

# Flow-Fill Trial Mix Design

Mix Designation: No. 021  
Colorado Department of Transportation  
CDOT Structure Backfill (Flow-Fill)

June 23, 2017  
Terracon Project No. 20171008



**Prepared for:**  
Loveland Ready Mix Concrete  
Loveland, Colorado

**Prepared by:**  
Terracon Consultants, Inc.  
Fort Collins, Colorado

Offices Nationwide  
Employee-Owned

Established in 1965  
[terracon.com](http://terracon.com)

# Terracon

Geotechnical   ■   Environmental   ■   Construction Materials   ■   Facilities



June 23, 2017

Loveland Ready Mix Concrete  
P.O. Box 299  
Loveland, Colorado 80539  
Attention: Mr. Brad Fancher / Ms. Amy Vandervort

Re: **Flow-Fill Trial Mix – CDOT Structure Backfill (Flow-Fill)**  
**Client Mix No. 021**  
**Loveland Ready Mix – 644 Namaqua Road, Loveland, Colorado**  
**Terracon Project No. 20171008**


Enclosed are the May 8, 2017 trial batch properties, suggested mix design proportions and strength test results proposed for use on Colorado Department of Transportation (CDOT) structure backfill (flow-fill) placements. This mixture was designed in general accordance with the revised Section 206 of the CDOT Standard Specifications for Road and Bridge Construction.


Specific physical property tests were performed in general accordance with the applicable Colorado Test Procedure, AASHTO, and/or ASTM procedures.

The source of the mix design components include: Loveland Pit aggregates (Size No. 57 rock and sand), Johnstown Pit aggregate (Size No. 8/pea gravel), Sika AIR, GCC Dacotah cement (Type I-II), and Class C fly ash supplied by Boral Material Technologies.

The trial mix design proportions may require adjustments due to variations in materials or other field conditions encountered. If you have any questions or if we may be of further service, please contact us at your convenience.

Sincerely,  
**Terracon Consultants, Inc.**

  
For Rachel Pott  
Geotechnical Intern

  
Eric D. Bernhardt, P.E.  
Geotechnical Department Manager



Attachments:      Appendix A – Trial Mix Design  
                         Appendix B – Aggregate Properties, incl. ASR graphs  
                         Appendix C – Mix Components Certified Reports

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## Flow-Fill Trial Mix Design

Mix Designations: CDOT Structural Backfill (Flow-Fill); I.D. 021

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### DESIGN CRITERIA AND MATERIAL SOURCE IDENTIFICATION

#### Design Criteria

Slump, inches:

Design Target (ASTM C143) ..... 7 to 10\*

Air Content, percent..... N/A

28-Day Strength, psi:

Field Required Minimum – Compressive (ASTM D4832)..... 50

Removability Modulus..... 1.5 maximum\*\* (206\*\*\*)

Fly ash ..... Class C (701.02\*\*\*)

of total cementitious ..... 50% maximum

Cement ..... ASTM C 150 (701.01\*\*\*)

Type..... I – II

of total cementitious..... 50% minimum

Aggregates\*\*\*\*

Coarse Aggregate Size, Nominal Maximum..... Size No. 57 and No. 8 (Table 703-2\*\*\*)

Fine Aggregate Gradation ..... (Table 703-01\*\*\*)

Chemical Admixtures

Air Entrainment..... AASHTO M 154 (711.02\*\*\*)

\* or the flow-fill shall have a minimum flow consistency of 6 inches (ASTM D6103)

\*\* in areas that require future excavation

\*\*\* denotes CDOT Standard Specifications for Road and Bridge Construction subsection reference

\*\*\*\* aggregates other than meeting Section 703 may be used if testing indicates acceptable results for strength and air content along with gradation presented in Section 206; included in Appendix B, aggregate properties



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**MIX DESIGN SHEET****SUGGESTED PROPORTIONS FOR FLOW-FILL TRIAL MIX DESIGN****CDOT Structure Backfill (Flow-Fill) – Supplier Mix Design I.D.: 021**

