordance to ASTM D4318									

Appendix B: Freezing and Thawing Reports

Hanson Coarse Aggregate

Resistance of Concrete to Rapid Freezing and Thawing, ASTM C666															
Project:				Charleroi L&D, Monogahela River Project											
Customer:				Pittsburgh District											
Mixture ID:				Hanson Test Coarse Aggregate											
Materials				Testing Specifics											
Fine Aggregate	Arkadelphia Control Sand			Maximum Cycles				300							
Coarse Aggregate	Hanson Test Coarse Aggregate			Min. Dynamic Modulus at Failure (%)				50							
Cement	Armstrong Type II (MH)			Slump (in.) ASTM C143				3							
Admixture	Eucon AEA 92			Air Content (%) ASTM C231				6							
Measurements															
Added	0	4	11	24	12	27	33	24	24	11	22	36	24	23	36
Cummulative	0	4	15	39	51	78	111	135	159	170	192	228	252	275	311
Specimen 1															
Measured Frequency	1844	1804	1795	1791	1781	1774	1745	1726	1704	1725	1679	1644	1631	1589	1546
Specimen Weight (lb)	21.51	21.53	21.53	21.53	21.52	21.5	21.47	21.44	21.39	21.37	21.33	21.26	21.2	21.15	21.05
Rel Dyn Elastic Modulus	-	96	95	94	93	93	90	88	85	88	83	79	78	74	70
Weight loss (lb)	-	0.02	0.02	0.02	0.01	-0.01	-0.04	-0.07	-0.12	-0.14	-0.18	-0.25	-0.31	-0.36	-0.46
Mass Loss (%)	-	0.09	0.09	0.09	0.05	0.05	0.19	0.33	0.56	0.65	0.84	1.16	1.44	1.67	2.14
Durability Factor	-	1	5	12	16	24	33	39	45	50	53	60	66	68	73
Specimen 2															
Measured Frequency	1831	1790	1780	1776	1760	1712	1674	1659	1630	1670	1613	1545	1507	1458	1425
Specimen Weight (lb)	21.29	21.31	21.32	21.32	21.31	21.3	21.22	21.17	21.12	21.09	21.01	20.94	20.88	20.82	20.74
Rel Dyn Elastic Modulus	-	96	95	94	92	87	84	82	79	83	78	71	68	63	61
Weight loss (lb)	-	0.02	0.03	0.03	0.02	0.01	-0.07	-0.12	-0.17	-0.2	-0.28	-0.35	-0.41	-0.47	-0.55
Mass Loss (%)	-	0.09	0.14	0.14	0.09	0.05	0.33	0.56	0.80	0.94	1.32	1.64	1.93	2.21	2.58
Durability Factor	-	1	5	12	16	23	31	37	42	47	50	54	57	58	63
Specimen 3															
Measured Frequency	1871	1838	1829	1823	1819	1820	1795	1785	1775	1797	1765	1739	1713	1681	1599
Specimen Weight (lb)	21.58	21.58	21.59	21.59	21.58	21.54	21.5	21.45	21.41	21.37	21.33	21.24	21.2	21.12	20.99
Rel Dyn Elastic Modulus	-	97	96	95	95	95	92	91	90	92	89	86	84	81	73
Weight loss (lb)	-	0	0.01	0.01	0	-0.04	-0.08	-0.13	-0.17	-0.21	-0.25	-0.34	-0.38	-0.46	-0.59
Mass Loss (%)	-	0.00	0.05	0.05	0.00	0.19	0.37	0.60	0.79	0.97	1.16	1.58	1.76	2.13	2.73
Durability Factor	-	1	5	12	16	25	34	41	48	52	57	66	70	74	76
Average															
Measured Frequency	1849	1811	1801	1797	1787	1769	1738	1723	1703	1731	1686	1643	1617	1576	1523
Specimen Weight (lb)	21.46	21.47	21.48	21.48	21.47	21.45	21.40	21.35	21.31	21.28	21.22	21.15	21.09	21.03	20.93
Rel Dyn Elastic Modulus	-	96	95	94	93	92	88	87	85	88	83	79	77	73	68
Weight loss (lb)	-	0.01	0.02	0.02	0.01	-0.01	-0.06	-0.11	-0.15	-0.18	-0.24	-0.31	-0.37	-0.43	-0.53
Mass Loss (%)	-	0.06	0.09	0.09	0.05	0.09	0.30	0.50	0.71	0.85	1.10	1.46	1.71	2.00	2.49
Durability Factor	-	1	5	12	16	24	33	39	45	50	53	60	64	67	70

Georgetown Sand Fine Aggregate

Resistance of Concrete to Rapid Freezing and Thawing, ASTM C666														
Project:					Charleroi L&D, Monogahela River Project									
Customer:					Pittsburgh District									
Mixture ID:					Georgetown Fine Aggregate									
Materials					Testing Specifics									
Fine Aggregate	Georgetown Test Aggregate				Maximum Cycles						300			
Coarse Aggregate	Calera Limestone Control Aggregate				Min. Dynamic Modulus at Failure (%)						50			
Cement	Armstrong Type II (MH)				Slump (in.) ASTM C143						3			
Admixture	Eucon AEA 92				Air Content (%) ASTM C231						6			
Measurements														
Added	0	20	20	20	20	20	20	20	20	20	20	48	36	16
Cummulative	0	20	40	60	80	100	120	140	160	180	200	248	284	300
Specimen 1														
Measured Frequency	2019	2006	1980	1973	1964	1963	1960	1955	1949	1938	1921	1822	1750	1703
Specimen Weight (lb)	21.41	21.4	21.4	21.4	21.4	21.41	21.4	21.41	21.4	21.35	21.29	21.18	21.18	21.15
Rel Dyn Elastic Modulus	-	99	96	95	95	95	94	94	93	92	91	81	75	71
Weight loss (lb)	-	-0.01	-0.01	-0.01	-0.01	0	-0.01	0	-0.01	-0.06	-0.12	-0.23	-0.23	-0.26
Mass Loss (%)		0.05	0.05	0.05	0.05	0.00	0.05	0.00	0.05	0.28	0.56	1.07	1.07	1.21
Durability Factor	-	7	13	19	25	32	38	44	50	55	60	67	71	71
Specimen 2														
Measured Frequency	2021	2007	1979	1971	1965	1963	1957	1953	1943	1929	1911	1810	1735	1690
Specimen Weight (lb)	21.56	21.55	21.55	21.54	21.55	21.55	21.54	21.54	21.52	21.49	21.42	21.35	21.3	21.29
Rel Dyn Elastic Modulus	-	99	96	95	95	94	94	93	92	91	89	80	74	70
Weight loss (lb)	-	-0.01	-0.01	-0.02	-0.01	-0.01	-0.02	-0.02	-0.04	-0.07	-0.14	-0.21	-0.26	-0.27
Mass Loss (%)		0.05	0.05	0.09	0.05	0.05	0.09	0.09	0.19	0.32	0.65	0.97	1.21	1.25
Durability Factor	-	7	13	19	25	31	38	44	49	55	60	66	70	70
Specimen 3														
Measured Frequency	2018	2008	1978	1970	1961	1961	1957	1954	1948	1931	1920	1820	1745	1700
Specimen Weight (lb)	21.58	21.57	21.57	21.57	21.57	21.58	21.57	21.57	21.56	21.51	21.44	21.42	21.38	21.3
Rel Dyn Elastic Modulus	-	99	96	95	94	94	94	94	93	92	91	81	75	71
Weight loss (lb)	-	-0.01	-0.01	-0.01	-0.01	0	-0.01	-0.01	-0.02	-0.07	-0.14	-0.16	-0.2	-0.28
Mass Loss (%)		0.05	0.05	0.05	0.05	0.00	0.05	0.05	0.09	0.32	0.65	0.74	0.93	1.30
Durability Factor	-	7	13	19	25	31	38	44	50	55	60	67	71	71
Specimen 4														
Measured Frequency	1790	1722	1704	1678	1662	1660	1649	1639	1626	1630	1627	1510	1450	1430
Specimen Weight (lb)	19.86	19.97	19.98	19.98	19.92	19.88	19.85	19.77	19.7	19.62	19.59	19.58	19.55	19.5
Rel Dyn Elastic Modulus	-	93	91	88	86	86	85	84	83	83	83	71	66	64
Weight loss (lb)	-	0.11	0.12	0.12	0.06	0.02	-0.01	-0.09	-0.16	-0.24	-0.27	-0.28	-0.31	-0.36
Mass Loss (%)		0.55	0.60	0.60	0.30	0.10	0.05	0.45	0.81	1.21	1.36	1.41	1.56	1.81
Durability Factor	-	6	12	18	23	29	34	39	44	50	55	59	62	64
Average														
Measured Frequency	1962	1936	1910	1898	1888	1887	1881	1875	1867	1857	1845	1740.5	1670	1630.75
Specimen Weight (lb)	21.10	21.12	21.13	21.12	21.11	21.11	21.09	21.07	21.05	20.99	20.94	20.8825	20.8525	20.81
Rel Dyn Elastic Modulus	-	97	95	93	92	92	92	91	90	89	88	79	72	69
Weight loss (lb)	-	0.02	0.02	0.02	0.01	0.00	-0.01	-0.03	-0.06	-0.11	-0.17	-0.22	-0.25	-0.2925
Mass Loss (%)		0.17	0.19	0.20	0.11	0.04	0.06	0.15	0.28	0.53	0.80	1.05	1.19	1.39
Durability Factor	-	6	13	19	25	31	37	43	48	54	59	65	68	69

