ERDC/GSL SR-17-1

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Interim Report on the Investigation of the Fresh Properties of Synthetic Fiber-Reinforced Concrete for the Richardson Landing Casting Field

Wendy R. Long, Kirk E. Walker, and Brian H. Green

April 2017

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Final report

Prepared for Delwick Warfield, P.E.
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Abstract

The U.S. Army Engineer District, Memphis uses the Richardson Landing mat casting field to produce articulated concrete mats that are tied together to form articulated concrete revetment "blankets" that are then placed on the riverbanks to serve as a form of erosion control. The Memphis District noted that the corners of some of these concrete mats were becoming damaged as the mats were moved from the casting field to the construction site. To combat this issue, the Memphis District, Construction Branch, decided to incorporate synthetic fibers in the current concrete mixture proportion to bridge cracks induced by moving the concrete mats. However, there was concern that the addition of fibers would significantly reduce the workability of the concrete mixture, making it labor intensive to place in the forms and difficult to discharge the fresh concrete from transport vehicles at the casting field.

The Memphis District contracted with the U. S. Army Engineer Research and Development Center's (ERDC's) Concrete and Materials Branch (CMB) to proportion three fiber-reinforced concrete mixtures containing 3-, 2-, and 1-lb(s)/yd^3, respectively, of synthetic (polypropylene) fiber into the current mixture proportion used at Richardson Landing mat casting field. The CMB performed aggregate testing, concrete trial batching, and hardened concrete strength testing to produce the new concrete mixture proportions. This interim report presents the results of testing conducted by the CMB as of 30 August 2016.

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Preface

This study was conducted for the U.S. Army Engineer District, Memphis-Construction Branch under MIPR No. W38XGR60986322 dated 7 April 2016.

The work was performed by the Concrete and Materials Branch (CMB) of the Engineering Systems and Materials Division (ESMD), Geotechnical and Structures Laboratory (GSL), U. S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. At the time of publication, Christopher M. Moore was Chief, CMB; Dr. Gordon W. McMahon was Chief, ESMD; and Dr. Pamela G. Kinnebrew was the Technical Director for Military Engineering. The Deputy Director of ERDC-GSL was Dr. William P. Grogan, and the Director was Bart P. Durst.

COL Bryan S. Green was the Commander of ERDC, and Dr. David W. Pittman was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pints (U.S. liquid)	0.473176	liters
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
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
square inches	6.4516 E-04	square meters
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

1 Introduction

The U.S. Army Corps of Engineers (USACE), Memphis District, uses the Richardson Landing mat casting field to produce the articulated concrete mats that are tied together to form articulated concrete revetment "blankets" that are placed on riverbanks to maintain the desired bank alignment and configuration and serve as a form of erosion control. The casting field has an established concrete mixture proportion that they use to produce the mats, and this proportion has undergone few changes during the last decade.

After the concrete mats are produced at the casting field, they are moved several times before they are placed on the riverbank. During the process of moving the mats, some breakage of the corners of the individual mats has been observed. In an effort to mitigate corner breakage of the concrete mats, the Memphis District has decided to incorporate synthetic fibers at a rate of up to 3 lb/yd^3 into the concrete mixture proportion to see if these fibers can help reduce corner breakage.

The Memphis District, Construction Branch, is concerned that the addition of conventional construction-grade synthetic fibers will significantly reduce the workability of the concrete mixture, which is typically quantified by the slump test. A reduction in workability would make the concrete more labor intensive to finish and place. It could also make it more difficult to effectively discharge the fresh concrete into the mat forms from the fresh concrete transport devices at the casting field.

The Memphis District-Construction Branch requested that the Concrete and Materials Branch (CMB) of the U.S. Army Engineer Research and Development Center (ERDC) modify the current concrete mixture proportion and incorporate synthetic fibers while maintaining the target 3-to4-in. slump and 3,000 psi compressive strength at 90-days age.

The concrete mixture proportion used in this study is similar to the one used to produce the articulated concrete mats in 2010 at the Richardson Landing mat casting field. The concrete mixture proportion was adjusted to incorporate synthetic (polypropylene) fibers at dosage rates of 1-lb, 2-lb, and 3-lb/ yd^3. Since the fiber content is already built into this year's

construction contract and the contractor has already selected the fiber, no additional testing to characterize the impact of the fiber content on the mechanical performance of the concrete was conducted.

The Memphis District-Construction Branch requested that the concrete mixture proportions include a 0.650 water-to-cementitious ratio, 25 percent fly ash by volume of cementitious material, and 300 to 500 lb/yd^3 of cementitious material. The target air content for this project was 4.0 to 7.0 percent (ASTM International 2014) (C231), and the target compressive strength was a minimum of 3,000 psi at 90 days (ASTM International 2016c) (C39).

The operating contractor at Richardson Landing sampled the constituent materials that are currently being used to produce concrete at the casting field and shipped the materials to the CMB laboratory facility in Vicksburg, MS.

Mill certificates and admixture data sheets for the materials used were supplied by the Memphis District Construction Branch, and can be found in Appendix A.

2 Aggregate Testing Results

The ASTM International (2006) (C136) gradation results for the coarse limestone aggregate are presented in Table 1. The results of Run 1 and Run 2 were much finer than the data that the Memphis District-Construction Branch had provided, so an additional two aggregate samples were tested a few weeks later. The results of Runs 3 and 4 were even finer than Runs 1 and 2 and struggled to meet the ASTM International C33 criteria for a #57 stone. Each of these gradations along with the ASTM International (2016b) (C33) gradation limits for a #57 stone are shown in Figure 1.

The bulk specific gravity at the saturated, surface-dry condition was comparable to the specific gravity provided in historical data for this aggregate as shown in Table 2. However, the absorption measured by the ERDC-CMB was lower than the historical data.

Table 1. ASTM (2006) (C136) gradations for #57 crushed limestone from the Cumberland Quarry, Pine Bluff Sand and Gravel (cumulative % passing).

Sieve Size	Gradation Testing by CMB, Cumulative % Passing					Historical Gradation Provided[1] By Memphis District
	Run 1	Run 2	Run 3	Run 4	CMB Average	
1 1/2 in.	100.0	100.0	100.0	100.0	**100.0**	100
1 in.	98.0	98.5	98.0	98.5	**98.3**	98
3/4 in.	81.6	86.3	87.9	91.2	**86.8**	72
1/2 in.	44.2	51.0	59.2	63.3	**54.4**	34
3/8 in.	25.1	31.3	37.8	41.1	**33.8**	15
No. 4	7.3	8.4	9.5	10.7	**9.0**	3
No. 8	4.6	4.8	5.0	5.5	5.0	2
No. 200 (ASTM C117)	2.9	3.0	3.1	3.3	3.1	1.8

[1]Data from materials reports provided by USACE Memphis District-Construction Branch (Appendix A).

Figure 1. Gradation of #57 crushed limestone from the Cumberland Quarry, Pine Bluff Sand and Gravel.

