MTW Pond Closure – Summary of 2011 Supplemental Pozzolan Treatability Testing

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Introduction

Supplemental treatability testing was conducted to evaluate pozzolans for solidification of the Honeywell MTW CaF_2 surface impoundment (pond) materials during in-place closure of Ponds B, C, D, and E. An estimated 113,000 tons of CaF_2 pond material is present within the four ponds.

Preliminary testing performed in 2009 and 2010 indicated that addition of 6% Portland cement would satisfy the unconfined compression strength (UCS) criterion of 25 psi at 28 days of curing. The supplemental testing performed in 2011 (the topic of this memorandum) focused on identifying alternative pozzolans that also satisfy this UCS criterion.

All treatability testing was conducted at a bench-scale in a laboratory with a license to handle the pond material samples containing residual radioactivity.

Preliminary Testing Background

Preliminary solidification tests were performed in 2009 and 2010 to evaluate the feasibility of solidifying the pond materials using Portland cement and a potential alternative pozzolan (TerraCem). The preliminary tests were performed on an equal-weight composite sample of material from Ponds B and C, due to sample material availability at the time of testing.

Various pozzolan types, doses, and combinations were initially tested on small aliquots of sample, and the relative 7-day UCS was tested with a pocket penetrometer. Based on results of these initial trials, further tests were performed with extended duration (7-days and 28-days) and larger sample volumes mixed with 6% Portland cement and 9% TerraCem. Tests were performed using a full-scale UCS test apparatus. At 7 days, both samples had gained approximately the same amount of strength (UCS of 18.6 and 18.2 psi, respectively). However, at 28 days, the Portland cement sample had nearly doubled in strength while the TerraCem sample did not gain additional strength (UCS of 36.4 and 18.6 psi, respectively).

2011 Testing

The scope of the supplemental pozzolan testing performed in 2011 was based in part on the results of the preliminary testing performed in 2009-2010. However, the supplemental testing included a wider range of pozzolans and mixes/doses and a more representative composite sample of the Ponds B, C, D, and E material than used in the preliminary testing.

Sample Collection and Compositing

Supplemental material from Ponds B, C, D and E was collected by Andrews Engineering during the week of May 16, 2011. A portion of the material from each pond was shipped to CH2M HILL's Applied Sciences Laboratory (ASL) the following week. Once received, samples remained sealed and stored in a secure area at ASL prior to, during, and following the testing.

Based upon the pond characterization conducted by Andrews Engineering in 2009, the materials in Ponds B and C were similar in consistency and percent moisture. Materials in Ponds D and E also had similar consistency to Ponds B and C, but higher moisture content. The materials from the four ponds were therefore combined into a weighted average composite sample of Pond B, C, D, and E based on the approximate in-situ pond material quantities (15%:15%:10%:60% weight fractions from Ponds B, C, D, and E, respectively), as summarized in Table 1. This weighted average composite sample is considered representative of the average condition of the four ponds, and was used to conduct the supplemental pozzolan treatability testing.

Table 1. Composite Sample Weight Proportions

Pond	In-Situ Volume	Composite Sample Weight Proportion	Mean U Concentration (as-is basis) *	Mean Percent Moisture
	(cubic feet)	%	ppm	(%)
B	356,125	15%	240	40.6
C	365,732	15%	287	44.3
D	240,533	10%	245	49.5
E	1,404,863	60%	203	46.1
Total	**2,367,253**	**100%**		

* Concentrations and moisture contents (used to calculate the mean) are based on samples documented in the Pond Characterization Report, Andrews Engineering, Inc., November 2010.

On arrival at the testing laboratory, the pond material samples were thick and cohesive, similar to a clayey mud, with a layer of clear liquid over the solids. Upon mixing the water and solids, the pond material became easier to stir, with a putty-like consistency. The composited pond material was kept covered in thick plastic at all times before and after mixing to prevent moisture loss. In addition, each time an aliquot was removed for testing, the sample was thoroughly homogenized.

Composite Sample Characterization

The composite sample was analyzed for a number of geotechnical and chemical parameters to establish baseline characterization of the composite pond material. Results of the characterization analysis are presented in Tables 2 and 3, and Figure 1.