Shelly Sand Fine Aggregate

Resistance of Concrete to Rapid Freezing and Thawing, ASTM C666																			
Project:					Charleroi L&D, Monogahela River Project														
Customer:					Pittsburgh District														
Mixture ID:					Shelly Sand Fine Aggregate														
Materials					Testing Specifics														
Fine Aggregate	Shelly Sand Test Aggregate				Maximum Cycles										300				
Coarse Aggregate	Calera Limestone Control Aggregate				Min. Dynamic Modulus at Failure (%)										50				
Cement	Armstrong Type II (MH)				Slump (in.) ASTM C143										3				
Admixture	Eucon AEA 92				Air Content (%) ASTM C231										6				
Measurements																			
Added	0	10	24	12	27	33	24	24	11	22	36	24	23	32					
Cummulative	0	10	34	46	73	106	130	154	165	187	223	247	270	302					
Specimen 1																			
Measured Frequency	1875	1805	1750	1740	1722	1669	1642	1640	1697	1598	1515	1540	1500	1490					
Specimen Weight (lb)	21.39	21.41	21.41	21.4	21.38	21.35	21.3	21.25	21.22	21.16	21.16	21.16	21.16	20.95					
Rel Dyn Elastic Modulus	-	93	87	86	84	79	77	77	82	73	65	67	64	63					
Weight loss (lb)	-	0.02	0.02	0.01	-0.01	-0.04	-0.09	-0.14	-0.17	-0.23	-0.23	-0.23	-0.23	-0.44					
Mass Loss (%)	-	0.09	0.09	0.05	0.05	0.19	0.42	0.65	0.79	1.08	1.08	1.08	1.08	2.06					
Durability Factor	-	3	10	13	21	28	33	39	45	45	49	56	58	64					
Specimen 2																			
Measured Frequency	1867	1807	1783	1777	1741	1692	1670	1661	1679	1619	1507	1487	1439	1439					
Specimen Weight (lb)	21.43	21.45	21.45	21.44	21.43	21.4	21.36	21.31	21.28	21.23	21.14	21.06	20.97	20.88					
Rel Dyn Elastic Modulus	-	94	91	91	87	82	80	79	81	75	65	63	59	59					
Weight loss (lb)	-	0.02	0.02	0.01	0	-0.03	-0.07	-0.12	-0.15	-0.2	-0.29	-0.37	-0.46	-0.55					
Mass Loss (%)	-	0.09	0.09	0.05	0.00	0.14	0.33	0.56	0.70	0.93	1.35	1.73	2.15	2.57					
Durability Factor	-	3	10	14	21	29	35	41	44	47	48	52	53	60					
Specimen 3																			
Measured Frequency	1847	1783	1762	1757	1736	1705	1675	1663	1682	1642	1592	1553	1447	1430					
Specimen Weight (lb)	21.22	21.24	21.23	21.22	21.2	21.13	21.09	21.04	21.02	20.97	20.9	20.82	20.76	20.65					
Rel Dyn Elastic Modulus	-	93	91	90	88	85	82	81	83	79	74	71	61	60					
Weight loss (lb)	-	0.02	0.01	0	-0.02	-0.09	-0.13	-0.18	-0.2	-0.25	-0.32	-0.4	-0.46	-0.57					
Mass Loss (%)	-	0.09	0.05	0.00	0.09	0.42	0.61	0.85	0.94	1.18	1.51	1.89	2.17	2.69					
Durability Factor	-	3	10	14	21	30	36	42	46	49	55	58	55	60					
Average																			
Measured Frequency	1863	1798	1765	1758	1733	1689	1662	1655	1686	1620	1538	1527	1462	1453					
Specimen Weight (lb)	21.35	21.37	21.36	21.35	21.34	21.29	21.25	21.20	21.17	21.12	21.07	21.01	20.96	20.83					
Rel Dyn Elastic Modulus	-	93	90	89	87	82	80	79	82	76	68	67	62	61					
Weight loss (lb)	-	0.02	0.02	0.01	-0.01	-0.05	-0.10	-0.15	-0.17	-0.23	-0.28	-0.33	-0.38	-0.52					
Mass Loss (%)	-	0.09	0.08	0.03	0.05	0.25	0.45	0.69	0.81	1.06	1.31	1.56	1.80	2.44					
Durability Factor	-	3	10	14	21	29	35	41	45	47	51	55	55	61					

Mix 7

Resistance of Concrete to Rapid Freezing and Thawing, ASTM C666											
Project:					Charlevoi L&D, Monongahela River Project						
Customer:					Pittsburgh District						
Mixture ID:					Mix 7						
Materials					Testing Specifics						
Fine Aggregate	Georgetown				Maximum Cycles				300		
Coarse Aggregate	Hanson				Min. Dynamic Modulus at Failure (%)				50		
Cement	Armstrong Type II (MH)				Specimen Cast Date				8/9/2017		
GGBFS, Grade 100	Argos-Essroc				Fabricating Agency				Pittsburgh District		
Class F Fly Ash	Sammis				Slump (in.) ASTM C143				3		
Admixtures	AEA-92 and Ret-75				Air Content (%) ASTM C231				5.9		
Additional Notes on Materials	After a visual inspection was made on all the specimens to ensure the specimen had been protected against loss of moisture and no damage had occurred during the transportation of the beams, the durability test was conducted according to ASTM C666, Procedure A. The specimens were saturated 3 days prior to the initial fundamental transverse frequency and mass of the specimens were recorded.										
Measurements											
Added	0	36	24	48	36	24	36	36	24	28	10
Cummulative	0	36	60	108	144	168	204	240	264	290	300
Specimen 1											
Measured Frequency	1843	1799	1793	1787	1771	1765	1748	1743	1727	1721	1719
Specimen Weight (lb)	20.17	20.22	20.19	20.18	20.16	20.15	20.11	20.06	20.02	19.98	19.96
Rel Dyn Elastic Modulus	-	95	95	94	92	92	90	89	88	87	87
Weight loss (lb)	-	0.05	0.02	0.01	-0.01	-0.02	-0.06	-0.11	-0.15	-0.19	-0.21
Mass Loss (%)	-	0.25	0.10	0.05	0.05	0.10	0.30	0.55	0.74	0.94	1.04
Durability Factor	-	11	19	34	44	51	61	72	77	84	87
Specimen 2											
Measured Frequency	1856	1756	1745	1734	1729	1732	1709	1703	1688	1679	1676
Specimen Weight (lb)	20.09	20.2	20.2	20.15	20.12	20.1	20.06	20.01	19.98	19.93	19.9
Rel Dyn Elastic Modulus	-	90	88	87	87	87	85	84	83	82	82
Weight loss (lb)	-	0.11	0.11	0.06	0.03	0.01	-0.03	-0.08	-0.11	-0.16	-0.19
Mass Loss (%)	-	0.55	0.55	0.30	0.15	0.05	0.15	0.40	0.55	0.80	0.95
Durability Factor	-	11	18	31	42	49	58	67	73	79	82
Specimen 3											
Measured Frequency	1807	1758	1747	1741	1739	1738	1721	1720	1714	1708	1708
Specimen Weight (lb)	19.92	19.99	19.99	19.97	19.97	19.95	19.92	19.85	19.8	19.76	19.74
Rel Dyn Elastic Modulus	-	95	93	93	93	93	91	91	90	89	89
Weight loss (lb)	-	0.07	0.07	0.05	0.05	0.03	0	-0.07	-0.12	-0.16	-0.18
Mass Loss (%)	-	0.35	0.35	0.25	0.25	0.15	0.00	0.35	0.60	0.80	0.90
Durability Factor	-	11	19	33	44	52	62	72	79	86	89
Specimen 4											
Measured Frequency	1790	1722	1704	1678	1662	1660	1649	1639	1626	1630	1627
Specimen Weight (lb)	19.86	19.97	19.98	19.98	19.92	19.88	19.85	19.77	19.7	19.62	19.59
Rel Dyn Elastic Modulus	-	91	89	86	85	84	83	82	81	81	81
Weight loss (lb)	-	0.11	0.12	0.12	0.06	0.02	-0.01	-0.09	-0.16	-0.24	-0.27
Mass Loss (%)	-	0.55	0.60	0.60	0.30	0.10	0.05	0.45	0.81	1.21	1.36
Durability Factor	-	11	18	31	41	47	57	66	71	79	81
Average											
Measured Frequency	1824	1759	1747	1735	1725	1724	1707	1701	1689	1685	1683
Specimen Weight (lb)	20.01	20.10	20.09	20.07	20.04	20.02	19.99	19.92	19.88	19.82	19.80
Rel Dyn Elastic Modulus	-	93	91	90	89	89	87	87	85	85	85
Weight loss (lb)	-	0.08	0.08	0.06	0.03	0.01	-0.03	-0.09	-0.14	-0.19	-0.21
Mass Loss (%)	-	0.43	0.40	0.30	0.19	0.10	0.12	0.44	0.67	0.94	1.06
Durability Factor	-	11	18	32	43	50	59	69	75	82	85