(Aggregates in SSD Condition) per One (1) Cubic Yard

Component	Weight or Volume	Absolute Volume, cf
Cement (0.32 sack)	30 lbs.	0.15
Fly Ash, Class C	30 lbs.	0.18
Water – 48 gallons	400 lbs.	6.41
Air Content/Entrainment	1.0 oz.	0.68
Coarse Aggregate (Size No. 57)	1,000 lbs.	6.05
Coarse Aggregate (Size No. 8)	565 lbs.	3.47
Fine Aggregate (Sand)	1,665 lbs.	10.15
<b>TOTAL(S):</b>	<b>3,690 lbs.</b>	<b>27.09 cf/cy</b>

Water-Cementitious Material Ratio: 6.67 lbs./lbs. (by weight) ..... 75.20 gallons/sack  
 Fly ash, % of total weight ..... 50  
 Cement, % of total weight ..... 50  
 Total Aggregate, % ..... Sand (52); Coarse - Size No. 57 & No. 8 (48)  
 Theoretical Unit Weight: (Field +2.0 pcf max.) ..... 136.2 pcf @ 2.5% air content  
 Theoretical Yield ..... 27.09 cf/cy @ 2.5% air content  
 Relative Yield ..... 1.00 (27.09/27.00)  
 Removability Modulus (RM) assuming 50 psi @ 28-days ..... 1.2

**Material Sources**

<b><u>Component</u></b>	<b><u>Manufacturer / Source</u></b>
Cement .....	GCC of America Type I-II / Pueblo Plant
Fly Ash .....	Boral Class C / Commerce City Colorado
Coarse Aggregate (Size No. 57) .....	Loveland Ready Mix / Loveland Pit
Coarse Aggregate (Size No. 8) .....	Johnstown Ready Mix / Johnstown Pit
Fine Aggregate (Sand) .....	Loveland Ready Mix / Loveland Pit
Water .....	Local
Air Entrainment .....	Sika / Sika AIR

Concrete Supplier: Loveland Ready Mix Concrete, 644 Namaqua Rd., Loveland, Colorado  
 Testing Laboratory: Terracon Consultants, Inc. – Fort Collins, Colorado

Rachel Pott  
 Geotechnical Intern

*Eric D. Bernhardt*  
 Eric D. Bernhardt, P.E.  
 Geotechnical Department Manager



## Appendix A

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### *Trial Mix Design Properties*

**Flow-Fill Trial Mix Design**

Mix Designations: CDOT Structural Backfill (Flow-Fill); I.D. 021

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**TRIAL BATCH TEST RESULTS (May 8, 2017)****5-Cubic Yard Trial Batch Proportions (Aggregates in SSD Condition)**

<b><u>Component</u></b>	<b><u>Weight or Quantity (per cubic yard)</u></b>
Cement, pounds .....	30
Fly Ash (Class C), pounds .....	30
Combined Cementitious (cement + fly ash), pounds .....	(60)
Water, pounds/gallons .....	400/48
Air Entrainment Agent – Sika AIR, ounces .....	1.0
Coarse Aggregate (Size No. 57), pounds .....	1,000
Coarse Aggregate (Size No. 8), pounds .....	565
Fine Aggregate, pounds .....	1,665

**Trial Mix Physical Property Test Results**

Slump, inches (ASTM C143) .....	7½
Air Content, % (ASTM C231) .....	2.5
Water-Cementitious Material Ratio, lbs/lbs. ....	6.67
Unit Weight, pcf (ASTM D6023) .....	130.5
Concrete Temperature, °F (ASTM C1064) .....	62
Air (ambient) Temperature, °F .....	66
Yield, cf/cy .....	28.28
Relative Yield .....	1.05
Removability Modulus, (RM) .....	1.10