Table 2. Composite Pond Material Geotechnical Characterization

Parameter	Result (as-is basis)
Percent Moisture	47.7 %
Liquid Limit	55
Plastic Limit	37
Plastic Index	18
Bulk Density	1.5 g/cm^3

Figure 1. Composite Pond Material Particle Size Distribution

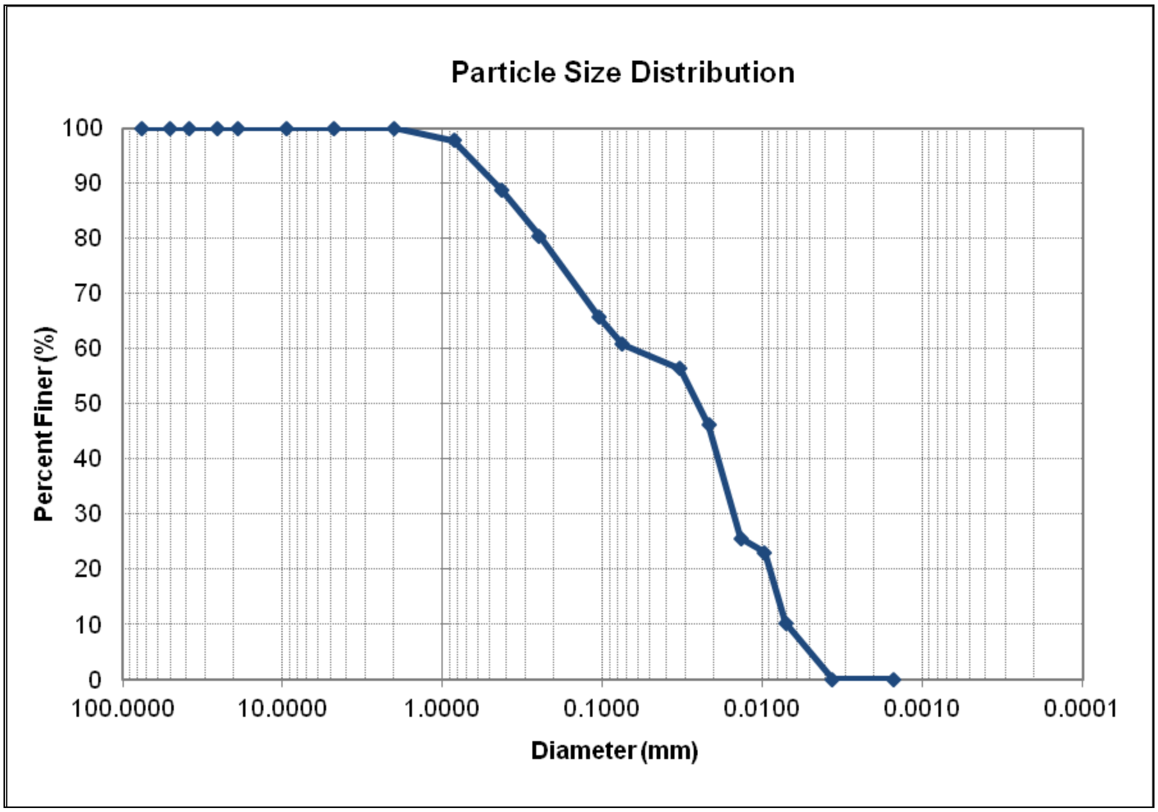


Table 3. Composite Pond Material Chemical Characterization

Parameter	Result [1]
pH of Pond Material Slurry (SW9045C)	
pH [2]	12.9
Pond Material Parameters (mg/kg as received)	
Fluoride	19.0
Chloride	23.3
Sulfide	134
Cyanide	< 0.0163
Potassium	3,002
Total Uranium	266
TCLP Extract Analysis (mg/L)	
TCLP-Arsenic	< 0.1
TCLP-Barium	< 0.1
TCLP-Cadmium	< 0.01
TCLP-Chromium	< 0.1
TCLP-Lead	< 0.05
TCLP-Mercury	< 0.001
TCLP-Selenium	< 0.3
TCLP-Silver	< 0.1
Radiological Parameters (pCi/g as received)	
Total Alpha	150
Total Beta	42

[1] All tests were performed on pond material as received; < indicates results below the laboratory reporting limit

[2] Per prior paint filter tests documented in November 2010 Andrews Engineering Report, pond material is not RCRA hazardous due to corrosivity.