Batch Plant and Field Data Sheets for Mix 7

Lower Merion Area Lab 1811 Schomaker Ave. Monroeville, PA 15146		COMPRESSIVE STRENGTH OF CYLINDERS, FIELD AND LABORATORY TEST DATA		CONTRACT NO. W11100-15-6-2001 TBSV REPORT# CS-1239	
TEST INFORMATION					
SPEC. MENT. STEEL: Carbon 6 x 12		CONCRETE TYPE: Exterior Mass		MIX NO. 7	
Shape: Cube		Designation: 3500		psi @ 90 days	
Address: L. F. 1001		EST. CY: 230		TEMPERATURE (deg. F):	
DATE: 10/6/17		CONCRETE: 5.8		TESTING DATE: 8-9-17	
SAMPLED FROM: 10606		SLUMP: 2 3/4"		CASTING TIME: 6:42am	
W/C RATIO (by weight):		Desired: 0.462		Actual: 0.461	
Flow: —		CY in Batch: 10		BATCH W. (lb): 38657	
TEST RESULTS					
TYPE OF MATERIALS IN BATCH:		PERCENT MOISTURE:		TARGET WEIGHTS BATCH (SSD):	
CEMENT:		ACTUAL WEIGHTS BATCH (SSD):		DESIGN WEIGHTS CY (SSD):	
POZZOLAN FLYASH:		% DIFFERENCE:		Actual:	
AGGREGATE:		Batch (SSD):		Allowed:	
WATER:		Batch (SSD):		% DIFFERENCE:	
ADJ. W. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. C. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. A. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. F. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. S. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. T. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. W. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. C. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. A. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. F. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. S. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. T. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. W. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. C. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. A. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. F. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. S. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. T. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. W. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. C. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. A. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. F. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. S. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. T. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. W. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. C. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. A. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. F. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. S. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. T. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. W. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. C. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. A. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. F. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. S. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. T. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. W. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. C. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. A. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. F. (SSD):		Batch (SSD):		% DIFFERENCE:	
ADJ. S. (SSD):		Batch (SSD):			

BATCH PLANT QC, FRESH CONCRETE TEST RESULTS

TBSV

M7 - Lift #10 (Top lift) Mix Number:

Sunny Partly Cloudy Cold Humid

1	6:42A	10606	10	54°	53°	2 3/4"	8.8%	—	—	35.3	141.8	Ø	—	8 cylinders ID# 8397829 RDH CHECK OK ✓
20	9:22	10625	10	63°	57°	5"	8.5%	—	—	35.2	141.4	Ø	—	RDH CHECK OK ✓

(Batched 230 yds) (Placed 229 yds) (Wasted 1 yd)

Remarks: (AIR METER CORRECTION FACTOR)

River Temp - 72°

Date: 8-9-17

LOWER MON AREA LAB
USACE-Pittsburgh District
c/o Lower Mon Area Office
1811 Schoonmaker Avenue, Monessen, PA 15062

CONCRETE FIELD TESTING DATA SHEET

TR5V

Date: 8-9-17

Placement Location: M-7 - Lift-10

Project: Charlevoix Locks & Dams, Contract 5 - Monoliths M22 - M27

Client: JB Fay - Company Contract: # W911WN-14-C-0003

Batch Time	Batch Ticket	Test Time	Slump (in)	Slump Flow	Conc Temp	Amb Temp	Air Content	BEAMS #	Logger Status
Mix TR 192A 6:42A	10606	7:00AM	3"	—	55	56	5.9	4	TR5V
Mix TR 192A 9:22A	10625	9:30AM	3"	—	61	71	5.8	—	TR5V

WEATHER CONDITION: Sunny / Overcast / Rain / Cool / Hot

Remarks: RIVER TEMP -72° MOULDED 4-BEAMS

QC Tech: F. [signature] & BRIAN H. NIGIE Date: 8-9-17
QA Rep: J. [signature] USACE Date: 8-9-17

LMAL Calibrated Equipment Used:

- | | |
|--|--------------------------------------|
| 1) Digital Thermometer # <u>DT-1</u> | 2) Slump Cone # <u>SC-3</u> |
| 3) Tamping Rod # <u>TR-788</u> | 4) Rubber Mallet # <u>RM-11</u> |
| 5) Strike-Off Plate/Bar # <u>SB-13</u> | 6) Pressure Air Meter # <u>PM-7</u> |
| 7) Digital Scale # <u>BA-7</u> | (if needed for Unit Weight testing.) |

Figure C1. XRD pattern for Hanson with calculated weight percentages from whole pattern fitting.

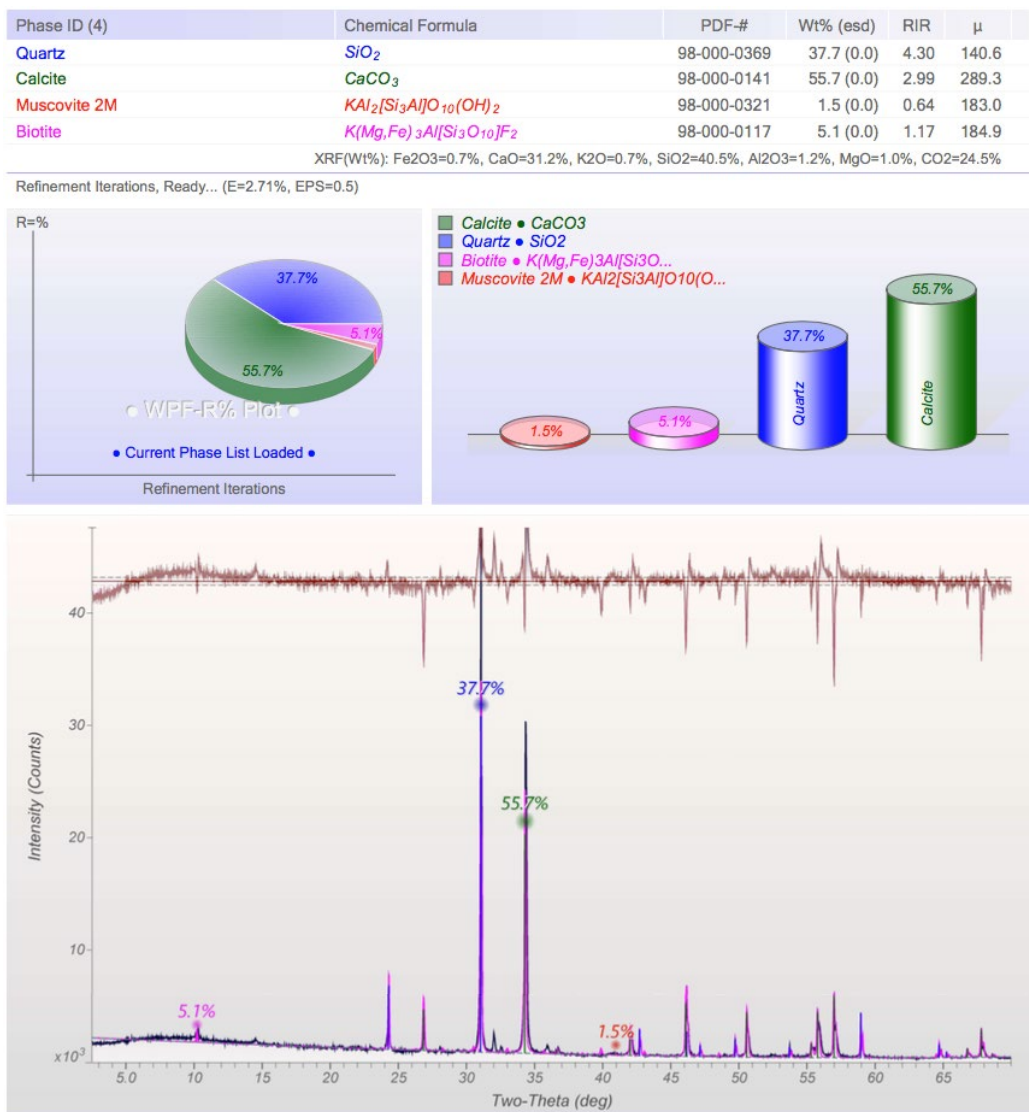


Table C2. Data table used in preparation of ASTM C-295 for the Shelley Sand aggregate.

ASTM C-295	Aggregate		Shelly Sand		CMB ID		160004		Date	7/5/18
Calculation of Results of Particle Counts										
Individual Percentage Retained on Sieve	Composition of Fractions Retained on Sieves Shown Below									
	3/8 in.		No. 4		No. 8		No. 16		No. 30	
	0		1.09		11.36		22.45		42.98	
Constituents	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%
A1			70	23.3	68	22.7	70	23.3	136	45.3
A2			22	7.3	21	7.0	22	7.3	40	13.3
B1			145	48.3	155	51.7	132	44.0	80	26.7
B2			38	12.7	30	10.0	34	11.3	24	8.0
C1			6	2.0	12	4.0	24	8.0	14	4.7
C2			19	6.3	14	4.7	18	6.0	6	2.0
Totals			300	100.0	300	100.0	300	100.0	300	100.0
Individual Percentage Retained on Sieve	Composition of Fractions Retained on Sieves Shown Below									
	No. 40		No. 50		No. 100		No. 200		Pan	
	70.4		88.33		98.12		99.73		100	
Constituents	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%
A1			186	62.0	208	69.3				
A2			66	22.0	58	19.3				
B1			32	10.7	22	7.3				
B2			16	5.3	12	4.0				
C1			0	0.0	0	0.0				
C2			0	0.0	0	0.0				
Totals			300	100.0	300	100.0				
A	Quartz									
B	Sandstone/Granite									
C	Limestone									
1	Fresh, dense									
2	Porous, friable									
Notes	A - varies in color and shape (angular to round), however appears to be pure quartz with minor occurrences of inclusions; B - shape is mostly round/subround but can vary, microcrystals are apparent in many, hematite coating common; C - the most weathered of three rock types observed, has dendritic precipitations likely manganese oxide									

Figure C2. XRD pattern for Shelly with calculated weight percentages from whole pattern fitting.

