TECHNICAL REPORT STANDARD PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/LA.13/516		
4. Title and Subtitle **Implementation of Slag Stabilized Blended Calcium Sulfate (BCS) in a Pavement Structure**	5. Report Date **July 2014** 6. Performing Organization Code **LTRC Project Number: 13-2GT** **State Project Number: 30000728**	
7. Author(s) **Gavin P. Gautreau, P.E.** **Khalil I. Hanifa, E.I.**	8. Performing Organization Report No. **Louisiana Transportation Research Center (LTRC)**	
9. Performing Organization Name and Address **Louisiana Transportation Research Center** **4101 Gourrier Avenue** **Baton Rouge, LA 70808**	10. Work Unit No. 11. Contract or Grant No.	
12. Sponsoring Agency Name and Address **Louisiana Department of Transportation and Development** **P.O. Box 94245** **Baton Rouge, LA 70804-9245**	13. Type of Report and Period Covered **Final Report** **July 2012-October 2013** 14. Sponsoring Agency Code	

15. Supplementary Notes

Conducted in Cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

This research project was the field implementation follow up to laboratory research conducted at LTRC. The research met a need and benefited District 61 staff by allowing an alternative to the removal and replacement of the old, non-standard blended calcium sulfate (BCS) found on site. The researchers used the previous research to draft, finalize, approve, and implement specifications to allow for the stabilization of BCS with ground granulated blast furnace slag grade 120 (slag) on the shoulders of US 61 just south of LA 22 in Sorrento, LA. Two specifications were used. The first addressed the inplace stabilization of BCS with slag. The second specification addressed a market-driven implementation of the research, specifically the applicability of Honeywell's "fines" material treated with slag in a pugmill for use as base material.

The researchers worked with Honeywell, District 61 staff, and the contractor to design a plan for the test sections. The partnership with Honeywell and its contractor, Brown Industries and their investment (financial & reputation) toward the project benefited the research. The four test sections were constructed and gained strength over time. The FWD, Dynaflect, DCP, and field cores confirmed the increase in strength over time. Stabilizing old, non-standard BCS inplace, provided a cost benefit of $15.5/s.y., which realized a saving of $55,000 for the test sections.

The use of BCS within DOTD as a base course material can be supplemented with the addition of a slag-stabilized BCS (inplace and pugmilled). Researchers recommend the use of slag stabilization in BCS encountered during forensic or rehabilitation operations as a cost effective way to deal with these areas of old, non-standard BCS. The design slag percentages should verified with laboratory testing and then increased slightly to account for spreading inconsistencies, and increased surface areas of old, non-standard BCS or new Honeywell "fines" material.

The original 08-3GT research proved that Slag-stabilization of BCS can reduce moisture sensitivity of BCS. A secondary benefit was that the slag-BCS reaction reduced the likelihood of expansive reactions, as compared to mixing BCS with cement. The pug-mill process is a way balance the construction moisture of the mixture to create the slag/BCS reaction without excess moisture that may cause pumping. Further refinements to the pugmill plant process are necessary to ensure consistency. This research also offered DOTD another base course alternative that addresses the "Green" philosophy and market need to dispose of BCS.

The researchers recommend that care, including site selection and specific testing with onsite materials, be used in selecting sites for the application and implementation of this research.

17. Key Words		18. Distribution Statement	
Calcium Sulfate, inplace and pugmill mixing and stabilization		**Unrestricted.** This document is available via the National Technical Information Service, Springfield, VA 21161**.**	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 133	22. Price

Project Review Committee

Each research project will have an advisory committee appointed by the LTRC Director. The Project Review Committee is responsible for assisting the LTRC Administrator or Manager in the development of acceptable research problem statements, requests for proposals, review of research proposals, oversight of approved research projects, and implementation of findings.

LTRC appreciates the dedication of the following Project Review Committee Members in guiding this research study to fruition.

LTRC Administrator

Zhongjie "Doc" Zhang

Pavement and Geotechnical Research Administrator

Members

Joey Tureau, District 61

Aaron Elisar, District 61

Travis Williams, Honeywell

Danny Smith, Construction

Ed Milner, Coastal Bridge

Directorate Implementation Sponsor

Richard Savoie

Implementation of Slag Stabilized Blended Calcium Sulfate (BCS) in a Pavement Structure

by

Gavin P. Gautreau, P.E.
Senior Geotechnical Research Engineer

and

Khalil I. Hanifa, E.I.
Geotechnical Research Engineer

Louisiana Transportation Research Center
Louisiana Department of Transportation & Development
4101 Gourrier Avenue
Baton Rouge, LA 70808
(225) 767-9108

July 2014

ABSTRACT

This research project was the field implementation follow up to laboratory research conducted at LTRC. The research met a need and benefited District 61 staff by allowing an alternative to the removal and replacement of the old, non-standard blended calcium sulfate (BCS) found on site. The researchers used the previous research to draft, finalize, approve, and implement specifications to allow for the stabilization of BCS with ground granulated blast furnace slag grade 120 (slag) on the shoulders of US 61 just south of LA 22 in Sorrento, LA. Two specifications were used. The first addressed the inplace stabilization of BCS with slag. The second specification addressed a market-driven implementation of the research, specifically the applicability of Honeywell's "fines" material treated with slag in a pugmill for use as base material.

The researchers worked with Honeywell, District 61 staff, and the contractor to design a plan for the test sections. The partnership with Honeywell and its contractor, Brown Industries and their investment (financial & reputation) toward the project benefited the research. The four test sections were constructed and gained strength over time. The Falling Weight Deflectometer (FWD), Dynaflect, Dynamic Cone Penetrometer (DCP), and field cores confirmed the increase in strength over time. Stabilizing old, non-standard BCS inplace, provided a cost benefit of $15.5/s.y., which realized a saving of $55,000 for the test sections.

The use of BCS within DOTD as a base course material can be supplemented with the addition of a slag-stabilized BCS (inplace and pugmilled). Researchers recommend the use of slag stabilization in BCS encountered during forensic or rehabilitation operations as a cost effective way to deal with these areas of old, non-standard BCS. The design slag percentages should verified with laboratory testing and then increased slightly to account for spreading inconsistencies, and increased surface areas of old, non-standard BCS or new Honeywell "fines" material.

The original 08-3GT research proved that Slag-stabilization of BCS can reduce moisture sensitivity of BCS. A secondary benefit was that the slag-BCS reaction reduced the likelihood of expansive reactions, as compared to mixing BCS with cement. The pug-mill process is a way balance the construction moisture of the mixture to create the slag/BCS reaction without excess moisture that may cause pumping. Further refinements to the pugmill plant process are necessary to ensure consistency. This research also offered DOTD another base course alternative that addresses the "Green" philosophy and market need to recycle BCS.

The researchers recommend that care, including specific testing with onsite materials, be used in selecting sites for the application and implementation of this research.

ACKNOWLEDGMENTS

The researchers would like to thank the following for their support and contributions to this research project: District 61 engineers and technicians, Honeywell International Inc., Brown Industries, Gebhart Construction Group, Coastal Bridge Contractors, Barriere Construction, and the LTRC Pavement and Geotechnical Group Staff.

IMPLEMENTATION STATEMENT

The technology of slag-treated BCS is not mainstream yet, but the advantages appear to be many, including the utilization of two byproducts to create a consistent and durable base course (and possibly surface course) material. The slag-stabilized BCS material may also provide an alternative to other, often more expensive, base course materials.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Blended calcium sulfate (BCS) is fluorogypsum (FG), an industrial byproduct, blended with lime or limestone. Approximately 90,000 metric tons (100,000 tons) of FG are generated annually in the United States, posing a serious problem for environmental disposal. The Louisiana Department of Transportation and Development (DOTD) has been using BCS in pavement construction for over 15 years. While this material has performed satisfactorily after construction, its moisture sensitivity has concerned DOTD engineers because of its construction difficulty in wet environments.

Therefore, the Louisiana Transportation Research Center (LTRC) research project 03-8GT, *Stability of Calcium Sulfate Base Course in a Wet Environment* (Final Report 419) sought to better understand the strength deterioration of BCS in a wet environment and ways to eliminate or reduce such deterioration by stabilizing BCS with various suitable cementitious agents.

In the 03-8GT study, 120-grade ground granulated blast furnace slag (slag) was used to stabilize BCS to improve its water resistance. Laboratory tests identified factors that affected the strength development of raw BCS and researchers found that when combined, BCS and slag created a very stable and durable material, comparable to lean concrete. This stabilization scheme reduced the water susceptibility of raw BCS. The study recommended that DOTD consider building several field test sections in different traffic and environmental conditions using the slag-stabilized BCS as pavement base course.

The 03-8GT report's tentative construction specifications proved adequate for construction of a full-scale test section at the LTRC Pavement Research Facility (PRF) site. The section was loaded using the LTRC Accelerated Loading Facility (ALF) and the performance was evaluated. Additional in-situ tests, such as DCP, FWD, and Dynaflect, were conducted to characterize the section's strength and structural properties. The PRF section achieved a fairly high stiffness and a structural layer coefficient of 0.30 that could be used for pavement design purposes. A major result from the 03-8GT research indicated that BCS stabilized by 10 percent slag by volume can serve as a good pavement base. Full-scale test sections on DOTD projects were recommended by the 03-8GT research report.

In 2012, District 61 engineers came to LTRC with a problem during a mill and overlay project. They discovered the base course on the project shoulders consisted of blended calcium sulfate. The material, historically distributed as Fluorolite, was commonly distributed in the Ascension Parish area. This Fluorolite material was generally of silt consistency and was causing edge failures along this stretch of Airline Highway due to its granular pumping nature.

District 61 planned to remove the old material from the project and replace it with an acceptable base course material because: (1) the material can cause pumping problems during construction when wet; and (2) the material can react and expand when treated with cement causing grade and ride quality issues. However, with ever-tightening budgets, this "remove and replace" option proved to be an expensive solution based on the volume of material in the shoulders of the project. Other options were sought.

LTRC and District 61 met to discuss possible solutions, in regards to the recent 03-8GT research report, utilizing the slag stabilization research results of 03-8GT as an option to deal with the in-place Fluorolite. At roughly the same time, Honeywell, the current manufacturer of a coarser BCS material, was seeking approval for a slightly different BCS gradation. Honeywell had recently taken over the distribution, coordination, and management of their BCS product in conjunction with Brown Industries. Honeywell was investing time and funds to develop a market for their product. Subsequent meetings followed to establish appropriate test sections.

Eliminating the "remove and replace" option and treating the BCS "in-place" appeared to be a feasible option, which would hopefully create a stiffer base course and serve as a test section for the 03-8GT research. Parallel conversations merged into one, and Honeywell offered to help with the test sections to foster material acceptance and promote the enhanced strength of BCS when treated with slag.

The specifications included in the 03-8GT study were evaluated and modified to create change order(s) necessary to allow for test sections. This report will document the implementation of slag stabilized blended calcium sulfate BCS in a pavement structure.

OBJECTIVE

The current project seeks to further the implementation of this stabilized material within DOTD and to a broader, commercial market (nationally, locally, contractors, etc.)

This project will focus on the variation of strengths obtained through stabilization of BCS with slag to meet the needs of highway and other commercial needs, like local roads, driveways, etc. The project will research and document slag-treated BCS test sections conducted by LTRC.

Objectives of the research are to determine the applicability and implementation of slag-treated BCS within DOTD projects, and develop potential applications for slag-treated BCS for lower volume roads and commercial applications.

SCOPE

This research project focused on the implementation of full-scale highway test sections including supporting laboratory and field-testing for verification. The highway project identified for the research was DOTD project, H.000329, which entailed an overlay on Airline Highway, US 61, from LA 22 to LA 74 in Ascension Parish.

This research project focused specifically on the outside shoulders of Airline Hwy, south of its intersection with LA 22 in Sorrento, LA, to about one-half mile south in both travel directions.

METHODOLOGY

The Project

Site Plan

The site plan in Figure 1 shows the stretch of shoulders addressed by this research project.

Figure 1
Site plan

The original shoulder cross section consisted of the layers described in Table 1.

Table 1
Airline Highway shoulder, original cross-section detail

3.0 Inches of Asphalt Concrete
8.5 Inches of BCS
Subgrade

On January 11, 2012, LTRC personnel met with District 61 crews at the site to view the project, view pavement distress, and collect samples for research. The asphalt peeled away easily with a backhoe, and the BCS was exposed and sampled. It appeared to be uniform and fine-grained. LTRC collected material and conducted subsequent gradation curves.

At the preconstruction meeting, held on March 7, 2012, at the District 61 office in Baton Rouge, LTRC discussed the potential benefit of the recent research (03-8GT) to address the existing BCS shoulders. Honeywell representatives were also in attendance and discussed their willingness to offer funding to assist with the test sections. The goal was to treat the shoulders with slag in two ways: (1) in-place, similar to treating a base course with cement (except with slag) and (2) provide a pug-milled material to replace the existing base course material. Later discussions were held between Coastal Bridge, the contractor, and Honeywell regarding a funding agreement.

