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May 20, 2016

Summary Report of
Laboratory Testing Services
Soil Stabilization with Calciment®
Kennesaw, Georgia
Geo-Hydro Project Number 160047.10

Dear Mr. Meyer:

Geo-Hydro Engineers has completed the authorized laboratory testing services for the above referenced project as outlined in our proposal 18599.1 dated January 12, 2016. This reports summarizes the findings of our laboratory testing.

INTRODUCTION

Geo-Hydro was tasked with performing soil engineering property testing and soil performance testing on soil samples before and after the amendment with Calciment®.

The purpose of the laboratory testing was to determine the potential benefits of amending soils with Calciment®, such as strength gain, soil drying, and improved pavement subgrade support.

The following tests were included in the study:

- ASTM D2487 *"Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*
- ASTM D4318 "*Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils"*
- ASTM D422 "*Standard Test Method for Particle-Size Analysis of Soils"*
- ASTM D698 *"Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort"*
- ASTM D558 *"Standard Test Method for Moisture Density Relations of Soil Cement Mixtures",* Method B
- ASTM D1633 *"Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders"*, Method A
- ASTM D2216 *"Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass"*
- ASTM D1883 *"Standard Test Method for California Bearing Ratio (CBR) of Laboratory Compacted Soils"*

INITIAL SAMPLE ANALYSIS

For this study, two soil types were selected to be amended with Calciment® for property and performance testing. The following table shows the characteristics of each soil type prior to amendment:

Sample ID	Sample Location Geologic Province	Liquid Limit	Plastic Limit	Plasticity Index	% Passing ¾ Sieve	% Passing No. 4 Sieve	% Passing No. 200 Sieve
1	Rome, Georgia Ridge & Valley	38	24	14	100.0	94.4	66.3
2	Cumming, Georgia Northern Piedmont	36	21	15	100.0	99.4	52.7

Sample ID	Soil Classification	Maximum Dry Density	Optimum Moisture	Unconfined Compressive Strength	CBR
1	Sandy Lean Clay (CL)	107.0 pcf	18.0%	60 psi	-
2	Sandy Lean Clay (CL)	113.0 pcf	15.0%	50 psi	10.4

SAMPLE ANALYSIS AFTER AMENDMENT WITH CALCIMENT

The following paragraphs and tables address the physical and performance characteristics of each sample once amended with Calciment®. For this study, each sample was amended with 4.0 percent and 6.0 percent Calciment® by dry weight of each unamended sample.

