Hydrogen Ionic Stabilization
For Expansive Clay Soils

CONTENTS

What is Clay Set and How Does it Work?

Put simply...Clay Set is a hydrogen ionic soil stabilizer that acts at the molecular level of the clay particle to permanently reduce or eliminate the swelling nature of the clay. (Detailed mechanism is explained at the end of this document). Treatment will reduce the swell potential to a low or insignificant classification and treated soil will be far less permeable to water. Clay Set is not water and can be used even on existing structures to prevent further heaving and pre-construction treatment is very economical and simple.

Although pre-construction treatment with Clay Set is done as easily (if not more easily) than a moisture conditioning operation, the difference in the effectiveness to reduce the swell is significant. Plus...Clay Set is permanent and requires only a single processing no matter the swell potential of the existing soil. On site soil can be used and sites with swelling clays that were once considered too expensive to develop, can now be treated for a fraction of the cost of methods used in the past.

In the table below you can see the results of comparative testing that was performed on soil samples from a KB Home site. The results show the effect that water had to reduce the swells compared to Clay Set. With water alone, the swells remained in the moderate to high classification. The same soil treated with Clay set to the same moisture contents achieved reductions to the low to insignificant classification, well within project specifications.

boring #	depth	Soil Description	MD	DD	Swell %		Passing #200	LL	PL	PI
_7	10	Recompacted Clay+Claystone: 95% @ Optimum	16.8	107.3	+7.4/500		94			
_7	11	Recompacted Clay+Claystone: 95% @ +3%	19.0	107.1	+4.3/500					
_9	0	Recompacted Clay: 95% @ Optimum	17.2	104.1	+7.1/500					
_10-CL	0	Recompacted Clay: 95% @ +1%	18.2	104.1	+5.2/500		92			
_10-CL	1	Recompacted Clay: 95% @ +3%	20.2	104.2	+2.3/500					
_10-CS	10	Recompacted Claystone: 95% @ +1%	18.8	103.2			95			
_10-CS	11	Recompacted Claystone: 95% @ +3%	20.5	103.2						
_Comp-CS	20.1	Recompacted Claystone: 95% @ Optimum	17.8	102.4	+9.1/500					
_Comp-CS	21	Recompacted Claystone: 95% @ +4%	21.4	101.7	+6.6/500					
_TP4 CL	0	LEAN CLAY PROCTOR	14.8	112.7						
_TP4 CL	0.1	LEAN CLAY w/ CLAY SET @ OPTIMUM	15.1	106.9	+0.6/500			40	23	17
_TP4 CL	0.2	LEAN CLAY w/ CLAY SET @ +3%	17.9	107.2	+0.6/500			40	23	17
_TP4/7 CS	0	CLAYSTONE BEDROCK PROCTOR	19.1	106.9						
_TP4/7 CS	0.1	CLAYSTONE BEDROCK W/CLAY SET @ OPTIMUM	19.0	101.7	+2.3/500			43	23	20
_TP4/7 CS	0.2	CLAYSTONE BEDROCK W/CLAY SET @ +3%	22.0	101.8	+0.7/500			43	23	20

The project was performed from December of 2018 through June of 2019. 420,000 cyds of soil were processed successfully using Clay Set. (More data and info on the following pages)

Soil from the same KB site were evaluated for potential strength increases with resilient modulus testing performed by GROUND Engineering. When compared to the testing on untreated soil, the soil treated with Clay Set showed an increase in strength of over 120% in a 21 day period.

KB Homes (Sweetgrass Filing 4) | Dacono, CO

	Test Sequence #	*Confining Pressure*	*Proposed Max. Deviator Stress*	*Applied Max. Deviator Stress*	*Applied Contact Stress*	*Applied Cyclic Stress*	*Recoverable Deformation LVDT #1*	*Recoverable Deformation LVDT #2*	*Average Recoverable Deformation LVDT #1, #2*	*Measured Resilient Strain*	*Resilient Modulus*	*% Mr Increase from Original*
		(psi)	*(psi)*	*(psi)*	*(psi)*	*(psi)*	*(mills)*	*(mills)*	*(mills)*	*(%)*	*(psi)*	
Virgin Soil (Original)	Conditioning:	6	4	4.11	0.38	3.72	-	-	-	-	-	
	1	6	2	2	0.18	1.82	1.5	1.49	1.5	0.019	9,606	
	2	6	4	3.98	0.41	3.57	4.16	4.13	4.15	0.053	6,790	
	3	6	6	6.04	0.64	5.39	8.25	8.24	8.25	0.105	5,151	
	4	6	8	8.07	0.85	7.22	13.6	13.83	13.72	0.174	4,147	
	5	6	10	10.1	1.04	9.06	20.64	20.81	20.73	0.263	3,444	
	6	4	2	2.02	0.23	1.79	1.62	1.64	1.63	0.021	8,659	
	7	4	4	4.01	0.41	3.6	4.65	4.69	4.67	0.059	6,072	
	8	4	6	6	0.61	5.39	8.84	8.95	8.9	0.113	4,779	
	9	4	8	8.04	0.83	7.21	14.16	14.31	14.24	0.181	3,991	
	10	4	10	10.04	1.06	8.98	20.16	20.24	20.2	0.256	3,503	
	11	2	2	2	0.19	1.81	1.71	1.78	1.75	0.022	8,182	
	12	2	4	4.04	0.39	3.65	4.93	5.03	4.98	0.063	5,783	
	13	2	6	6.04	0.62	5.41	9.36	9.48	9.42	0.119	4,530	
	14	2	8	8.02	0.86	7.16	14.64	14.78	14.71	0.187	3,837	
	15	2	10	10.04	1.07	8.97	20.59	20.66	20.63	0.262	3,428	
Soil + ClaySet @ 3 Days	Conditioning:	6	4	4.05	0.41	3.63	-	-	-	-	-	
	1	6	2	1.99	0.22	1.78	1.13	1.13	1.13	0.014	12,838	33.65%
	2	6	4	3.99	0.4	3.59	2.86	2.79	2.83	0.035	10,340	52.28%
	3	6	6	6	0.6	5.41	5.15	5.02	5.09	0.062	8,664	68.20%
	4	6	8	8	0.82	7.18	7.99	7.81	7.9	0.097	7,412	78.73%
	5	6	10	9.99	1.03	8.96	11.45	11.3	11.38	0.14	6,419	86.38%
	6	4	2	2	0.17	1.83	1.23	1.21	1.22	0.015	12,245	41.41%
	7	4	4	3.98	0.38	3.6	3.19	3.13	3.16	0.039	9,271	52.68%
	8	4	6	6	0.63	5.37	5.76	5.67	5.72	0.07	7,657	60.22%
	9	4	8	7.98	0.83	7.15	8.73	8.58	8.66	0.106	6,732	68.68%
	10	4	10	9.99	1.01	8.99	11.96	11.86	11.91	0.146	6,151	75.59%
	11	2	2	1.98	0.22	1.76	1.24	1.22	1.23	0.015	11,653	42.42%
	12	2	4	4	0.42	3.58	3.37	3.3	3.34	0.041	8,747	51.25%
	13	2	6	6.02	0.61	5.41	6.13	6.04	6.09	0.075	7,252	60.09%
	14	2	8	8	0.8	7.2	9.19	9.12	9.16	0.112	6,406	66.95%
	15	2	10	10.03	1.01	9.02	12.6	12.56	12.58	0.154	5,843	70.45%

(Data continued on the following page)