**Compressive Strength, psi**

<b>Lab No.</b>	<b>Date Tested</b>	<b>Age, Days</b>	<b>Compressive Strength</b>
1	5/12/17	4 days	10
2	5/15/17	7 days	10
3	5/15/17	7 days	10
		<b>7 Day Average:</b>	<b>10</b>
4	5/22/17	14 days	30
5	5/22/17	14 days	30
		<b>14 Day Average:</b>	<b>30</b>
6	5/29/17	21 days	40
7	5/29/17	21 days	40
		<b>21 Day Average:</b>	<b>40</b>
8	6/05/17	28 days	50
9	6/05/17	28 days	50
10	6/05/17	28 days	50
		<b>28 Day Average:</b>	<b>50</b>



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### FLOW-FILL TRIAL MIX DESIGN

Client: **Loveland Ready Mix Concrete**

Project: **Miscellaneous Lab Testing**

Location: **Various**

Terracon Project No: **20171008**

Trial Batch Mix Date: **8-May-17**

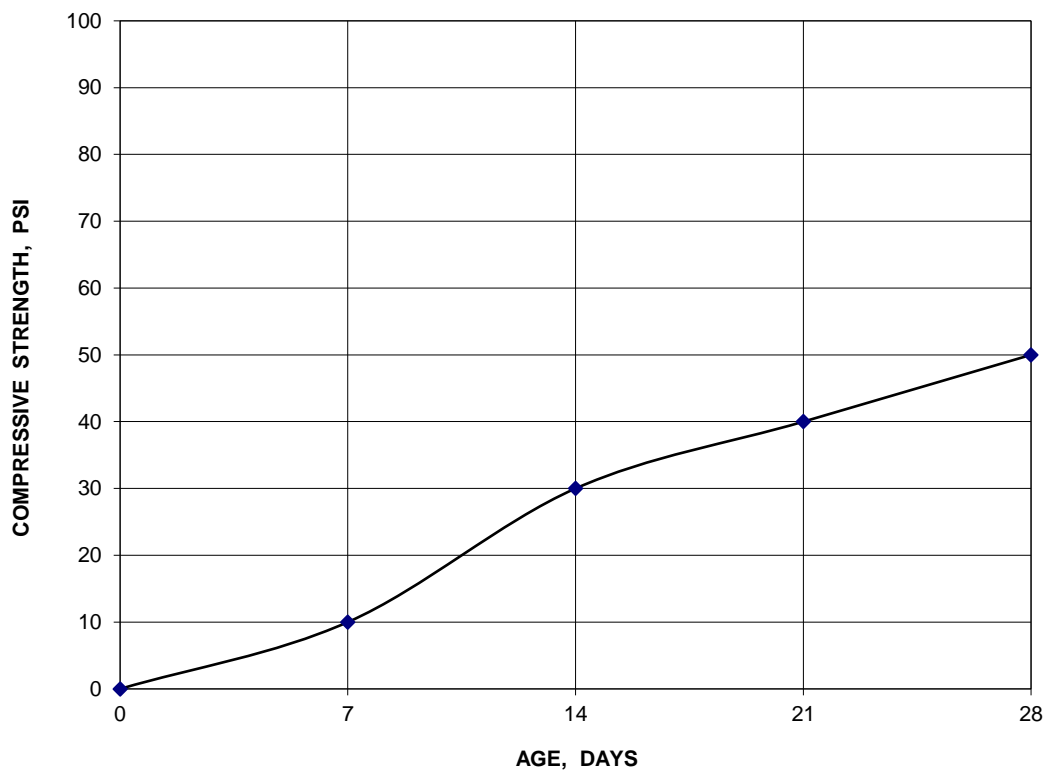
Mix ID: **CDOT Structure Backfill (Flow-Fill)**

Supplier Mix ID: **021**

### FLOW-FILL COMPRESSIVE STRENGTH TEST RESULTS LABORATORY TRIAL BATCH MIX DESIGN

4-DAY COMPRESSIVE STRENGTH, PSI	7-DAY COMPRESSIVE STRENGTH, PSI	14-DAY COMPRESSIVE STRENGTH, PSI	21-DAY COMPRESSIVE STRENGTH, PSI	28-DAY COMPRESSIVE STRENGTH, PSI
10	10	30	40	50

COMPRESSIVE STRENGTH VS. AGE  
(excluding 4-day results)