Sample 1

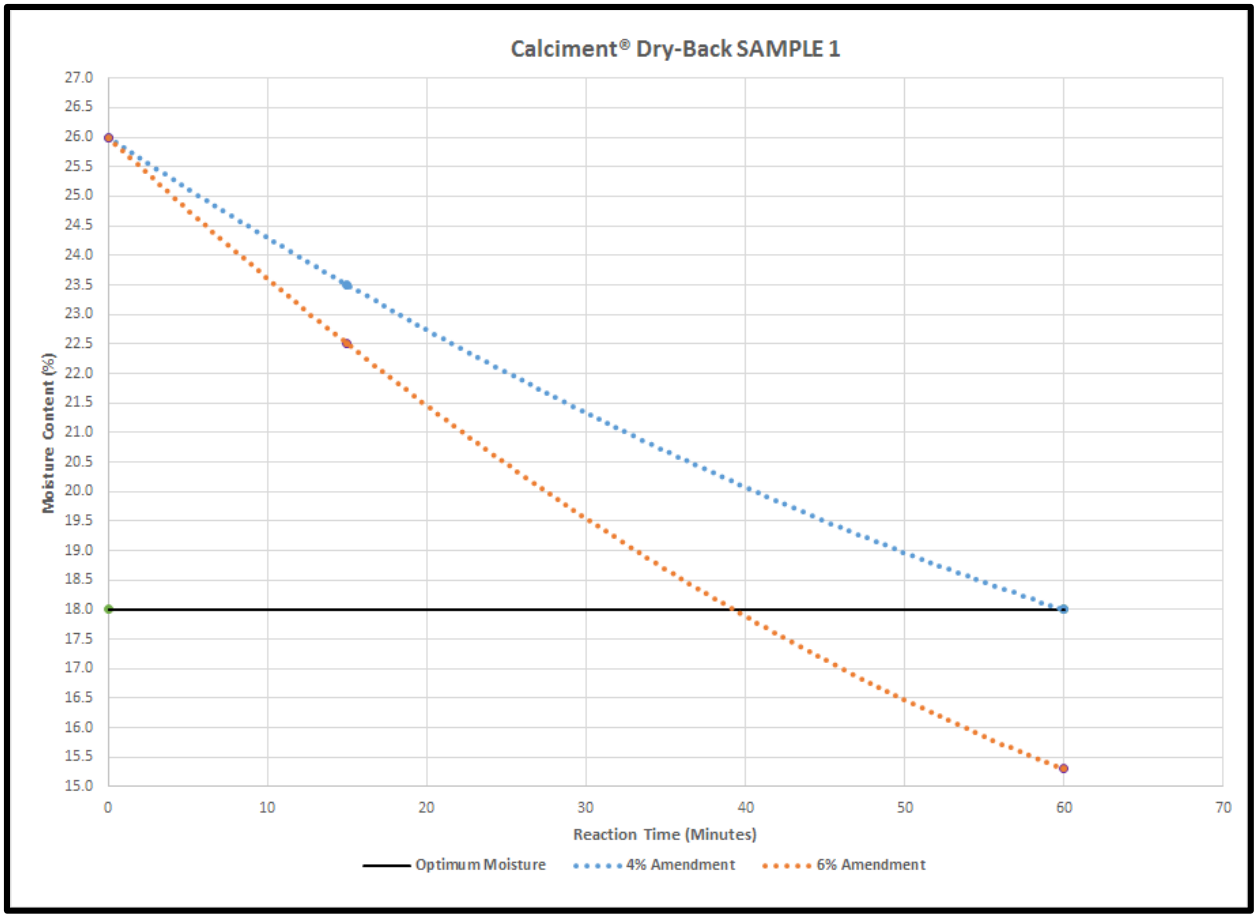
Sample ID	Liquid Limit	Plastic Limit	Plasticity Index	% Passing ¾ Sieve	% Passing No. 4 Sieve	% Passing No. 200 Sieve
1 – Unamended	38	24	14	100.0	94.4	66.3
1 – 4% Amendment	42	31	11	100.0	91.8	61.5
1 – 6% Amendment	41	30	11	100.0	92.9	56.1

Sample ID	Soil Classification	Maximum Dry Density	Optimum Moisture	Unconfined Compressive Strength
1 – Unamended	Sandy Lean Clay (CL)	107.0 pcf	18.0%	60 psi
1 – 4% Amendment	Sandy Silt (ML)	108.0 pcf	18.5%	150 psi
1 – 6% Amendment	Sandy Silt (ML)	108.0 pcf	18.0%	185 psi

The test results show a slight change in the physical properties (gradation and Atterberg limits) of the unamended **Sample 1** compared to the amended **Sample 1**. However, it is possible that the variances in test results can be attributed to the inherent variance of the material regardless of the addition of Calciment®.