Specifications were subsequently created by LTRC to detail the research effort and direct the contractor via change order. The specifications were designed to keep the stabilization process above the subgrade soils (8.0 in. vs. 8.5 in.), so as not to contaminate the BCS material with soil with the stabilizer. This would allow the field test sections to more closely relate to the 03-8GT research.

Laboratory Testing

Laboratory tests were conducted to determine the material properties of the BCS. Proctor curves and slag curves were conducted to determine the optimum moisture and maximum dry density, and the amount of slag necessary to achieve the desired strength requirements.

Field Testing

Samples collected from the field from the stabilization process, after mixing, but before compaction, were brought to the LTRC soil laboratory to create samples for strength testing. Additional testing devices included the DCP and the Nuclear Density Gauge, to determine the stiffness of the layers and the level of compaction. These results will also be compared against the District 61 acceptance testing.

Performance Monitoring

Dynamic Cone Penetrometer (DCP)

The DCP is a simple and effective tool for the assessment of in-situ strength of pavement layers and subgrades. Figure 2 shows the DCP device used in this investigation. It consists of an upper fixed 22.7-in. travel rod with 17.6-lb. falling weight hammer, a lower rod containing an anvil, and a replaceable 60° cone of ¾ in. diameter. DCP tests were conducted in the field through the new shoulders at different times after construction.
The test involves lifting and dropping the hammer to strike the anvil, which then penetrated the ¾ in. diameter cylindrical cone from the surface down, providing continuous

measurements of in-situ strength and stiffness without destructive sampling. During the test, the penetration for each hammer blow was recorded and later plotted. Flatter plots represent stiffer layers and steeper plots represent weaker layers. Very stiff layers reduce penetration rates so much (< 1 mm/blow) that the test is ceased to prevent damage to the equipment.

Figure 2
Dynamic cone penetrometer (DCP)

Surface Monitoring
The pavement surface was visually monitored for cracking, rutting, potholes, and any forms of distress.

Dynaflect
The "Dynamic Deflection Determination System" (DYNAFLECT) is a trailer- mounted electro-mechanical device. A dynamic load is induced on the pavement and the resulting deflections are measured with five geophones spaced at 1-ft. intervals from point of load application. The pavement is subjected to a 1,000-lb. dynamic load at a frequency of eight cycles per second produced by the counter rotation of two unbalanced flywheels. The load is transmitted vertically to the pavement through two steel wheels spaced 20 in. center-to-center. The deflection measurements are expressed in terms of milli-inches (thousandths of an inch). The Dynaflect was used to determine a structural number and modulus for the pavement layers.

Falling Weight Deflectometer (FWD)
The falling weight deflectometer is a trailer-mounted device, which delivers an impulse load to the pavement. The equipment uses a weight lifted to a given height and dropped onto a 300-mm circular load plate. The plate is mounted with a thin rubber pad underneath. A load cell measures the force caused by the applied load to the pavement under the plate. The deflections caused by the impulse load are measured by seven sensors and can be displayed by the computer in either mils or microns. The peak load magnitude can be measured as both force and pressure in metric units kPa and kN/m^2, or English units lbf and psi. The first sensor is always mounted in the center of the load plate, while sensors 2-7 are spaced at

various distances up to 10 ft. from the load center. The impulse load can be varied by changing the mass of the falling weight, the drop height, or both. The FWD was used to back-calculate a correlated subgrade modulus. Both the Dynaflect and the FWD collected measurements over several time periods to show any gains in pavement layer strength.

Field Cores

LTRC crews cored the test sections with a drilling rig outfitted with a core barrel. Samples were collected and returned to the LTRC laboratory for strength testing.

DISCUSSION OF RESULTS

The specifications developed for this project utilizing the slag treated BCS research in the test sections are included as Appendix A.

Laboratory Work

Grain Size Analysis

LTRC conducted grain size analyses on material collected from the site prior to construction activities. The gradation curves for the material found onsite is shown in Figure 3, along with specification ranges for currently allowed BCS base course material. The onsite material was non-plastic and light grey in color.

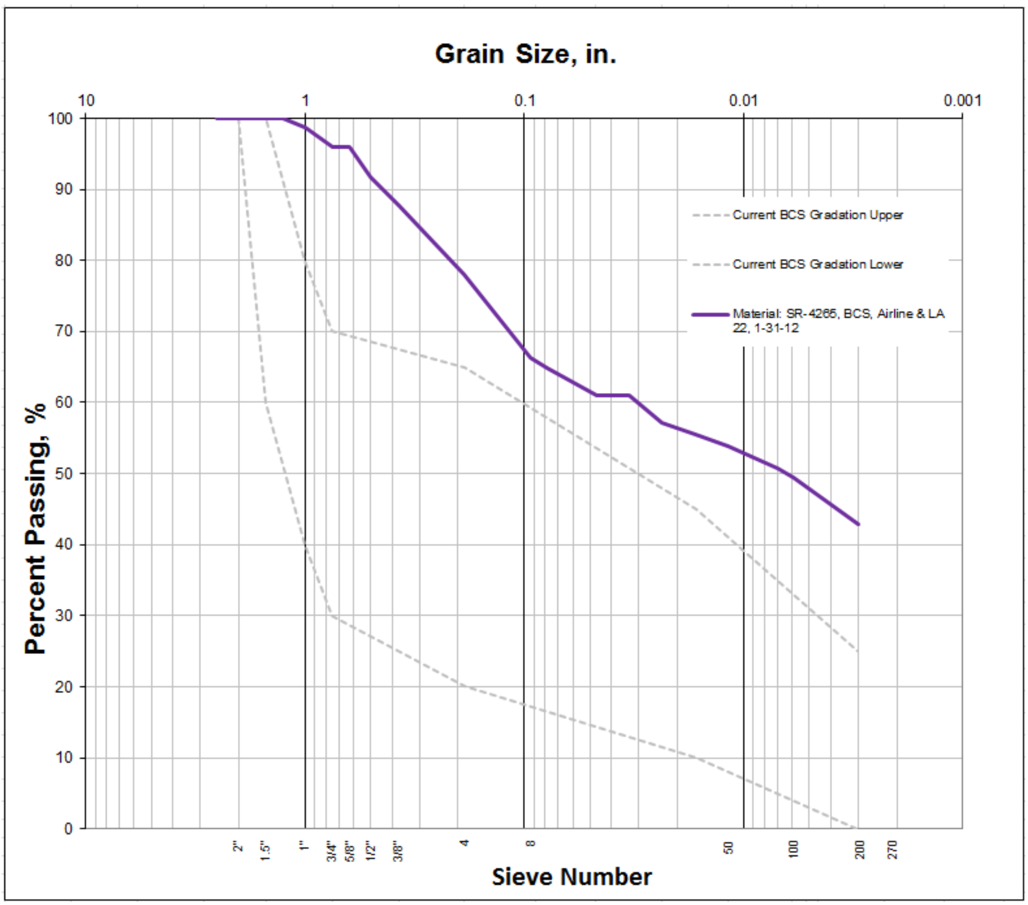


Figure 3
Grain size analysis

Slag Stabilization Percentages for BCS

Utilizing the material obtained from the site during the initial preconstruction visit, LTRC molded samples with various amounts of slag, and at different moistures, to determine the appropriate additive rate of slag to create a more stable shoulder base. The results indicated that 5 percent slag by weight (8 percent by volume) at 14 percent moisture would produce the needed shoulder strengths.

Table 2
BCS with slag at 10 percent moisture

% slag by weight	Sample #	Dry Density pcf	7 day UCS psi	28 day UCS psi	Molding Moisture %	Break Moisture %	Average Dry Density pcf	Average UCS psi	Average Molding Moisture %	Average Break Moisture %
0	1	98.1	37	--	8.5	7.4	98.6	50.3	8.5	6.5
	2	98.2	62	--	9.0	6				
	3	99.6	52	--	7.9	6.2				
3	1	98	360	--	8.5	5.2	99.0	280.0	8.0	5.8
	2	100	200	--	7.7	6				
	3	96.9	--	221	8.9	4.4	--	--	--	--
5	1	99.3	190	--	8.4	3.9	99.5	186.5	8.2	4.4
	2	99.7	183	--	7.9	4.8				
	3	98.6	--	124	8.4	4.5	--	--	--	--
8	1	102.2	244	--	8.4	7.2	101.2	237.0	9.3	6.9
	2	100.2	230	--	10.2	6.6				
	3	101.9	--	150	10.0	5.9	--	--	--	--

* Samples were cured in 100% humidity room, and then placed in lab to air dry at room temperature for 4 hours.

Table 3
BCS with slag at 14 percent moisture

% slag by weight	Sample #	Dry Density pcf	7 day UCS psi	28 day UCS psi	Molding Moisture %	Break Moisture %	Average Dry Density pcf	Average UCS psi	Average Molding Moisture %	Average Break Moisture %
0	*1	94.2	66	--	11.9	1.3	93.6	62.7	12.5	1.0
	*2	94.2	68	--	13	1.2				
	*3	92.5	54	--	12.5	0.6				
3	1	100.0	160	--	13.4	10.1	100.0	167.5	12.6	10.1
	2	100.0	175	--	11.8	10.1				
	3	100.4	--	130	12.2	10.2	--	--	--	--
5	1	103.8	245	--	11.7	10.7	102.7	247.0	12.1	10.9
	2	101.5	249	--	12.5	11				
	3	101.6	--	179	12.1	10.9	95.8	359.3	9.1	7.4
	4	94.0	--	410	8	6.1				
	5	94.5	--	438	7.7	6.4				
	6	93.0	--	410	8.7	6.2				
8	1	100.6	282	--	11.7	8.2	101.2	289.0	11.8	8.5
	2	101.8	296	--	11.9	8.7				
	3	101.3	--	193	11.3	8.6	96.2	500.8	9.3	7.0
	4	94.9	--	586	8.5	6.5				
	5	94.1	--	549	7.9	6.4				
	6	94.3	--	675	9.4	6.3				

* Samples were cured in 100% humidity room, and then placed in lab to air dry at room temperature for 4 hours.

Field Work

Southbound Shoulder

The southbound outside shoulder (SB) was the first section engaged by the contractor. The intent of this section was to pulverize and stabilize the BCS in-place with slag to 8 in. to minimize contamination with embankment soils.

On June 28, 2012, the contractor began pulverizing the shoulders on the southbound shoulder to prepare for stabilization operations. During the pulverization activities, the contractor hit an old railroad spur, damaging his stabilizer. The stabilizer was repaired within a few days and continued pulverization.

On the first day of stabilization, June 29, 2012, slag was spread across the shoulder and stabilization started from the north heading south. However, about midway through the stabilization, LTRC noticed the stabilized material's color was darker than the normal light grey color of BCS. LTRC investigated this and discovered that the operator was cutting too deep, in contrast to the intent of stabilizing only 8 in. to stay above the subgrade. The contractor had also previously pulverized to a depth of 12 in. (vs. 8 in.).

From the point of discovery toward the south, the operator raised the stabilizer to the appropriate depth of 8 in. as defined in the specification. This left two different cross-sections on the southbound shoulder, shown in Figure 4. Neither of these met the original intent of the research. These stations were therefore delineated as SB-1 and SB-2 to reflect this difference in slag concentration and depth of slag cut.

SB-1. The deeper pulverization (12 in. vs. 8 in.) blended subgrade soil with the BCS, contaminating the BCS along the entire southbound shoulder. In hindsight, this deeper than intended cut may be why the stabilizer snagged the old railroad spur.

The design amount of slag was spread on this section, but blended with the stabilizer over a larger (deeper) volume, thus diluting the percentage of slag and its effectiveness.

SB-2. Like SB-1, the BCS was contaminated with subgrade soil during the pulverization process; however, in this section (station 15+70 and lower) the designed percentage of slag was applied and cut to the correct depth. This left the correct amount of slag to work on BCS contaminated with subgrade soil.