Resilient modulus testing results continued

KB Homes (Sweetgrass Filing 4) | Dacono, CO												
	Test Sequence #	*Confining Pressure*	*Proposed Max. Deviator Stress*	*Applied Max. Deviator Stress*	*Applied Contact Stress*	*Applied Cyclic Stress*	*Recoverable Deformation LVDT #1*	*Recoverable Deformation LVDT #2*	*Average Recoverable Deformation LVDT #1, #2*	*Measured Resilient Strain*	*Resilient Modulus*	*% Mr Increase from Original*
		(psi)	*(psi)*	*(psi)*	*(psi)*	*(psi)*	*(mills)*	*(mills)*	*(mills)*	*(%)*	*(psi)*	
Soil + ClaySet @ 7 Days	Conditioning:	6	4	4.02	0.42	3.6	-	-	-	-	-	
	1	6	2	2.01	0.21	1.79	1.04	1.02	1.03	0.013	14,184	47.66%
	2	6	4	4.01	0.39	3.62	2.65	2.56	2.61	0.032	11,327	66.82%
	3	6	6	6	0.59	5.42	4.68	4.55	4.62	0.057	9,558	85.56%
	4	6	8	8.01	0.81	7.2	7.24	7.06	7.15	0.088	8,208	97.93%
	5	6	10	9.94	1.03	8.92	10.25	10.05	10.15	0.125	7,162	107.96%
	6	4	2	2.02	0.18	1.84	1.1	1.09	1.1	0.013	13,691	58.11%
	7	4	4	3.99	0.4	3.6	2.93	2.84	2.89	0.035	10,161	67.34%
	8	4	6	6	0.62	5.38	5.27	5.13	5.2	0.064	8,428	76.35%
	9	4	8	8	0.8	7.2	7.95	7.77	7.86	0.096	7,466	87.07%
	10	4	10	9.99	1	9	10.77	10.64	10.71	0.131	6,852	95.60%
	11	2	2	2	0.22	1.78	1.16	1.15	1.16	0.014	12,567	53.59%
	12	2	4	4.01	0.42	3.59	3.11	3.03	3.07	0.038	9,520	64.62%
	13	2	6	6.04	0.6	5.44	5.66	5.52	5.59	0.069	7,928	75.01%
	14	2	8	8.03	0.8	7.23	8.44	8.3	8.37	0.103	7,040	83.48%
	15	2	10	10.03	1.02	9	11.39	11.28	11.34	0.139	6,472	88.80%
Soil + ClaySet @ 21 Days	Conditioning:	6	4	4	0.42	3.59	-	-	-	-	-	
	1	6	2	2.01	0.18	1.82	0.91	0.91	0.91	0.011	16,242	69.08%
	2	6	4	4.02	0.39	3.63	2.36	2.34	2.35	0.029	12,535	84.61%
	3	6	6	6.02	0.61	5.41	4.17	4.15	4.16	0.051	10,571	105.22%
	4	6	8	8.01	0.83	7.19	6.3	6.26	6.28	0.077	9,304	124.35%
	5	6	10	9.98	1.01	8.97	8.73	8.72	8.73	0.107	8,364	142.86%
	6	4	2	2.01	0.21	1.8	0.98	0.97	0.98	0.012	14,996	73.18%
	7	4	4	3.99	0.42	3.57	2.57	2.57	2.57	0.032	11,303	86.15%
	8	4	6	6.01	0.61	5.41	4.56	4.54	4.55	0.056	9,666	102.26%
	9	4	8	8.01	0.78	7.23	6.8	6.75	6.78	0.083	8,679	117.46%
	10	4	10	10.01	0.99	9.02	9.13	9.13	9.13	0.112	8,030	129.23%
	11	2	2	2	0.22	1.78	1.04	1.01	1.03	0.013	14,132	72.72%
	12	2	4	4	0.39	3.61	2.75	2.72	2.74	0.034	10,724	85.44%
	13	2	6	6.01	0.58	5.43	4.84	4.79	4.82	0.059	9,162	102.25%
	14	2	8	8.01	0.81	7.2	7.2	7.18	7.19	0.088	8,142	112.20%
	15	2	10	9.99	1.03	8.96	9.61	9.6	9.61	0.118	7,583	121.21%

Clay Set not only gives superior results in permanently reducing swell in difficult soils, but it also reduces soil suction/capillary action which means a reduced risk of future movement.

CTL | THOMPSON
INCORPORATED

January 10, 2020

Century Communities
8390 East Crescent Parkway, Suite 650
Greenwood Village, Colorado 80111

Attention: Cindy Myers

Subject: Evaluation of Sub-Excavation Mitigation
Lot 1, Block 2, Interlocken 485, Filing No. 4
Broomfield, Colorado
Project No. DN49,201.001-145-L1

"The Clay Set average swells are lower than water only. The Clay Set addition appears to reduce suction more consistently than water. Since suction was reduced, future reductions in suction would be smaller; this means less potential heave".

We performed a Geotechnical Investigation for the subject Interlocken project and presented results in a report dated February 6, 2019 (Project No. DN49,201.001-115-R2). We found very highly expansive soils and bedrock which are typical for the Interlocken area and discussed foundation alternatives including drilled piers bottomed in bedrock and footing or post-tensioned slabs-on-grade after sub-excavation (a.k.a. "over-excavation") and moisture treatment of compacted fill derived from on-site soils and bedrock. Century is considering the use of Clay Set additive to help mitigate potential swell of the fill. We were asked to design a testing program to evaluate the relative impacts of moisture treatment with and without Clay Set. Information on Clay Set can be reviewed at SoilScientific.com. We were asked to prepare this letter with results of the testing to date from a lay perspective and our opinion of the benefits of use of Clay Set.

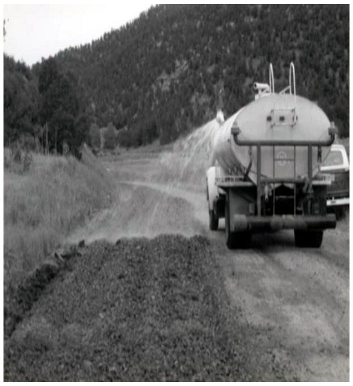
The field testing was performed by excavating three large test pits using scrapers and compacting moisture treated fill with and without Clay Set into the pits. At Soil Scientific's suggestion, the moisture added during compaction included water only (no additive), and water combined with Clay Set at ratios of 300 and 200 parts water to 1-part Clay set.

Prior to excavation, we obtained samples of the claystone bedrock in the test area from test pits excavated with a backhoe. The materials obtained from the test pits were returned to our laboratory, combined and then split for testing. The lab samples were prepared to simulate the field treatments described above and tested for potential swell.

We obtained samples of the compacted fill during placement by driving thin-walled brass tubes into the fill; these are referred to as "hand drives." We also obtained samples after the test fills were completed by drilling and sampling using standard local methods. Samples of the undisturbed claystone outside the test fill areas were also obtained by drilling.

Ronald M. McOmber, P.E
CTL│T PROJECT NO. DN49,201-001-145-L1
Supplemental report - 1/10/2020

Road stabilization and pre-construction treatment



Clay Set can be used to stabilize unfinished road surfaces as well as subgrades. Clay set is mixed into the specified depth of soil, lifts are compacted and the surfaces is rolled smooth to finish. Clay set will improve performance and decrease maintenance requirements.

For new construction projects, the onsite soil is treated with Clay Set to the full depth specified. The soil is removed and replaced in lifts to produce a treatment zone suitable for footer foundations, eliminating the need for select fill, deep pier foundations, etc.

The Clay Set concentrate is mixed into the specified amount of water while the pull or truck is being filled. A metered pump is used to add the correct amount of concentrate through a plastic line running from the pump to the water chute. This is accurate, quick and there is minimal need to the handle the Clay Set concentrate.

The final Clay Set solution is applied to the surface of each lift in the amount and concentration specified for the specific project and soil type. This will vary depending on native soil conditions and swell potentials.

A construction disc or other suitable tiller is then used to thoroughly mix the Clay Set throughout the lift.

Each lift is brought to the specified moisture content (typically optimum to +2%) and % compaction using the Clay Set solution. Compaction can be done with any large wheeled equipment. Less compactive effort will be required because Clay Set will immediately diminish the negative charges of the clay particle, thereby allowing each particle to more easily "come together" to create a strong and stabilized zone of soil.

Existing Structures and Limited Access Pre-construction Sites

For existing structures or pre-construction sites with limited access, hand injection can be used. If soil conditions allow, large injection rigs can also be used. The injection pressures vary depending on site soil conditions. Depths of injections can vary from shallow to a maximum depth of 15 feet. Injection is not suitable in very stiff clays.

Existing structures can be safely treated through a careful injection process. The Clay Set is contained on a trailer that is outfitted with pumps. Clay Set is injected to the specified depth a to arrest any further heaving.

On pre-construction sites where access is limited for large equipment, hand injection can also be used. If soil conditions allow, large injection rigs (the same type used for water injection) can be used to treat up to 10,000 SF a day to a depth of 10-12 feet.

CASE HISTORY

Hydrogen Ionic Chemical Treatment of Swelling Clays
Residential and Commercial Property
North Las Vegas, Nevada

This case history is written to provide the results of the laboratory swell testing of the samples taken from the subject site, and to describe the grading process and the application of the ionic chemical solution to treat the swelling clays. The five acre subject site was overexcavated approximately 10 feet beneath the building pads and 3 feet beneath all other areas. The site subgrade soils consisted of a variety of soil types including highly plastic clays, clayey sands, silty clays, and silty sands with gravel. A diluted ionic chemical solution was applied and mixed with the overexcavated soil as it was replaced as fill. One gallon of the concentrated ionic chemical solution was mixed with the previously determined ratio of water to produce the final ionic chemical solution that was mixed with the on-sites soils that had been previously excavated.