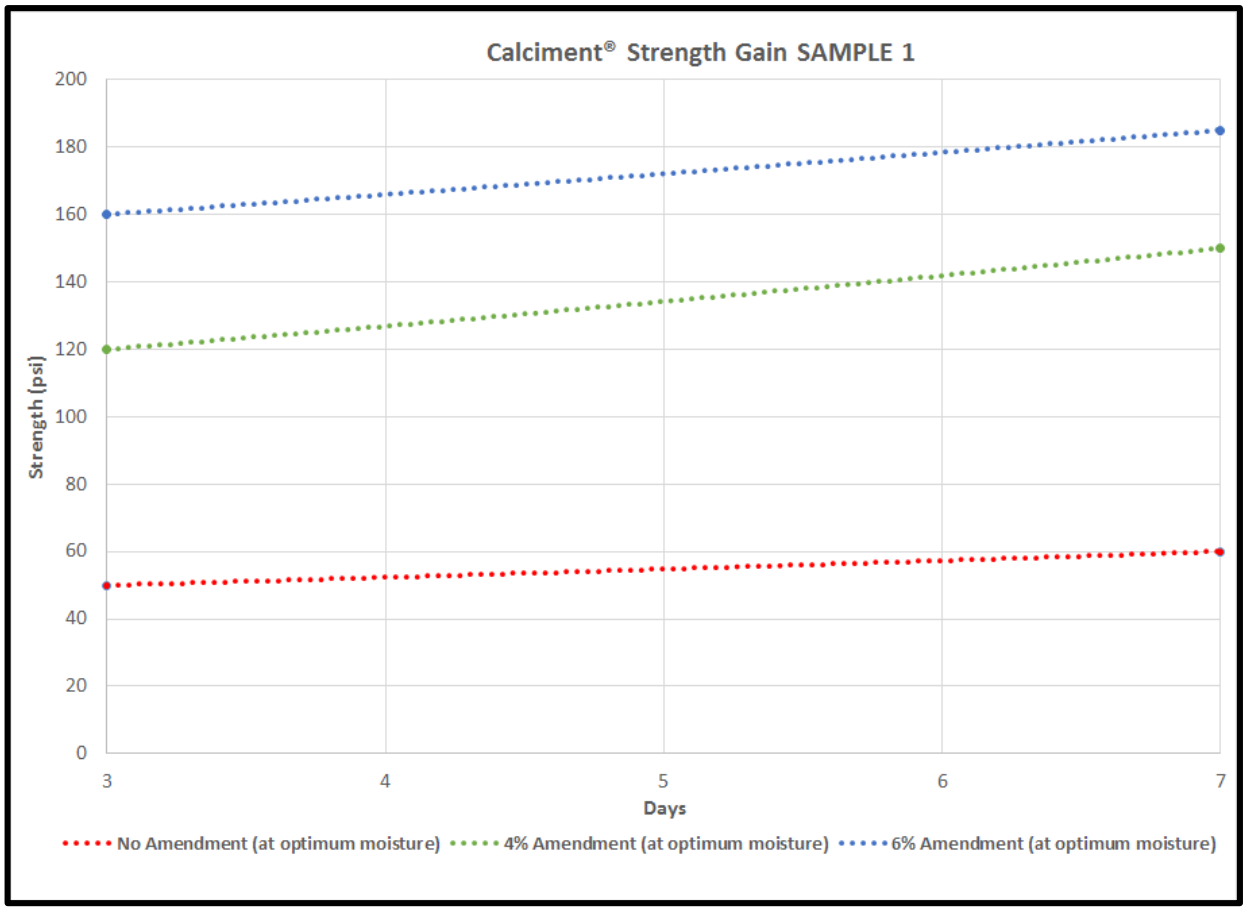
Regarding *performance* properties of the soil with the addition of Calciment®, results were favorable in terms of strength gain and the ability to "dry-back" soils in comparison to other chemical stabilization approaches.

The graph below shows the results of "dry-back" testing after amendment with Calciment®.



"Dry-back" analysis of **Sample 1** shows that for every 1.0 percent of Calciment®, there was a loss (drying) of about 2.0 percent moisture.

Regarding strength, our results show a 90 and 125 psi increase in compressive strength for the 4 percent and 6 percent amendments of **Sample 1** when at optimum moisture. Compressive strength testing results are shown below, as well as the dry density and moisture contents of the tested samples.