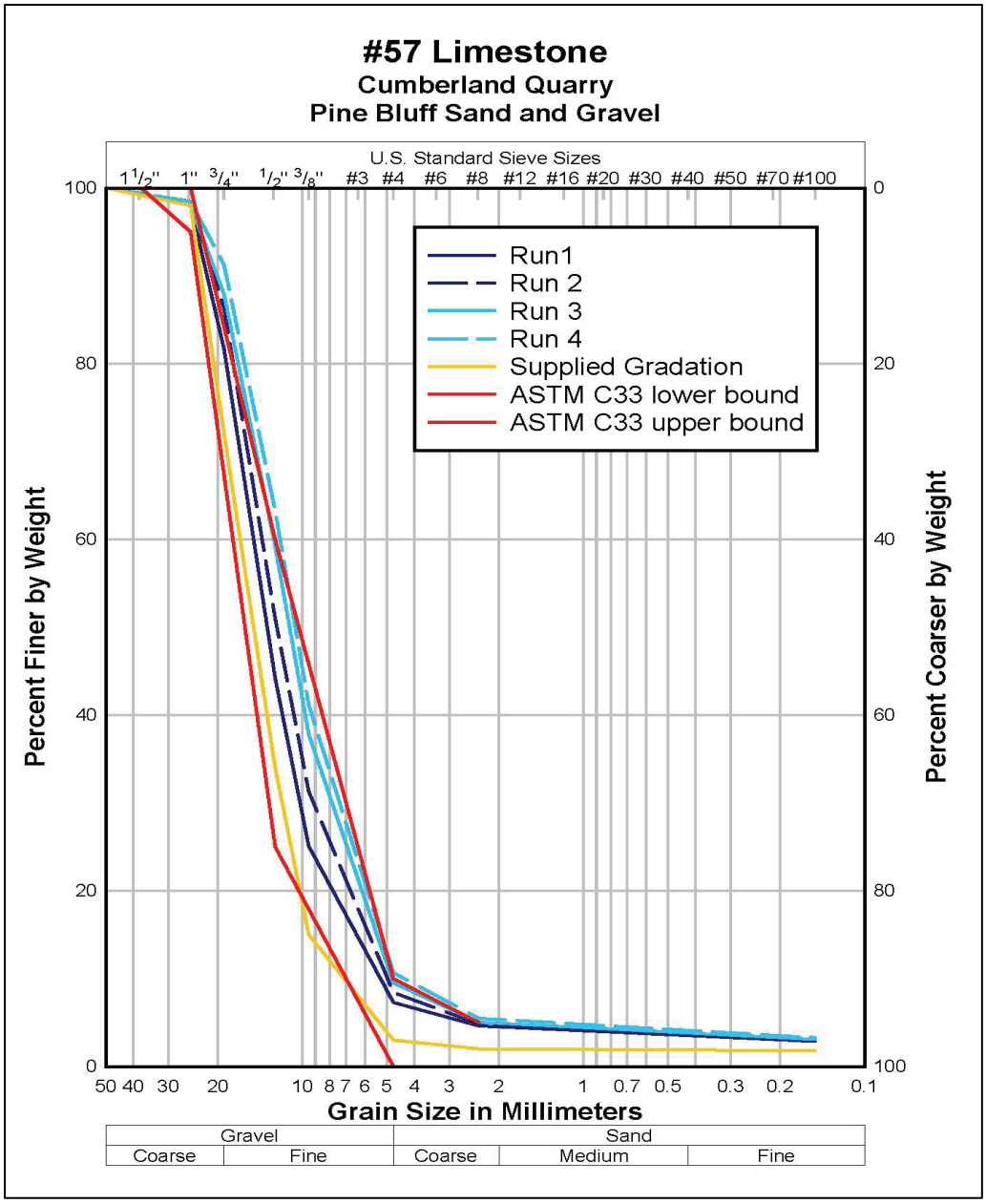


Table 2. ASTM (2015a) (C127), bulk specific gravity and absorption of #57 crushed limestone from the Cumberland Quarry, Pine Bluff Sand and Gravel (material retained on No. 4 sieve).

Property	Testing by CMB					Historical Data Provided[1] By Memphis District
	Run 1	Run 2	Run 3	Run 4	Average	
Bulk specific gravity (SSD)	2.696	2.693	2.682	2.685	**2.689**	2.669
Absorption, %	0.69	0.82	0.91	0.93	**0.84**	1.2

[1]Data from materials reports provided by USACE Memphis District-Construction Branch (Appendix A).

The fine aggregate used for this project is a dredged, natural river sand sourced from Mississippi River at Mile 769.2 AHP (Above Head of Passes). The gradation, absorption, and specific gravity results for this material are at Tables 3 and 4.

Table 3. ASTM (2006) (C136) gradations for dredged fine aggregate (cumulative % passing).

	Gradation Testing by CMB, Cumulative % Passing		
Sieve Size	Run 1	Run 2	Average
3/8 in.	99.6	98.9	**99**
No. 4	98.1	95.6	**97**
No. 8	92.3	89.4	**91**
No. 16	75.4	73.7	**75**
No. 30	45.5	44.9	**45**
No. 40	25.4	25.2	**25**
No. 50	13.1	13.0	**13**
No. 100	1.5	1.6	**1.6**
No. 200	0.6	0.6	**0.6**
No. 200 (ASTM 2013b (C117)	0.6	0.6	**0.6**

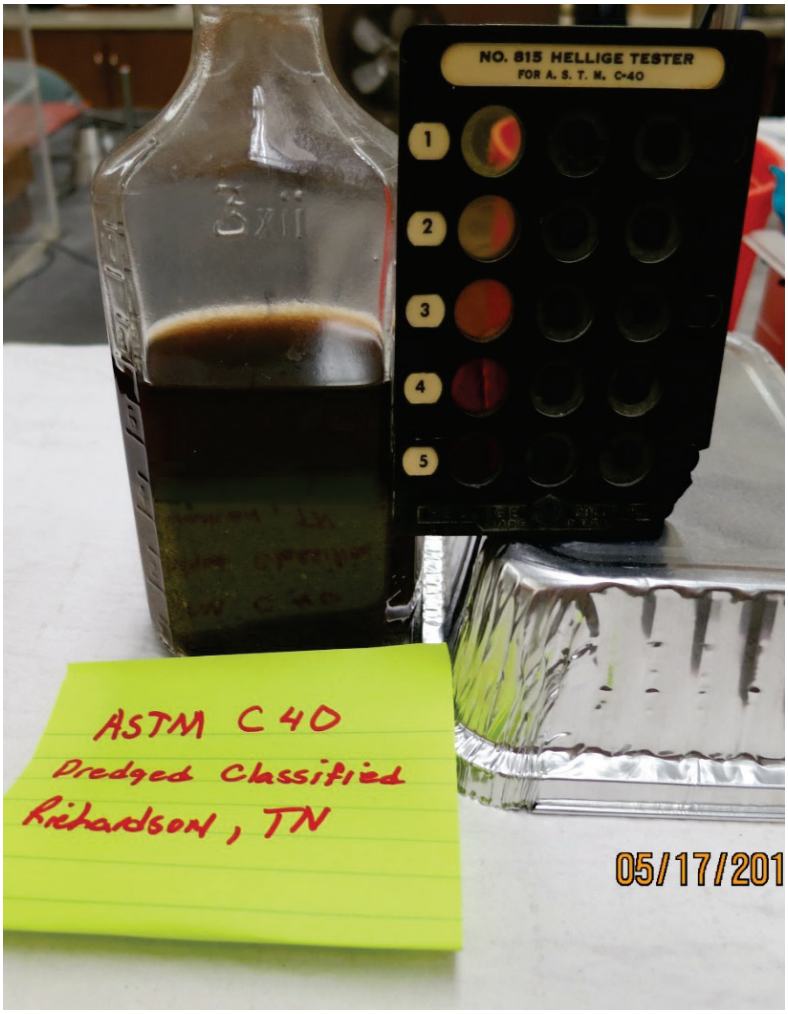
Table 4. ASTM (2015b) (C128), bulk specific gravity and absorption of dredged fine aggregate.