During the fill placement process the maximum allowable loose lift thickness varied between 6 to 8 inches. The diluted ionic chemical solution was applied with a water pull followed by disking. This sequence was continued until the ionic chemical solution was mixed uniformly throughout the soil at a moisture content that was at least 3 percent above optimum if not higher. A key factor in this process is that no untreated water is applied to any site soils (even dust control has the ionic chemical).

To adequately evaluate the effectiveness of the ionic chemical solution to reduce the swell potential of the sites soils, we excavated fifteen Test Pits throughout the 5 acre site before any earthwork began and took bulk samples from each Test Pit at every foot of depth. Due to the variation of ground surface elevation the Test Pit depths varied between 8 to 14 feet. These untreated Test Pit samples were stored in our laboratory until the earthwork was completed and we had performed swell testing on the treated undisturbed ring samples that were taken after the placement of each foot of compacted fill. Ninety six treated undisturbed ring samples were swell tested 21 days after sampling. A statistical mean was determined for the percent swell of the sample, dry density of the sample, and moisture content of the sample. Next seventy three soil samples were taken from the previously sampled untreated Test Pit bulk samples. The sampling process from each Test Pits bulk samples was performed in a manner to produce a uniform unbiased distribution of untreated samples. Each of these untreated samples were then remolded into 2.5 inch ring samples. The untreated samples were remolded to the mean dry density and mean moisture content of the treated samples that had been previously swell tested. Swell tests were then performed on each of these untreated remolded samples. A modified version of ASTM D 2435 "Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading", and ASTM D 4546 "Standard Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils" was used to determine the swell potential of the untreated and treated soil samples. Normally we use Method B from ASTM D 2435 to measure the swell potential for clay soils, however; in Clark County, Nevada we have to use the Southern Nevada Amendments to the 2009 International Building Code which require all clay soil swell testing to be performed using a surcharge of 60 psf, regardless of depth of sampling. All the treated test samples were tested at placement moisture content without being air dried or oven dried before water immersion and subsequent saturation. The untreated samples were remolded to the mean dry density and mean moisture content of the treated samples before performing the swell test at this mean moisture content without being air dried or oven dried before water immersion and subsequent saturation.

The results of laboratory testing of the treated and untreated samples from the site are presented below. There is not only a dramatic difference in the swell potential between treated and untreated soils, but also a significant difference in soil suction as demonstrated by the different moisture content increases after inundation from swell tests.

LABORATORY SWELL TEST SUMMARY FOR RESIDENTIAL AND COMMERCIAL PROJECT NORTH LAS VEGAS, NEVADA

Test Type	Statistical Parameter	Dry Density (pcf)	Pre-swell Moisture Content (%)	Post-swell Moisture Content (%)	Percent Swell (%)
Treated Undisturbed Swell Tests (21 day test results)	Number Sampled & Tested	96	96	96	96
	Mean	95.6	22.5	27.2	**2.4**
	Standard Deviation	6.38	4.24	4.70	1.49
	Range	72.7 – 105.8	16.4 – 41.0	20.7 – 47.7	0.3 – 7.5
Untreated (water only) Remolded Swell Tests	Number Sampled & Tested	73	73	73	73
	Mean	94.5	23.9	40.9	**20.4**
	Standard	1.91	1.67	16.9	22.3

These results show that the mean swell of the untreated soil was 20.4 % as compared with the 2.4 % of the treated soil. This constitutes a difference of 18.0 % of swell or approximately an 88 percent reduction in swell between the untreated samples to the treated samples.

To test if the ionic chemical process continues with time, we also tested thirty seven (3) day swell tests from treated samples taken from the same ring set tubes that we also performed (21) day treated swell tests on. The (3) day and (21) day time increments were the time measurements between ionic chemical application and sampling in the field to the time of initiating laboratory swell testing. The results of these laboratory swell tests are presented in the following table:

THREE DAY AND TWENTY ONE DAY LABORATORY SWELL TEST SUMMARY ON TREATED SAMPLES FOR THE RESIDENTIAL AND COMMERCIAL PROJECT NORTH LAS VEGAS, NEVADA

Test Type	Statistical Parameter	Dry Density (pcf)	Pre-swell Moisture Content (%)	Post-swell Moisture Content (%)	Percent Swell (%)
3 Day Swell Test Results for Treated Undisturbed Samples	Number Sampled & Tested	37	37	37	37
	Mean	92.0	24.9	30.0	**2.52**
	Standard Deviation	9.10	7.21	8.29	1.67
	Range	63.3 – 105.6	13.6 – 51.1	20.0 – 62.4	1.0 – 10.3
21 Day Swell Test Results for Treated Undisturbed Samples	Number Sampled & Tested	37	37	37	37
	Mean	92.8	24.1	29.1	**1.80**
	Standard Deviation	7.42	5.26	5.91	1.39
	Range	72.7 – 105.8	16.7 – 41.0	20.7 – 47.7	0.3 – 7.2

These results show that the mean swell of the 3 day test of the treated undisturbed samples is 2.52 % as compared to 1.80 % swell for the 21 day test of the treated undisturbed samples. This constitutes a difference of 0.72 percent of swell or approximately a 29 percent furter reduction in swell between the 3 day test and the 21 day test.

Progressive Insurance Claims Center-Over excavation operation - 8-2008

CASE HISTORY

DATA SUMMARY OF IONIC CHEMICAL TREATMENT ON LARGE COMMERCIAL BUILDING (4080 BOULDER HIGHWAY, LAS VEGAS, NEVADA)					
LOCATION	DRY DENSITY (PCF)	INITIAL MOISTURE CONTENT (%)	FINAL MOISTURE CONTENT (%)	SWELL (%) FOR UNTREATED SOIL	SWELL (%) FOR TREATED SOIL
4080 Boulder Hwy. N.W. - 2.0 feet	90.6	22.6	36.1	**13**	
4080 Boulder Hwy. N.W. – 2.0 feet	92.1	22.6	25.7		**0**
4080 Boulder Hwy. S.W. – 2.0 feet	94.7	17.4	23.5	**11**	
4080 Boulder Hwy. S.W. – 2.0 feet	96.1	17.6	24.5		**0**
4080 Boulder Hwy. N.E. – 2.0 feet	95.8	10.0	24.8	**15**	
4080 Boulder Hwy. N.E. – 2.0 feet	97.0	10.4	21.4		**1**
4080 Boulder Hwy. C.E. – 2.0 feet	98.2	11.6	23.0	**16**	
4080 Boulder Hwy. C.E. – 2.0 feet	99.0	12.3	16.8		**1**
4080 Boulder Hwy. N.C. – 1.5 feet	106.7	14.0	16.9	**10**	
4080 Boulder Hwy. N.C. – 1.5 feet	107.5	15.5	17.4		**0**