## Appendix B

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### *Aggregate Properties*



**Flow-Fill Trial Mix Design**

Mix Designations: CDOT Structural Backfill (Flow-Fill); I.D. 021

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**AGGREGATE PROPERTIES****Coarse Aggregate (Sampled February 9, 2017)****(1" Nominal Maximum, Size No. 57) – Loveland Pit**

Screen or Sieve Size	Percent Passing	Specifications
1-1/2"	100	100
1"	100	95-100
3/4"	87	
1/2"	38	25 - 60
3/8"	20	
No. 4	2	0 - 10
No. 8	1	0 - 5
No. 200	0.4	0 - 1
Fineness Modulus	6.86	
<u>Specific Gravity</u>		
• Bulk, dry	2.621	
• SSD	2.647	
• Apparent	2.691	
Absorption, percent	1.0	
Alkali Silica Reactivity, % expansion	0.08	Less than 0.10
Dry-Rodded Unit Weight, pcf	102	
Dry Loose Unit Weight, pcf	97	
Voids in Aggregate Compacted by Rodding, %	38 Bulk Specific (OD): 2.621	
Sodium Sulfate Soundness, Loss, %	2	12 Maximum
Los Angeles Abrasion, Loss, %	34	45 Maximum
Clay Lumps and Friable Particles, %	0.2	2.0 max. <sup>(a)</sup>
<u>Lightweight Particles, % Float</u>		
-Coal & Lignite (Sp.G. = 2.0)	0.33	0.5 max. <sup>(a)</sup>
-Chert & Shale (Sp.G. = 2.4)	3.56 <sup>(b)</sup>	3.0 max. <sup>(a)</sup>
Sum of Clay Lumps, Friable Particles and Chert, %	4.09	3.0 max. <sup>(a)</sup>

(a) AASHTO Aggregate Class "A"; application, severe weather exposure and ASTM C33 Class 5S designation. Uses other than Designation A are outlined in the applicable project specifications or applicable AASHTO Standard.

(b) These impurities apply only to aggregate in which chert appears as an impurity. Visual examination of the lightweight particles retained from testing consisted of recycled concrete.