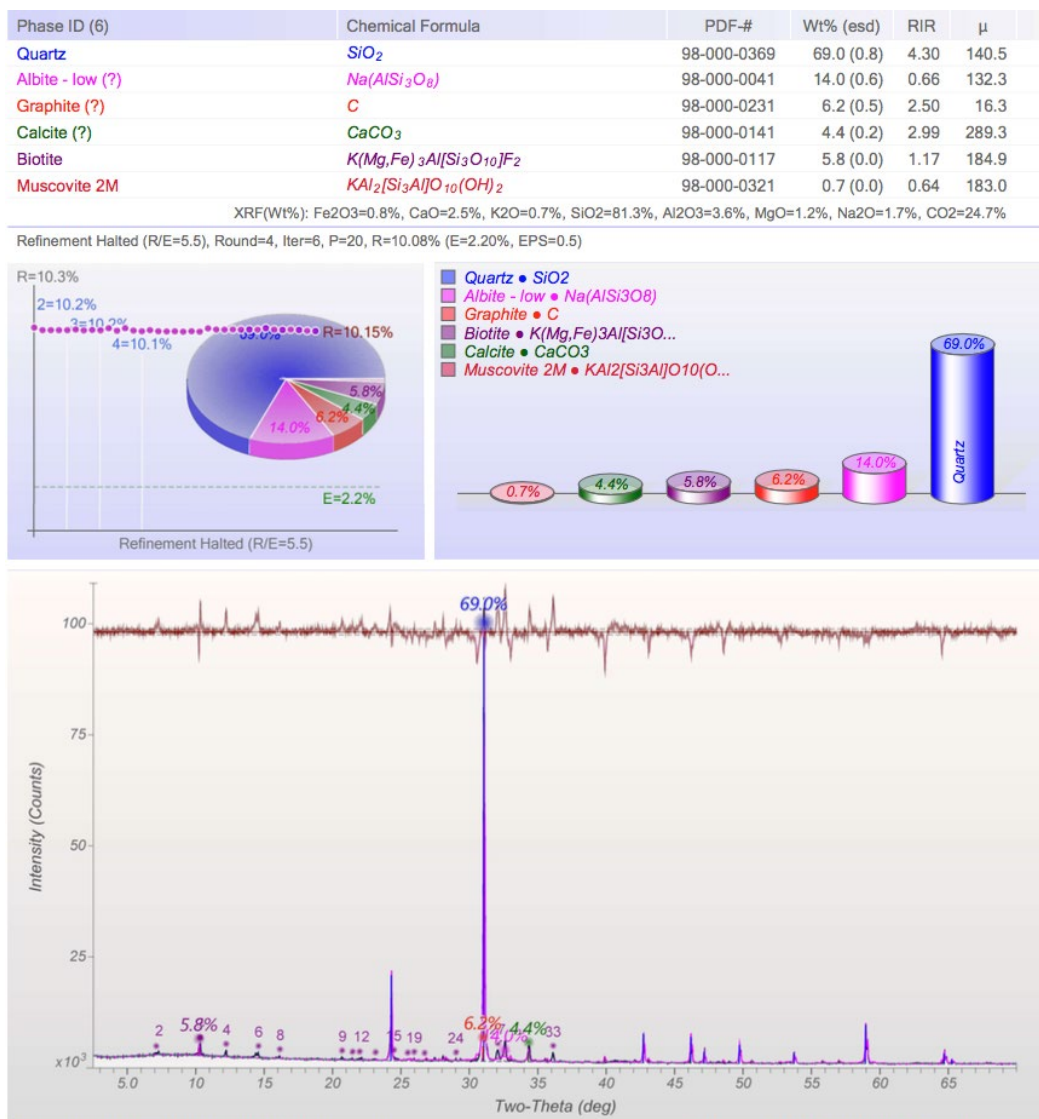
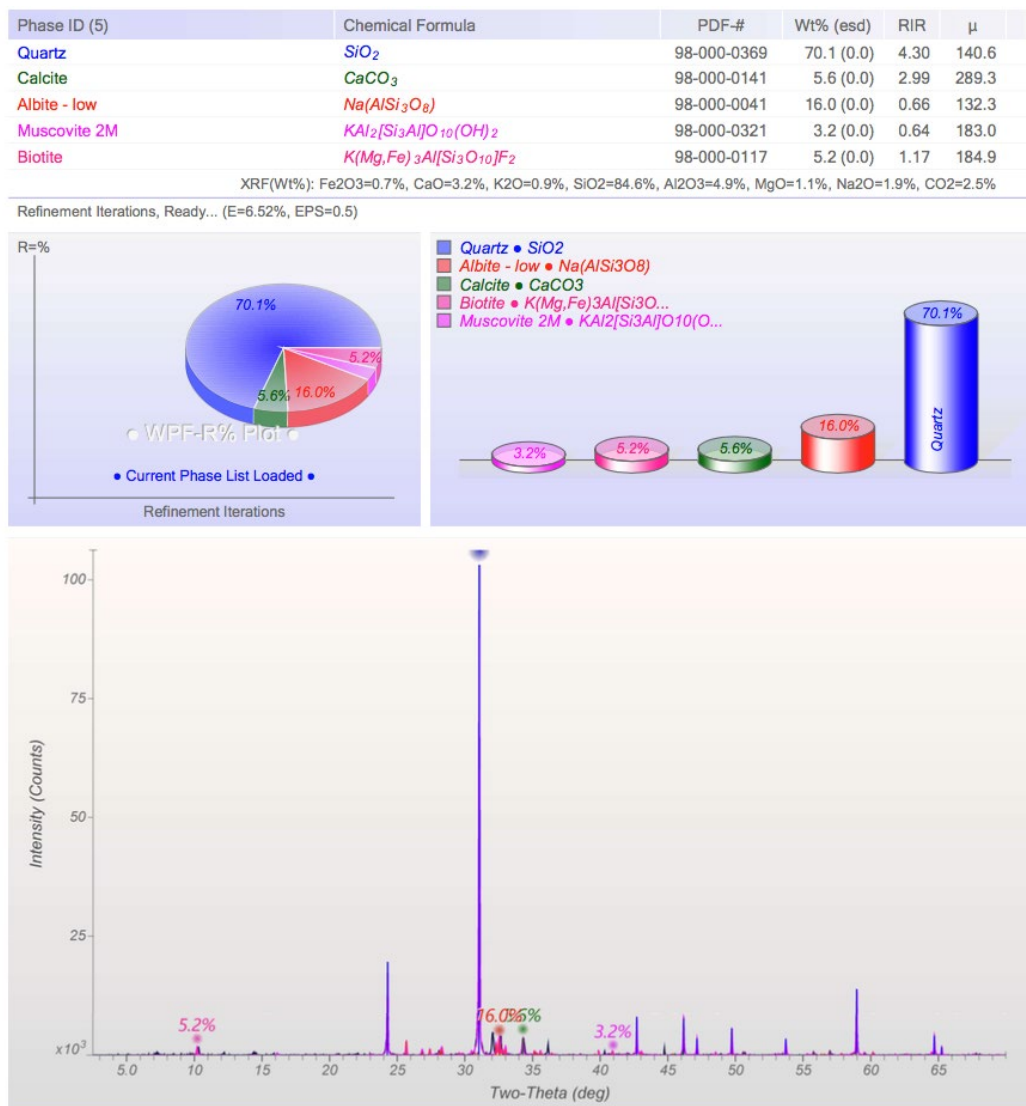


Table C3. Data table used in preparation of ASTM C-295 for the Georgetown aggregate.

ASTM C-295	Aggregate		Georgetown		CMB ID		150069		Date	7/6/18
Calculation of Results of Particle Counts										
Individual Percentage Retained on Sieve	Composition of Fractions Retained on Sieves Shown Below									
	3/8 in.		No. 4		No. 8		No. 16		No. 30	
	0		2.0		14.0		26.2		44.8	
Constituents	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%
A1					76	25.3	105	35.0	179	59.7
A2					16	5.3	38	12.7	20	6.7
B1					144	48.0	106	35.3	69	23.0
B2					42	14.0	21	7.0	16	5.3
C1					16	5.3	26	8.7	16	5.3
C2					6	2.0	4	1.3	0	0.0
Totals					300		300		300	
Individual Percentage Retained on Sieve	Composition of Fractions Retained on Sieves Shown Below									
	No. 40		No. 50		No. 100		No. 200		Pan	
	67.1		86.4		97.5		99.7		100.0	
Constituents	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%
A1			190	63.3	242	80.7				
A2			52	17.3	22	7.3				
B1			38	12.7	24	8.0				
B2			12	4.0	12	4.0				
C1			6	2.0	0	0.0				
C2			2	0.7	0	0.0				
Totals			300		300					
A	Quartz									
B	Sandstone/Granite									
C	Limestone									
1	Fresh, dense									
2	Porous, friable									
Notes	A - range from angular to round with variations in luster (glassy to opaque), often have an orange hue and are dense, mostly quartz with few inclusions/heterogenities; B - mostly round/sub-round when microcrystalline, some have visible quartz and feldspar crystals that are cemented together; C - often a very porous texture indicating dissolution, some fossiliferous grains present									

Figure C3. XRD pattern for Georgetown with calculated weight percentages from whole pattern fitting.