PROGRESSIVE INSURANCE CLAIMS CENTER - LAS VEGAS, NV

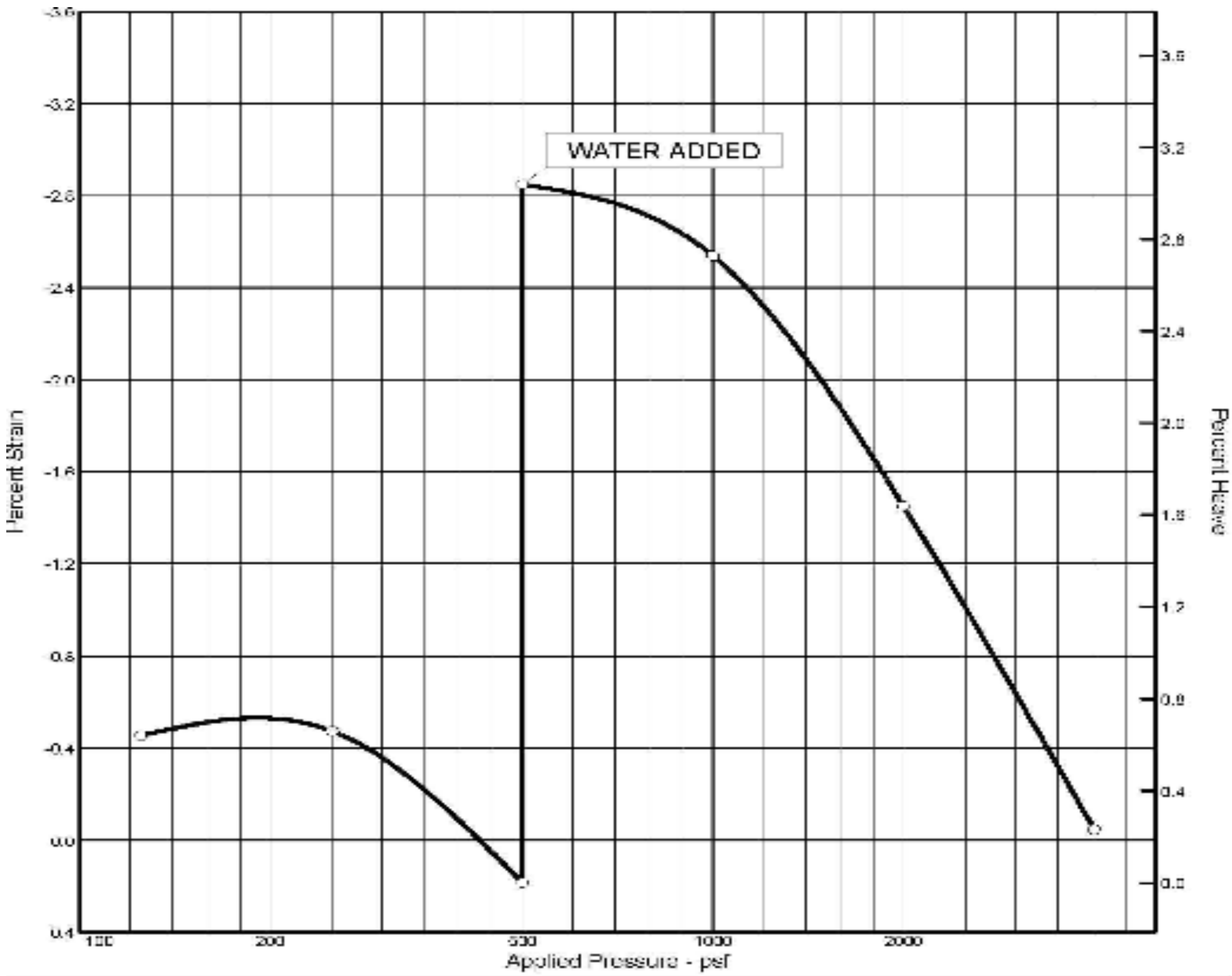
The following photos were taken in 2017 and demonstrate that 9 years after construction, the CMU structure has had no issues with movement or cracking, including the slabs, sidewalks and pavements. After speaking with Austin Foote (the facility maintenance manager) in 2019, he confirmed that the building continues to be in perfect condition and is happy to speak with those interested in learning more. You can find his contact information on our list of references.


Clearance 10'-0"
Clearance 12'-0"

Porter Home Site – WY 10/2012

The following are the pre & post swell potential results on a mixing operation. Pre-treatment testing showed swell results as high as 8.3% with an average of 5.5%. After ionic stabilization the swell averaged 0.06%. These are typical results. We are happy to provide more before and after data upon request.

Pre-treatment Boring #1: Swell potential - 3.1%



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	USCS	AASHTO	Initial Void Ratio
Saturation	Moisture							
77.0 %	18.3 %	101.5			2.65			0.629

MATERIAL DESCRIPTION

Gray CLAYSTONE

Project No. G1120758A **Client:** Dr. David Porter

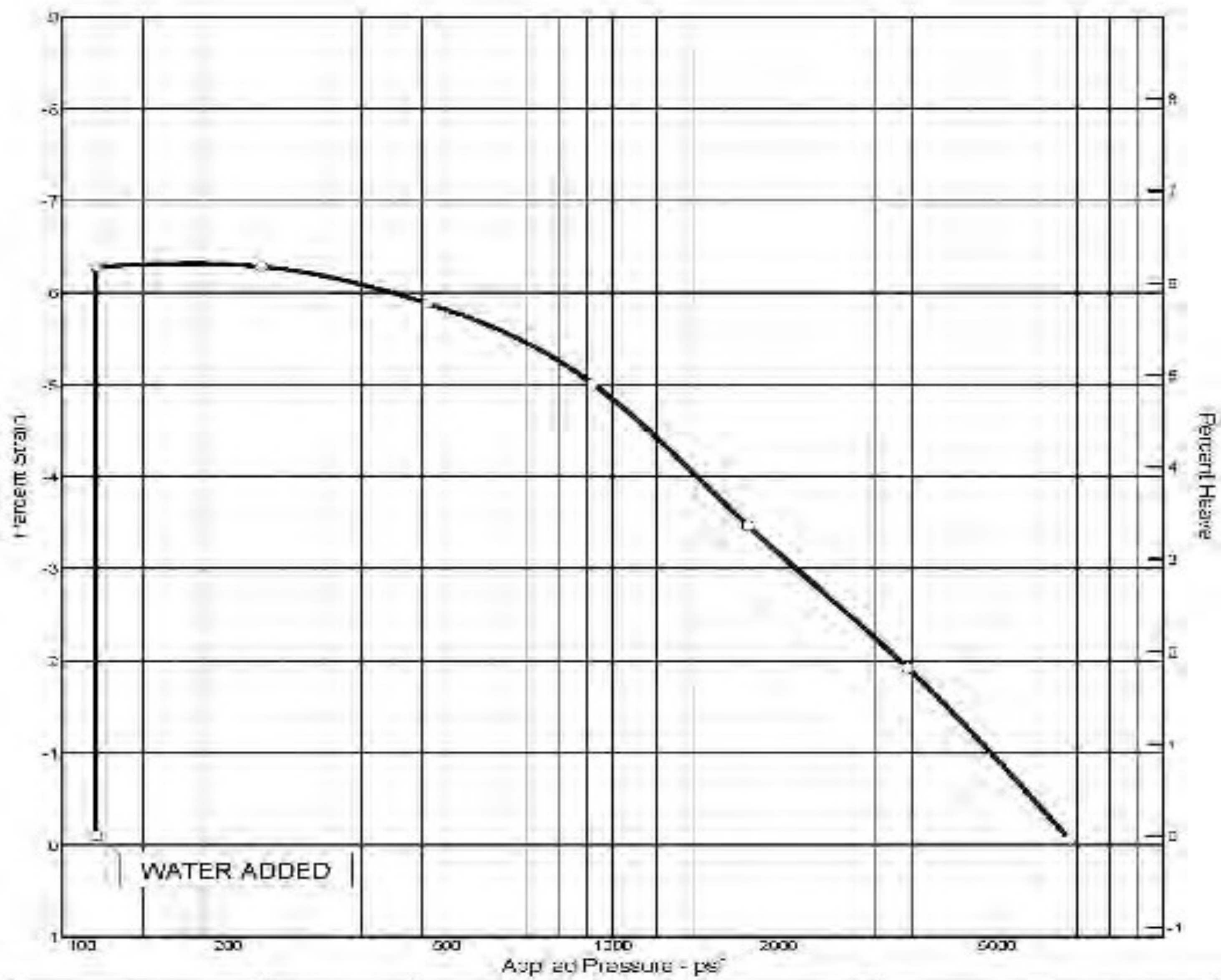
Project: New House - J-Mills Tracts, Lot 8

Location: B-1 @ 5 ft.

Remarks:

inundated at 500 psf

Porter Home Site - Gillette WY **Pre-treament Boring #2: Swell potential - 6.3%**



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	USCS	AASHTO	Initial Void Ratio
96.6 %	16.9 %	113.1			2.65			0.463

MATERIAL DESCRIPTION

Light brown CLAYSTONE

Project No. [illegible] **Client:** Dr David Porter

Project: New House - [illegible] Lot 8

Location: B-1 @ 10 ft.