Pozzolans Tested

Table 4 below identifies the pozzolan mixes, amendment type, and dose that were tested during the supplemental treatability testing.

Table 4. Tested Amendment Blends and Ratios

Mix ID	Amendment Type	Amendment Dose
1	LaFarge Type I/II Portland Cement (Control)	5%
17 *		5%
2		8%
18 *	LaFarge NewCem (Blast Furnace Slag @100 mesh)	5%
3	LaFarge NewCem (Blast Furnace Slag @100 mesh - 75%) & LaFarge Type I/II Portland Cement - 25%	5%
4		7.5%
5		10%
6	LaFarge MaxCem (70% Joppa Type I/II PC and 30% Slag Cement)	5%
19 *		7.5%
7		10%
8	RECON Low Solids Stabilization (LSS) Blend A Class C Fly Ash & Circulating Fluidized Bed (CFB) Fly Ash: 67% C-ash: 33% CFB-ash	5%
9		10%
10	RECON Low Solids Stabilization (LSS) Blend A Class C Fly Ash & Circulating Fluidized Bed (CFB) Fly Ash: 50% C-ash: 50% CFB-ash	5%
11		10%
12	RECON Low Solids Stabilization (LSS) Blend AB: Lime Kiln Dust (LKD), CFB-ash & C-ash 25% LKD: 25% CFB: 50% C-ash	5%
13		10%
14	Honeywell Geismar buffered Crude Gypsum / Fluorogypsum material ($CaSO_4.2H_2O$), from Hydrofluoric Acid Production	5%
15		10%
16		15%

* Mix IDs 17, 18, and 19 were added after 7-day results for the initial 16 mixes.

Note that the LaFarge NewCem (Blast Furnace Slag) was tested instead of TerraCem identified during the preliminary testing to offer a categorically different option to round out the alternate pozzolan testing.

Representative material safety data sheets (MSDS) for the various pozzolans are included in Attachment A.

Preparation of Geismar Works Crude Gypsum

The Honeywell Geismar Works crude gypsum (direct furnace residue) required preparation prior to use as an amendment in the solidification testing. Slaked lime was added to the crude gypsum to neutralize any free acid. The preparation procedure that was followed was provided by Honeywell.

Testing Procedure

Following the acquisition of Pond B, C, D, and E samples, a single composite sample was created (using the weighted volume of material from each pond as indicated above) by mixing well within a clean 5–gallon pail. Each amended mixture was prepared by weighing a homogenized aliquot of composite pond material, adding the appropriate dose of amendment, and mixing well. The amended pond material was loaded into a disposable plastic mold in lifts, and rodded to remove air voids. The samples were capped to prevent desiccation, and placed in a humid chamber at 120 degrees F. The temperature was reduced by 10 degrees each day, until ambient lab temperature was reached (70 F). This curing procedure was instituted to mimic field conditions where a gradual loss of heat of hydration would occur. The samples were maintained in a humid environment at room temperature for the remaining curing time. The samples were tested for unconfined compressive strength (UCS) at 7 days, 28 days, and 60 days. Photographs showing

60-day cylinders for each mix prior to compression testing are provided in Attachment B. Per the ASTM test method, any cylinders that were misshapen were trimmed to provide a flat surface for the test.

Testing Results

The unconfined compressive strength (UCS) results for all samples, at each cure time, are listed in Table 5. The results are also presented graphically in Figures 2 and 3. Figure 2 is subdivided into 3 charts, a through c, for the LaFarge Portland cement, NewCem/MaxCem, and LSS mixes, respectively. Because the fluorogypsum material did not gain any strength for any of the mixes (14 – 16), as shown in Table 5, a figure was not developed. A discussion of the performance of each amendment type follows the figures.