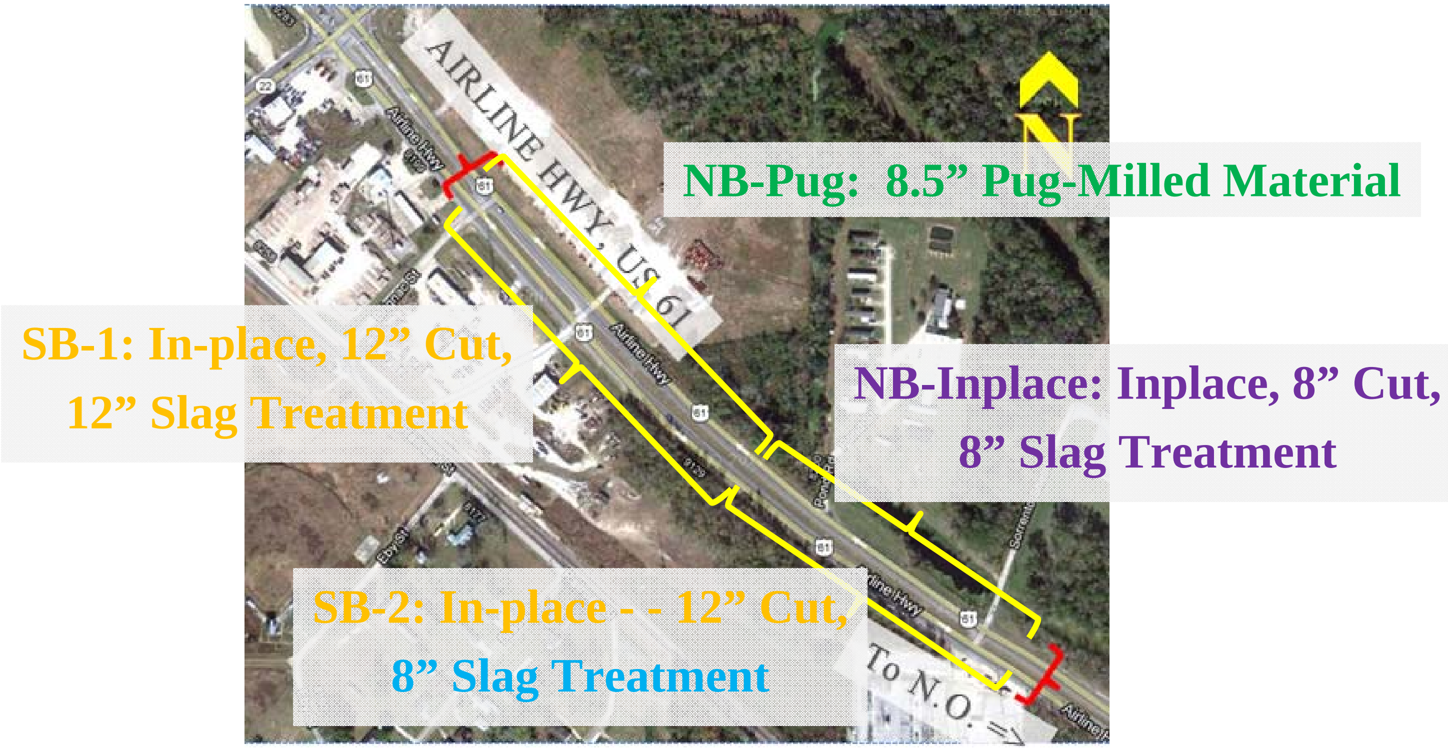


Figure 4
Constructed test sections

Both sections were left to see if they would meet acceptable strengths, even with the cutting error. The seven-day strength tests, the DCP, and FWD tests would be reviewed to determine if the shoulders needed to be removed.

Compressive strength results of samples composed of field mixed material (molded in the laboratory from the sections SB-1 and SB-2) are shown in Table 4. The seven-day strengths were very low, similar to raw BCS. These results were likely low because of the soil-contaminated BCS, and the dilution of the prescribed slag over the deeper cut. There was one exceptional strength, 12+00, 28-day, at the end of the job where the slag cut was to 8 in., not diluting the slag, and possibly at higher percentages where the slag distribution truck may have over applied before departing the job.

Table 4
Southbound field compressive strengths

	Station	Molding Moisture (%)	Dry Density (pcf)	Compressive Strength (psi)		Break Moisture (%)
		7-day Compressive Strengths				
SB-1 12" Pulverized with 12" Stabilized	24+50	12.0	113.5	30.0	32.7	--
		12.6	112.6	34.2		12.3
		12.8	111.7	33.8		11.5
	19+95	13.2	110.0	45.4	35.7	11.3
		14.7	107.8	34.2		13.1
		13.9	107.9	27.5		12.8
SB-2 12" Pulverized with 8" Stabilized	15+00	14.8	106.8	25.5	23.8	14.4
		13.9	107.8	22.7		15.5
		15.5	105.7	23.1		14.3
	12+00	13.1	107.1	33.8	37.9	11.4
		13.2	106.9	38.6		13.0
		13.1	106.7	41.4		13.5

	Station	Molding Moisture (%)	Dry Density (pcf)	Compressive Strength (psi)		Break Moisture (%)
		28-day Compressive Strengths				
SB-1 12" Pulverize d with 12" Stabilized	24+50	13.4	111.3	54.0	51.7	14.3
		14.2	110.2	47.7		13.3
		13.0	111.9	53.4		18.5
	19+95	15.1	107.6	74.5	86.6	17.4
		12.6	110.1	85.5		12.1
		11.4	111.0	99.9		12.3
SB-2 12" Pulverize d with 8" Stabilized	15+00	15.3	106.9	60.3	49.7	12.1
		14.2	107.7	39.7		13.7
		14.0	107.7	49.2		12.4
	12+00	13.3	106.6	486.0	381.8	10.7
		13.9	105.9	331.6		11.2
		14.4	105.6	327.7		11.6

FWD results for the southbound shoulder are shown in Table 5 and average FWD values are shown in Figure 5. Dynaflect results for the southbound shoulder are shown in Table 6 and average Dynaflect values are shown in Figure 6. The 28-day results (July 30) for the slag, BCS, and soil showed marginal FWD modulus results at the time of analysis. Three values were over 300 ksi, but a couple values were around 150 ksi, and one value was 12 ksi. For reference, cement treated soil has a typical FWD modulus of about 200 ksi.

The FWD and Dynaflect results did show an improvement over time with subsequent measurement events on September 26, October 18, October 25, January 3, and April 2, roughly representing, 3-month, 3.5-month, 6-month, and 7-month readings after construction. The most remarkable improvement was in SB-2 at station 12+00.

Table 5
Southbound FWD results

		US 61 South Bound Shoulder BCS & Slag FWD Modulus Data (ksi)										US 61 South Bound Shoulder BCS & Slag FWD Modulus Data (ksi)											
		7/30/2012			9/26/2012			10/18/2012				10/25/2012				1/3/2013				4/2/2013			
	Station	Slag, BCS, & Soil	Pulverized BCS & Soil, SB-2 Only	Correlated Subgrade	Slag, BCS, & Soil	Pulverized BCS & Soil, SB-2 Only	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 73°	Slag, BCS, & Soil	Pulverized BCS & Soil, SB-2 Only	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 75°	Slag, BCS, & Soil	Pulverized BCS & Soil, SB-2 Only	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 44°	Slag, BCS, & Soil	Pulverized BCS & Soil, SB-2 Only	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 44°	Slag, BCS, & Soil	Pulverized BCS & Soil, SB-2 Only	Correlated Subgrade
SB-1	28+00	154.1		8.3	--		--	239.6	53.9		10.5	166.1	64.8		11.1	198.0	95.9		9.4	229.2	61.0		9.9
	26+00	394.0		6.8	450.7		7.3	118.1	391.8		11.7	131.2	183.6		13.1	131.2	329.0		12.2	162.0	364.5		11.6
	24+00	381.3		13.4	722.2		23.5	112.2	224.7		48.9	106.3	239.6		48.4	131.2	342.4		35.1	131.2	380.9		35.9
	22+00	250.7		7.1	167.4		8.8	178.2	137.8		12.1	149.4	80.0		14.3	160.4	165.8		13.0	69.7	202.9		13.8
	20+00	153.7		6.7	327.2		8.5	150.1	296.2		13.2	145.8	266.8		14.2	145.8	263.8		12.3	145.8	300.1		11.9
	18+00	--		--	37.7		8.9	198.0	56.9		11.2	175.3	63.9		11.1	203.0	50.4		10.6	169.3	108.3		12.3
	16+00	308.1		7.3	462.3		8.4	142.2	282.6		13.9	86.6	368.8		13.3	174.5	106.2		10.8	73.4	327.1		10.9
	AVG.	**273.7**	**--**	**8.3**	**361.3**	**--**	**10.9**	**162.6**	**206.3**	**--**	**17.4**	**137.2**	**181.1**	**--**	**17.9**	**163.4**	**193.4**	**--**	**14.8**	**140.1**	**249.3**	**--**	**15.2**
SB-2	14+00	12.9	6.5	10.2	1047.6	1.0	14.7	59.0	333.3	36.4	13.1	39.7	480.0	40.3	12.6	75.8	346.3	23.6	11.3	47.5	456.1	19.8	11.7
	12+00	515.4	257.5	10.8	341.3	100.9	10.5	37.3	394.3	36.0	12.2	33.4	342.7	39.6	12.8	50.8	581.9	23.3	10.8	38.6	1058.3	21.9	10.9
	AVG.	**264.2**	**132.0**	**10.5**	**694.5**	**51.0**	**12.6**	**48.2**	**363.8**	**36.2**	**12.7**	**36.6**	**411.4**	**40.0**	**12.7**	**63.3**	**464.1**	**23.5**	**11.1**	**43.1**	**757.2**	**20.9**	**11.3**

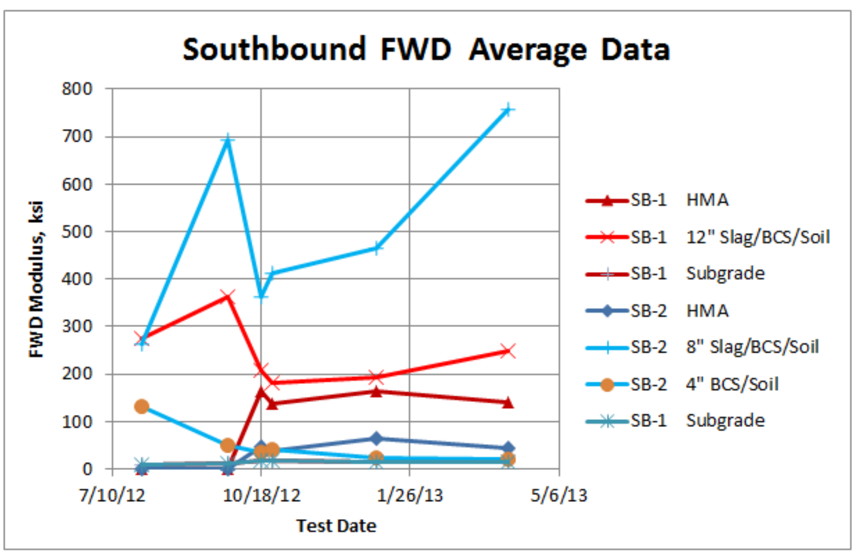


Figure 5
Southbound FWD averages

Table 6
Southbound Dynaflect results

	Station	6/27/2012 SN	6/27/2012 Es (ksi)	7/30/2012 SN	7/30/2012 Es (ksi)	9/26/2012 SN	9/26/2012 Es (ksi)	10/18/2012 SN	10/18/2012 Es (ksi)	10/25/2012 SN	10/25/2012 Es (ksi)	1/3/2013 SN	1/3/2013 Es (ksi)
		US 61 South Bound Shoulder BCS & Slag Dynaflect Data											
SB-1	28+00	1.2	3.7	1.5	3.6			1.0	3.8	1.2	3.8	1.5	4.1
SB-1	26+00	1.3	3.6	1.9	3.4	2.7	3.6	3.2	3.7	3.1	3.6	3.5	4.0
SB-1	24+00	3.1	4.6	2.6	4.6	3.9	4.8	4.6	5.0	4.5	5.1	4.4	5.5
SB-1	22+00	1.4	3.6	1.9	3.6	2.0	3.6	2.3	3.7	2.4	3.7	2.7	4.1
SB-1	20+00	1.7	3.6	1.8	3.5	2.6	3.7	3.0	3.7	3.0	3.7	3.3	4.1
SB-1	18+00	2.3	3.7	--	--	1.1	3.7	1.5	3.7	1.4	3.7	1.2	4.1
SB-1	16+00	1.7	3.7	2.1	3.7	2.7	3.7	3.1	3.7	3.1	3.8	2.2	4.0
	AVG.	**1.8**	**3.8**	**2.0**	**3.7**	**2.5**	**3.8**	**2.7**	**3.9**	**2.7**	**3.9**	**2.7**	**4.3**
SB-2	14+00	1.3	3.7	0.4	3.8	1.6	3.7	2.5	3.9	2.1	3.8	2.1	4.0
SB-2	12+00	1.8	3.8	2.7	3.9	2.4	3.8	2.4	3.8	2.5	3.7	2.7	4.1
	AVG.	**1.6**	**3.8**	**1.6**	**3.8**	**2.0**	**3.8**	**2.5**	**3.8**	**2.3**	**3.8**	**2.4**	**4.0**