**POTENTIAL ALKALI REACTIVITY OF AGGREGATES (Mortar Bar Method)**  
**ASTM C1260**

**Terracon**

1505 Old Happy Jack Road  
 Cheyenne, Wyoming 82001

**Date:** April 24, 2017

**Cast Date:** April 7, 2017

**Laboratory No.:** Terracon - 24

**Project No.:** 20171008

**Aggregate Source:** Loveland Ready Mix

**Cement:** GCC Dacotah, Type I-II

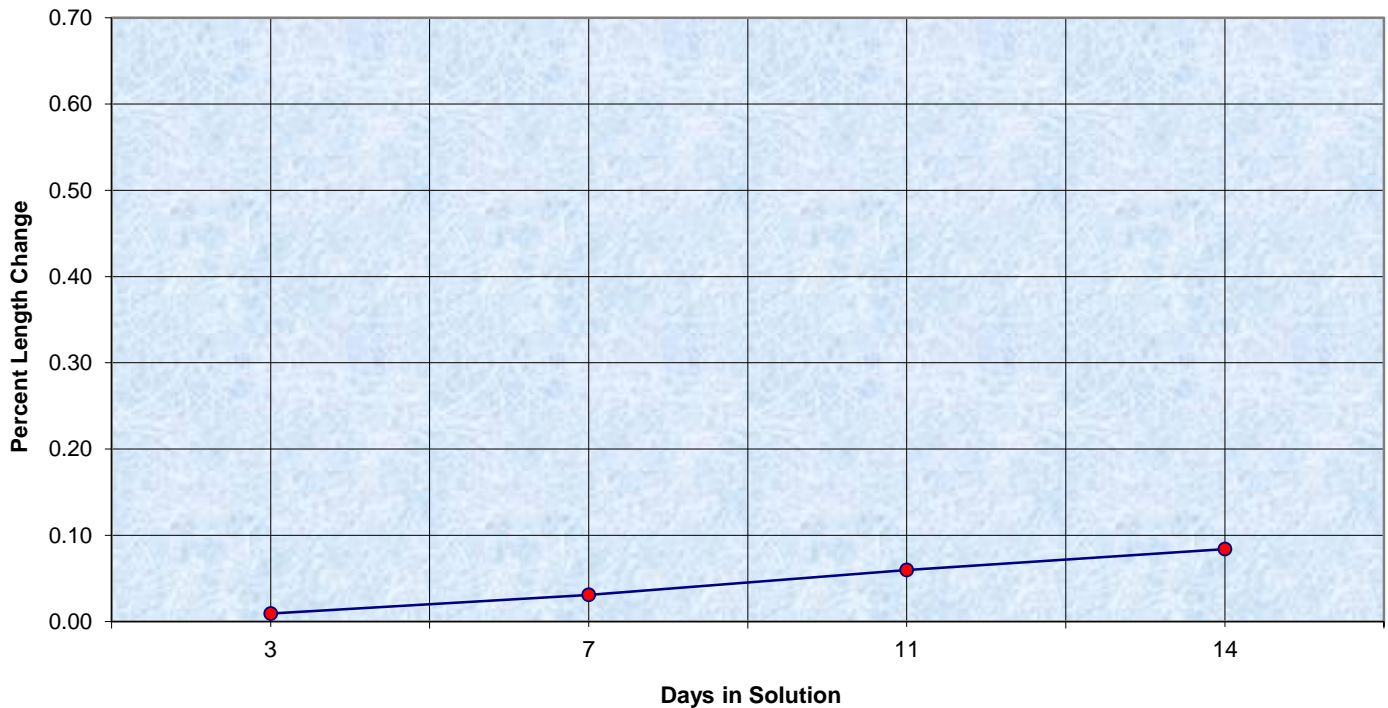
**Aggregate Size:** Concrete Coarse Aggregate (No. 57 Rock)

**Equivalent Cement Alkalis:** Not Reported

**Aggregate/Cement Ratio:** 990/440 g

**Water/Cement Ratio:** 0.47

	Initial Reading	Zero (48 hrs)	Day Reading	% Change	Day Reading	% Change	Day Reading	% Change	Day Reading	% Change
			3		7		11		14	
Date	4/8/17	4/9/17	4/12/17		4/16/17		4/20/17		4/23/17	
Comparator Length										
1	-0.0267	-0.0199	-0.0192	0.007	-0.0172	0.027	-0.0143	0.056	-0.0120	0.079
2	-0.0672	-0.0608	-0.0599	0.009	-0.0576	0.032	-0.0547	0.061	-0.0522	0.086
3	-0.0455	-0.0390	-0.0378	0.012	-0.0356	0.034	-0.0328	0.062	-0.0303	0.087
Average				0.009		0.031		0.060		0.084



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June 23, 2017 ■ Terracon Project No. 20171008



**AGGREGATE PROPERTIES**  
**Coarse Aggregate (Sampled February 9, 2017)**  
**(3/8" Nominal Maximum, Size No. 8) – Johnstown Pit**

Screen or Sieve Size	Percent Passing	Specifications
1-1/2"	100	
1"	100	
3/4"	100	
1/2"	100	100
3/8"	100	85 - 100
No. 4	28	10 - 30
No. 8	4	0 - 10
No. 16	3	0 - 5
Fineness Modulus	5.61	
<u>Specific Gravity</u>		
• Bulk, dry	2.559	
• SSD	2.608	
• Apparent	2.692	
Absorption, percent	1.9	
Alkali Silica Reactivity, % expansion	0.08	Less than 0.10
Dry-Rodded Unit Weight, pcf	97	
Dry Loose Unit Weight, pcf	90	
Voids in Aggregate Compacted by Rodding, %	39 Bulk Specific (OD): 2.559	
Sodium Sulfate Soundness, Loss, %	3	12 Maximum
Los Angeles Abrasion, Loss, %	38	45 Maximum
Clay Lumps and Friable Particles, %	0.0	2.0 max. <sup>(a)</sup>
<u>Lightweight Particles, % Float</u>		
-Coal & Lignite (Sp.G. = 2.0)	0.15	0.5 max. <sup>(a)</sup>
-Chert & Shale (Sp.G. = 2.4)	3.84 <sup>(b)</sup>	3.0 max. <sup>(a)</sup>
Sum of Clay Lumps, Friable Particles and Chert, %	3.99	3.0 max. <sup>(a)</sup>