Appendix D: Cementitious Material Reports

ASTM C150 Report: Armstrong Type II (MH) Portland Cement

	Report on Test Specification: ASTM C150, Standard Specification for Portland Cement	
	<u>Performing Organization:</u> US Army Engineer Research and Development Center Geotechnical and Structures Laboratory 3909 Halls Ferry Road Vicksburg, MS 39180-6199	<u>Sponsoring Organization:</u> US Army Corps of Engineers Pittsburgh District, Lower Mon Area Office 1811 Schoonmaker Ave., Monessen, PA 15062
Material Description: Type II (MH) Cement Manufacturer: Armstrong Location: Cabot, PA CMB Serial #: 150063 Project: Charlevoix Lock and Dam Monongahela River Reconstruction Project		
Chemical Analysis	Test Results	ASTM C150 Spec Limits; Type II (MH)
SiO ₂ , %	20.48	-
Al ₂ O ₃ , %	4.59	6.0% max
Fe ₂ O ₃ , %	6.3	^A 6.0% max
CaO, %	62.7	-
MgO, %	1.24	6.0% max
SO ₃ , %	2	3.0% max
Na ₂ O, %	0.13	-
K ₂ O, %	0.66	-
Equivalent Alkalies-total as Na ₂ O, %	0.56	^B 0.60% max
TiO ₂ , %	0.32	-
Loss on ignition, %	0.45	3.0% max
Tricalcium silicate (C ₃ S)	54	-
Dicalcium silicate (C ₂ S)	18	-
Tricalcium aluminate (C ₃ A)	2	8.0% max
Tetracalcium aluminoferrite (C ₄ AF)	19	-
Sum of C ₃ S + 4.75C ₃ A	63.5	100
Physical Analysis	Test Results	ASTM C150 Spec Limits; Type II (MH)
Air content, %; ASTM C 185	7.9	12% (max)
Surface area, m ² /kg (air permeability); ASTM C 204	329	260 m ² /kg (min)
Autoclave expansion, %; ASTM C 151	0.02	0.80% max
Initial set, min. (Vicat); ASTM C 191	155	45 (min)
Final set, min. (Vicat); ASTM C 191	290	375 (max)
Compressive strength, 3-day, (psi), ASTM C 109	1525	^B 1020 psi (min)
Compressive strength, 7-day, (psi); ASTM C 109	1920	^B 1740 psi (min)
Compressive strength, 28-day, (psi), ASTM C 109	4175	^C 3190 psi (min)
Heat of Hydration, 3-days, max, (kJ/kg); ASTM C 1702	185	^C 255 kJ/kg (max)
Heat of Hydration, 7-days, max, (kJ/kg); ASTM C 1702	240	-
Heat of Hydration, 28-days, max, (kJ/kg); ASTM C 1702	330	-
False set (final penetration), %; ASTM C 451	80	50% (min)
Remarks: ^A Does not apply when heat of hydration limit in table 4 is specified ^B Limit in table 2 for low-alkali cement ^C Required only when optional heat of hydration in Table 4 is specified ^D As specified in table 4 optional physical requirements Tested by: MAR Reviewed by: ABC		
<i>Information in this report shall not be used in advertising or sales promotion to indicate endorsement of this product by the U.S. Government.</i>		

ASTM C618 Report: Fort Martin Class F Fly Ash

 US Army Corps of Engineers BUILDING STRONG.	Report on Test Specification: ASTM C 618, Standard Specification for Coal Fly Ash	
	Performing Organization: US Army Engineer Research and Development Center Geotechnical and Structures Laboratory (CEERD-GMC) 3909 Halls Ferry Road Vicksburg, MS 39180-6199	Sponsoring Organization: US Army Corps of Engineers Pittsburgh District, Lower Mon Area Office 1811 Schoonmaker Ave., Monessen, PA 15062
Material Description: Class F Fly Ash Manufacturer: Ft. Martin Plant from Headwater Resources Location: Maidsville, WV CMB Serial #: 150064 Project: Charlevoix Lock and Dam Monongahela River Reconstruction Project		
Chemical Analysis	Test Results	Spec Limits; Class F
SiO ₂ , %	52.6	-
Al ₂ O ₃ , %	22.5	-
Fe ₂ O ₃ , %	13.5	-
Sum, %	88.6	70.0% min
Na ₂ O, %	2.49	-
K ₂ O, %	2	-
CaO, %	1.1	-
MgO, %	0.9	-
SO ₃ , %	0.3	5.0% max
Loss on ignition, %	3.1	6.0% max
Moisture Content, %	0.13	3.0% max
Physical Analysis	Test Results	Spec Limits; Class F
Strength Activity Index, (%) 7-day, ASTM C311	64	75% min
Strength Activity Index, (%) 28-day, ASTM C311	65	75% min
Water Requirement, % control, ASTM C 311, C109	100	105% max
Specific Gravity, ASTM C188	2.52	5% max
Autoclave Soundness, %, ASTM C311, C151	0.001	0.8% max
Fineness, % Retained on #325; ASTM C311	23.85	34% max
Supplementary Optional Physical Analysis	Test Results	Spec Limits; Class F
Increase of drying shrinkage of mortar bars at 28 days, ASTM C618	0.001	-
Uniformity Requirement, amount of Vinsol, ASTM C618	0.2	-
Remarks: 1 Armstrong Type II (MH) project cement used for reference cement Tested by: MAR Reviewed by: ABC		
<i>Information in this report shall not be used in advertising or sales promotion to indicate endorsement of this product by the U.S. Government.</i>		

ASTM C618 Report: Sammis Class F Fly Ash

	Report on Test Specification: ASTM C 618, Standard Specification for Coal Fly Ash	
	Performing Organization: US Army Engineer Research and Development Center Geotechnical and Structures Laboratory (CEERD-GMC) 3909 Halls Ferry Road Vicksburg, MS 39180-6199	Sponsoring Organization: US Army Corps of Engineers Pittsburgh District, Lower Mon Area Office 1811 Schoonmaker Ave., Monessen, PA 15062
Material Description: Class F Fly Ash Manufacturer: W.H. Sammis Plant, Headwaters Resources Location: Stratton, OH CMB Serial #: 150065 Project: Charlevoix Lock and Dam Monongahela River Reconstruction Project		
Chemical Analysis	Test Results	Spec Limits, Class F
SiO ₂ , %	44.2	-
Al ₂ O ₃ , %	20.2	-
Fe ₂ O ₃ , %	24.2	-
Sum, %	88.6	70.0% min
Na ₂ O, %	2.87	-
K ₂ O, %	2.05	-
CaO, %	0	-
MgO, %	0.9	-
SO ₃ , %	0.6	5.0% max
Loss on ignition, %	2.99	6.0% max
Moisture Content, %	0.11	3.0% max
Physical Analysis	Test Results	Spec Limits, Class F
Strength Activity Index, (%) 7-day, ASTM C311	71	75% min
Strength Activity Index, (%) 28-day, ASTM C311	72	75% min
Water Requirement, % control, ASTM C 311, C109	100	105% max
Specific Gravity, ASTM C188	2.6	5% max
Autoclave Soundness, %, ASTM C311, C151	0.001	0.8% max
Fineness, % Retained on #325; ASTM C311	25.92	34% max
Supplementary Optional Physical Analysis	Test Results	Spec Limits, Class F
Increase of drying shrinkage of mortar bars at 28 days, ASTM C618	0.05	-
Uniformity Requirement, amount of Vinsol, ASTM C618	0.2	-
Remarks: ¹ Armstrong Type II (MH) project cement used for reference cement Tested by: MAR Reviewed by: ABC		
<i>Information in this report shall not be used in advertising or sales promotion to indicate endorsement of this product by the U.S. Government.</i>		

ASTM C618 Report: Longview Class F Fly Ash

 US Army Corps of Engineers BUL/DWG 576260	Report on Test Specification: ASTM C 618, Standard Specification for Coal Fly Ash	
	Performing Organization: US Army Engineer Research and Development Center Geotechnical and Structures Laboratory (CEERD-GMC) 3909 Halls Ferry Road Vicksburg, MS 39180-6199	Sponsoring Organization: US Army Corps of Engineers Pittsburgh District, Lower Mon Area Office 1811 Schoonmaker Ave., Monessen, PA 15062
Material Description: Class F Fly Ash Manufacturer: Longview Location: Maidsville, WV CMB Serial #: 180005 Project: Charlevoix Lock and Dam Monongahela River Reconstruction Project		
Chemical Analysis	Test Results	ASTM C618 Spec Limits; Class F
SiO ₂ , %	50.81	-
Al ₂ O ₃ , %	21.75	-
Fe ₂ O ₃ , %	15.64	-
Sum, %	88.2	70.0% min
Na ₂ O, %	0.62	-
K ₂ O, %	2.36	-
CaO, %	3.37	-
MgO, %	1.07	-
SO ₃ , %	0.92	5.0% max
Loss on ignition, %	1.9	6.0% max
Moisture Content, %	0.13	3.0% max
Physical Analysis	Test Results	ASTM C618 Spec Limits; Class F
Initial Test	-	
Compressive strength, (psi) 7-day, ¹ Reference ASTM C311	2410	-
Compressive strength, (psi) 28-day, ¹ Reference, ASTM C311	3820	-
Compressive strength, (psi) 7-day, Fly Ash/Cement, ASTM C311	1640	-
Compressive strength, (psi) 28-day, Fly Ash/Cement, ASTM C311	2980	-
Strength Activity Index, (%) 7-day, ASTM C311	68	75% min
Strength Activity Index, (%) 28-day, ASTM C311	78	75% min
Second Test	-	
Compressive strength, (psi) 7-day, ¹ Reference ASTM C311	2520	-
Compressive strength, (psi) 28-day, ¹ Reference, ASTM C311	4080	-
Compressive strength, (psi) 7-day, Fly Ash/Cement, ASTM C311	1690	-
Compressive strength, (psi) 28-day, Fly Ash/Cement, ASTM C311	3190	-
Strength Activity Index, (%) 7-day, ASTM C311	67	75% min
Strength Activity Index, (%) 28-day, ASTM C311	78	75% min
Water Requirement, % control, ASTM C 311, C109	99	105% max
Specific Gravity, ASTM C 188	2.34	5% max
Autoclave Soundness, %, ASTM C311, C151	-0.03	0.8% max
Fineness, % Retained on #325; ASTM C311	38.6	34% max
(Re-Test) Fineness, % Retained on #325; ASTM C311	38.5	34% max
Supplementary Optional Physical Analysis	Test Results	ASTM C618 Spec Limits; Class F
Increase of drying shrinkage of mortar bars at 28 days, ASTM C618	0.01	-
Uniformity Requirement, amount of Vinsol, ASTM C618	0.16 g	-
Remarks: ¹ Arms from Type II (MH) project cement used for reference cement		
Tested by: SLC Reviewed by: MAR		
Information in this report shall not be used in advertising or sales promotion to indicate endorsement of this product by the U.S. Government.		