Table 5. Unconfined Compressive Strength Results

Mix ID	Amendment Type	Amendment Dose (%)	Short Name	UCS (psi) 7 Days	UCS (psi) 28 Days	UCS (psi) 60 Days
1	LaFarge Type I/II Portland Cement (Control)	5.0%	PC-5%	9	6	17
17		5.0%	PC-5% Dup	5	6	10
2		8.0%	PC-8%	36	41	39
18	LaFarge NewCem (Blast Furnace Slag @100 mesh)	5.0%	NC-5%	23	58	68
3	LaFarge NewCem/Portland Cement (Blast Furnace Slag @100 mesh - 75%) & LaFarge Type I/II Portland Cement - 25%	5.0%	NC/PC-5%	58	102	47 [a]
4		7.5%	NC/PC-7.5%	> 113 [b]	> 113 [b]	> 113 [b]
5		10.0%	NC/PC-10%	> 113 [b]	> 113 [b]	> 113 [b]
6	LaFarge MaxCem (70% Joppa Type I/II PC and 30% Slag Cement)	5.0%	MC-5%	20	20	21
19		7.5%	MC-7.5%	31	53	65
7		10.0%	MC-10%	> 113 [b]	> 113 [b]	> 113 [b]
RECON Low Solids Stabilization (LSS) Blend A Class C Fly Ash & Circulating Fluidized Bed (CFB) Ash						
8	67% C-ash: 33% CFB-ash	5.0%	LSSA 67/33-5%	0	0	0
9	67% C-ash: 33% CFB-ash	10.0%	LSSA 67/33-10%	23	52	68
10	50% C-ash: 50% CFB-ash	5.0%	LSSA 50/50-5%	0	0	0
11	50% C-ash: 50% CFB-ash	10.0%	LSSA 50/50-10%	11	23	39
RECON Low Solids Stabilization (LSS) Blend AB Lime Kiln Dust (LKD), CFB-ash & C-ash						
12	25% LKD: 25% CFB: 50% C-ash	5.0%	LSSAB 25/25/50-5%	0	0	0
13	25% LKD: 25% CFB: 50% C-ash	10.0%	LSSAB 25/25/50-10%	11	23	33
14	Honeywell Geismar Buffered Crude Gypsum / Fluorogypsum Material (CaSO4 Anhydrite), from Hydrofluoric Acid Production*	5.0%	HG-5%	0	0	0
15		10.0%	HG-10%	0	0	0
16		15.0%	HG-15%	0	0	0