Sample 1 amended with (4.0%) Calciment®

Sample ID	Dry Density, (pcf)	Moisture Content, (%)
4% A	107.3	17.8
4% B	107.5	18.3
4% C	108.4	17.8

Sample 1 amended with (6.0%) Calciment®

Sample ID	Dry Density, (pcf)	Moisture Content, (%)
6% A	107.8	17.7
6% B	108.8	17.4
6% C	108.0	17.5

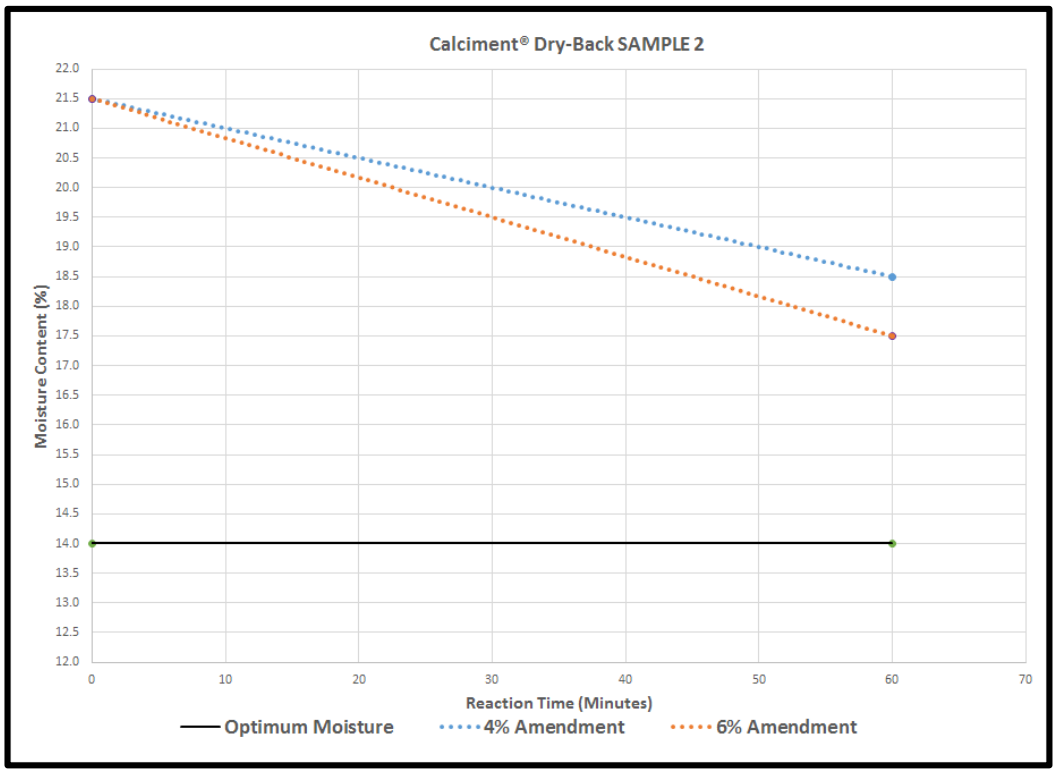
Sample 2

Sample ID	Liquid Limit	Plastic Limit	Plasticity Index	% Passing ¾ Sieve	% Passing No. 4 Sieve	% Passing No. 200 Sieve
2 – Unamended	36	21	15	100.0	99.4	52.7
2 – 4% Amendment	36	26	10	100.0	99.5	51.1
2 – 6% Amendment	37	30	7	100.0	99.8	52.0

Sample ID	Soil Classification	Maximum Dry Density	Optimum Moisture	Unconfined Compressive Strength
2 – Unamended	Sandy Lean Clay (CL)	113.0 pcf	15.0%	50 psi
2 – 4% Amendment	Sandy Lean Clay (CL)	108.0 pcf	14.0%	150 psi
2 – 6% Amendment	Sandy Clayey-Silt (ML-CL)	108.0 pcf	13.5%	210 psi