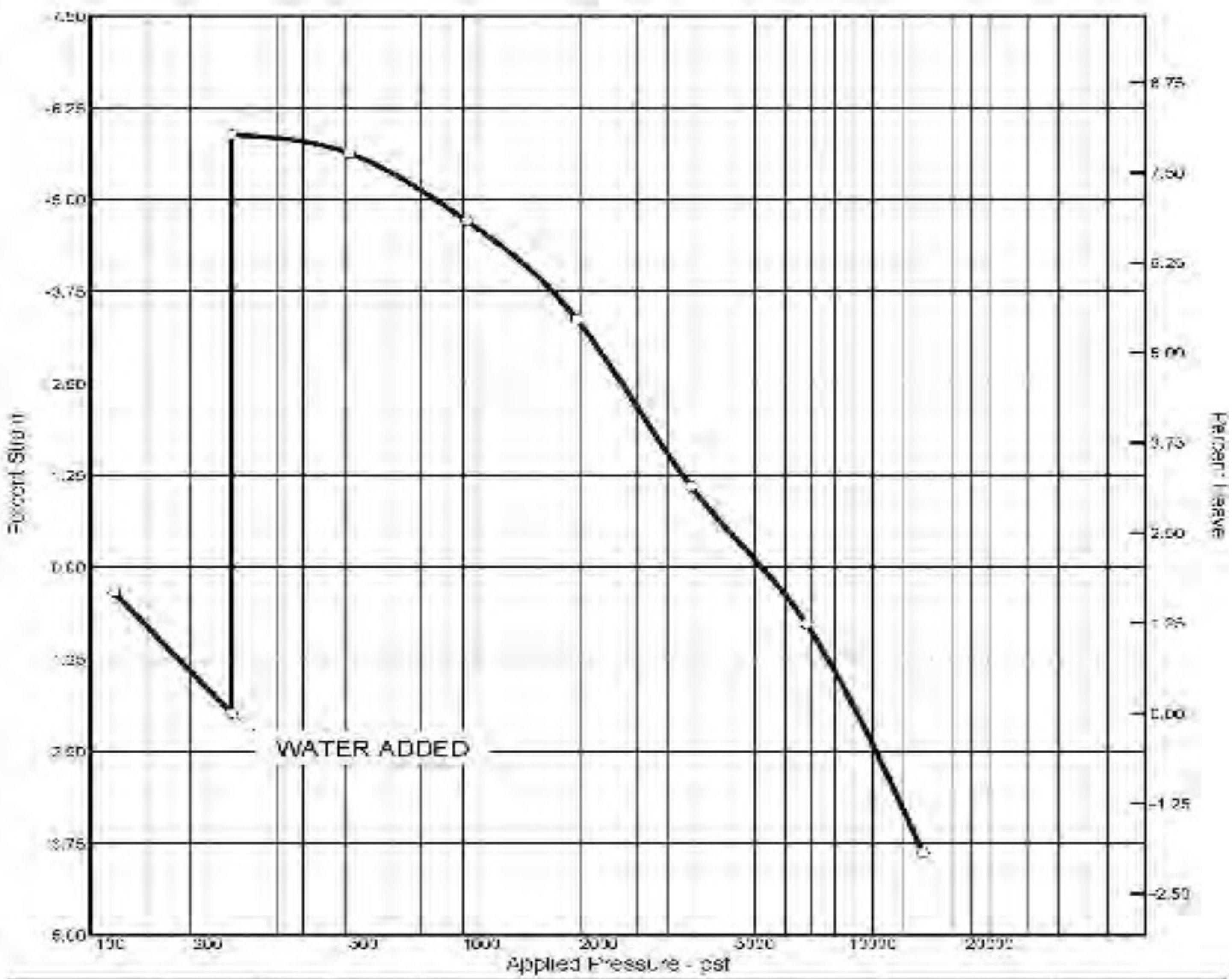
Remarks:
Inundated at 115 psf

GEOTECHNICAL INVESTIG

Porter Home Site, Gillette WY **Pre-treatment Boring #3: Swell potential - 8.3%**

9

CONSOLIDATION TEST RESULTS



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	USCS	AASHTO	Initial Void Ratio
Saturation	Moisture							
88.5 %	22.5 %	99.5			3.05			0.662

MATERIAL DESCRIPTION

Brownish gray CLAYSTONE

Project No. GI12078A **Client:** Dr. David Porter

Project: New House - [illegible]

Location: B-2 @ 12.5 ft

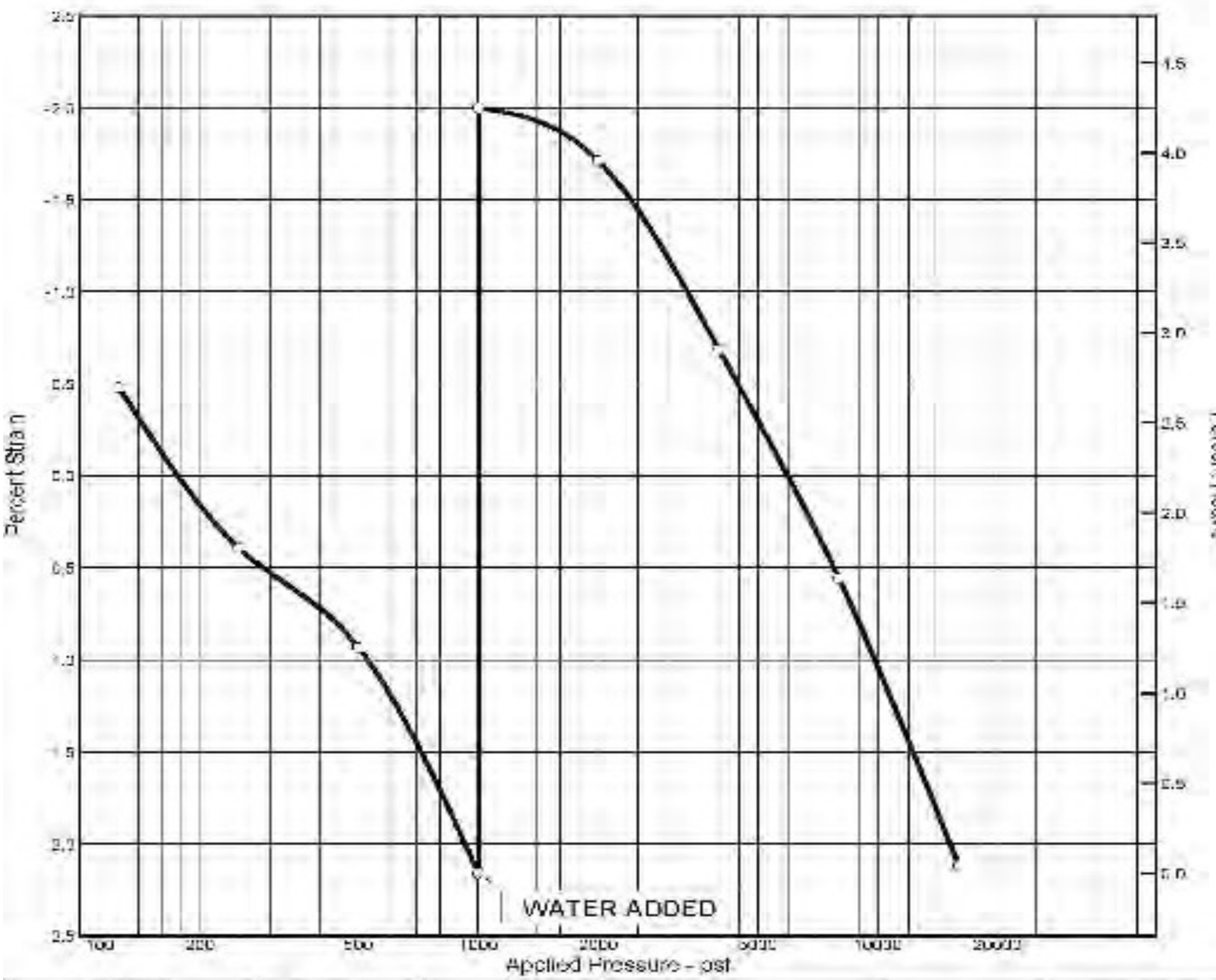
Remarks:

inundated at 200 psf

Porter Home Site, Gillette WY   Pre-treatment Boring #4: Swell potential - 4.25%

10

CONSOLIDATION TEST RESULTS



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	USCS	AASHTO	Initial Void Ratio
Saturation	Moisture							
82.1%	18.6%	103.5			2.65			0.598

MATERIAL DESCRIPTION

Brown to gray CLAYSTONE

Project No. GI12078A **Client:** Dr. David Porter

Project: New House - J Mills Tracts, Lot 8

Location: B-4 @ 15.0

Remarks:

Inundated at 1000 psf

Porter Home Site, Gillette WY   Post-treatment Boring #1: Swell potential - 0.2%

SWELL TEST REPORT

Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	USCS	AASHTO	Initial Void Ratio
Saturation	Moisture							
55.7 %	12.1 %	104.9			2.65	CL		0.576