Figure 2a. UCS Results – Strength Gain Over Time, Portland Cement Mixes

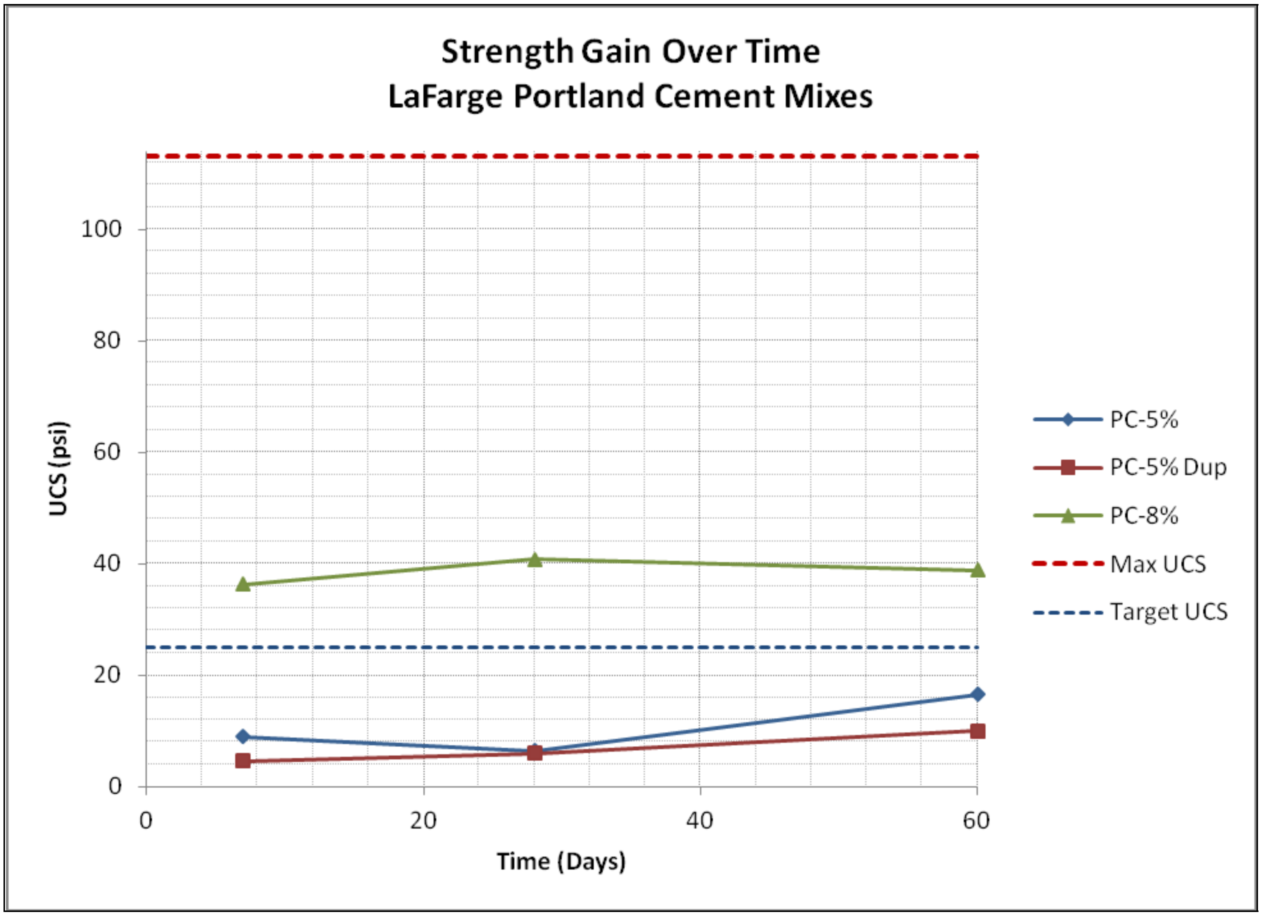