Property	Run 1	Run 2	Average	Historical Data Provided[1] By Memphis District
Bulk specific gravity (SSD)	2.64	2.64	**2.64**	**2.62**
Absorption	0.49%	0.48%	**0.49%**	**0.80%**

[1]Data from materials reports provided by USACE Memphis District-Construction Branch (Appendix A).

The fine aggregate had an unusually dark color when tested in accordance with ASTM International (2011) (C40). The ASTM C40 organic impurity color was reported as a 4. Aggregates with this dark of a color may have problems with air entrainment, freeze thaw durability, and compressive strength due to organic impurities being present in the fine aggregate. Problems with air entrainment were not observed during the trial batching process, and the Memphis District has indicated that this fine aggregate has not caused problems with the concrete produced in the field. Figure 2 shows the results of the ASTM C40 test.

Figure 2. ASTM (2011) (C40) organic impurities testing of dredged sand.



3 Mixture Proportioning

Concrete mixture proportioning trial batches of 1.5 cu ft each were produced using the CMB laboratory's 5.0-cu ft capacity Gilson Mixer. Standard laboratory mixing procedures were followed in accordance with ASTM International (2016a) (C192). Six trial batches were produced and five of the six are reported in this Interim Report. Trial Batch 4 is not reported because it did not meet the project requirements. The concrete mixture proportions, mixture characteristics, materials used, and test results for each of the mixtures are documented at Table 5 through Table 9.

Trial Batch 1 (Table 9) and Trial Batch 2 (Table 8) did not include fibers and are included in this report for information purposes only. These two mixtures are beyond the original scope of this project, but help show the effects of chemical admixture and fiber dosages.

Trial Batch 1 (Table 9) had a lower slump and air content than is allowable for this project. To improve these fresh properties, more air-entraining admixture was added to Trial Batch 2 (Table 8).

Trial Batch 2 (Table 8) has the same admixture dosage as Trial Batch 3 (Table 7). Trial Batch 3 included a fiber dosage rate of 1 lb of fiber/ yd^3. However, the addition of 1 lb of fiber/ yd^3 in Trial Batch 3 reduced the slump from 6.0 in. (Trial Batch 2) to 3.0 in.

Table 5. Concrete mixture proportions for mixture no. 169-16 RLM-T6.

REPORT OF CONCRETE MIXTURE PROPORTIONS

Project: FRC for Articulated Concrete Matress — **3 lbs. of fiber per cu. yd. mixture**
Proportioned for: USACE Memphis District — Proportioned: 17-Jun-16
Proportioned by: USACE ERDC-Concrete — 25% Class F fly ash
and Materials Branch — Mixture No. 169-16 RLM-T6

1. MIXTURE PROPORTIONS

Material	Aggregate, %		Solid Volume		Mass, S.S.D.		Bulk Sp. Gr.	Absorption,
	by vol.	by wt.	ft^3	m^3	lb/yd^3	kg/m^3	S.S.D.	%
Portland cement			1.445	0.054	284	169	3.15	
Fly ash			0.482	0.018	72	43	2.39[a]	
Fine aggregate	43.0	42.5	8.526	0.316	1405	834	2.64	0.49
Coarse Aggregate	57.0	57.5	11.302	0.419	1897	1126	2.69	0.76
Fiber			0.054	0.002	3.1	1.8	0.91[a]	0.00
Batch water			3.706	0.137	231	137.3	1.0	
Air Entraining Admixture					3 fl. oz	0.1 Ltrs		
Water-Reducing Admixture					15.8 fl. oz	0.6 Ltrs		
Air			1.485	0.055				
Totals:	100	100	27.00	1.000	3892	2310		

2. MIXTURE CHARACTERISTICS

S/A, % :by volume	43.0%	Theo. Unit Wt., kg/m^3 (lb/ft^3)	2310	145.3
W/(C+M), by weight:	0.650	Cementitious Factor, kg/m^3 (lb/yd^3):	211	356

3. TEST RESULTS

Batch Number	Fresh Properties						Unconfined Compressive Strength, MPa (psi)[c]			
	Slump in.	Air Content %	Air Content[b] %	Unit Weight lb/ft^3	Relative Yield	Temp. °F	7-day[d]	14-Day	28-day	56-day
1	3.75	6.0	5.8	142.8	98.3%	75.8	2800	3480	3980	4210

4. MATERIALS:

COARSE AGGREGATE: Crushed limestone, ASTM C33 #57, Cumberland Quarry, Pine Bluff Sand & Gravel; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

FINE AGGREGATE: Dredged sand from the Mississippi River at Mile 769.2 AHP; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

CEMENT: Type I/II portland cement, Buzzi Unicem, Festus Plant

POZZOLANS: Fly ash, class F, Headwaters Resources, Prairie State

FIBER: Synthetic fiber, Tuf-Strand MaxTen, Euclid Chemical Company, length 3/4-in., polypropylene/polyethylene blend

ADMIXTURES: AEA-92S, ASTM C260 and CRD C-13 air entraining admixture, Euclid Chemical Company
WR-91, ASTM C494 Type A water reducer, Euclid Chemical Company

REMARKS:

a During trial batching, a specific gravity of 2.39 was used for the fly ash as is reflected in a mill report from 3/14/16. a specific gravity of 0.91 was used for the Tuf-Strand synthetic fibers, as is reflected in the manufacturer's data sheet

b Aggregate correction factor = 0.2 percent applied

c Compressive strength tests made on nominal 4 x 8-in. cylinders per ASTM C39

d Specimens cured at 72°F in 100% relative humidity room per ASTM C192

Table 6. Concrete mixture proportions for mixture no. 169-16 RLM-T5.