MATERIAL DESCRIPTION

Brown LEAN CLAY - recompacted controlled fill

Project No. GI12078A **Client:** Dr. David Porter

Project: New House - J-Mill Iron Tracts, Lot 8

Location: Reco Specimen - Bottom Lift

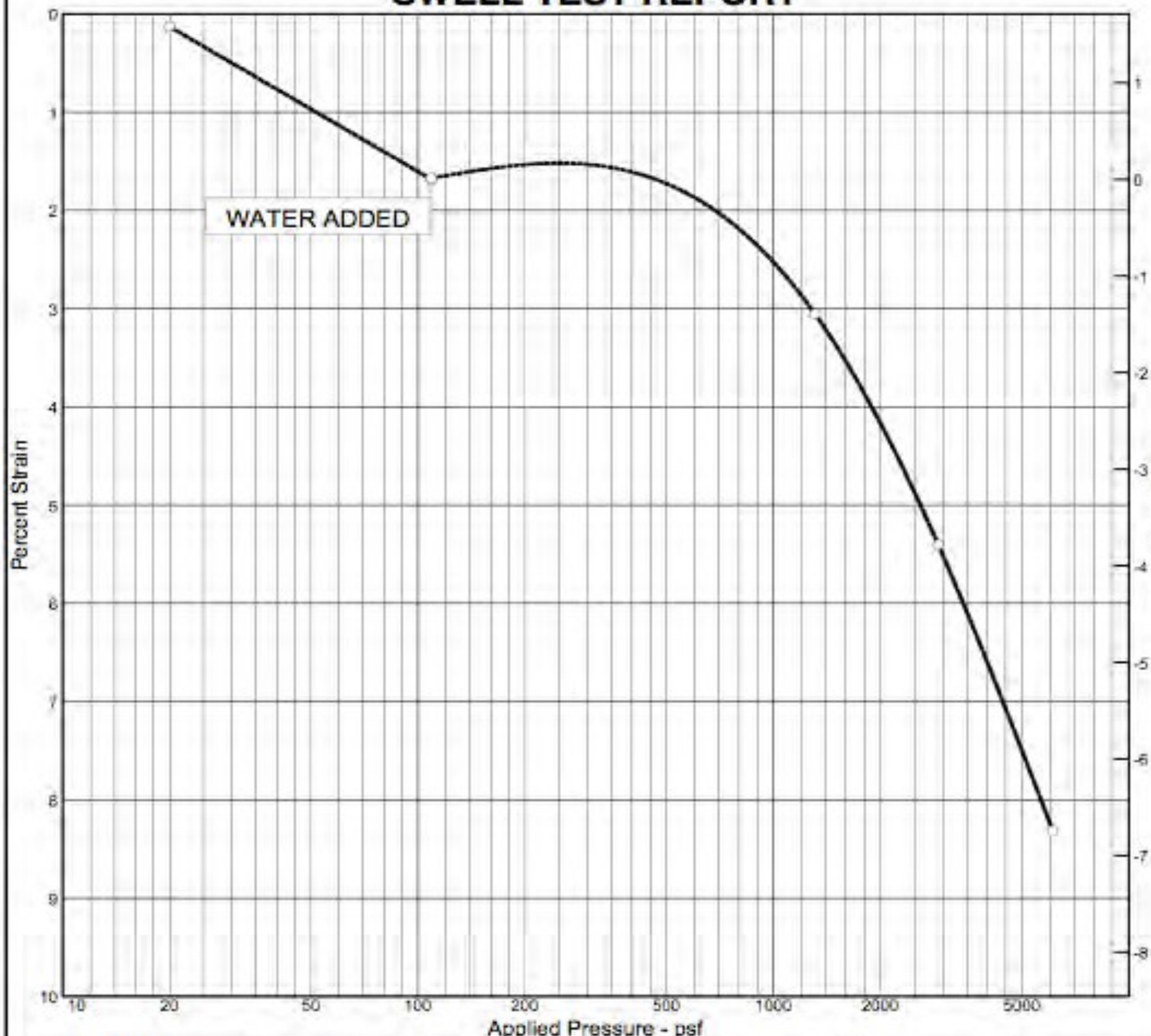
Remarks:
Inundated @ "W'Jfd ea.! d:c:::- d
sample

STRATA
Gliiette; WY

Figure

Porter Home Site, Gillette WY   Post-treatment Boring #2: Swell potential - 0.0%

SWELL TEST REPORT



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	USCS	AASHTO	Initial Void Ratio
Saturation	Moisture							
82.7 %	19.9 %	101.0			2.65	CL		0.637

MATERIAL DESCRIPTION

Brown LEAN CLAY - recompacted controlled fill

Project No. GI12078A **Client:** Dr. David Porter

Project: New House - J-Mill Iron Tracts, Lot 8

Location: Center of Basement - 5' Below Basement Floor

STRATA

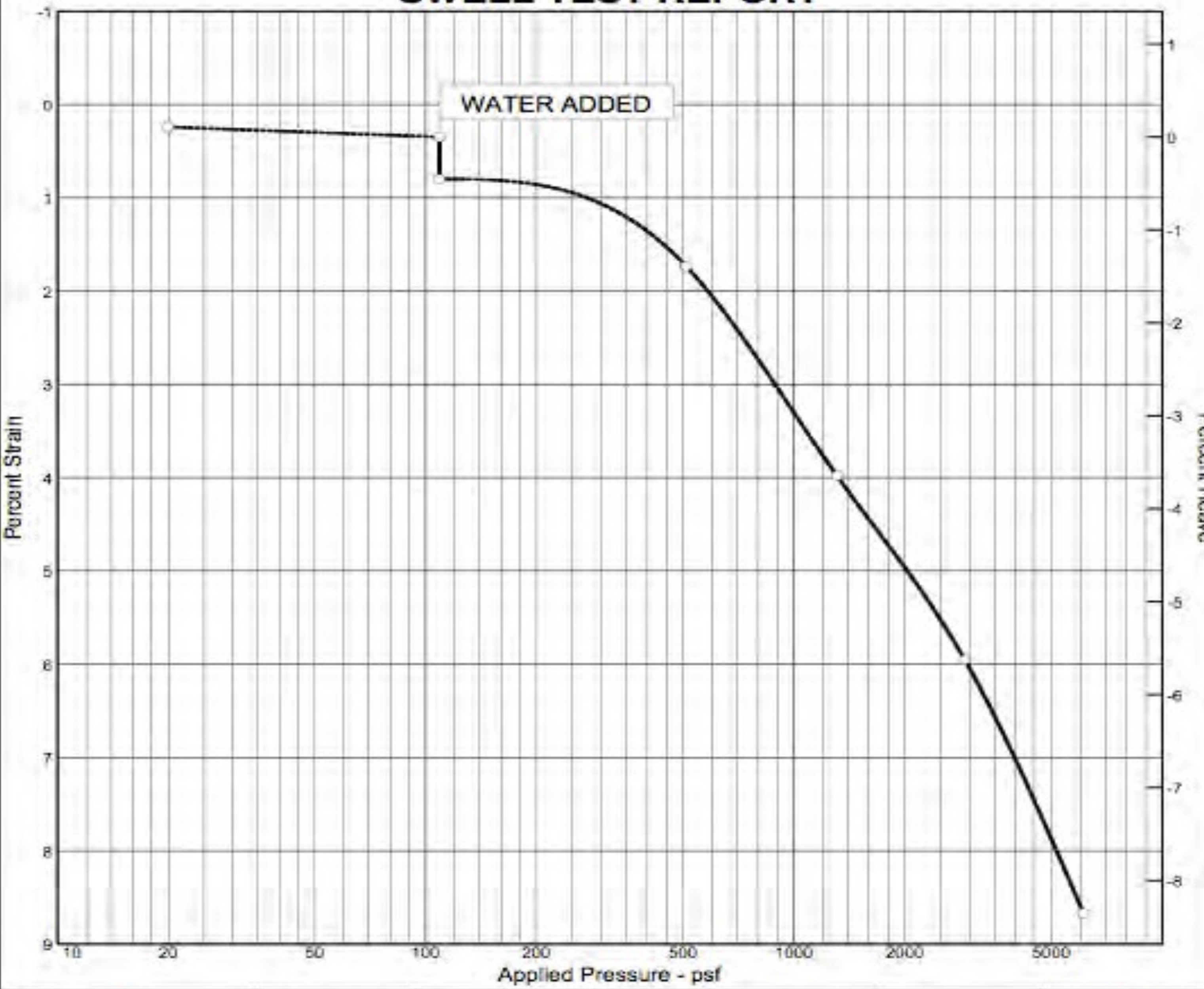
Gillette, WY

Remarks:
Inundated @ 100 psf
sampled in field
treated with chemcial

Figure

Porter Home Site, Gillette WY **Post-treatment Boring #3: Swell potential - 0.0%**

SWELL TEST REPORT



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	USCS	AASHTO	Initial Void Ratio
Saturation	Moisture							
87.6 %	18.6 %	105.8			2.65	CL		0.563