(c) AASHTO Aggregate Class "A"; application, severe weather exposure and ASTM C33 Class 5S designation. Uses other than Designation A are outlined in the applicable project specifications or applicable AASHTO Standard.

(d) These impurities apply only to aggregate in which chert appears as an impurity. Visual examination of the lightweight particles retained from testing consisted of recycled concrete.

POTENTIAL ALKALI REACTIVITY OF AGGREGATES (Mortar Bar Method)  
ASTM C 1260

**Terracon**

1505 Old Happy Jack Road  
Cheyenne, Wyoming 82001

Date: March 17, 2017

Cast Date: March 1, 2017

Laboratory No.: Terracon - 24

Project No.: 20171008

Aggregate Source: Johnstown Ready Mix

Cement: GCC Dacotah, Type I-II

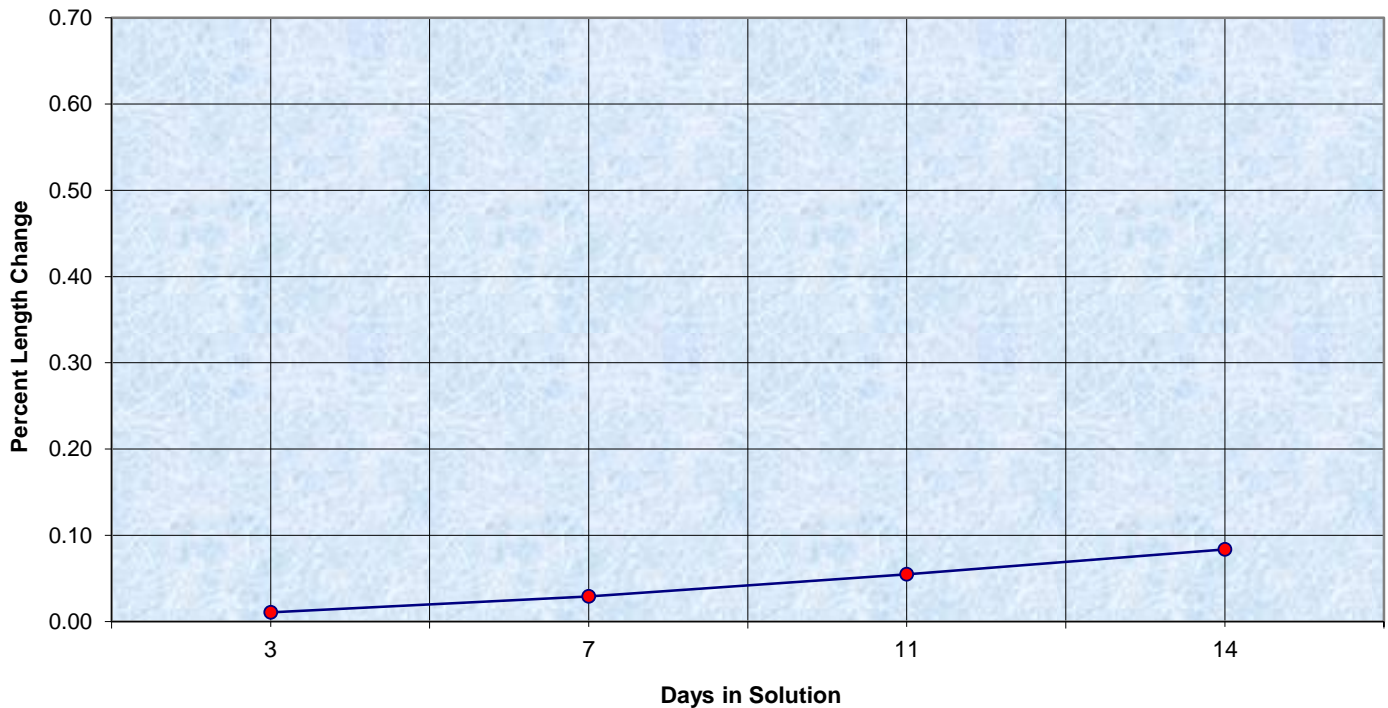
Aggregate Size: Concrete Coarse Aggregate (no. 8 Rock)