Figure 2b. UCS Results – Strength Gain Over Time, NewCem and MaxCem

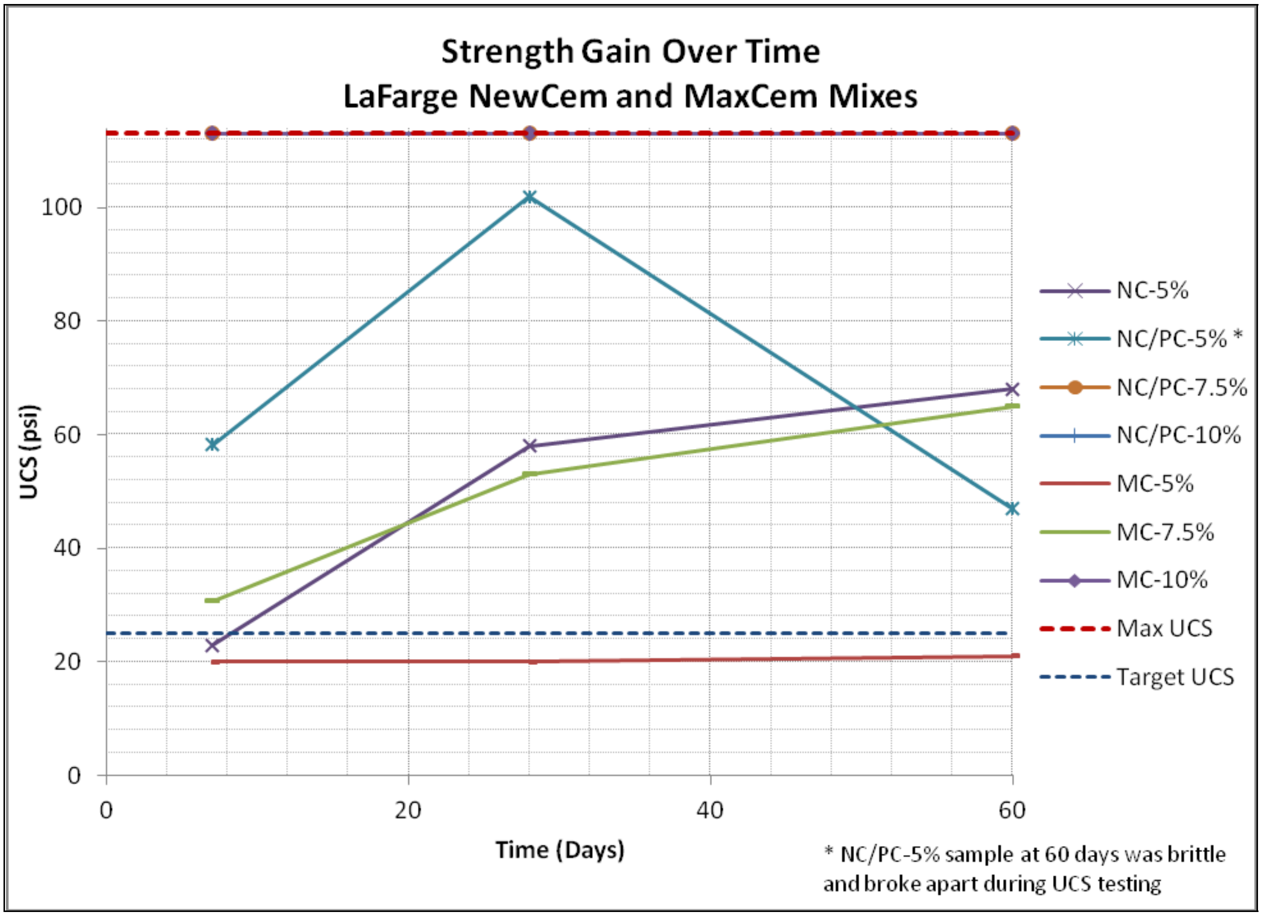


Figure 2c. UCS Results – Strength Gain Over Time, RECON LSS

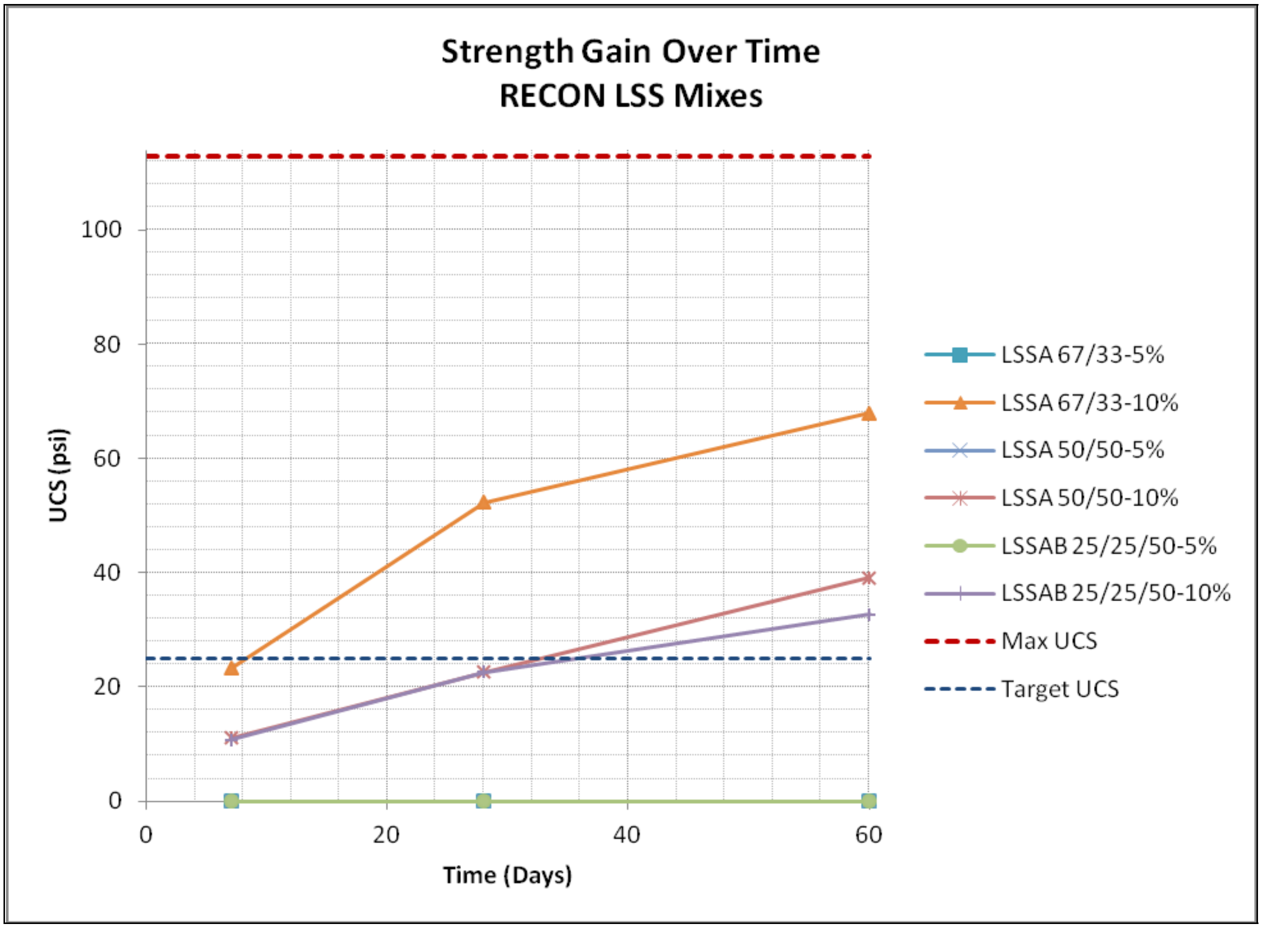
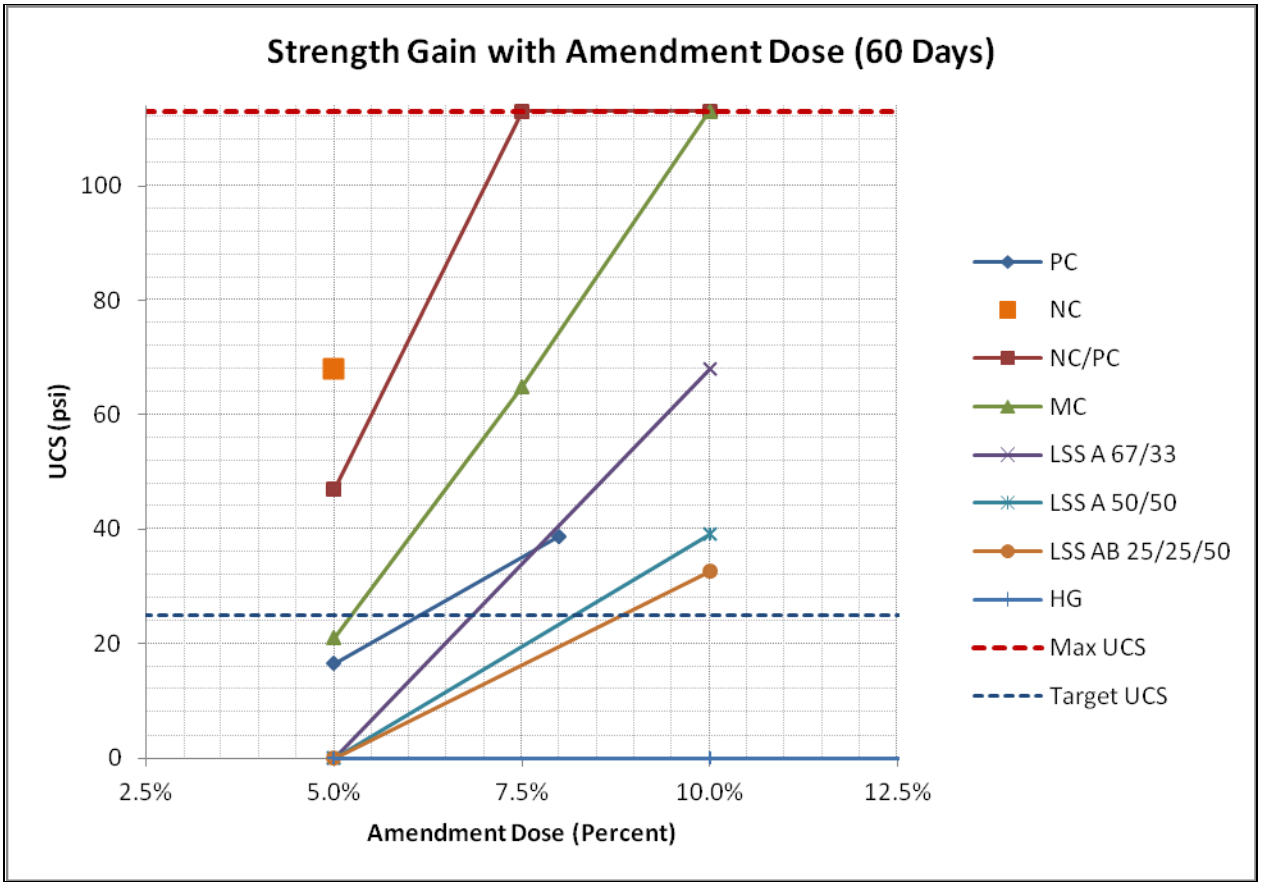