Note: SN = Structure Number; Es = Correlated Es

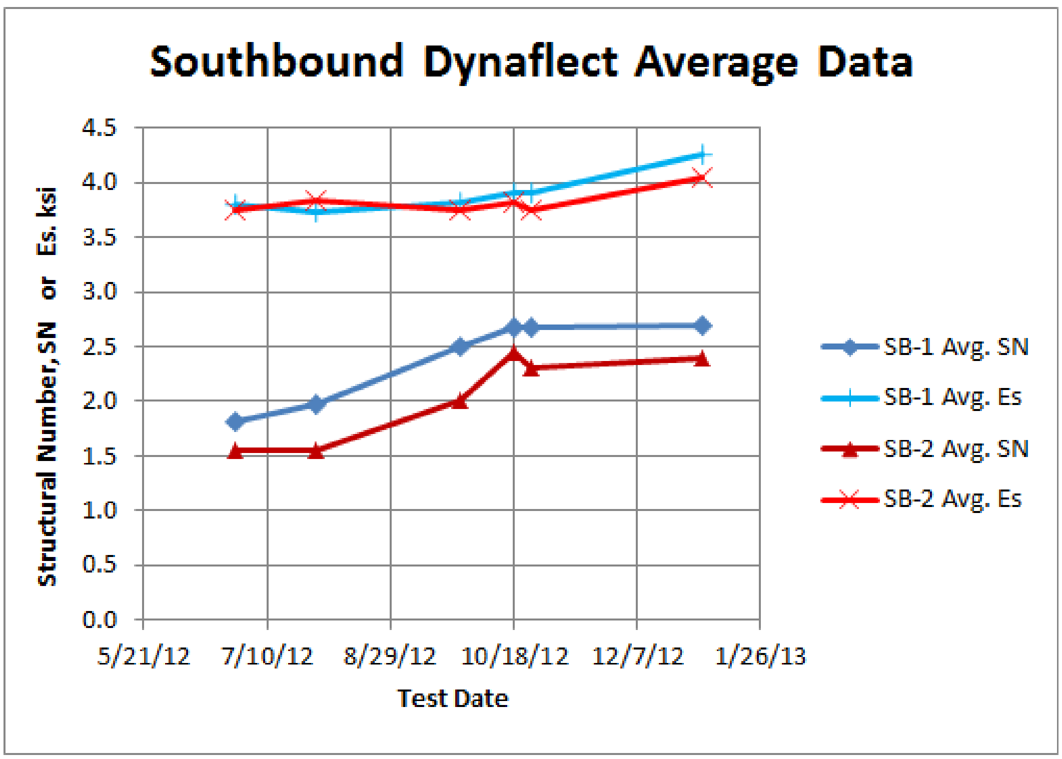


Figure 6
Southbound Dynaflect averages

The DCP results, collected from 3, 10, 18, and 28 days after compaction, are shown in Figure 7 through Figure 12. The results show various locations and the penetration vs. the blow count. Steeper lines on the charts indicate softer material, while in contrast, flatter lines indicate stiffer material (i.e., more blows to penetrate). The figures show flatter lines with each subsequent event indicating strength/stiffness gains with time. Yet by the 28th day,

Figure 12, not all stations increased to the desired/anticipated minimum range (roughly equal to crushed stone base course) of 3 to 5 mm/blow.

After review of the 28-day data (weak strengths, marginal FWD and Dynaflect, and marginal DCP results), the decision was made in conjunction with Honeywell to remove this material, even though marginal. Honeywell did not want to have questionable sections and potential confusion (with their material) should that shoulder not perform well in the long-term. They elected to excavate the SB-1 and SB-2 material and replace with BCS aggregate material currently allowed by the Department.

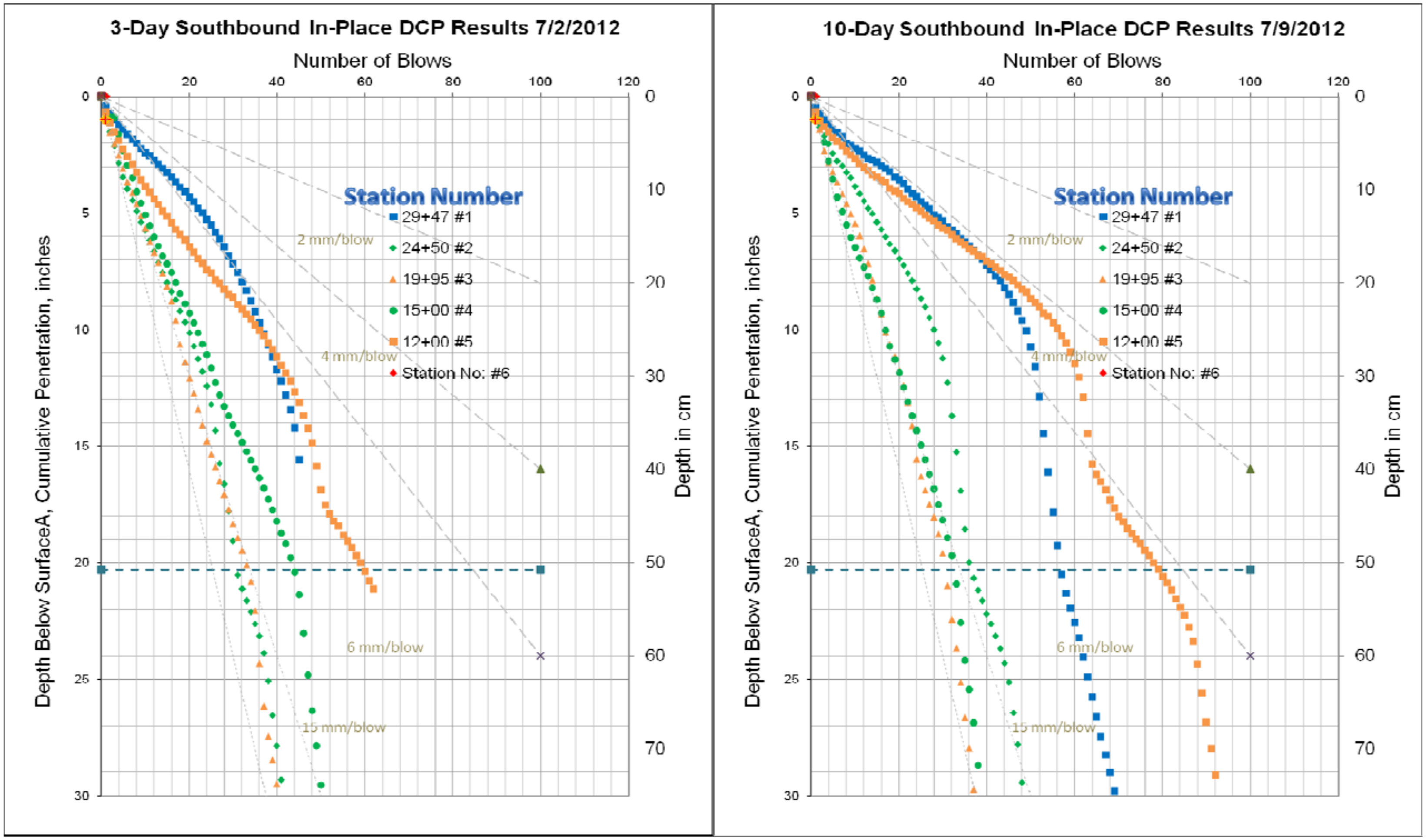


Figure 7
Southbound 3-day and 10-day DCP results

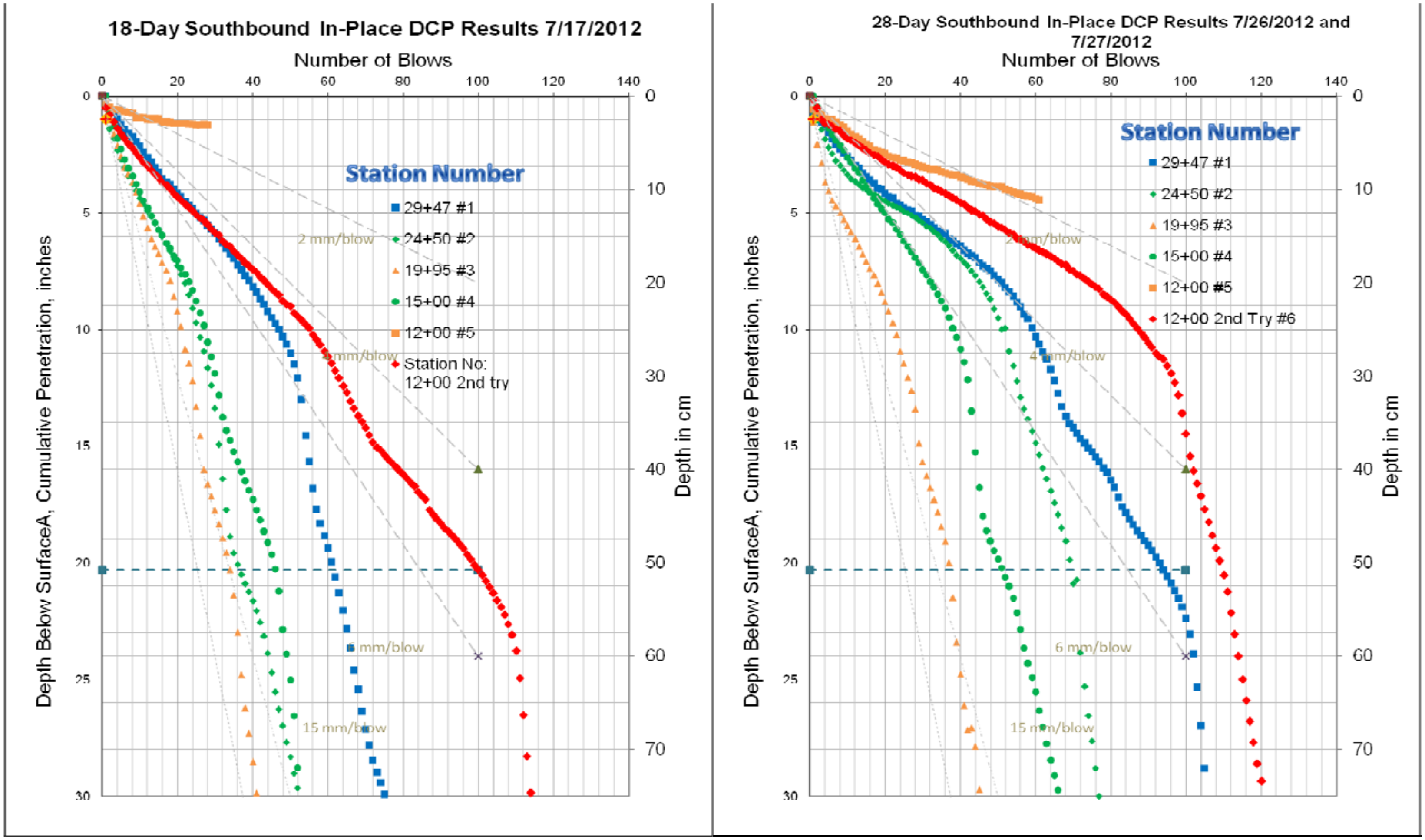


Figure 8
Southbound 18-day and 28-day DCP results

Table 7
Southbound DCP results

	Station No.	Layer Thickness (in.)	Layer Type	3-day	10-day	18-day	28-day	9-month
				DCP Index (mm/blow)				
Southbound In-Place BCS	29+50 SB-1	4	BCS	5.2	4.2	5.7	4.7	--
		4	BCS	7.4	4.8	5.0	3.2	--
		12	Embankment	14.9	22.9	13.9	7.3	--
	24+50 SB-1	4	BCS	15.4	8.6	10.0	6.1	2.0
		4	BCS	11.3	7.9	7.8	3.3	1.1
		12	Embankment	19.9	23.6	21.9	12.6	--
	19+95 SB-1	4	BCS	13.0	14.7	13.1	18.8	3.8
		4	BCS	12.8	13.4	11.3	7.8	1.1
		12	Embankment	16.9	18.6	20.3	16.3	--
	15+00 SB-2	4	BCS	13.5	20.7	10.9	6.6	Refusal
		4	BCS	11.0	13.2	7.5	6.1	Refusal
		12	Embankment	11.5	16.2	13.6	16.4	--
	12+00 SB-2	4	BCS	8.8	4.8	5.2	3.0	Refusal
		4	BCS	6.2	3.6	4.0	2.5	Refusal
		4	Embankment	9.5	9.6	5.6	8.7	--

Corrective Action. Weeks later, at the time of excavation, the shoulder material had gained further strength, preventing removal with an excavator. The decision was made to leave the shoulder alone and cancel the removal. This follows with the 03-8GT research that slag reacts slower than cement, and may take longer to gain the required strength. This was further confirmed by the stiff and refusal readings collected at the 9-month date.