Equivalent Cement Alkalis: Not Reported

Aggregate/Cement Ratio: 990/440 g

Water/Cement Ratio: 0.47

	Initial Reading	Zero (48 hrs)	Day Reading	% Change	Day Reading	% Change	Day Reading	% Change	Day Reading	% Change
			3		7		11		14	
Date	3/2/17	3/3/17	3/6/17		3/10/17		3/14/17		3/17/17	
Comparator Length										
1	-0.0269	-0.0197	-0.0186	0.011	-0.0168	0.029	-0.0140	0.057	-0.0112	0.085
2	-0.0292	-0.0219	-0.0209	0.010	-0.0190	0.029	-0.0168	0.051	-0.0138	0.081
3	-0.0376	-0.0305	-0.0294	0.011	-0.0276	0.029	-0.0249	0.056	-0.0220	0.085
Average				0.011		0.029		0.055		0.084



**Flow-Fill Trial Mix Design**

Mix Designations: CDOT Structural Backfill (Flow-Fill); I.D. 021

June 23, 2017 ■ Terracon Project No. 20171008

**AGGREGATE PROPERTIES - Continued****Fine Aggregate (Sand) – Loveland Pit (Sampled February 9, 2017)**

Screen or Sieve Size	Percent Passing	Specifications
3/8"	100	100
No. 4	99	95 – 100
No. 8	86	80 - 100
No. 16	67	50 – 85
No. 30	39	25 - 60
No. 50	14	10 – 30
No. 100	3	2 – 10
No. 200	1.6	0 – 3
Fineness Modulus	2.92	2.5 – 3.5
<u>Specific Gravity</u> <ul style="list-style-type: none"> <li>• Bulk, dry</li> <li>• SSD</li> <li>• Apparent</li> </ul>	2.587 2.628 2.696	
Absorption, percent	1.6	
Alkali Silica Reactivity, % expansion	0.099	Less than 0.10
Sand Equivalent Value	90	80 Minimum
Dry-Rodded Unit Weight, pcf	98	
Dry Loose Unit Weight, pcf	92	
Sodium Sulfate Soundness, Loss, %	3	10 Maximum
Organic Impurities	Color Plate No. 1	Less than 3
Clay Lumps and Friable Particles, %	0.0	3.0 Maximum
Voids in Aggregate compacted by rodding, %	39 Bulk Specific (OD): 2.587	
<u>Lightweight Particles, % Float</u> <ul style="list-style-type: none"> <li>-Coal &amp; Lignite (Sp.G. = 2.0)</li> <li>-Chert &amp; Shale (Sp.G. = 2.4)</li> </ul>	< 0.01 1.00	(b)