REPORT OF CONCRETE MIXTURE PROPORTIONS

Project: FRC for Articulated Concrete Matress — **2 lbs. of fiber per cu. yd. mixture**
Proportioned for: USACE Memphis District — Proportioned: 17-Jun-16
Proportioned by: USACE ERDC-Concrete — 25% Class F fly ash
and Materials Branch — Mixture No. 169-16 RLM-T5

1. MIXTURE PROPORTIONS

Material	Aggregate, %		Solid Volume		Mass, S.S.D.		Bulk Sp. Gr.	Absorption,
	by vol.	by wt.	ft^3	m^3	lb/yd^3	kg/m^3	S.S.D.	%
Portland cement			1.445	0.054	284	169	3.15	
Fly ash			0.482	0.018	72	43	2.39[a]	
Fine aggregate	43.0	42.5	8.533	0.316	1406	834	2.64	0.49
Coarse Aggregate	57.0	57.5	11.312	0.419	1899	1127	2.69	0.76
Fiber			0.038	0.001	2.1	1.3	0.91[a]	0.00
Batch water			3.706	0.137	231	137.3	1.0	
Air Entraining Admixture					3 fl. oz	0.1 Ltrs		
Water-Reducing Admixture					13.6 fl. oz	0.5 Ltrs		
Air			1.485	0.055				
Totals:	100	100.0	27.00	1.000	3894	2311		

2. MIXTURE CHARACTERISTICS

S/A, % :by volume	43.0%	Theo. Unit Wt., kg/m^3 (lb/ft^3)	2311	145.3
W/(C+M), by weight:	0.650	Cementitious Factor, kg/m^3 (lb/yd^3):	211	356

3. TEST RESULTS

Batch Number	Fresh Properties						Unconfined Compressive Strength, MPa (psi)[c]			
	Slump in.	Air Content %	Air Content[b] %	Unit Weight lb/ft^3	Relative Yield	Temp. °F	7-day[d]	14-Day	28-day	56-day
1	3.50	6.0	5.8	0	0.0%	74.8	3030	3450	4010	4190

4. MATERIALS:

COARSE AGGREGATE: Crushed limestone, ASTM C33 #57, Cumberland Quarry, Pine Bluff Sand & Gravel; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

FINE AGGREGATE: Dredged sand from the Mississippi River at Mile 769.2 AHP; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

CEMENT: Type I/II portland cement, Buzzi Unicem, Festus Plant

POZZOLANS: Fly ash, class F, Headwaters Resources, Prairie State

FIBER: Synthetic fiber, Tuf-Strand MaxTen, Euclid Chemical Company, length 3/4-in., polypropylene/polyethylene blend

ADMIXTURES: AEA-92S, ASTM C260 and CRD C-13 air entraining admixture, Euclid Chemical Company
WR-91, ASTM C494 Type A water reducer, Euclid Chemical Company

REMARKS:

a During trial batching, a specific gravity of 2.39 was used for the fly ash as is reflected in a mill report from 3/14/16. a specific gravity of 0.91 was used for the Tuf-Strand synthetic fibers, as is reflected in the manufacturer's data sheet

b Aggregate correction factor = 0.2 percent applied

c Compressive strength tests made on nominal 4 x 8-in. cylinders per ASTM C39

d Specimens cured at 72°F in 100% relative humidity room per ASTM C192

Table 7. Concrete mixture proportions for mixture no. 158-16 RLM-T3.

REPORT OF CONCRETE MIXTURE PROPORTIONS

Project: FRC for Articulated Concrete Matress
Proportioned for: USACE Memphis District
Proportioned by: USACE ERDC-Concrete and Materials Branch

1 lbs. of fiber per cu. yd. mixture
Proportioned: 06-Jun-16
25% Class F fly ash
Mixture No. 158-16 RLM-T3

1. MIXTURE PROPORTIONS

Material	Aggregate, %		Solid Volume		Mass, S.S.D.		Bulk Sp. Gr.	Absorption,
	by vol.	by wt.	ft^3	m^3	lb/yd^3	kg/m^3	S.S.D.	%
Portland cement			1.445	0.054	284	169	3.15	
Fly ash			0.482	0.018	72	43	2.39[a]	
Fine aggregate	43.0	42.5	8.542	0.316	1407	835	2.64	0.49
Coarse Aggregate	57.0	57.5	11.323	0.419	1901	1128	2.69	0.76
Fiber			0.018	0.001	1.0	0.6	0.91[a]	0.00
Batch water			3.706	0.137	231	137.3	1.0	
Air Entraining Admixture					3 fl. oz	0.1 Ltrs		
Water-Reducing Admixture					10.6 fl. oz	0.4 Ltrs		
Air			1.485	0.055				
Totals:	100	100.0	27.00	1.000	3896	2312		

2. MIXTURE CHARACTERISTICS

S/A, % :by volume	43.0%	Theo. Unit Wt., kg/m^3 (lb/ft^3)	2312 145.5
W/(C+M), by weight:	0.650	Cementitious Factor, kg/m^3 (lb/yd^3):	211 356

3. TEST RESULTS

Batch Number	Fresh Properties						Unconfined Compressive Strength, MPa (psi)[c]			
	Slump in.	Air Content %	Air Content[b] %	Unit Weight lb/ft^3	Relative Yield	Temp. °F	7-day[d]	14-Day	28-day	56-day
1	3.00	5.8	5.6	0	0.0%	74.4	2970	3520	3960	4310

4. MATERIALS:

COARSE AGGREGATE: Crushed limestone, ASTM C33 #57, Cumberland Quarry, Pine Bluff Sand & Gravel; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

FINE AGGREGATE: Dredged sand from the Mississippi River at Mile 769.2 AHP; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

CEMENT: Type I/II portland cement, Buzzi Unicem, Festus Plant

POZZOLANS: Fly ash, class F, Headwaters Resources, Prairie State

FIBER: Synthetic fiber, Tuf-Strand MaxTen, Euclid Chemical Company, length 3/4-in., polypropylene/polyethylene blend

ADMIXTURES: AEA-92S, ASTM C260 and CRD C-13 air entraining admixture, Euclid Chemical Company
WR-91, ASTM C494 Type A water reducer, Euclid Chemical Company

REMARKS:

a During trial batching, a specific gravity of 2.39 was used for the fly ash as is reflected in a mill report from 3/14/16. a specific gravity of 0.91 was used for the Tuf-Strand synthetic fibers, as is reflected in the manufacturer's data sheet

b Aggregate correction factor = 0.2 percent applied

c Compressive strength tests made on nominal 4 x 8-in. cylinders per ASTM C39

d Specimens cured at 72°F in 100% relative humidity room per ASTM C192

Table 8. Concrete mixture proportions for mixture no. 146-16 RLM-T2.