Since the original intent and objective of the research was not met by the southbound shoulder, the decision was made to attempt it on the northbound shoulder. To squeeze everything in, the pug-milled section would be shorter than originally designed, and not enough room for a proposed section of Honeywell BCS with a new (coarser) gradation. The constructed sections are previously shown in Figure 4 and detailed in Table 8.

Table 8
Airline Highway shoulder, constructed cross-section detail

<table>
<tr><td>Direction</td><td>Original Construction</td><td>Southbound Shoulder</td><td>Southbound Shoulder</td><td>Northbound Shoulder</td><td>Northbound Shoulder</td></tr>
<tr><td>Name</td><td>--</td><td>SB-1</td><td>SB-2</td><td>NB-Inplace</td><td>NB-Pug</td></tr>
<tr><td>Station</td><td>--</td><td>~29+50 to 15+70</td><td>15+70 to 10+00</td><td>10+00 to 19+50</td><td>19+50 to ~29+50</td></tr>
<tr><td>Asphalt Concrete</td><td>3.0 in.</td><td>3.0 in.</td><td>3.0 in.</td><td>3.0 in.</td><td>3.0 in.</td></tr>
<tr><td rowspan="2">Base Course</td><td rowspan="2">8.5 in. BCS</td><td rowspan="3">Pulverized with a 12 in. cut, Stabilized with Slag to 12 in.</td><td>Pulverized with a 12 in. cut, Stabilized with Slag to 8 in.</td><td>Pulverized with 8 in. cut, Stabilized with slag to 8 in.</td><td rowspan="2">Existing Base Excavated.

New Fines BCS Pug-Milled with Slag Offsite.

8.5 in. Placed Onsite</td></tr>
<tr><td rowspan="2">Pulverized & Compacted, Not Treated</td><td>0.5 in. BCS</td></tr>
<tr><td rowspan="2">Subgrade</td><td rowspan="2">Subgrade</td><td rowspan="2">Subgrade</td><td rowspan="2">Subgrade</td></tr>
<tr><td>Subgrade</td><td>Subgrade</td></tr>
</table>

Northbound Shoulder

Two different cross sections were created on the northbound shoulder of US 61. The first section, NB-Inplace, begins at the southernmost shoulder of the northbound US 61 lane. This section would replicate the original intent of the southbound shoulder, an in-place slag treated BCS. Figure 4 previously showed the location and differences of the test sections at the site.

The latter of the northbound sections, NB-Pug, would consist of pug-milled material created off-site. The existing material was removed and replaced with the pug-milled slag-BCS mixture. The material was prepared, placed, and compacted by Brown Industries.

NB-Inplace. The construction of this section began at station 10+00, heading north. The moisture in the stabilizer was high at the start of the day's operations. Higher moisture contents usually benefit the slag-BCS reaction; however, the higher moistures created a pumping problem that revealed itself during compaction operations. Pumping and moisture sensitivity has been a troubling point for the BCS material.

After mixing, the contractor found the material pumped and was difficult to shape and (obtain) grade. Figure 9 shows a picture of the rough surface of the wet slag-BCS after compaction.

Figure 9
Wet slag-BCS with pumping issue

The samples molded in the field were allowed to cure, but were so soft, they slumped under their own weight. They were able to be tested; however, their results were weak at the 7- and 28-day breaks. The results are shown in Table 9.

FWD and Dynaflect results were conducted on the NB-Inplace and are shown in Table 10 and Table 11. The June 27 Dynaflect reading indicates a reference measurement taken on the original BCS after the old asphalt was removed. Both sets of results appear to be relatively flat over the course of 3.5 months after construction. An extra measurement was collected with the FWD on April 2, which also continues the trend.

The DCP results are shown in Figure 10 through Figure 12 with a general trend of flattening over time as seen with subsequent curves flattening (stiffening). Eventually some DCP results reached refusal (<1 mm/blow penetration) indicating very stiff material.

Table 9
NB-Inplace field compressive strengths

	7-day Compressive Strengths				
Location	Molding Moisture (%)	Dry Density (pcf)	Compressive Strength (psi)		Break Moisture (%)
Station 11+00	15.9	107.6	14.8	13.8	13.5
	15.9	106.4	13.0		15.8
	15.9	106.3	13.5		14.5
Station 13+50	14.8	103.5	19.6	20.6	14.6
	14.8	103.6	21.6		13.2
	--	--	--		--
Station 16+00	15.7	104.4	20.6	19.9	15.2
	15.7	104.9	19.3		15.5
	15.7	104.7	19.8		14.8
Station 18+00	15.9	108.0	17.6	18.1	13.2
	15.9	108.3	18.4		13.9
	15.9	107.3	18.4		14.6

	28-day Compressive Strengths				
Location	Molding Moisture (%)	Dry Density (pcf)	Compressive Strength (psi)		Break Moisture (%)
Station 11+00	14.2	108.7	110.8	111.8	14.1
	14.2	108.1	88.5		13.2
	14.2	107.8	136.2		11.7
Station 13+50	15.5	103.4	108.6	95.5	14.1
	15.5	103.7	112.7		13.4
	15.5	103.3	65.1		14.1
Station 16+00	16.0	105.0	61.6	61.8	13.7
	16.0	106.1	59.5		13.3
	16.0	105.4	64.3		12.5
Station 18+00	15.9	107.2	18.8	20.5	13.8
	15.9	106.6	21.5		15.0
	15.9	106.0	21.2		11.5

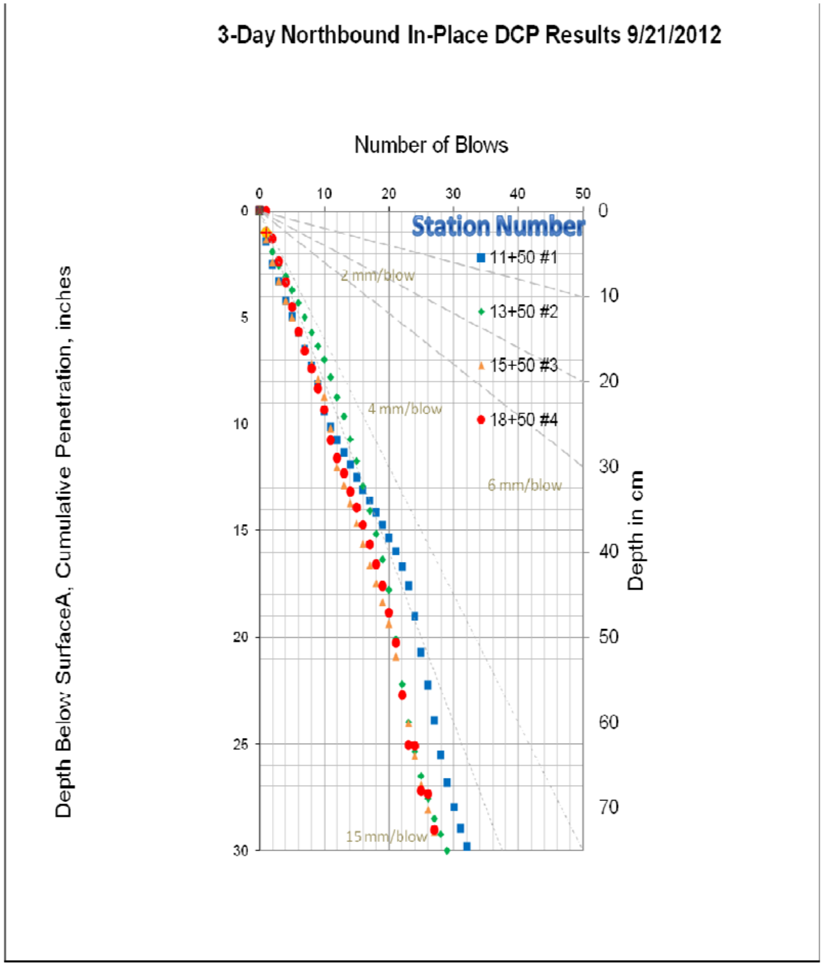
Table 10
NB-Inplace Dynaflect results

	Station	US 61 North Bound Shoulder BCS & Slag Dynaflect Data							
		6/27/2012		10/18/2012		10/25/2012		1/3/2013	
		SN	Es (ksi)	SN	Es (ksi)	SN	Es (ksi)	SN	Es (ksi)
NB-Inplace	11+75			1.7	3.7	1.3	3.7	2.1	4.2
	12+00	0.1	3.8	1.6	3.9	1.6	3.9	2.0	4.5
	13+50			-0.5	3.8	1.2	3.7	1.9	4.4
	14+00	0.7	3.8	-0.7	3.8	0.9	3.7	2.6	4.1
	16+00	-0.2	3.9	2.6	3.8	2.6	3.9	3.5	4.3
	18+00	1.1	3.4	-0.6	3.4	0.9	3.5	1.9	4.1
	18+50			-0.9	3.7	0.7	3.6	2.9	4.1
	AVG.	0.4	3.7	0.5	3.7	1.3	3.7	2.4	4.2

Note: SN = Structure Number; Es = Correlated Es

Table 11
NB-Inplace FWD results

	Station	US 61 North Bound Shoulder BCS & Slag FWD Modulus Data (ksi)											
		10/18/2012			10/25/2012			1/3/2013			4/2/2013		
		1.5" HMA, Seed Value 200, Prev. Day Temp. 73°	8" Slag / BCS	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 75°	8" Slag / BCS	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 44°	8" Slag / BCS	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 44°	8" Slag / BCS	Correlated Subgrade
NB-Inplace	11+75	124.7	298.2	12.3	112.2	244.6	12.0	152.0	375.3	13.0	233.6	279.6	10.4
	12+00	215.6	155.6	13.6	191.1	193.7	13.8	162.5	232.8	13.0	206.9	109.1	11.9
	13+50	198.0	134.4	12.0	145.8	324.4	11.9	146.2	418.6	9.9	152.4	372.0	10.8
	14+00	162.0	134.7	11.6	178.2	148.3	12.0	153.9	482.3	10.6	180.9	341.2	10.5
	16+00	124.7	339.8	16.1	69.7	968.7	13.3	37.2	1386.1	12.2	96.1	1413.2	11.6
	18+00	138.6	89.8	9.6	187.1	138.0	10.1	212.4	202.5	9.6	116.9	365.1	8.7
	18+50	217.8	77.7	9.6	161.6	124.3	10.9	99.2	604.5	11.7	32.1	774.4	11.2
	AVG.	168.8	175.7	12.1	149.4	306.0	12.0	137.6	528.9	11.4	145.6	522.1	10.7