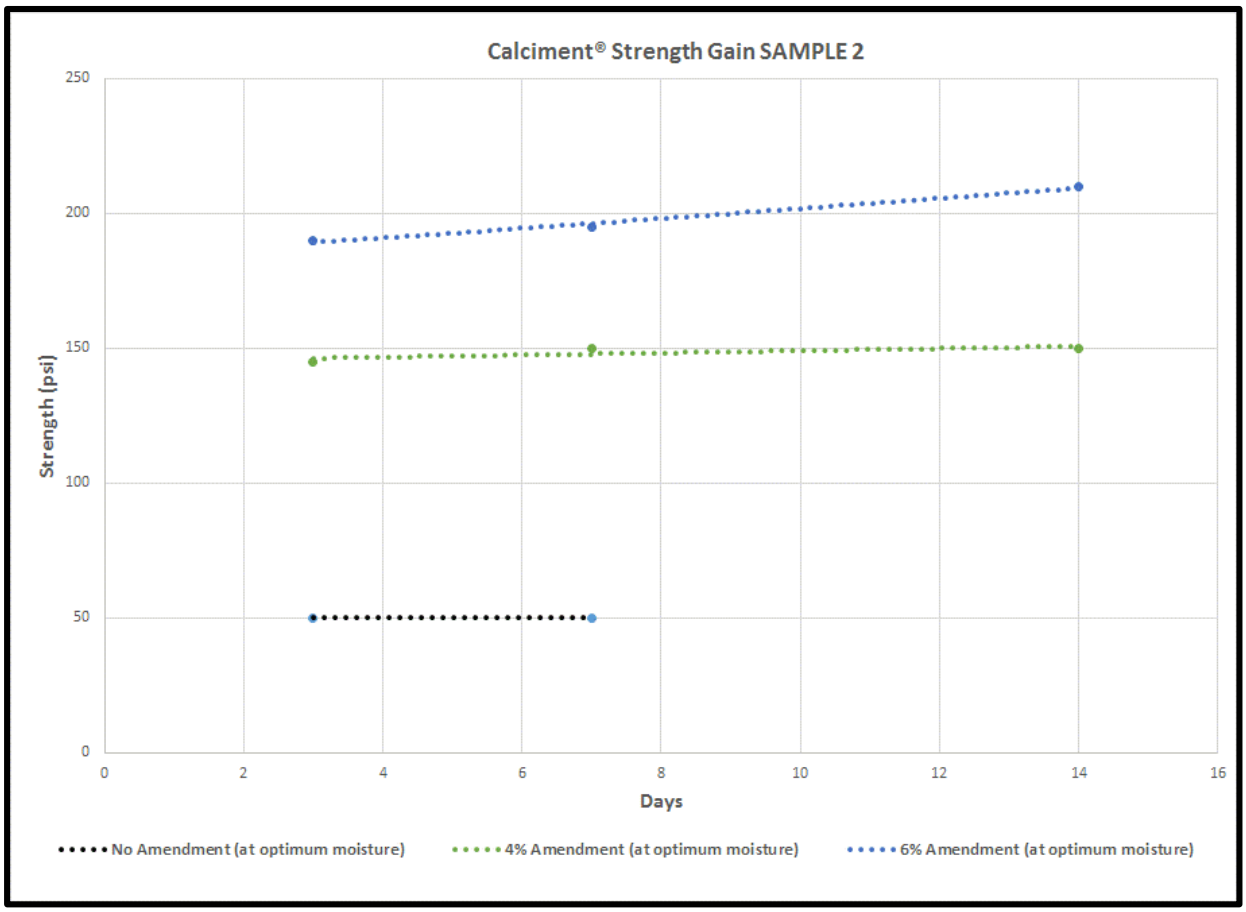
It is our opinion that for **Sample 2**, Calciment® appears to have altered the soils plasticity and unit weight. Regarding particle size, virtually no change was observed between the unamended and amended samples.

Concerning *performance* properties of **Sample 2** with the addition of Calciment®, results were favorable in terms of strength gain but marginal for "dry-back". The graph below shows the results of "dry-back" testing after amendment with Calciment®.



"Dry-back" analysis of **Sample 2** shows that for every 1.0 percent of Calciment®, there was a loss (drying) of slightly less than 1.0 percent moisture.