REPORT OF CONCRETE MIXTURE PROPORTIONS

Project: FRC for Articulated Concrete Matress — **No Fiber Mix**
Proportioned for: USACE Memphis District — Proportioned: 25-May-16
Proportioned by: USACE ERDC-Concrete — 25% Class F fly ash
and Materials Branch — Mixture No. 146-16 RLM-T2

1. MIXTURE PROPORTIONS

Material	Aggregate, %		Solid Volume		Mass, S.S.D.		Bulk Sp. Gr.	Absorption,
	by vol.	by wt.	ft^3	m^3	lb/yd^3	kg/m^3	S.S.D.	%
Portland cement			1.445	0.054	284	169	3.15	
Fly ash			0.482	0.018	72	43	2.39[a]	
Fine aggregate	43.0	42.5	8.550	0.317	1409	836	2.64	0.49
Coarse Aggregate	57.0	57.5	11.333	0.420	1903	1129	2.69	0.76
Batch water			3.706	0.137	231	137.3	1.0	
Air Entraining Admixture					3 fl. oz	0.1 Ltrs		
Water-Reducing Admixture					10.6 fl. oz	0.4 Ltrs		
Air			1.485	0.055				
Totals:	100	100.0	27.00	1.000	3898	2314		

2. MIXTURE CHARACTERISTICS

S/A, % :by volume	43.0%	Theo. Unit Wt., kg/m^3 (lb/ft^3)	2314	145.6
W/(C+M), by weight:	0.650	Cementitious Factor, kg/m^3 (lb/yd^3):	211	356

3. TEST RESULTS

Batch Number	Fresh Properties						Unconfined Compressive Strength, MPa (psi)[c]			
	Slump in.	Air Content %	Air Content[b] %	Unit Weight lb/ft^3	Relative Yield	Temp. °F	7-day[d]	14-Day	28-day	56-day
1	6.00	5.9	5.7	142.4	97.8%	74.5	2430	3060	3380	#DIV/0!

4. MATERIALS:

COARSE AGGREGATE: Crushed limestone, ASTM C33 #57, Cumberland Quarry, Pine Bluff Sand & Gravel; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

FINE AGGREGATE: Dredged sand from the Mississippi River at Mile 769.2 AHP; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

CEMENT: Type I/II portland cement, Buzzi Unicem, Festus Plant

POZZOLANS: Fly ash, class F, Headwaters Resources, Prairie State

ADMIXTURES: AEA-92S, ASTM C260 and CRD C-13 air entraining admixture, Euclid Chemical Company
WR-91, ASTM C494 Type A water reducer, Euclid Chemical Company

REMARKS:

a During trial batching, a specific gravity of 2.39 was used for the fly ash as is reflected in a mill report from 3/14/16.
b Aggregate correction factor = 0.2 percent applied
c Compressive strength tests made on nominal 4 x 8-in. cylinders per ASTM C39
d Specimens cured at 72°F in 100% relative humidity room per ASTM C192

Table 9. Concrete mixture proportions for mixture no. 145-16 RLM-T1.

REPORT OF CONCRETE MIXTURE PROPORTIONS

Project: FRC for Articulated Concrete Matress — **No Fiber Mix**
Proportioned for: USACE Memphis District — Proportioned: 24-May-16
Proportioned by: USACE ERDC-Concrete — 25% Class F fly ash
and Materials Branch — Mixture No. 145-16 RLM-T1

1. MIXTURE PROPORTIONS

Material	Aggregate, % by vol.	Aggregate, % by wt.	Solid Volume ft^3	Solid Volume m^3	Mass, S.S.D. lb/yd^3	Mass, S.S.D. kg/m^3	Bulk Sp. Gr. S.S.D.	Absorption, %
Portland cement			1.445	0.054	284	169	3.15	
Fly ash			0.482	0.018	72	43	2.39[a]	
Fine aggregate	43.0	42.5	8.550	0.317	1409	836	2.64	0.49
Coarse Aggregate	57.0	57.5	11.333	0.420	1903	1129	2.69	0.76
Batch water			3.706	0.137	231	137.3	1.0	
Air Entraining Admixture					1.7 fl. oz	0.1 Ltrs		
Water-Reducing Admixture					10.6 fl. oz	0.4 Ltrs		
Air			1.485	0.055				
Totals:	100	100.0	27.00	1.000	3898	2314		

2. MIXTURE CHARACTERISTICS

S/A, % :by volume	43.0%	Theo. Unit Wt., kg/m^3 (lb/ft^3)	2314	146.3
W/(C+M), by weight:	0.650	Cementitious Factor, kg/m^3 (lb/yd^3):	211	356

3. TEST RESULTS

Batch Number	Fresh Properties: Slump in.	Air Content %	Air Content[b] %	Unit Weight lb/ft^3	Relative Yield	Temp. °F	Unconfined Compressive Strength, MPa (psi)[c]: 7-day[d]	14-Day	28-day	56-day
1	2.25	4.5	4.3	146	99.8%	71.8	2900	3620	4170	#DIV/0!

4. MATERIALS:

COARSE AGGREGATE: Crushed limestone, ASTM C33 #57, Cumberland Quarry, Pine Bluff Sand & Gravel; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

FINE AGGREGATE: Dredged sand from the Mississippi River at Mile 769.2 AHP; aggregate gradation, specific gravity, and absorption values determined in ERDC-CMB aggregate testing laboratory

CEMENT: Type I/II portland cement, Buzzi Unicem, Festus Plant

POZZOLANS: Fly ash, class F, Headwaters Resources, Prairie State

ADMIXTURES: AEA-92S, ASTM C260 and CRD C-13 air entraining admixture, Euclid Chemical Company
WR-91, ASTM C494 Type A water reducer, Euclid Chemical Company

REMARKS:

a During trial batching, a specific gravity of 2.39 was used for the fly ash as is reflected in a mill report from 3/14/16.
b Aggregate correction factor = 0.2 percent applied
c Compressive strength tests made on nominal 4 x 8-in. cylinders per ASTM C39
d Specimens cured at 72°F in 100% relative humidity room per ASTM C192

4 Project Delivery Team

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References

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_____. 2016a. *Standard practice for making and curing concrete teste specimens in the laboratory*. Designation C192-16. Philadelphia, PA: ASTM International.

_____. 2016b. *Standard specification for concrete aggregates*. Designation C33-16. Philadelphia, PA: ASTM International.

_____. 2016c. *Standard test method for compressive strength of concrete specimens*. Designation C39-16a. Philadelphia, PA: ASTM International.

Appendix A: Materials Information

Mill certificates and admixture data sheets for the materials used were supplied by the U.S. Army Engineer District, Memphis, Construction Branch.