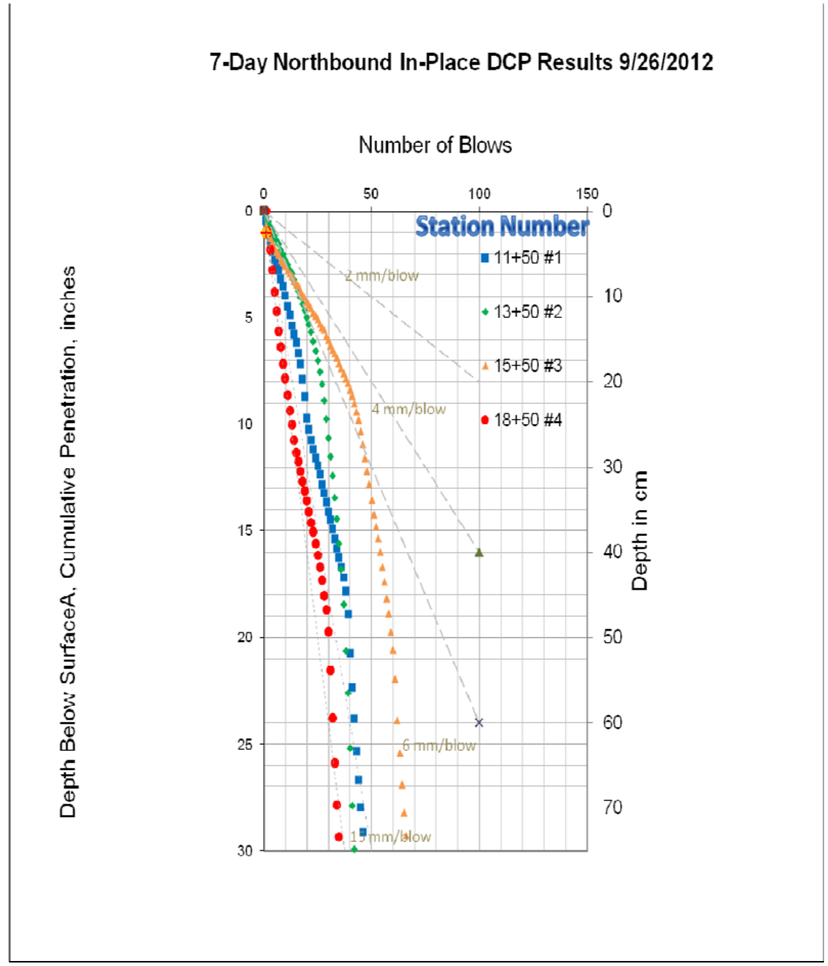
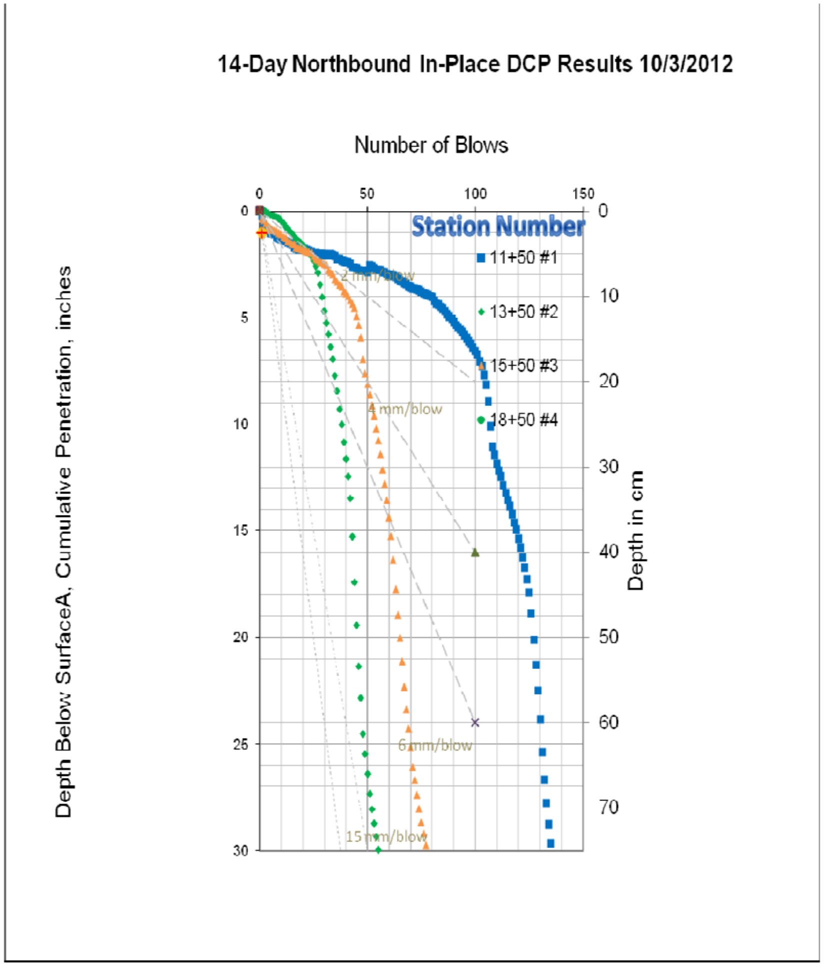


Figure 10
NB-Inplace 3-day and 7-day DCP results



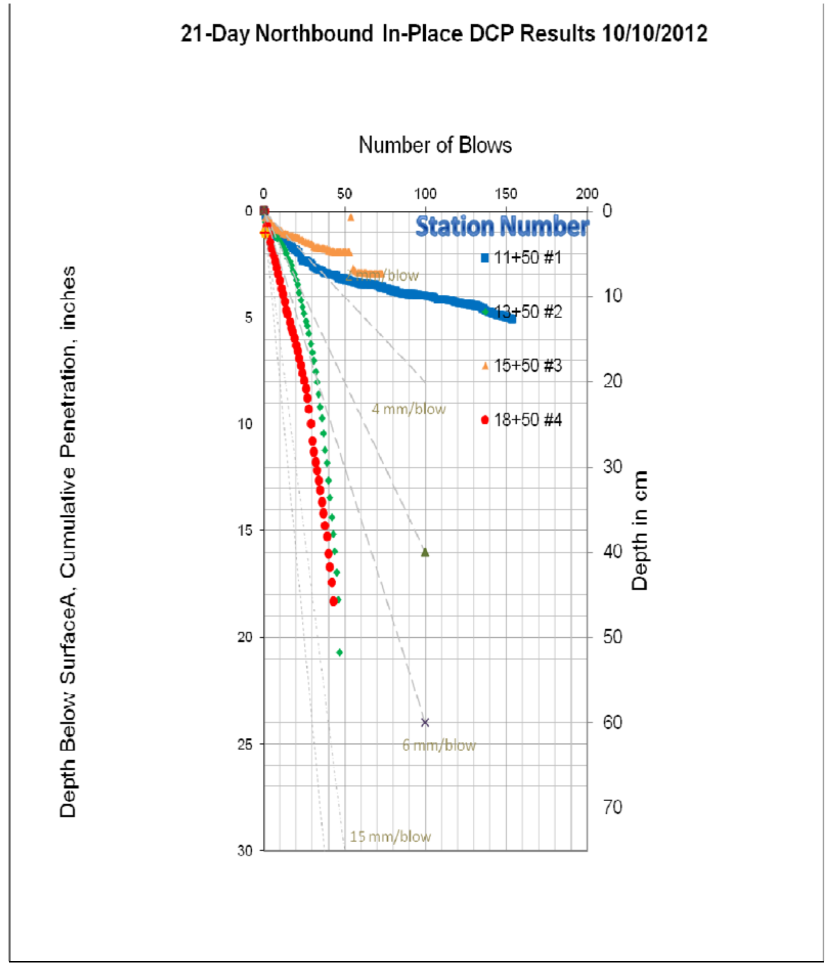


Figure 11
NB-Inplace 14-day and 21-day DCP results

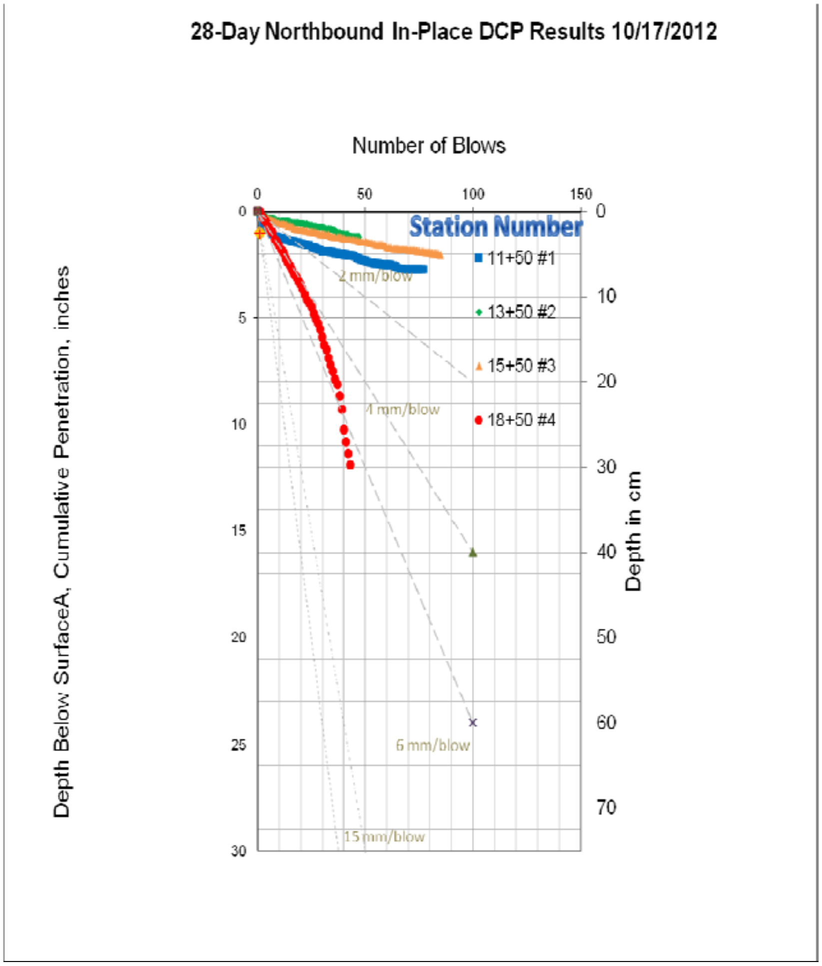


Figure 12
NB-Inplace 28-day DCP results

NB-Pug. This section originated via meetings with Honeywell prior to construction regarding another of their byproducts similar to what was originally found at the US 61 shoulder, a finely graded BCS product. Honeywell's "fines" product was explored as a material to benefit from previous LTRC research (Zhang, Tao, 2007). This "fines" material had roughly 78 percent passing the #200 sieve (per Honeywell). LTRC conducted slag curves to determine the required slag percentage for stabilization.

The "fines" material was mixed with slag in the laboratory at various percentages to determine the appropriate amount for stabilization in the field. The results indicated very high strengths were attainable as shown in Table 12. Based on these results, 5 percent by weight was selected for the NB-Pug section.

Table 12
Honeywell BCS fines slag treatment - laboratory

<table>
<tr><th>% Slag by weight</th><th>Sample #</th><th>Molding Moisture (%)</th><th>Dry Density (pcf)</th><th colspan="2">7-day Compressive Strength (psi)</th><th colspan="2">28-day Compressive Strength (psi)</th><th>Break Moisture (%)</th></tr>
<tr><td rowspan="6">3</td><td>1</td><td>11.3</td><td>--</td><td>109.0</td><td rowspan="3">121</td><td>--</td><td rowspan="3">--</td><td>10.5</td></tr>
<tr><td>2</td><td>11.5</td><td>--</td><td>123.0</td><td>--</td><td>10.4</td></tr>
<tr><td>3</td><td>11.6</td><td>--</td><td>130.8</td><td>--</td><td>10.4</td></tr>
<tr><td>4</td><td>11.3</td><td>103.4</td><td>--</td><td rowspan="3">--</td><td>425.0</td><td rowspan="3">417</td><td>9.9</td></tr>
<tr><td>5</td><td>11.7</td><td>104.6</td><td>--</td><td>395.0</td><td>9.8</td></tr>
<tr><td>6</td><td>11.8</td><td>103.8</td><td>--</td><td>432.0</td><td>10.1</td></tr>
<tr><td rowspan="6">5</td><td>7</td><td>11.4</td><td>--</td><td>621.0</td><td rowspan="3">538</td><td>--</td><td rowspan="3">--</td><td>9.7</td></tr>
<tr><td>8</td><td>11.7</td><td>--</td><td>373.0</td><td>--</td><td>10.2</td></tr>
<tr><td>9</td><td>11.8</td><td>--</td><td>619.0</td><td>--</td><td>9.8</td></tr>
<tr><td>10</td><td>11.3</td><td>104.9</td><td>--</td><td rowspan="3">--</td><td>993.6</td><td rowspan="3">948</td><td>9.3</td></tr>
<tr><td>11</td><td>11.7</td><td>105.3</td><td>--</td><td>999.4</td><td>--</td></tr>
<tr><td>12</td><td>11.9</td><td>104.1</td><td>--</td><td>850.0</td><td>--</td></tr>
<tr><td rowspan="6">8</td><td>*13</td><td>11.8</td><td>--</td><td>868.0</td><td rowspan="3">968</td><td>--</td><td rowspan="3">--</td><td>8.8</td></tr>
<tr><td>*14</td><td>11.4</td><td>--</td><td>943.0</td><td>--</td><td>9.3</td></tr>
<tr><td>*15</td><td>12.5</td><td>--</td><td>1,094.0</td><td>--</td><td>--</td></tr>
<tr><td>16</td><td>11.3</td><td>106.1</td><td>--</td><td rowspan="3">--</td><td>1,120.7</td><td rowspan="3">1,031</td><td>--</td></tr>
<tr><td>17</td><td>12.2</td><td>105.8</td><td>--</td><td>1,033.7</td><td>--</td></tr>
<tr><td>18</td><td>12.1</td><td>106.0</td><td>--</td><td>937.3</td><td>--</td></tr>
</table>

Note: Samples 13 and 14 were 6-day breaks; sample 15 was a 9-day break due to a hurricane threat.

During field construction of the northbound shoulders, the existing shoulder base course BCS material was removed and replaced with pug-milled material (BCS “fines” treated with slag). After placement of the material, but prior to compaction, the material was sampled and returned to the laboratory for molding. These samples were later broken at 7 and 28 days like the previous sections. The results are presented in Table 13. There was a noticeable difference between the first day’s sampled material (Stations 20+50 thru 22+50) and the second day’s sampled material (Stations 23+50 thru 25+75) in that the second section was roughly five times stiffer than the first.