MATERIAL DESCRIPTION

Brown LEAN CLAY - recompacted controlled fill

Project No. GI12078A **Client:** Dr. David Porter

Project: New House - J-Mill Iron Tracts, Lot 8

Location: Southwest Basement Corner - 5' Below Basement Floor

STRATA

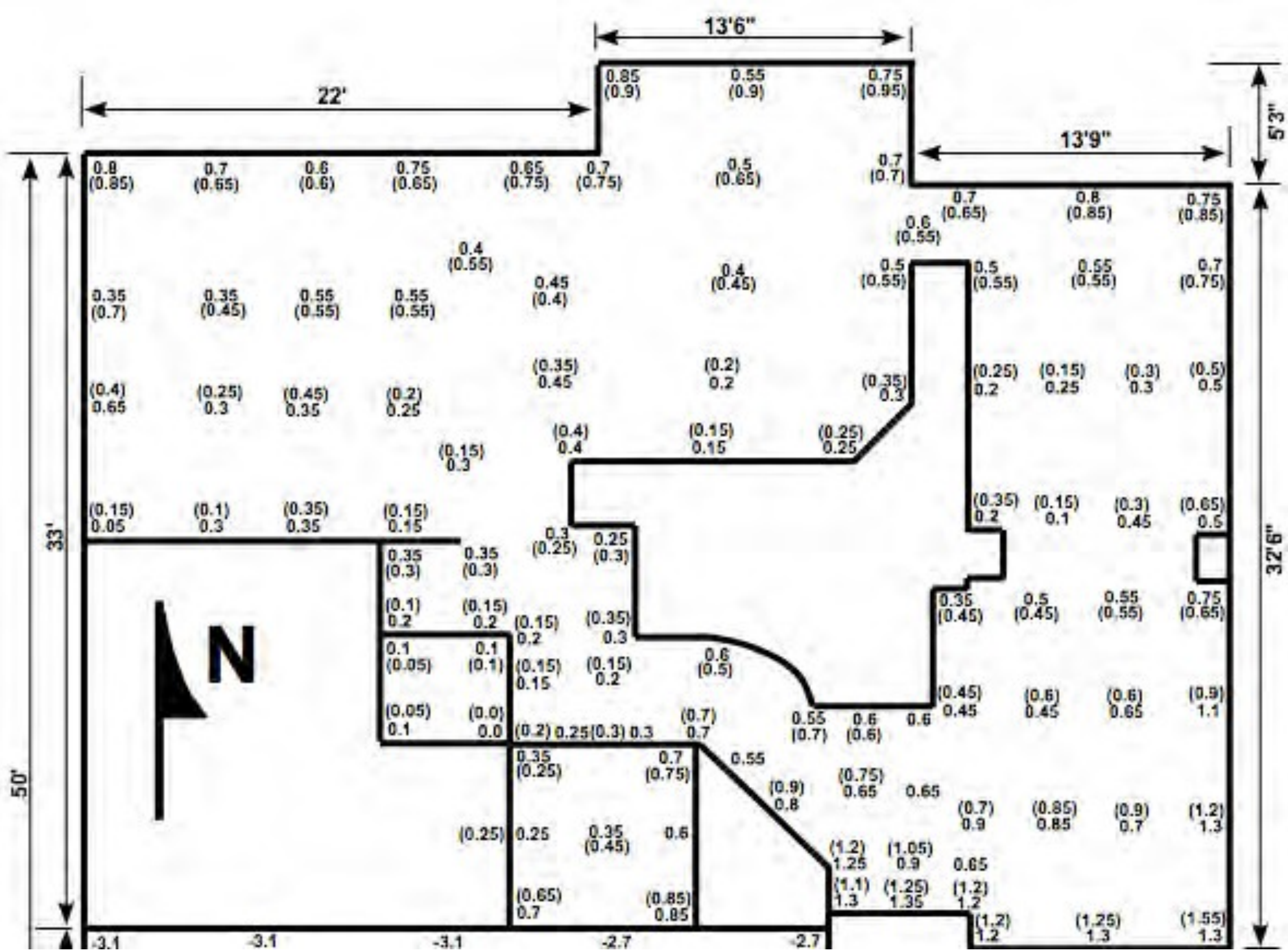
Gillette, WY

Remarks:

Inundated @ 100 PSF
sampled in field
treated with chemical

Figure

Typical Existing Structure Elevation Reading – Pre: 3/23/08 Post: (9/2/09): When treatment is done on an existing structure, elevations are taken prior to beginning treatment and months after. As is shown in the results below, elevation studies consistently show a lack of movement or even a relaxation of the previously swelled soils.



Clay Set Pre-Proposal Soil Testing Recommendations For Existing Structures

- California Modified Ring Sampler (if possible)
- Boring to extend to minimum of 10’ below slab/foundation level
- First sample to be taken at 2’ below slab/foundation level, 2nd at 5’ below & then every 5’ thereafter
- Record blow counts & soil classification during sampling
- Swell tests* per ASTM 4546B (real world overburden pressures for depth of sample)
- Dry unit weight & moisture content on each sample
- Specific gravity on each sample
- For existing structures we DO NOT need a full geotech report, but simply transfer of the boring logs and test/data results

* To save the client money on testing, If soil in a sample taken at a individual depth is classified as a type other than what is typically an expansive clay (like sandstone, etc), there would not be the need for the swell testing in that sample. Typically 1-2 boring for a home & 4 for a large commercial building.

Please contact (or refer your selected engineer to) Pamela Degenhardt Langan with questions at 720-220-9559 or Pamela.Langan@SoilScientific.com

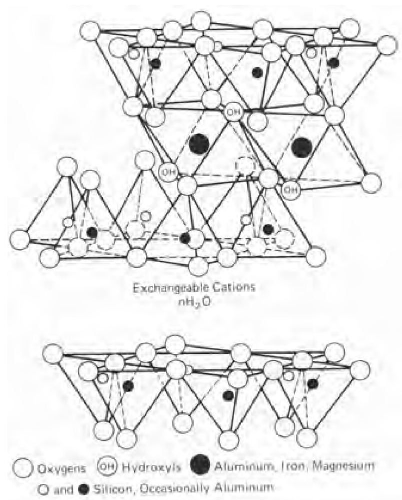
Field and laboratory testing to evaluate the performance of Clay Set in an over-excavation and mixing operation

- After the Clay Set chemical solution has been applied by the water pulls or water trucks, the treated soil will be processed by construction disks, or comparable equipment such as reclaimers or asphalt zippers, and then compacted. Following the compaction of the treated soil, modified ring hand samplers should be used to take undisturbed samples of the treated fill soil. Seal the end caps of the treated ring sampling tubes with duct tape to ensure that there is no drying of the treated sample.
- Store treated undisturbed ring samples at the end of each day in the laboratory or facility that has a controlled environment (temperature). Do not store or transport in very hot or freezing conditions.
- After 1 day of storage, perform swell tests on treated undisturbed samples at a pressure equivalent to the expected over burden pressure. Use the *"ASTM D4546 – Method B, One-Dimensional Swell or Settlement Potential of Cohesive Soils,"* laboratory test method to determine the swell potential of the treated sample. If this test result does not meet the swell criteria then another ring should be tested after 3 days or later (7, 14 days and/or 28 days). Due to the very small particle size of the clay particles the penetration of the chemical into the deeper recesses of the clay lattices will be an ongoing process for months so later tests will likely demonstrate a further reduction in swell as compared to the tests done after 24 hours.
- For each swell test determine the placement moisture content (pre-swell moisture content), final moisture content (post swell moisture content), and dry density of the sample. Initiate swell test at the field placement moisture content .