Buzzi Unicem USA

MILL CERTIFICATION REPORT
PORTLAND CEMENT - TYPE I/II LOW ALKALI

Certification date: 3/9/2016
Cement Type: I/II Low Alkali
Laboratory: Festus Plant

We hereby certify that this cement complies with current ASTM C150 and AASHTO M85 Specifications
The following data represents the average for the Buzzi Unicem USA cement that was produced in the month of
FEBRUARY 2016

ASTM STANDARD REQUIREMENTS		MILL CERTIFICATION VALUES	
CHEMICAL DATA C150			
SiO_2 - %	*	SiO_2 - %	18 98
Al_2O_3 - %	max 6 0	Al_2O_3 - %	4 95
Fe_2O_3 - %	max 6 0	Fe_2O_3 - %	3 73
CaO - %	*	CaO - %	62 69
MgO - %	max 6 0	MgO - %	2 76
SO_3 - %	max 3 0***	SO_3 - %	3 19
Loss on Ignition - %	max 3 0	Loss on Ignition - %	2 65
Insoluble Residue - %	max 0 75	Insoluble Residue - %	0 2
CO2 in Cement - %	*	CO2 in Cement - %	1 34
Limestone - %	max 5 0	Limestone - %	3 18
CaCO3 in Limestone - %	min 70 0	CaCO3 in Limestone - %	95 58
Potential Phase Compounds:**		Potential Phase Compounds:**	
C_3S - %	*	C_3S - %	57 6
C_2S - %	*	C_2S - %	10 7
C_3A - %	max 8	C_3A - %	6 8
C_4AF - %	*	C_4AF - %	11 3
$C_4AF + 2(C_3A)$ - %	*	$C_4AF + 2(C_3A)$ - %	24 9
$C_3S + 4\ 75C_3A$ - %	max 100	$C_3S + 4\ 75C_3A$ - %	89 8
Na_2O Equivalent - %	max 0 60	Na_2O Equivalent - %	0 39
PHYSICAL DATA C150			
Fineness- Blaine - m^2/kg	min 260	Fineness- Blaine - m^2/kg	383
Autoclave Expansion %	max 0 80	Autoclave Expansion %	0 06
Time of Set		Time of Set	
Vicat (minutes)	min 45	Vicat (minutes) Initial	81
	max 375	Final	191
Air Content %	max 12	Air Content %	7 5
Compressive Strength:		Compressive Strength:	
1 day - psi (MPa)	*	1 day - psi (MPa)	2150 (14 8)
3 day - psi (MPa)	1740 (12 0)	3 day - psi (MPa)	3553 (24 5)
7 day - psi (MPa)	2760 (19 0)	7 day - psi (MPa)	4890 (33 7)
Mortar Bar expansion % (C1038) ***		Mortar Bar expansion % (C1038)	0 012

By Nicholas Rice
Quality Control Manager or Quality Supervisor

" Not applicable
"*" Adjusted per ASTM C150 Annex A1.6
"**" It is permissible to exceed the values for SO3 content, provided that the Mortar Bar Expansion C1038 does not exceed 0.020 % at 14 days

BUZZI UNICEM USA, Festus Plant
1000 River Cement Road,Festus, MO 63028-0903, P O. Box 1003. Phone 636.931 0900

3/9/2016 Rev 2 1 October 2013

HEADWATERS RESOURCES

ASTM C618 / AASHTO M295 Testing of
Prairie State Fly Ash

Sample Type: Monthly **Report Date:** 3/14/2016

Sample Date: 1/1 - 1/31/16 **MTRF ID:** 270PS

Sample ID:

Chemical Analysis			ASTM / AASHTO Limits Class F	Class C	ASTM Test Method
Silicon Dioxide (SiO2)	56.75	%			
Aluminum Oxide (Al2O3)	18.56	%			
Iron Oxide (Fe2O3)	10.04	%			
Sum of Constituents	85.35	%	70 0% min	50 0% min	D4326
Sulfur Trioxide (SO3)	0 93	%	5 0% max	5 0% max	D4326
Calcium Oxide (CaO)	5.56	%			D4326
Magnesium Oxide (MgO)	1 47	%			
Sodium Oxide (Na2O)	1.26	%			
Potassium Oxide (K2O)	2.75	%			
Total Alkali as Na2Oeq	3 07	%			
Moisture	0.04	%	3 0% max	3 0% max	C311
Loss on Ignition	0.50	%	6 0% max 5 0% max	6 0% max 5 0% max	C311 AASHTO M295
Physical Analysis					
Fineness, % retained on #325	19.78	%	34% max	34% max	C311, C430
Strength Activity Index - 7 or 28 day requirement					C311, C109
7 day, % of control	78	%	75% min	75% min	
28 day, % of control	88	%	75% min	75% min	
Water Requirement, % control	97	%	105% max	105% max	
Autoclave Soundness	-0.01	%	0 8% max	0 8% max	C311, C151
Density	2 39				C604

The strength activity index is not to be considered a measure of the compressive strength of concrete containing the fly ash.

Headwaters Resources certifies that pursuant to current ASTM C618 protocol for testing, the test data listed herein was generated by applicable ASTM methods and meets the requirements of ASTM C618.

Doug Rhodes, CET
Facility Manager

AAR AASHTO R18

Materials Testing & Research Facility
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Taylorsville, Georgia 30178
P: 770 684 0102
F: 770.684.5114
www.headwaters.com

BOWSER-MORNER, INC.

Delivery Address: 4518 Taylorsville Road • Dayton, Ohio 45424 **Mailing Address**: P O. Box 51 • Dayton, Ohio 45401

AASHTO/ISO 17025 Accredited • USACE Validated ACIL INDEPENDENCE

LABORATORY REPORT

Report To: Pine Bluff Sand & Gravel – 2016
Attn: Mike Nelson
780 Spencer Road
Salem, KY 42078

Report Date: November 20, 2015
Job No.: 172312
Report No.: 715891
No. of Pages: 3

Report On: Laboratory Analysis of One No. 57 Crushed Limestone Sample
Source: Cumberland Quarry

On October 6, 2015, one No 57 crushed limestone sample was submitted for selected laboratory analysis from the above referenced source. Testing was performed as specified by the client and in accordance with the following procedures:

ASTM C 29, "Unit Weight and Voids in Aggregate".

ASTM C 88, "Soundness of Aggregates by Use of Sodium Sulfate".

ASTM C 117, "Material Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing".

ASTM C 127, "Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate".

ASTM C 131, "Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine".

ASTM C 136 "Sieve Analysis of Fine and Coarse Aggregates".

ASTM C 142, "Clay Lumps and Friable Particles in Aggregates".

Results are detailed on the attached data sheet

Should you have any questions, or if we may be of further service, please contact me at (937) 236-8805, extension 322.

Respectfully submitted,
BOWSER-MORNER, INC.