(b) AASHTO M6 indicates Maximum Mass, percent: Class A = 0.25 and Class B = 1.0

POTENTIAL ALKALI REACTIVITY OF AGGREGATES (Mortar Bar Method)  
ASTM C1260

**Terracon**

1505 Old Happy Jack Road  
Cheyenne, Wyoming 82001

Date: April 24, 2017

Cast Date: April 7, 2017

Laboratory No.: Terracon - 24

Project No.: 20171008

Aggregate Source: Loveland Ready Mix

Cement: GCC Dacotah, Type I-II

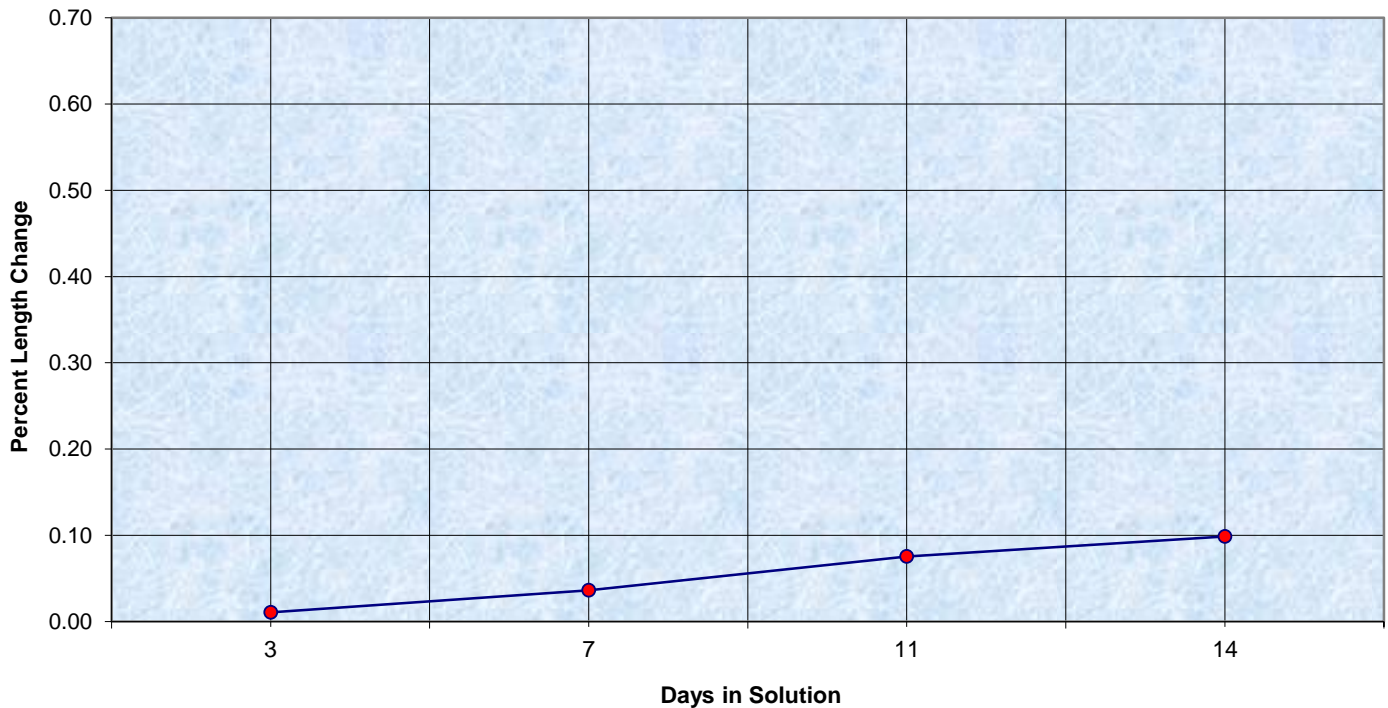
Aggregate Size: Sand

Equivalent Cement Alkalis: Not Reported

Aggregate/Cement Ratio: 990/440 g

Water/Cement Ratio: 0.47

	Initial Reading	Zero (48 hrs)	Day Reading	% Change	Day Reading	% Change	Day Reading	% Change	Day Reading	% Change
			3		7		11		14	
Date	4/8/17	4/9/17	4/12/17		4/16/17		4/20/17		4/23/17	
Comparator Length										
1	-0.0495	-0.0425	-0.0416	0.009	-0.0390	0.035	-0.0350	0.075	-0.0326	0.099
2	-0.0226	-0.0159	-0.0146	0.013	-0.0120	0.039	-0.0082	0.077	-0.0061	0.098
3	-0.0453	-0.0382	-0.0372	0.010	-0.0347	0.035	-0.0308	0.074	-0.0283	0.099
Average				0.011		0.036		0.075		0.099





## Appendix C

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*Mix Components Certified Reports and/or CDOT  
Approved Products List Reference  
(client provided)*