For compressive strength testing, our results show a 100 and 160 psi increase in compressive strength for the 4 percent and 6 percent amendments of **Sample 2** when at optimum moisture. Compressive strength testing results are shown below, as well as the dry density and moisture contents of the tested samples.



Sample 2 amended with (4.0%) Calciment®

Sample ID	Dry Density, (pcf)	Moisture Content, (%)
4% A	106.5	14.1
4% B	107.2	14.1
4% C	107.9	14.2

Sample 2 amended with (6.0%) Calciment®

Sample ID	Dry Density, (pcf)	Moisture Content, (%)
6% A	105.4	13.6
6% B	105.4	13.5
6% C	107.4	12.9

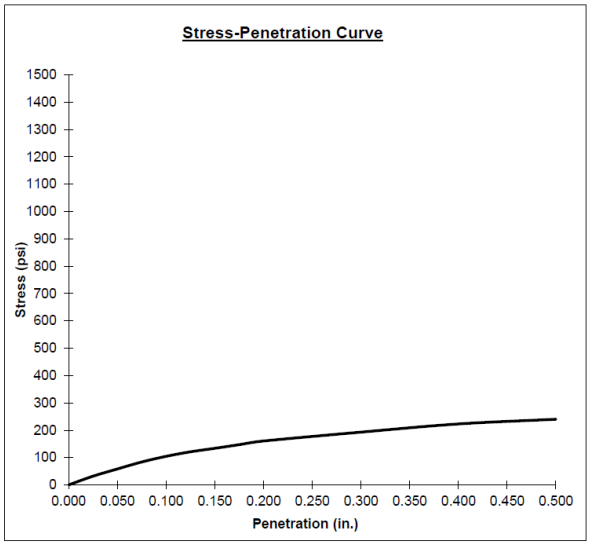
Additionally, we performed California Bearing Ratio (CBR) testing on **Sample 2,** unamended and amended with 4 and 6 percent Calciment®.

CBR test results are shown on the following tables.

For CBR testing, our results show CBR values increased from 10.4 to 51.5 and 43.6 for the 4 percent and 6 percent amendments of **Sample 2**, respectively, when compacted to at least 95 of the standard Proctor maximum dry density at or near the optimum moisture.

Furthermore, less than 1 percent swell was observed in the CBR test specimens.

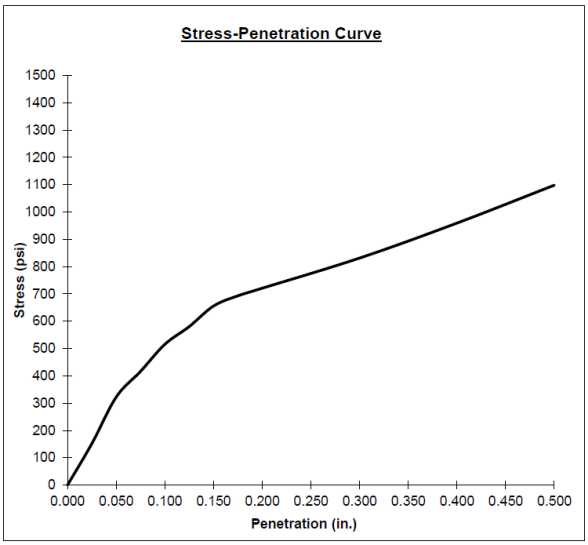
Sample Designation: NO AMENDMENT



Note: CBR specimen soaked for 96 hours as per ASTM D-1883

Proctor Method:	ASTM D698		Surcharge Weight:	10.0	lbs
Maximum Dry Density:	113.0	pcf	Moisture Content (Top 1"):	19.7	%
Optimum Moisture Content	15.0	%	Swell (% of Height):	0.09	%
Actual Dry Density:	107.6	pcf	Final Dry Density:	107.5	pcf
Actual Moisture Content:	18.5	%			
Percent Compaction:	95	%	**CBR at 0.1 in.:**	**10.4**	
			CBR at 0.2 in.:	**8.9**	