Karl A Fletcher, Manager
Construction Materials and
Geotechnical Laboratories

KAF/gls/crh
715891
1-File
1-mike nelson@pbsg.com

Report To: Pine Bluff Sand & Gravel
Source: Cumberland Quarry

BMI Job No.: 172312
BMI Report No : 715891

Sample ID: No. 57 Crushed Limestone

TABLE I
Sieve Analysis (ASTM C 136)

Sieve Size	Percent Passing
1 1/2"	**100**
1"	**98**
3/4"	**72**
1/2"	**34**
3/8"	**15**
No. 4	**3**
No. 8	**2**
No. 200 Decant, %:	**1.8**

** Gradation Provided By Client*

TABLE II
Summary of Results

Test Parameter	Test Method	Results
Los Angeles Abrasion - Grading B, %:	ASTM C 131	**29.6**
Sodium Sulfate Soundness, %:	ASTM C 88	**7.9**
Clay Lumps & Friable Particles, %:	ASTM C 142	**0.23**
Dry-Rodded Bulk Density, pcf:	ASTM C 29	**95.0**
Dry-Rodded Bulk Density, tcy:	ASTM C 29	**1.282**
Loose Bulk Density, pcf:	ASTM C 29	**86.4**
Loose Bulk Density, tcy:	ASTM C 29	**1.166**
Bulk Dry Specific Gravity:	ASTM C 127	**2.639**
Bulk SSD Specific Gravity:	ASTM C 127	**2.669**
Apparent Specific Gravity:	ASTM C 127	**2.722**
Absorption, %:	ASTM C 127	**1.2**

TABLE III
Five Cycle Sodium Sulfate Soundness (ASTM C 88) - Detailed by Size Fraction

Size Fraction	Percent Loss	Gradation Factor	Weighted Percent Loss
1" to 3/4"	5.91	0.285	1.68
3/4" to 1/2"	6.71	0.379	2.54
1/2" to 3/8"	11.82	0.182	2.15
3/8" to No. 4	9.83	0.154	1.51
Total	---	---	**7.9**

LEHMAN ROBERTS

COARSE AND FINE AGGREGATE SPECIFIC GRAVITY

AGGREGATE Coarse Sand
DATE 03/22/2016

Agg source MLC
Tested by Collins

COARSE AGGREGATE

%OF MIX 0

	TEST 1	TEST 2	TEST 3
WT OF SSD			
WEIGHT IN WATER			
WT. OF OVEN DRY			
BULK SPECIFIC GRAVITY	ERR	ERR	ERR
APPARENT SPECIFIC GRAVITY	ERR	ERR	ERR
ABSORBTION %	ERR	ERR	ERR

FINE AGGREGATE

% OF MIX 100

FLASK A--1266.0g
FLASK B--1265.6g

	TEST 1	TEST 2	TEST 3
FLASK A OR B	A	B	
WT OF SSD	537.2	509.3	
FLASK+SSD+H2O	988.7	971.6	
FLASK+WATER	655.2	655.2	
WEIGHT IN H2O	333.5	316.4	0
WT. OF OVEN DRY	533.7	505	
BULK SPECIFIC GRAVITY	2.620	2.618	ERR
APPARENT SPECIFIC GRAVITY	2.666	2.678	ERR
ABSORBTION %	0.7	0.9	ERR

COMBINED BULK SPEC GRAVITY	2.620	2.618	
COMBINED APPT SPEC GRAVITY	2.666	2.678	
COMBINED ABSORBTION %	0.7	0.9	

AVERAGE BULK SPECIFIC GRAVITY	2.619
AVERAGE APPARENT SPECIFIC GRAVITY	2.672
AVG COMBINED ABSORBTION%	0.8

The Euclid Chemical Company

EUCON AEA-92S

AIR ENTRAINING AGENT FOR CONCRETE

EUCLID CHEMICAL

AIR ENTRAINERS

EUCON AEA-92S

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

DESCRIPTION

EUCON AEA-92S 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-92S is an aqueous solution compound of organic chemicals It is compatible with concrete mixes containing other commonly used Euclid Chemical Company admixtures

PACKAGING

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

- Corps of Engineers Specification CRD C-13
- ASTM Specification C 260
- AASHTO Specification M 154

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

DIRECTIONS FOR USE

EUCON AEA-92S is typically dosed at a rate of 0.5 to 2 oz per 100 lbs (30 to 130 mL per 100 kg) of total cementitious material to entrain 3% - 6% air content The amount of EUCON AEA-92S will vary depending on type of cement, fineness of sand, temperature, design of the mix, other admixtures, etc. Concrete mixes must be tested regularly to confirm that proper air content is achieved. EUCON AEA 92S should be added directly to the sand to achieve maximum performance.

PRECAUTIONS/LIMITATIONS

- Consult your local Euclid Chemical representative for the proper dosage rate adjustments when using fly ash, slag or high range water reducers.
- Add to the mix independent of other admixtures
- In all cases, consult the Safety Data Sheet before use

Rev. 2.15

The Euclid Chemical Company

EUCON WR 91

WATER REDUCING, SET RETARDING ADMIXTURE

EUCLID CHEMICAL

WATER REDUCERS

EUCON WR 91

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

DESCRIPTION

EUCON WR 91 is a liquid, water-reducing and set retarding admixture for concrete EUCON WR 91 shows improved setting and finishing characteristics when compared to other commonly used ASTM C 494 Type A water reducers. EUCON WR 91 may be used at a wide range of dosage rates EUCON WR 91 does not contain calcium chloride or other potential corrosion-enhancing ingredients

PRIMARY APPLICATIONS

- Flatwork concrete
- General ready mix concrete
- Architectural concrete
- Mass concrete
- Bridge decks
- Hot weather concrete

FEATURES/BENEFITS

Plastic Concrete

- Improves finishability
- Improves workability
- Reduces water requirement
- Reduces segregation
- Improves setting times
- Compatible with air entraining agents

Hardened Concrete

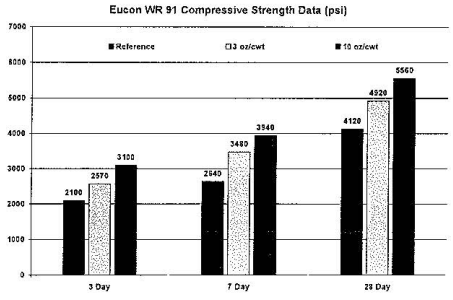
- Increases strength at all ages
- Reduces permeability
- Improves finished appearance
- Reduces cracking
- Increases durability
- Non staining

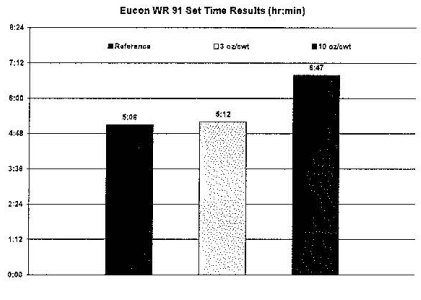
TECHNICAL INFORMATION

Perfomance 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 (± 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 91.





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

PACKAGING

EUCON WR 91 is packaged in bulk, 275 gal (1041 L) totes, 55 gal (208 L) drums, and 5 gal (18 9 L) pails.

SHELF LIFE

1 year in original, unopened container.

SPECIFICATIONS/COMPLIANCES

EUCON WR 91 meets or exceeds the requirements of:

- ASTM C 494, Type A & D
- AASHTO M 194
- ANSI/NSF STD 61

DIRECTIONS FOR USE

EUCON WR 91 is typically used at dosages of 2 to 10 oz per 100 lbs (130 to 650 mL per 100 kg) of cementitious material. Higher dosages are acceptable with prior testing and confirmation of the desired performance with specific materials being used

EUCON WR 91 should be added to the initial batch water of the concrete mixture. Do not dispense onto dry cement.