ASTM C618 Report: Brandon Shores Class F Fly Ash

	Report on Test Specification: ASTM C 618, Standard Specification for Coal Fly Ash	
	Performing Organization: US Army Engineer Research and Development Center Geotechnical and Structures Laboratory (CEERD-GMC) 3809 Halls Ferry Road Vicksburg, MS 39180-6199	Sponsoring Organization: US Army Corps of Engineers Pittsburgh District, Lower Mon Area Office 1811 Schoonmaker Ave., Monessen, PA 15062
Material Description: Class F Fly Ash Manufacturer: Brandon Shores Location: Curtis Bay, MD CMB Serial #: 180018 Project: Charlevoix Lock and Dam Monongahela River Reconstruction Project		
Chemical Analysis	Test Results	Spec Limits; Class F
SiO ₂ , %	45.95	-
Al ₂ O ₃ , %	22.42	-
Fe ₂ O ₃ , %	21.49	-
Sum, %	89.86	70.0% min
Na ₂ O, %	0.45	-
K ₂ O, %	1.85	-
CaO, %	2.64	-
MgO, %	0.79	-
SO ₃ , %	0.82	5.0% max
Loss on ignition, %	2	6.0% max
Moisture Content, %	0.3	3.0% max
Physical Analysis	Test Results	Spec Limits; Class F
Compressive strength, (psi) 7-day, *Reference ASTM C311	1785	-
Compressive strength, (psi) 28-day, *Reference, ASTM C311	3130	-
Compressive strength, (psi) 7-day, Fly Ash/Cement, ASTM C311	2320	-
Compressive strength, (psi) 28-day, Fly Ash/Cement, ASTM C311	4100	-
Strength Activity Index, (%) 7-day, ASTM C311	77	75% min
Strength Activity Index, (%) 28-day, ASTM C311	76	75% min
Water Requirement, % control, ASTM C 311, C109	98	105% max
Specific Gravity, ASTM C188	2.41	5% max
Autoclave Soundness, %, ASTM C311, C151	-0.06	0.8% max
Fineness, % Retained on #325; ASTM C311	19.12	34% max
Supplementary Optional Physical Analysis	Test Results	Spec Limits; Class F
Increase of drying shrinkage of mortar bars at 28 days, ASTM C618	0.01	-
Uniformity Requirement, amount of Vinsol, ASTM C618	0.15	-
Remarks: *Armstrong Type II (MH) project cement used for reference cement Tested by: SLC Reviewed by: MAR		
<i>Information in this report shall not be used in advertising or sales promotion to indicate endorsement of this product by the U.S. Government.</i>		

ASTM C989 Report: Argos-Essroc Slag Cement, Grade 100

	Report on Test Specification: ASTM C 989, Standard Specification for Slag Cement	
	Performing Organization: US Army Engineer Research and Development Center Geotechnical and Structures Laboratory (CEERD-GMC) 3909 Halls Ferry Road Vicksburg, MS 39180-6199	Sponsoring Organization: US Army Corps of Engineers Pittsburgh District, Lower Mon Area Office 1811 Schoonmaker Ave., Monessen, PA 15062
Material Description: Slag Cement, Grade 100 Manufacturer: Argos-Essroc Location: Middlebranch, OH CMB Serial #: 150066 Project: Charleroi Lock and Dam Monongahela River Reconstruction Project		
Chemical Analysis	Test Results	Spec Limits
Sulfide Sulfur, S %	2.02	2.5% max
Sulfate Sulfur, (as SO ₃) %	0.04	4% max
Aluminum Oxide, (as Al ₂ O ₃) %	10.15	-
Chloride Content of Slag	0.05	-
Na ₂ O, %	0.27	-
K ₂ O, %	0.47	-
Equivalent Alkalies-total as Na ₂ O, %	0.57	-
Physical Analysis	Test Results	Spec Limits
Compressive strength (psi) 7-day ¹ Reference ASTM C311	1880	-
Compressive strength (psi) 28-day ¹ Reference, ASTM C311	3956	-
Compressive strength (psi) 7-day Slag/Cement, ASTM C311	1583	-
Compressive strength (psi) 28-day Slag/Cement, ASTM C311	3802	-
Strength Activity Index, (%) 7-day, ASTM C311	88	70% min
Strength Activity Index, (%) 28-day, ASTM C311	96	90% min
Surface area, m ² /kg (air permeability); ASTM C 204	626	260 m ² /kg min
Specific Gravity, ASTM C188	2.81	-
Fineness, % Retained on #325; ASTM C311	2.8	20% max
Air content, %; ASTM C 185	4.2	12% max
Remarks: ¹ Armstrong Type II (MH) project cement used for reference cement		
		Tested by: MAR Reviewed by: ABC
<i>Information in this report shall not be used in advertising or sales promotion to indicate endorsement of this product by the U.S. Government.</i>		

ASTM C1240: Elkem Materials Silica Fume

 US Army Corps of Engineers BUILDING STRONG	Report on Test Specification: ASTM C1240, Silica Fume Used in Cementitious Mixtures	
	<u>Performing Organization:</u> US Army Engineer Research and Development Center Geotechnical and Structures Laboratory (CEERD-GMC) 3909 Halls Ferry Road Vicksburg, MS 39180-6199	<u>Sponsoring Organization:</u> US Army Corps of Engineers Pittsburgh District, Lower Mon Area Office 1811 Schoonmaker Ave., Monessen, PA 15062
Material Description: Microsilica Grade 970 D Manufacturer: Elkem Materials Inc. Location: Pittsburgh, PA CMB Serial#: 150086 Project: Charleroi Lock and Dam Monongahela River Reconstruction Project		
Chemical Analysis	Test Results	ASTM C1240 Spec. Limits
SiO ₂ , %	95.16	85%, min.
Al ₂ O ₃ , %	0.24	-
Fe ₂ O ₃ , %	0.52	-
Sum, %	95.92	-
Na ₂ O, %	0.3	-
K ₂ O, %	0.49	-
MgO, %	0.25	-
SO ₃ , %	0.01	-
Loss on ignition, %	2.61	6%, max
Moisture %	0.61	3%, max
Physical Analysis	Test Results	ASTM C1240 Spec. Limits
Control Mixture ¹ : Compressive strength, (psi) 7-day, ASTM C 311	1990	-
Test Mixture ² : Compressive strength, (psi) 7-day, ASTM C 311	3280	-
Strength Activity Index, (%) 7-day, ASTM C 311	165	105%, min
Water Requirement, ASTM C 311, C 109	³	100-115%
Specific Gravity, ASTM C 188	2.32	-
Supplementary Optional Physical Tests	Test Results	ASTM C1240 Spec. Limits
Uniformity Requirement, amount of Vinsol, ASTM C 618	0.04 g	-
Effectiveness in Controlling ASR at 14 days, ASTM C 618, C 311, C 441	95%	80%, min.
Remarks: ^{1,2} Armstrong Type II (MH) project cement used for reference cement ³ Following the standard ASTM C 1240 method, 2 mL of HRWRA required with test mixture to produce flow limits using 242 mL of water Tested by: MAR Reviewed by: ABC		
<i>Information in this report shall not be used in advertising or sales promotion to indicate endorsement of this product by the U.S. Government.</i>		

Appendix E: Admixture Reports

The Euclid Chemical Company

EUCON AEA-92

AIR ENTRAINING AGENT FOR CONCRETE



DESCRIPTION

EUCON AEA-92 is formulated for use as an air entraining admixture for concrete of all types and is manufactured under rigid control which assures uniform and precise performance. It should be added to the mix independently and not with other admixtures.

PRIMARY APPLICATIONS

- Ready mix concrete
- Structural concrete
- Mass concrete
- Paving concrete
- All exterior concrete

FEATURES/BENEFITS

- Provides a stable air void system with proper bubble size and spacing. This air void system protects concrete against damage caused by repeated freeze/thaw cycles
- Concrete is made more resistant to de-icing salts, sulfate attack and corrosive water
- Less mixing water can be used per yard (meter) of concrete and placeability is improved
- Minimizes bleeding and segregation of the concrete

TECHNICAL INFORMATION

EUCON AEA-92 is an aqueous solution compound of synthetic organic chemicals. It is compatible with concrete mixes containing calcium chloride, water reducing admixtures, retarding admixtures, or high range water reducers.

PACKAGING

EUCON AEA-92 is packaged in bulk, 275 gal (1041 L) totes, 55 gal (208 L) drums and 5 gal (18.9 L) pails.

SHELF LIFE

2 years in original, unopened package.

SPECIFICATIONS/COMPLIANCES

EUCON AEA-92 meets or exceeds the requirements of the following specifications:

- Corps of Engineers Specification CRD C-13
- ASTM Specification C 260
- AASHTO Specification M 154
- ANSI/NSF STD 61

AIR ENTRAINERS

EUCON AEA-92

MASTER FORMAT #:
03 30 00 03 40 00
03 70 00

19215 Redwood Road • Cleveland, OH 44110
800-321-7628 t • 216-531-9596 f

www.euclidchemical.com

The Euclid Chemical Company

EUCON RETARDER 75

CONCRETE WATER REDUCING SET CONTROLLING RETARDER



EUCLID CHEMICAL

DESCRIPTION

EUCON RETARDER 75 is a synthetically produced liquid water-reducing and set retarding admixture for concrete. EUCON RETARDER 75 does not contain calcium chloride or other potential corroding materials, and may be used in the presence of aluminum or zinc metals. It is compatible with air-entraining agents, water reducers and calcium chloride, but they must be added separately to the mix.