Details of Clay Set (Hydrogen Ionic Clay Stabilization) Mechanism

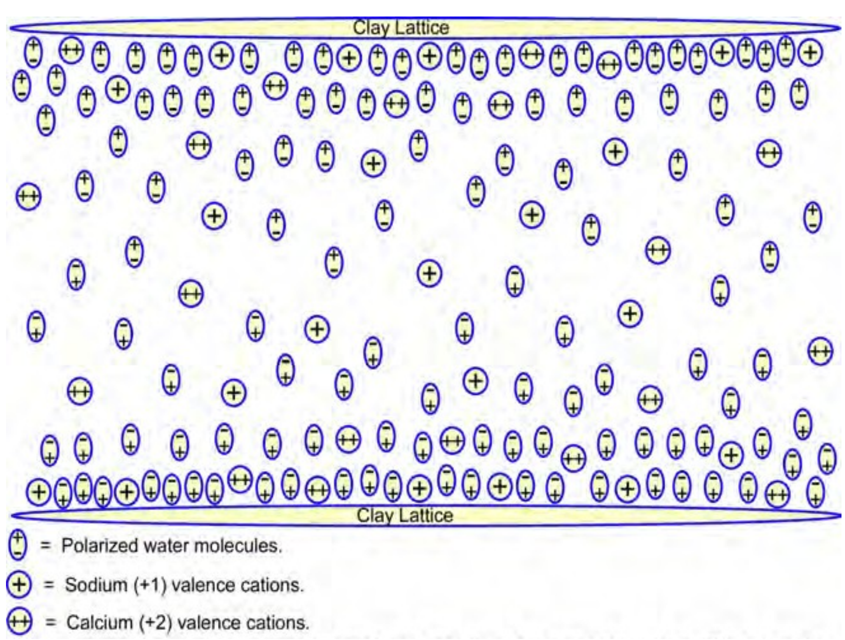
Theory of Expansive Clays

Montmorillonite Clay Lattice Structure



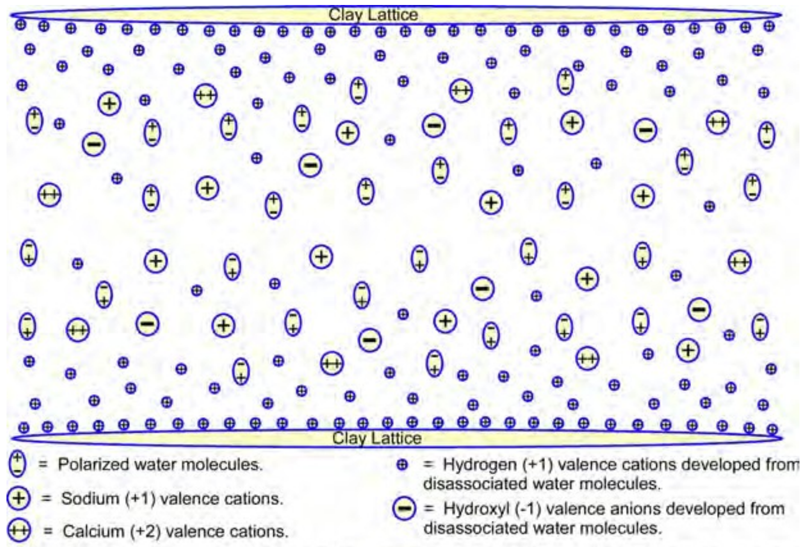
Expansive clay soils can experience significant changes in volume with changes in moisture content. The cause of this expansion potential is due to the electrical charge characteristics of the clay lattice structure. Clay particles are made up of a series of clay lattice structures. The clay lattice structure of the montomorillonite clay is shown above. The montomorillonite clay is a form of smectite clay and is one of the more common high swell clays. As illustrated in the figure above the montomorillonite clay lattice structure is made up of (2) tetrahedral sheets and (1) octahedral sheet. The tetrahedral sheet is made up of a sheet of tetrahedrals with a silica cation in the center surrounded by (4) oxygen's. The octahedral sheet is made up of a sheet of octahedrals with either aluminum, iron, or magnesium at the center surrounded by (6) hydroxyls. Between the clay lattice sheets is a diffuse double layer of polarized water molecules and exchangeable cations.

As a result of missing cations in the tetrahedral and octahedral sheets or the substitution of aluminum for silica in the tetrahedral sheet and iron or magnesium for aluminum in the octahedral sheets produces a negative internal charge. Adding to the internal negative charge of the clay lattice is a negative exterior charge resulting from the geometry of the exterior tetrahedral sheets. The outer exterior of the clay lattice consists of tetrahedral sheets with negatively charged oxygen anions on the outside of the tetrahedral sheets which are on the outside of the clay lattice sheets. The swell potential of a clay is determined by the magnitude of the electrical charge of the clay lattice and the surface area of the clay particle. To offset or neutralize the electrical charge of the clay particles, exchangeable cations and polarized water molecules are attracted around the surfaces of the negatively charged clay particles. The combination of exchangeable cations and polarized water molecules form a layer around the clay particle called the diffuse double layer. The expansion capabilities of the diffuse double layer will determine whether the clay soil has a higher or lower potential for swell.



How Clay Set Works to Stabilize Clay Soils

Treating expansive clay soils with Clay Set significantly reduces the clay soils ability to expand and also reduces their soil suction capabilities. Treatment with Clay Set utilizes chemical soil principles to change the swell/shrink characteristics of the clay soils. The processes that produce these results are referred to as isomorphic substitution and cation exchange which results in a reduction of the internal and external negative charges in the clay lattice. Isomorphic substitution of missing cations in the tetrahedral and octahedral clay lattice sheets reduces the internal negative charges of the clay lattice sheets. Aluminum substitutes for silica in the tetrahedral sheets and iron and magnesium substitutes for aluminum in the octahedral sheets. The external negative charges of the clay lattice are reduced by a chemical process called cation exchange. The Clay Set chemical solution neutralizes the negative charges on the surface of the clay lattice by providing very large amounts of the hydrogen cation in the diffuse double layer that is present between the clay lattices. These hydrogen cations are then attracted to the outer negatively charged surface of the clay lattice, thus neutralizing their negative charge. The diffuse double layer between the clay lattices normally contains polarized water molecules and positive and negative ions. The cation exchange process that occurs is the exchange of the existing large cations that are in the diffuse double layer (primarily sodium and calcium) with the hydrogen cation that is the smallest cation that exists. Due to the very high charge density of very small hydrogen cations (H^{+1}), they can easily exchange with the much larger sodium (Na^{+1}) and calcium (Ca^{+2}) cations and more effectively neutralize the negative charges on the surface of the clay lattices and collapse the diffuse double layer.



As the negative charges of the clay lattice structure are neutralized the swell potential of the clay lattices are reduced significantly. The reduction of negative charges of the clay lattice will allow for attractive forces to become more dominant and repulsive forces less dominant between the clay lattice structures. These increased attractive forces between the clay lattices results in a collapse of the diffuse double layer between the clay lattices with a subsequent tendency for the clay lattices to become more flocculent (edge to face) and less dispersed (face to face). Clay lattices with greater attractive forces will have more flocculent tendencies and will result in significantly lower swell potential and a reduction in soil suction (approximately a ten times reduction in soil suction). The reduction of soil suction will act like a moisture barrier in clay soils that have been treated since the ability for moisture to migrate into clay soils that have been treated with Clay Set is significantly reduced.

Although many scientific studies have been done on ionic chemical stabilization of swelling clay soils, one of the most thorough studies was performed by Dr. Shondeep L. Sarkar and Dr. Bruce E. Herbert with Texas A&M University. It fully explores and explains the mechanism of ionic clay stabilization and the evidence and conclusions help to explain the effects on the clay soils that are routinely seen in the field and in the long term proven results for roads, railroads, parking areas, and structures. A summary of the conclusions from their research is provided below:

- Identifiable smectite peaks were noted to be absent in the Hydrogen Ion Exchange Chemical – treated coarse and fine factions.
- The treatment of clay samples reduced the Zeta potential of the treated sample by 32 % as compared with the untreated clay sample. The Zeta potential is a measure of the negative charge in the clay and on the clay surface. As the Zeta potential decreases it is considered that the double diffuse layer is also reducing.
- Soluble ions analysis of Al and Fe supports the hypothesis that the Hydrogen Ion Exchange Chemical treatment changes the surface chemistry of clays through a complex precipitation-dissolution process; the low pH may be a contributory factor. The treatment of the clay with the Hydrogen Ion Exchange Chemical reduced the soluble Al ions by 43 % and increased the soluble Fe ions by 173 %.
- The Environmental Scanning Electron Microscope examination showed that no morphological changes occur when clay sample is treated with the Hydrogen Ion Exchange Chemical solution, but swelling becomes evident in the counterpart water-treated sample.
- The Transmission Electron Microscope examination revealed that the crystalline electron diffraction pattern of smectite in the treated sample is replaced by diffuse halos, implying a change in the clay structure or a smearing of the smectite particles by an amorphous or non-crystalline material.
- During sample handling and processing, the treated sample was continually recognized as having different behavior compared to the untreated sample. The untreated sample was more "stickier", as opposed to the treated sample that was much more difficult to disperse.
- The dominant conclusion of this study is that soil samples amended with the Hydrogen Ion Exchange Chemical solution exhibit a change in the crystallographic characteristics of the soil, which can be associated with a change in the shrink-swell behavior of smectite.

The question is asked how effective and how permanent is the treatment of the clay soils with Hydrogen Ionic Stabilization? We have accumulated a significant amount of field and laboratory testing and monitoring data that has shown conclusively the successful performance of the Hydrogen Ionic treated clays. With regard to the question of how permanent is the Hydrogen Ionic treatment on clay soils can best be answered by considering the results of the previously described research and our own experiences. We can say that the Hydrogen Ionic treatment of clay soils is permanent. If the crystallographic characteristics of the soil are changed, then we can conclude that the treatment of the clay soils is permanent.