PRECAUTIONS/LIMITATIONS

- Care should be taken to maintain EUCON WR 91 above freezing, however, freezing and subsequent thawing will not harm the material if thoroughly agitated.
- Never agitate with air.
- Add to mix independent of other admixtures.
- In all cases, consult the Safety Data Sheet before use.

Rev. 11.14

The Euclid Chemical Company

TUF-STRAND MAXTEN™

MACRO SYNTHETIC FIBER

EUCLID CHEMICAL

FIBER PRODUCTS

TUF-STRAND MAXTEN

MASTER FORMAT #: 03 24 00

DESCRIPTION

TUF-STRAND MAXTEN is a macro synthetic fiber successfully used as an alternate to steel fibers and welded wire mesh in a wide variety of secondary reinforcement applications TUF-STRAND MaxTen fibers comply with ASTM C1116, Standard Specification for Fiber Reinforced Concrete and Shotcrete, and are specifically used for the reduction of plastic shrinkage cracks, to improve impact, shatter and abrasion resistance, to increase fatigue resistance, to increase toughness of concrete and provide long term durability of concrete and cement based building products Dosage rates will vary depending upon the reinforcing requirements and can range typically from 3 0 to 5 0 lbs/yd³ (1 8 to 3 0 kg/m³) TUF-STRAND MaxTen synthetic macro-fibers comply with applicable portions of the International Code Council (ICC) Acceptance Criteria AC32 for synthetic fibers and can save time and money on construction projects by eliminating the purchase, storage, handling, cutting, placing and waste of welded wire mesh. These fibers are chemically inert and will not corrode

PRIMARY APPLICATIONS

- Industrial and residential floors
- Whitetoppings, bridge decks and pavements
- Thin walled pre-cast (septic tanks, vaults, walls, etc)
- Mass concrete

FEATURES/BENEFITS

- Increases impact, shatter and abrasion resistance of concrete
- Reduces segregation, plastic settlement, and shrinkage cracking of concrete
- Provides three-dimensional reinforcement against micro and macro-cracking
- Increases overall durability, fatigue resistance and flexural toughness
- Reduction of in-place cost versus wire mesh for temperature / shrinkage crack control
- Easily added to concrete mixture at any time prior to placement
- Tested in accordance with ASTM C 1399 and C 1609 (formerly C 1018)

TECHNICAL INFORMATION

Typical Engineering Data

Material	polypropylene/polyethylene blend
Specific Gravity	0.91
Typical Dosage Rates	3 to 5 lbs/yd³ (1 8 to 3 0 kg/m³)
Available Lengths	¾" (19 mm), 1 ½" (38 mm)
Aspect Ratio	39 / 79
Tensile Strength	87-94 ksi (600 to 650 MPa)
Melt Point	320°F (160°C)
Electrical and Thermal Conductivity	low
Water Absorption	negligible
Acid and Alkali Resistance	excellent
Color	white

PACKAGING

TUF-STRAND MaxTen fibers are packaged in 3 0 lb (1 36 kg), 4 0 lb (1 81 kg) and 5 0 lb (2 27 kg) water soluble bags.

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

Shelf Life

3 years in original, unopened package.

Directions for Use

TUF-STRAND MaxTen fibers can be added to the concrete mixture at any time prior to placement of the concrete. It is generally recommended to add any fiber material at the ready-mix concrete plant during batching. Fibers must be mixed with concrete for a minimum of three (3) to five (5) minutes at maximum mixing speed, depending on the mixer type, to ensure complete dispersion and uniformity. When adding 3 to 5 lbs/yd^3 (1.8 to 3 kg/m^3), a slump loss of up to 2" (50 mm) can be expected for a typical ready-mix concrete design. For higher dosages, increased loss in slump can be expected depending upon the mixture design The use of water reducers and/ or superplasticizers, such as Eucon 1037, Eucon MRX or the Plastol series of admixtures may be necessary to maintain desired workability

Add other admixtures independently from fiber addition. TUF-STRAND MaxTen fibers are compatible with all Euclid Chemical admixtures. When used properly, and placed in a concrete mix of sufficient workability, the fibers will not adversely alter the compressive or flexural strength of concrete or shotcrete

Clean-up

Loose fiber material may be disposed in proper receptacles for refuse Finishing equipment with fibers embedded in concrete should be thoroughly cleaned

Precautions/Limitations

- Use of fibers may cause an apparent loss in measured slump of concrete. This may be offset with the use of a water reducing admixture if necessary.
- Fibers should never be added to a "zero-slump" concrete Ensure a minimum concrete slump of 3" (80 mm) prior to addition of any fiber material. Fibers may also be added in loose form to aggregate charging devices.
- In all cases, consult the Safety Data Sheet before use

Rev. 11.14

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
April 2017	Final report	

4. TITLE AND SUBTITLE
Interim Report on the Investigation of the Fresh Properties of Synthetic Fiber-Reinforced Concrete for the Richardson Landing Casting Field

5a. CONTRACT NUMBER
W912EQ-16-C-0006

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Wendy R. Long, Kirk E. Walker, and Brian H. Green

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER

ERDC/GSL SR-17-1

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Delwick Warfield, P.E.
Construction Branch (EC-C)
U.S. Army Engineer District, Memphis

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

MIPR number, W38XGR60986322 dated 7 April 2016

14. ABSTRACT

The U.S. Army Engineer District, Memphis, uses the Richardson Landing mat casting field to produce articulated concrete mats that are tied together to form articulated concrete revetment "blankets" that are then placed on the riverbanks to serve as a form of erosion control. The Memphis District noted that the corners of some of these concrete mats were becoming damaged as the mats were moved from the casting field to the construction site. To combat this issue, the Memphis District, Construction Branch decided to incorporate synthetic fibers in the current concrete mixture proportion to bridge cracks induced by moving the concrete mats. However, there was concern that the addition of fibers would significantly reduce the workability of the concrete mixture, making it labor intensive to place in the forms and difficult to discharge the fresh concrete from transport vehicles at the casting field.

The Memphis District contracted with the U. S. Army Engineer Research and Development Center's (ERDC's) Concrete and Materials Branch (CMB) to proportion three fiber-reinforced concrete mixtures containing 3-, 2-, and 1-lb/yd^3, respectively, of synthetic (polypropylene) fiber into the current mixture proportion used at Richardson Landing mat casting field. The CMB performed aggregate testing, concrete trial batching, and hardened concrete strength testing to produce the new concrete mixture proportions. This interim report presents the results of testing conducted by the CMB as of 30 August 2016.

15. SUBJECT TERMS
Fiber – reinforced concrete
Concrete - Mixing
Concrete – Mechanical properties
Concrete – Testing
Revetments
Soil erosion

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
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