PRIMARY APPLICATIONS

- Prestressed concrete
- Concrete requiring water reduction and set time control
- Architectural concrete
- Hot weather concrete placement

FEATURES/BENEFITS

Plastic Concrete

- Retards setting characteristics
- Improves finishability
- Improves workability
- Reduces water requirements
- Reduces segregation

Hardened Concrete

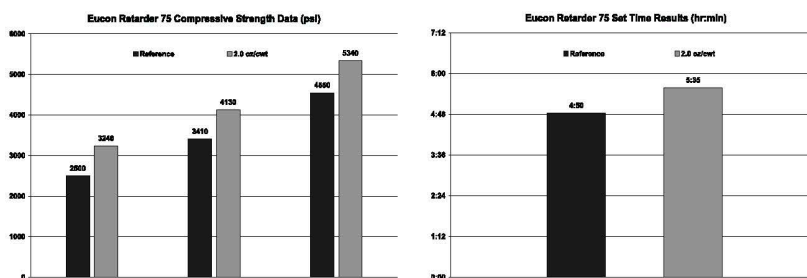
- Increases strengths
- Improves finished appearance
- Reduces cracking
- Reduces permeability
- Non staining

TECHNICAL INFORMATION

Performance Data

The following test results were achieved using typical ASTM C 494 mix design requirements, 517 lb/yd³ (307 kg/m³) cement content and similar ($\pm 0.5\%$) air content.

These results were obtained under laboratory conditions with materials and mix designs meeting the specifications of ASTM C 494. Changes in materials and mix designs can affect the dosage response of EUCON RETARDER 75.



RETARDERS

EUCON RETARDER 75

MASTER FORMAT #:
03 30 00 03 40 00
03 70 00

19215 Redwood Road • Cleveland, OH 44110
800-321-7628 t • 216-531-9596 f

www.euclidchemical.com

The Euclid Chemical Company

EUCON WR

WATER REDUCING ADMIXTURE



DESCRIPTION

EUCON WR is an aqueous solution of refined lignosulfonate which is completely free of any added chloride ions. It is a water-reducing, normal-set admixture for concrete. It provides a more plastic and cohesive mix in the fresh concrete and better durability, reduced shrinkage and less permeability in the hardened concrete.

PRIMARY APPLICATIONS

- Ready mixed concrete
- Prestressed concrete
- Precast concrete
- General use concrete
- Lightweight concrete
- Expansive concrete

FEATURES/BENEFITS

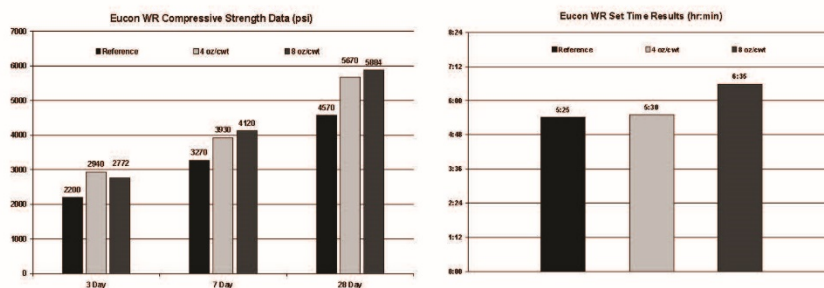
- Provides easier handling and finishing
- Increases strength
- Provides increased durability
- Reduces shrinkage and permeability

TECHNICAL INFORMATION

Performance Data

The following test results were achieved using typical ASTM C 494 mix design requirements, 517 lb/yd³ (307 kg/m³) cement content and similar ($\pm 0.5\%$) air content.

These results were obtained under laboratory conditions with materials and mix designs meeting the specifications of ASTM C 494. Changes in materials and mix designs can affect the dosage response of EUCON WR.



WATER REDUCERS

EUCON WR®

MASTER FORMAT #:
03 30 00 - 03 40 00
03 70 00

19215 Redwood Road • Cleveland, OH 44110
800-321-7628 t • 216-531-9596 f

www.euclidchemical.com

The Euclid Chemical Company

EUCON AWA

ANTI-WASHOUT ADMIXTURE



DESCRIPTION

EUCON AWA is a ready to use liquid admixture designed to prevent the loss of cement and fine aggregate during the placement of underwater concrete. EUCON AWA is a blend of different powerful ingredients and colloidal agents that act primarily on the water preventing the cement paste from washing out during casting under water. EUCON AWA provides superior slump retention while greatly reducing the environmental impact due to cement wash out in below water applications.

PRIMARY APPLICATIONS

- Underwater bridge repair
- Dam repair below the waterline
- Underwater grouting and mortar application
- Damming underground rivers/lakes in mining operations
- Anti-segregation aid for use with lightweight and heavyweight aggregates
- Reduction or elimination of concrete bleed water for use with fast track construction

FEATURES/BENEFITS

- Minimal environmental impact due to cement washout
- Eliminates the need for expensive de-watering during underwater construction
- Greatly reduces or eliminates concrete bleed water
- Superior slump retention
- Does not effect water demand when slump is maintained
- Easily metered with standard admixture dispensing equipment

TECHNICAL INFORMATION

Appearance

EUCON AWA is a medium viscosity, dark brown liquid which will not discolor concrete.

PACKAGING

EUCON AWA is packaged in 275 gal (1041 L) totes, 55 gal (208 L) drums and 5 gal (18.9 L) pails.

SHELF LIFE

6 months in original, unopened container.

SPECIFICATIONS/COMPLIANCES

- Meets ASTM C 494 Types S

SPECIALTY PRODUCTS

EUCON AWA

MASTER FORMAT #:
03 30 00 03 37 26

19215 Redwood Road • Cleveland, OH 44110
800-321-7628 t • 216-531-9596 f

www.euclidchemical.com

The Euclid Chemical Company

EUCON 37

HIGH RANGE WATER REDUCER - SUPERPLASTICIZER**EUCLID CHEMICAL****DESCRIPTION**

EUCON 37 is a high range water-reducing admixture. It may be added to the concrete at the job site or at the ready mix concrete plant. **EUCON 37** is formulated to retain plastic consistency for 30-60 minutes after dosing depending on the initial slumps, dosage rates, and ambient temperature. No chlorides are used in its formulation; consequently, it is recommended for prestressed concrete. It is also compatible with air-entraining agents, waterproofing agents, calcium chloride and many other admixtures; however, each material should be added to the concrete separately.

PRIMARY APPLICATIONS

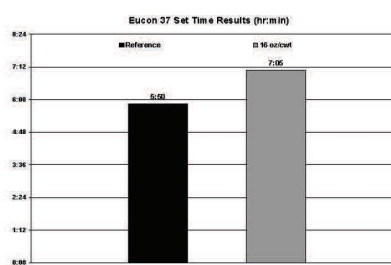
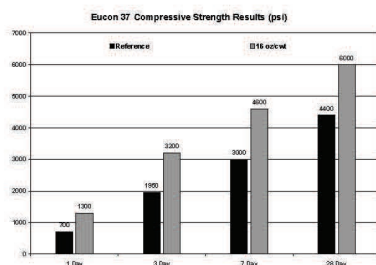
- High performance concrete
- General ready mix concrete
- Heavily reinforced concrete
- Flatwork and mass concrete
- Minimum water content concrete
- Low water/cement ratio concrete
- High slump, flowable concrete

FEATURES/BENEFITS

- Produces low water content and low water/cement ratio concrete allowing higher strengths
- Produces flowing concrete with better than normal strengths
- Aids in concrete placement and reduces labor cost
- When used in precast work with Type I cement will produce the high early strengths

TECHNICAL INFORMATION**Performance Data:**

The following test results were achieved using typical ASTM C 494 mix design requirements, 517 lb/yd³ (307 kg/m³) cement content and similar ($\pm 0.5\%$) air content. These results were obtained under laboratory conditions with materials and mix designs meeting the specifications of ASTM C 494. Changes in materials and mix designs can affect the dosage response of **EUCON 37**.



HIGH-RANGE WATER REDUCERS

EUCON 37

 MASTER FORMAT #:
 03 30 00 - 03 40 00
 03 70 00

 19215 Redwood Road • Cleveland, OH 44110
 800-321-7628 t • 216-531-9596 f

www.euclidchemical.com

Appendix F: Water Quality Test Reports



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

12 August 2016

Monica Ramsey
ERDC – Vicksburg (EL)
ERDC, 3909 Halls Ferry Road
Vicksburg, MS 39180
RE: Chapteroi L&D

Enclosed are the results of analyses for samples received by the laboratory on 25-Apr-2016. The samples associated with this report will be held for 90 days from the date of this report. The raw data associated with this report will be held for 5 years from the date of this report. If you need us to hold onto the samples or the data longer than these specified times, you will need to notify us in writing at least 30 days before the expiration dates. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jenifer Milam For Allyson Holman
Biologist



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

ERDC -- Vicksburg (EL)	Project: Chapleroi L&D	
ERDC, 3909 Halls Ferry Road		Reported:
Vicksburg MS, 39180	Project Manager: Monica Ramsey	12-Aug-2016

WORK ORDER SUMMARY

Sample ID	Laboratory ID	Matrix	Date Sampled	Date of Work Order
150088	6042502-01	Water	25-Apr-2016	25-Apr-2016
150089	6042502-02	Water	25-Apr-2016	25-Apr-2016



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

ERDC -- Vicksburg (EL)
ERDC, 3909 Halls Ferry Road
Vicksburg MS, 39180

Project: Chapleroi L&D
Project Manager: Monica Ramsey

Reported:
12-Aug-2016

Case Narrative

No issues were experienced during the analysis of Work Order 6042502 unless specified below.