Table 13
NB-Pug field compressive strengths

	7-day Compressive Strengths					28-day Compressive Strengths				
Station	Molding Moisture (%)	Dry Density (pcf)	Compressive Strength (psi)		Break Moisture (%)	Molding Moisture (%)	Dry Density (pcf)	Compressive Strength (psi)		Break Moisture (%)
20+50 Day 1	13.1	103.6	69.4	69.0	12.1	11.9	104.1	57.5	64.0	10.4
	13.1	104.1	64.6		12.6	11.9	106.0	70.5		10.5
	13.1	104.6	72.9		12.7	11.9	104.0	64.0		10.2
21+00 Day 1	13.4	105.4	55.7	60.8	13.5	13.7	104.3	56.6	64.9	12.1
	13.4	105.6	66.9		12.5	13.7	104.6	66.9		11.5
	13.4	105.4	59.9		12.6	13.7	104.2	71.3		10.9
22+50 Day 1	11.6	107.0	63.3	64.4	10.7	11.9	106.5	110.3	101	10.1
	11.6	106.1	53.1		11.4	11.9	106.5	100.9		10.6
	11.6	106.7	76.9		11.8	11.9	106.1	92.6		9.9
23+50 Day 2	10.9	104.4	396.0	405	9.9	11.7	102.4	557.5	630	10.2
	10.9	105.0	376.0		10.0	11.7	104.7	704.1		10.0
	10.9	105.1	441.7		10.1	11.7	104.7	628.3		10.5
24+50 Day 2	11.8	102.9	369.1	457	10.3	12.4	105.1	846.1	728	11.0
	11.8	105.1	496.2		10.3	12.4	103.5	564.0		11.1
	11.8	105.1	505.0		10.0	12.4	105.2	773.4		10.6
25+75 Day 2	12.7	104.4	313.2	310	10.7	11.4	105.9	518.4	490	9.5
	12.7	103.8	294.1		11.2	11.4	104.6	451.2		10.1
	12.7	104.3	321.7		10.8	11.4	106.3	499.9		9.6

FWD and Dynaflect results were also conducted on the NB-Pug section. The results are shown in Table 14 and Table 15. The Dynaflect results generally improved over the monitoring period. The FWD results peaked a little, but remained relatively unchanged.

Table 14
NB-Pug Dynaflect results

Station	US 61 North Bound Shoulder BCS & Slag Dynaflect Data							
	6/27/2012		10/18/2012		10/25/2012		1/3/2013	
	Preconstruction		~24 Days		~ 30 Days		~3 Months	
	SN	Es (ksi)	SN	Es (ksi)	SN	Es (ksi)	SN	Es (ksi)
20+00	0.3	3.6	-1.7	3.7	0.9	3.7	2.6	4.2
20+50			-1.9	3.8	-0.5	3.8	0.7	4.3
21+00			-1.0	3.8	0.7	3.7	2.0	4.1
22+00	0.7	3.8	1.9	3.6	2.1	3.7	3.2	4.2
22+50			-2.4	3.7	1.0	3.6	1.3	4.2
23+00			-1.6	3.7	1.0	3.6	1.3	4.2
24+50			1.1	3.7	1.5	3.7	2.8	4.3
AVG.	0.5	3.7	-0.8	3.7	1.0	3.7	2.0	4.2

Note: SN = Structure Number; Es = Correlated Es

Table 15
NB-Pug FWD results

Station	US 61 North Bound Shoulder BCS & Slag FWD Modulus Data (ksi)											
	10/18/2012			10/25/2012			1/3/2013			4/2/2013		
	1.5" HMA, Seed Value 200, Prev. Day Temp. 73°	8" Slag / BCS	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 75°	8" Slag / BCS	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 44°	8" Slag / BCS	Correlated Subgrade	1.5" HMA, Seed Value 200, Prev. Day Temp. 44°	8" Slag / BCS	Correlated Subgrade
20+00	161.6	87.9	9.5	239.4	234.6	10.9	98.4	395.1	13.6	86.6	452.9	11.2
20+50	207.9	32.3	8.2	180.0	38.2	9.4	154.0	59.7	8.8	180.0	35.2	8.1
21+00	164.0	59.4	10.4	193.1	107.7	10.9	185.3	194.9	11.9	160.4	230.8	10.4
22+00	128.3	346.0	10.3	129.5	641.5	10.1	237.2	1081.6	10.4	129.9	911.0	8.8
22+50	196.0	76.6	9.9	142.2	108.3	10.1	188.5	74.5	10.7	144.0	83.8	9.3
23+00	178.2	259.6	10.0	179.5	337.1	9.9	62.9	7.7	14.4	200.0	30.7	10.6
24+50	215.5	376.9	11.1	169.7	410.8	11.1	106.3	136.5	16.6	138.6	212.1	12.1
AVG.	178.8	177.0	9.9	176.2	268.3	10.3	147.5	278.6	12.3	148.5	279.5	10.1

For comparison of northbound test sections, the Dynaflect and FWD average values are plotted in Figure 13 and Figure 14. The Dynaflect results show the preconstruction value in June, then measurements around 24 to 36 days after construction, followed by another measurement at roughly 3.5 months, which shows an increasing trend with time. The FWD measurements showed an initial increase, but remain flat from 3.5 to about 6 months.

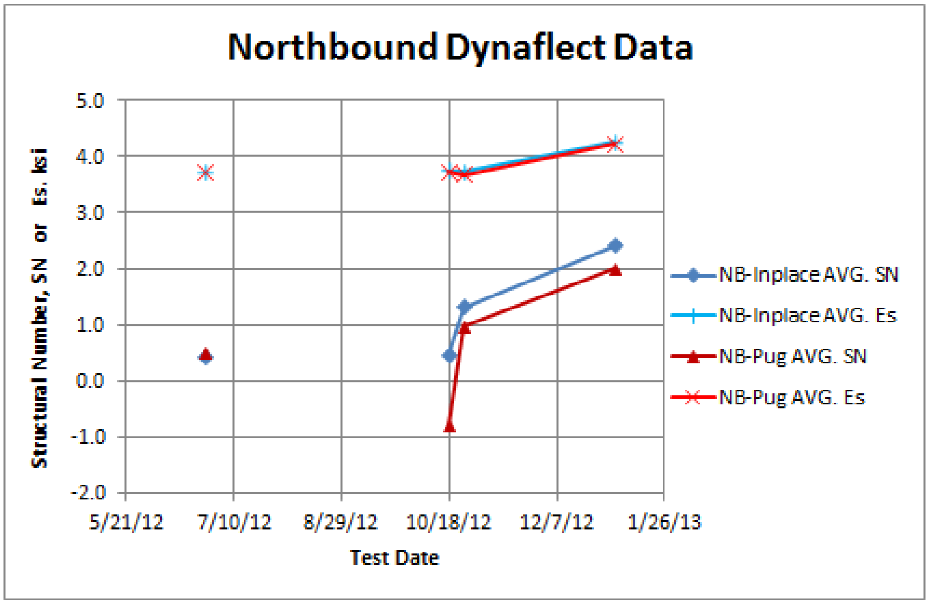


Figure 13
NB-Inplace and NB-Pug Dynaflect average results comparison

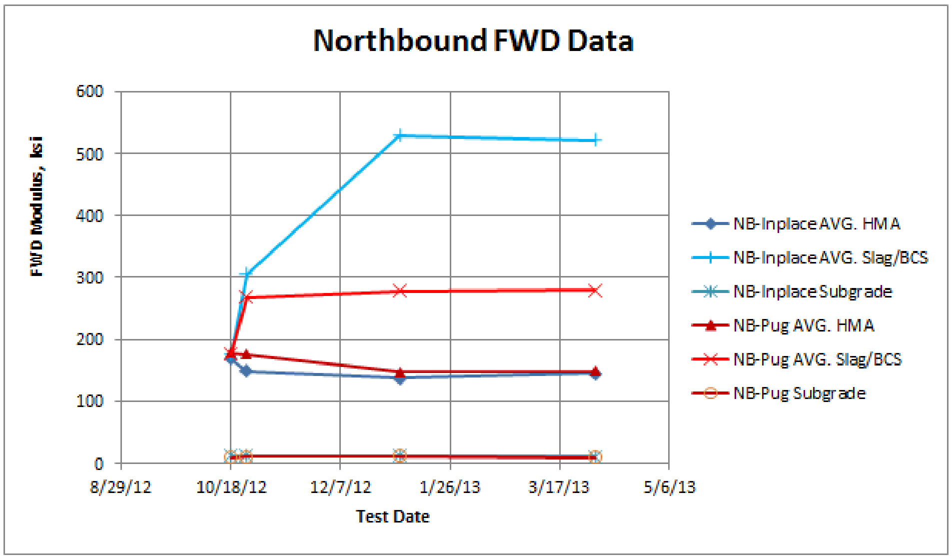
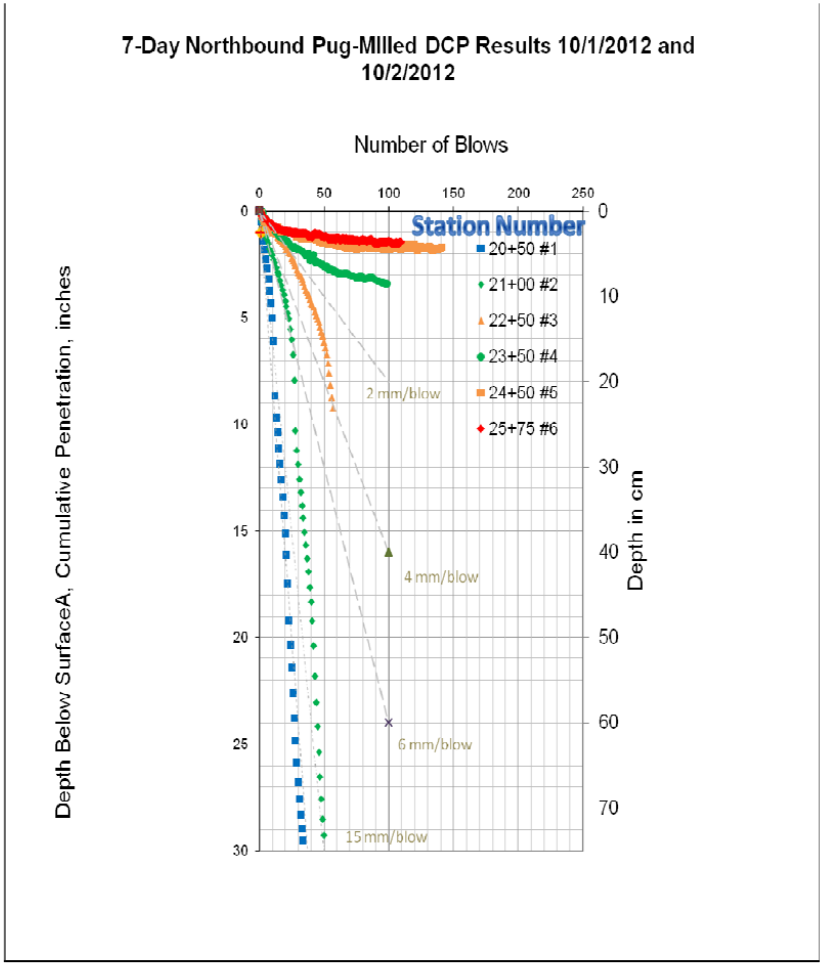