Figure 3. UCS Results – Strength Gain with Amendment Dose



LaFarge Portland Cement

Portland cement at 5% did not meet the target strength goal of 25 psi, with less than 10 psi at 7 and 28 days, and less than 20 psi at 60 days. However, at 8%, Portland cement exceeded the target at 7 days (36 psi), although there was little additional strength gain out to 60 days of cure time.

LaFarge NewCem

The NewCem/Portland Cement product (70% NewCem, 30% Portland Cement) at doses of 7.5% and 10% exceeded the limits of the test equipment at only 7 days (UCS >100 psi). At a lower dose (5%), the UCS reached 50 psi at 7 days, and continued to gain at 28 days (doubled in strength). At 60 days, the 5% NewCem/PC sample was brittle, and broke apart during the test.

An additional test was conducted with NewCem only (no Portland Cement addition) at 5%. This sample strength was close to the target of 25 psi at 7 days, and more than doubled in strength at 28 and 60 days.

LaFarge MaxCem

MaxCem at 5% reached a UCS of 20 psi at 7 days, but did not gain any additional strength out to 60 days, and did not meet the 25 psi target. However, the 7.5% MaxCem sample was over 30 psi at 7 days, and greater than 50 psi at 28 and 60 days, clearly exceeding the target. The 10% MaxCem dose exceeded the limits of the testing equipment (>100 psi) in a short time (7 days).

LSS Blend A

The RECON Low Solids Stabilization (LSS) Blend A was tested at two different mixture combinations: 1) 67% Class C Fly Ash, 33% Circulating Fluidized Bed (CFB) Fly Ash, and 2) 50% Class C Fly Ash, 50% CFB Fly Ash.

Both mixtures at low doses (5%) did not result in any strength gain over the duration of the curing period. The 5% samples were soft and pliable at 7, 28, and 60 days. However, at 10%, both mixtures met the UCS target of 25 psi at 60 days. The 67/33 mix was close to the target at 7 days (23 psi), reached 52 psi at 28 days, and 68 psi at 60 days. The 50/50 mix did not meet the target at 7 days (11 psi), but was close at 28 days (23 psi), and exceeded the target at 60 days (39 psi).

LSS Blend AB

The RECON LSS Blend AB was composed of 25% Lime Kiln Dust (LKD), 25% CFB Fly Ash, and 50% Class C Fly Ash. Performance of the LSS Blend AB was similar to the Blend A 50/50 mixture. At a dose of 5%, no strength was observed over the duration of the curing period. However, at 10% Blend A did meet the UCS target at 60 days (33 psi), slowly gaining strength over the cure time.

Crude Gypsum Product

The Honeywell Geismar buffered Crude Gypsum / Fluorogypsum material ($CaSO_4$ anhydrite), from Hydrofluoric Acid Production had no solidification effect on the pond material. After the extended curing period of 60 days, the samples were soft and wet, with a layer of free water on top of the sample. The samples exhibited no strength gain.

General Conclusions

The treatability tests show that several pozzolans will satisfy the UCS criteria of 25 psi at 28 days. The pozzolan amendments and mixes that met this criteria, in the order shown in Table 5, include:

- **Mix 2 –** LaFarge Portland Cement at 8%
- **Mix 18 -** LaFarge NewCem at 5%
- **Mixes 3, 4, and 5 –** LaFarge NewCem/Portland Cement at 5%, 7.5%, and 10%
- **Mixes 19 and 7 –** LaFarge MaxCem at 7.5% and 10%
- **Mix 9 –** Recon LSS Blend A, 67%/33% at 10%

List of Attachments

A MSDS for Selected Pozzolans
- LaFarge Portland Cement
- LaFarge NewCem
- LaFarge MaxCem
- Recon LSS Bed Ash
- Recon LSS Fly Ash
- Recon Lime Kiln Dust

B Photograph Log; 60-day Cylinders, Pre-Strength Testing