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

ERDC -- Vicksburg (EL)
ERDC, 3909 Halls Ferry Road
Vicksburg MS, 39180

Project: Chapleroi L&D
Project Manager: Monica Ramsey

Reported:
12-Aug-2016

Notes and Definitions

U	Analyte included in the analysis, but not detected
J	Detected but below the Reporting Limit; therefore, result is an estimated concentration.
DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

ERDC -- Vicksburg (EL)
ERDC, 3909 Halls Ferry Road
Vicksburg MS, 39180

Project: Chapleroi L&D
Project Manager: Monica Ramsey

Reported:
12-Aug-2016

150088

6042502-01 (Water)

Analyte	Result	Detection Limit	Reporting Limit	Units	Prepared	Analyzed	Method	Notes
---------	--------	-----------------	-----------------	-------	----------	----------	--------	-------

ERDC-EL-EP-C

Anions by EPA Method 300.0

Chloride, filtered	34.1	1.00	3.00	mg/L	28-Apr-2016	28-Apr-2016	EPA 300.0	
Sulfate, filtered	94.8	1.00	3.00	mg/L	28-Apr-2016	28-Apr-2016	EPA 300.0	

Metals (Dissolved) by EPA 6000/7000 Series Methods

Iron	0.0553	0.00200	0.0400	mg/L	27-Apr-2016	27-Apr-2016	EPA 6020	
------	--------	---------	--------	------	-------------	-------------	----------	--

Miscellaneous Physical/Conventional Chemistry Parameters

pH	7.82			pH Units	25-Apr-2016	26-Apr-2016	EPA 150.1	
----	------	--	--	----------	-------------	-------------	-----------	--

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

ERDC -- Vicksburg (EL)
ERDC, 3909 Halls Ferry Road
Vicksburg MS, 39180

Project: Chapleroi L&D
Project Manager: Monica Ramsey

Reported:
12-Aug-2016

150089

6042502-02 (Water)

Analyte	Result	Detect on Limit	Reporting Limit	Units	Prepared	Analyzed	Method	Notes
---------	--------	--------------------	--------------------	-------	----------	----------	--------	-------

ERDC-EL-EP-C

Anions by EPA Method 300.0

Chloride, unfiltered	14800	20.0	100	mg/L	28-Apr-2016	28-Apr-2016	EPA 300.0	
Sulfate, unfiltered	ND	10.0	30.0	mg/L	28-Apr-2016	28-Apr-2016	EPA 300.0	

Metals by EPA 6000/7000 Series Methods

Iron	31.0	0.00200	0.0400	mg/L	27-Apr-2016	27-Apr-2016	EPA 6010	
------	------	---------	--------	------	-------------	-------------	----------	--

Miscellaneous Physical/Conventional Chemistry Parameters

pH	7.71			pH Units	25-Apr-2016	26-Apr-2016	EPA 150.1	
----	------	--	--	----------	-------------	-------------	-----------	--

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

ERDC -- Vicksburg (EL)
ERDC, 3909 Halls Ferry Road
Vicksburg MS, 39180

Project: Chapleroi L&D
Project Manager: Monica Ramsey

Reported:
12-Aug-2016

Anions by EPA Method 300.0 - Quality Control

ERDC-EL-EP-C

Analyte	Detection Result	Reporting Limit	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD Limit	Notes
Batch B605197 - Default Prep GenChem									
Blank (B605197-BLK1)					Prepared & Analyzed: 28-Apr-2016				
Chloride, filtered	ND	0.100	0.300	mg/L					U
Chloride, unfiltered	ND	0.100	0.500	mg/L					U
Sulfate, filtered	ND	0.100	0.300	mg/L					
Sulfate, unfiltered	ND	0.100	0.300	mg/L					
LCS (B605197-BS1)					Prepared & Analyzed: 28-Apr-2016				
Chloride, filtered	1.91	0.100	0.300	mg/L	2.000	95.6	80-120		
Sulfate, filtered	1.97	0.100	0.300	mg/L	2.000	98.7	85-115		
Sulfate, unfiltered	1.97	0.100	0.300	mg/L	2.000	98.7	85-115		
Duplicate (B605197-DUP1)					Source: 6042502-01 Prepared & Analyzed: 28-Apr-2016				
Chloride, filtered	34.0	1.00	3.00	mg/L		34.1		0.314	20
Sulfate, filtered	95.3	1.00	3.00	mg/L		94.8		0.505	20
Matrix Spike (B605197-MS1)					Source: 6042502-01 Prepared & Analyzed: 28-Apr-2016				
Chloride, filtered	85.4	0.100	0.300	mg/L	50.00	34.1	103	80-120	
Sulfate, filtered	149	1.00	3.00	mg/L	50.00	94.8	109	85-115	

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

ERDC -- Vicksburg (EL)
ERDC, 3909 Halls Ferry Road
Vicksburg MS, 39180

Project: Chapleroi L&D
Project Manager: Monica Ramsey

Reported:
12-Aug-2016

Metals (Dissolved) by EPA 6000/7000 Series Methods - Quality Control

ERDC-EL-EP-C

Analyte	Detection Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD Limit	Notes
Batch B605060 - Default Prep Metals								
Blank (B605060-BLK1)								
Prepared & Analyzed: 27-Apr-2016								
Iron	0.00171	0.00100	0.0200 mg/L					
LCS (B605060-BS1)								
Prepared & Analyzed: 27-Apr-2016								
Iron	49.4	0.00100	0.0200 mg/L	50.00	98.8	85-115		
Duplicate (B605060-DUP1)								
Source: 6042502-01 Prepared & Analyzed: 27-Apr-2016								
Iron	0.0544	0.00200	0.0400 mg/L		0.0553		1.78	20
Matrix Spike (B605060-MS1)								
Source: 6042502-01 Prepared & Analyzed: 27-Apr-2016								
Iron	101	0.00200	0.0400 mg/L	100.0	0.0553	101	75-125	

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

ERDC -- Vicksburg (EL)
ERDC, 3909 Halls Ferry Road
Vicksburg MS, 39180

Project: Chapleroi L&D
Project Manager: Monica Ramsey

Reported:
12-Aug-2016

Metals by EPA 6000/7000 Series Methods - Quality Control

ERDC-EL-EP-C

Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B605059 - Default Prep Metals											
Blank (B605059-BLK1)						Prepared & Analyzed: 27-Apr-2016					
Iron	0.00171	0.00100	0.0200	mg/L							J
LCS (B605059-BS1)						Prepared & Analyzed: 27-Apr-2016					
Iron	49.4	0.00100	0.0200	mg/L	50.00		98.8	80-120			
Duplicate (B605059-DUP1)						Source: 6042502-02 Prepared & Analyzed: 27-Apr-2016					
Iron	31.8	0.00200	0.0400	mg/L		31.0			2.69	20	
Matrix Spike (B605059-MS1)						Source: 6042502-02 Prepared & Analyzed: 27-Apr-2016					
Iron	128	0.00200	0.0400	mg/L	100.0	31.0	97.2	80-120			

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

ERDC -- Vicksburg (EL)
ERDC, 3909 Halls Ferry Road
Vicksburg MS, 39180

Project: Chapleroi L&D
Project Manager: Monica Ramsey

Reported:
12-Aug-2016

Items for Project Manager Review

Lab Number	Analysis	Analyte	Exception
------------	----------	---------	-----------

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (US liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
mils	0.0254	millimeters
ounces (US fluid)	2.957353 E-05	cubic meters
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
quarts (US liquid)	9.463529 E-04	cubic meters
square inches	6.4516 E-04	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter
yards	0.9144	meters

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY) May 2020		2. REPORT TYPE Final		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Investigation of Materials for Charleroi Lock and Dam Monongahela River Reconstruction Project				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Monica A. Ramsey and Cody M. Strack				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Geotechnical and Structures Laboratory U.S. Army Engineer Research and Development Center 3909 Halls Ferry Road Vicksburg, MS 39180-6199				8. PERFORMING ORGANIZATION REPORT NUMBER ERDC/GSL TR-20-20	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Corps of Engineers Pittsburgh District Pittsburgh, PA 15222				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES MIPR W81ET491842462, Lower Monongahela River Navigation System Feasibility Study					
14. ABSTRACT The investigation described in this report was conducted for the U.S. Army Engineer District, Pittsburgh as part of a preliminary investigation of cementitious materials and concrete design pursuant to construction of Charleroi Lock and Dam Monongahela River Reconstruction Project. Local materials provided to the U.S. Army Engineer Research Development Center (ERDC) for testing included three different coarse aggregate gradations, two fine aggregate sources, a type II (MH) cement, four fly ash sources, a slag cement, a silica fume, a limestone powder, five admixtures, and two water sources. Aggregate tests consisted of sieve analysis, specific gravity, absorption, materials finer than No. 200, organic impurities, soundness, LA abrasion, clay lumps and friable particles, flat and elongated particles, lightweight particles, and petrography. All cementitious, admixtures, and water-source materials were tested for chemical and physical properties based on appropriate specifications. In addition, four mixture proportions developed by the ERDC for this project in 2005 were scaled to determine the early stiffening of mortar, freezing and thawing, and heat of hydration. This report presents the material characteristic results determined by laboratory testing in accordance with American Society for Testing and Materials procedures or regulating specification criteria.					
15. SUBJECT TERMS Material testing Aggregates Aggregates (Building materials)--Testing Hydraulic structures		Admixtures Cementitious materials Heat of hydration Charleroi (Pa.) Monongahela River (W. Va. and Pa.)		Concrete rehabilitation Locks and dams Concrete—Testing Cement composites--Testing	
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 101	19a. NAME OF RESPONSIBLE PERSON
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code)