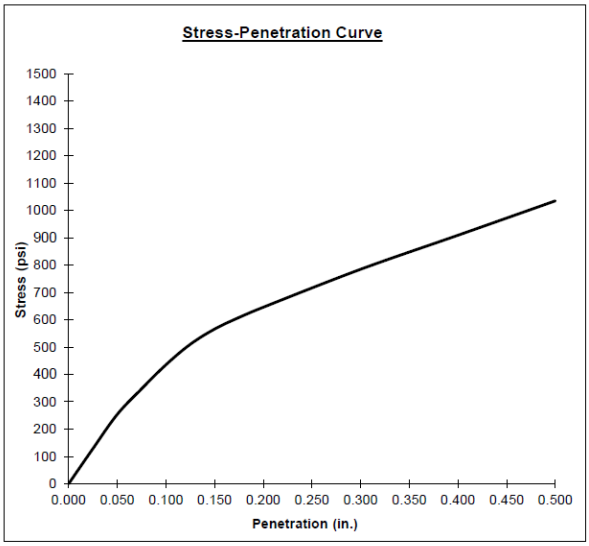
Sample Designation: 4% CALCIMENT



Note: CBR specimen soaked for 96 hours as per ASTM D-1883

Proctor Method:	ASTM D698		Surcharge Weight:	10.0	lbs
Maximum Dry Density:	108.0	pcf	Moisture Content (Top 1"):	24.5	%
Optimum Moisture Content	14.0	%	Swell (% of Height):	0.52	%
Actual Dry Density:	104.0	pcf	Final Dry Density:	103.5	pcf
Actual Moisture Content:	17.5	%			
Percent Compaction:	96	%	**CBR at 0.1 in.:**	**51.5**	
			CBR at 0.2 in.:	**43.7**	

Sample Designation: 6% CALCIMENT



Note: CBR specimen soaked for 96 hours as per ASTM D-1883

Proctor Method:	ASTM D698		Surcharge Weight:	10.0	lbs
Maximum Dry Density:	106.0	pcf	Moisture Content (Top 1"):	26.4	%
Optimum Moisture Content	13.5	%	Swell (% of Height):	0.81	%
Actual Dry Density:	101.4	pcf	Final Dry Density:	100.6	pcf
Actual Moisture Content:	16.6	%			
Percent Compaction:	96	%	**CBR at 0.1 in.:**	**43.6**	
			CBR at 0.2 in.:	**37.7**	

CONCLUSIONS

The following conclusions are based on our review and understanding of test results, our engineering judgements and opinions, and our experience with chemical stabilization methods in general.

- A decrease in plasticity index (PI) was noted in each sample. For **Sample 1**, the PI decreased by 3 and for **Sample 2** the PI decreased by 8. A decrease in PI or an *increase in friability*, can be desirable when working with fine grained soils. Modification of other physical characteristics, such as grain size and unit weight, etc., varied between **Sample 1** and **Sample 2**.

- On the contrary to our findings to physical attribute alterations, we found conclusive and overall favorable results in Calciment's® ability to alter a soils performance. These categories are shown below:

    - ***Compressive Strength:*** The ultimate compressive strength at a ***reasonable*** and ***"real-world"*** amendment rate of 6 percent at optimum moisture content was found to be approximately 200 psi. This compressive strength would be reasonable for subgrade stabilization in building pads and pavement subgrades.

    - ***Drying:*** For every percent of Calciment®, we observed approximately 1 to 2 percent moisture loss.

    - ***CBR:*** We observed an average CBR of 37 with the addition of Calciment® at ***reasonable*** and ***"real-world"*** amendment rates. The increase in a soils CBR will usually allow for the reduction of graded aggregate base and/or asphaltic concrete thicknesses during pavement design.

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We appreciate the opportunity to perform this study for Mintek Resources and Calciment®.

Please contact us if you have any questions.

Respectfully,

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