Figure 14
NB-Inplace and NB-Pug FWD average results comparison



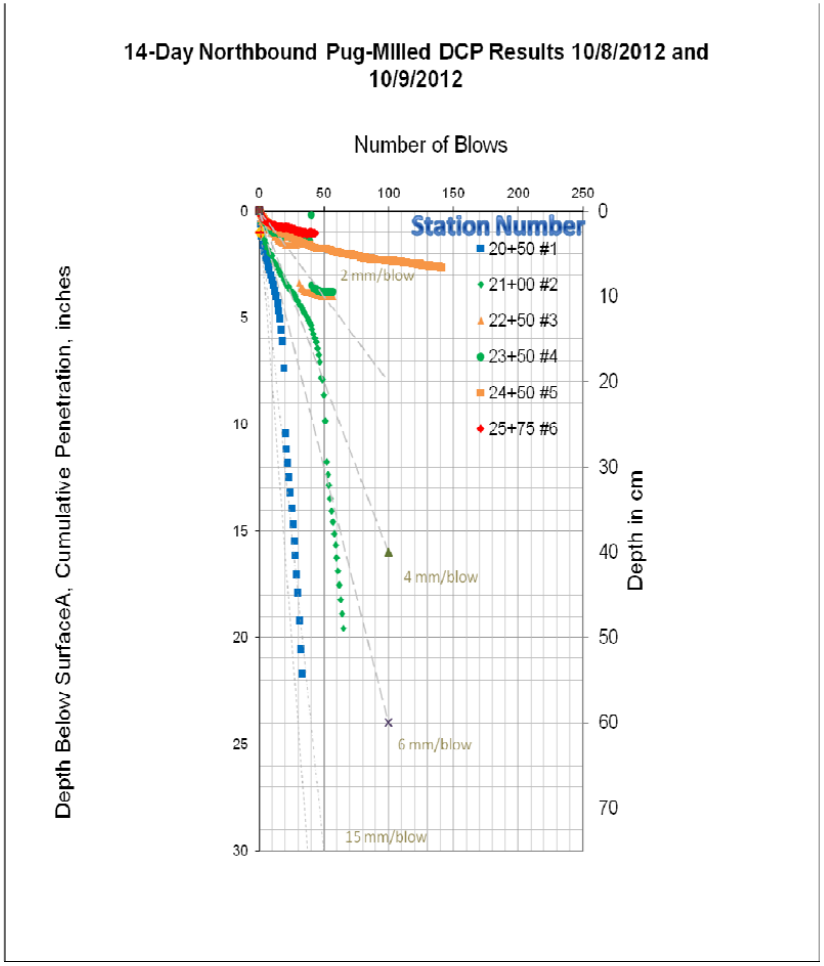


Figure 15
NB-Pug 7-day and 14-day DCP results

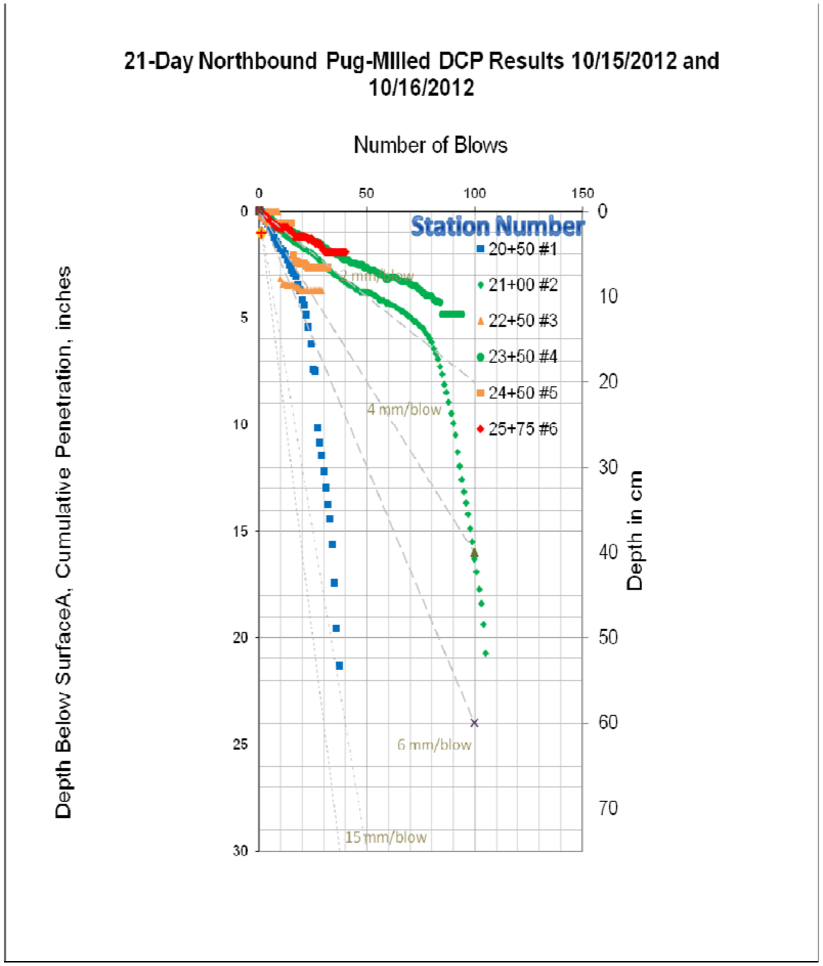


Figure 16
NB-Pug 21-day DCP results

Performance Monitoring

DCP Results

As part of the monitoring process, the test sections were revisited to collect DCP and Cores. Dynaflect and FWD results from this time frame were presented in previous sections' data for simplicity.

Southbound. The DCP results from the southbound section show a clear difference between the SB-1 and SB-2. The SB-2 results are stiffer, which reflects the higher slag/volume of the section. The SB-1 results, where the slag was mixed over the full 12 in., has stiffness values better than 2 mm/blow. The SB-1 and SB-2 DCP results are presented in Figure 17.

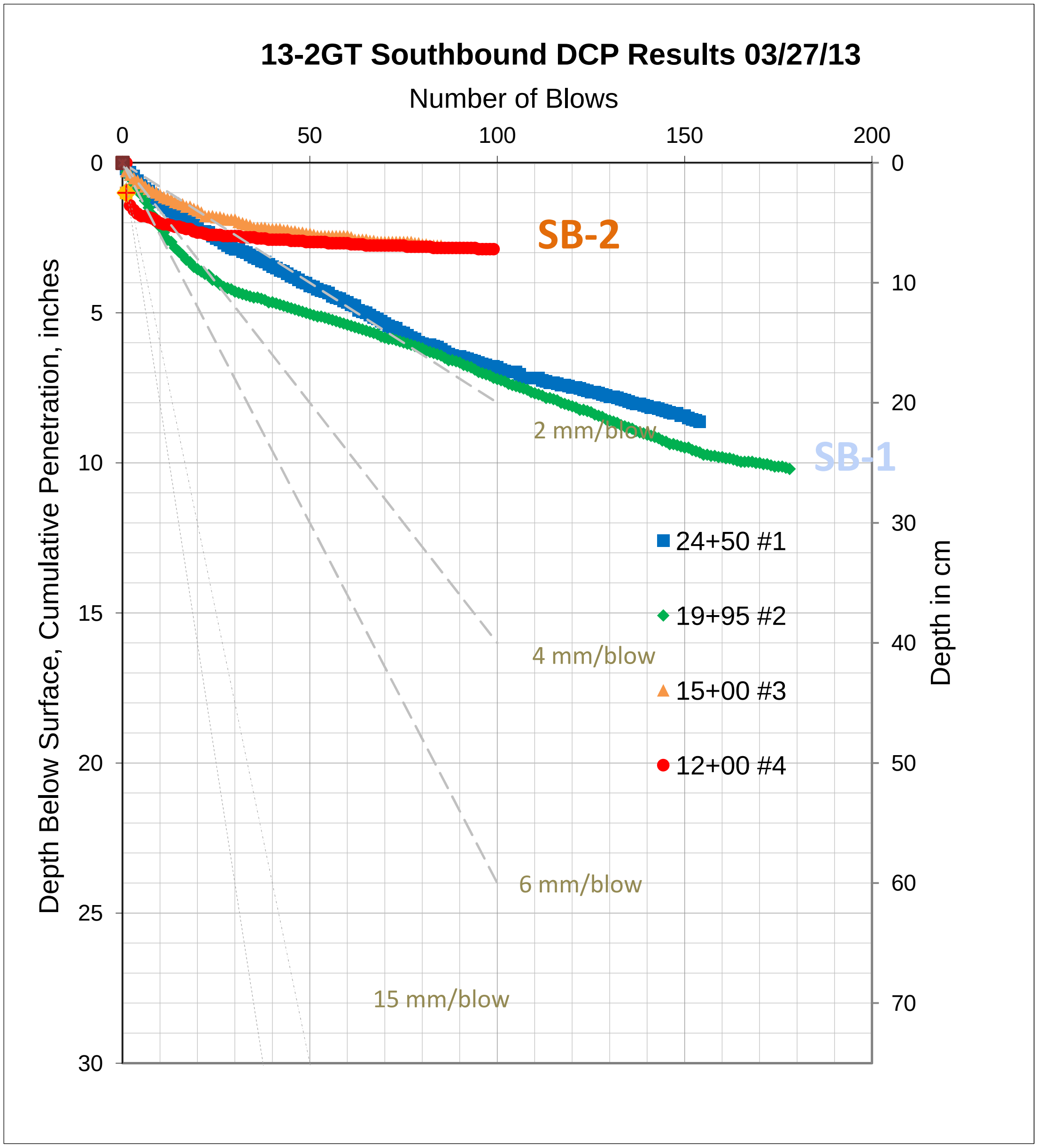


Figure 17
SB-1 & SB-2 ~9-month DCP results

NB-Inplace. DCP results from NB-Inplace are presented in Figure 18. The results show DCP rates of roughly 2 mm/blow (or better) with the slight exception of station 11+00 that was near the start of the stabilization process. The horizontal line in the figure represents the bottom of the slag stabilized BCS.

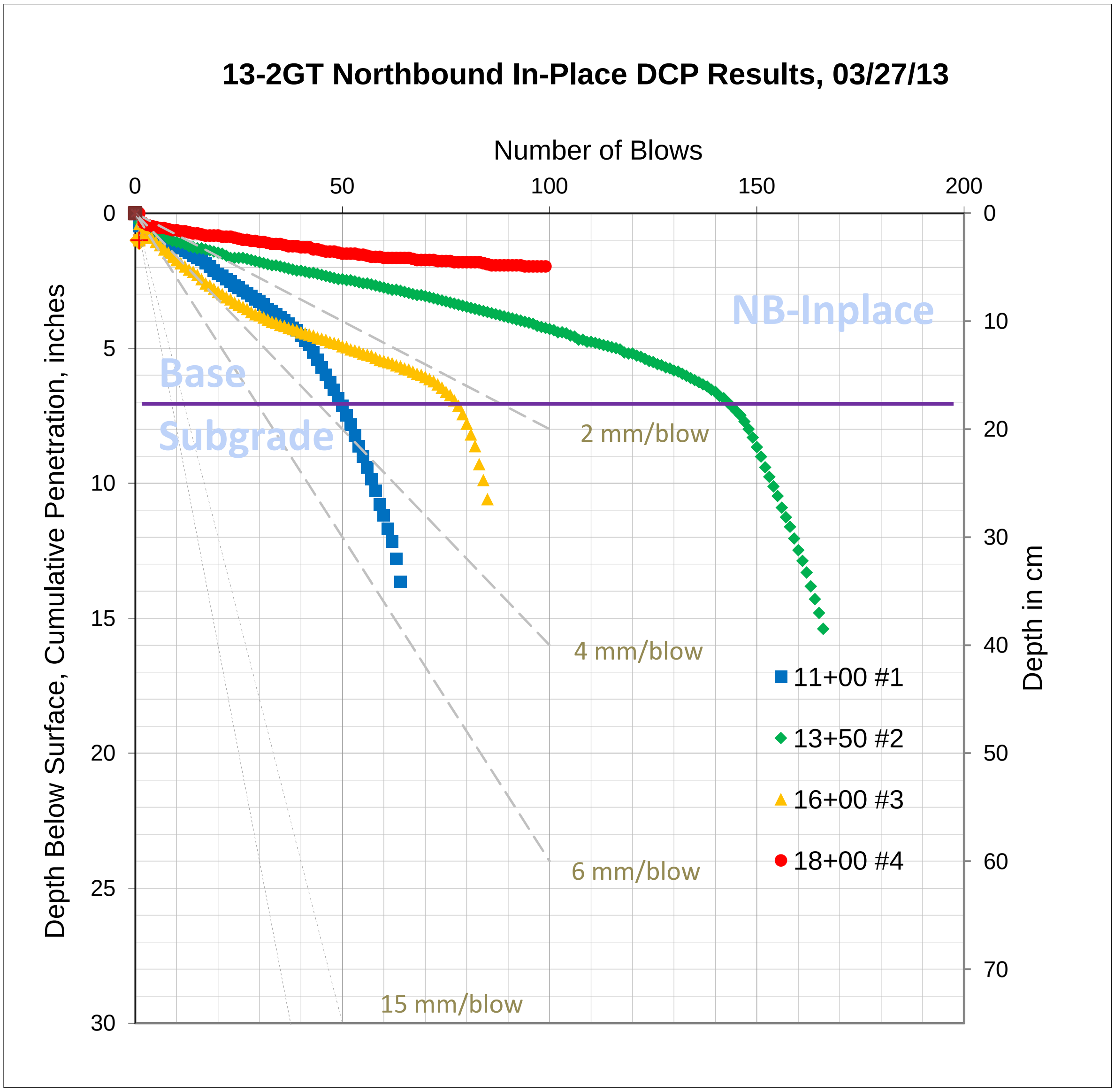


Figure 18
NB-Inplace ~5.5-month DCP results

NB-Pug. DCP results from NB-Pug are presented in Figure 19. The figure shows differences between Day 1 and Day 2 of pug-mill operations, which were also apparent in Table 13. Day 1 placement areas (tested stations 20+50, 21+00, and 22+50) were weaker than Day 2 areas (tested stations 23+50 and 24+50).

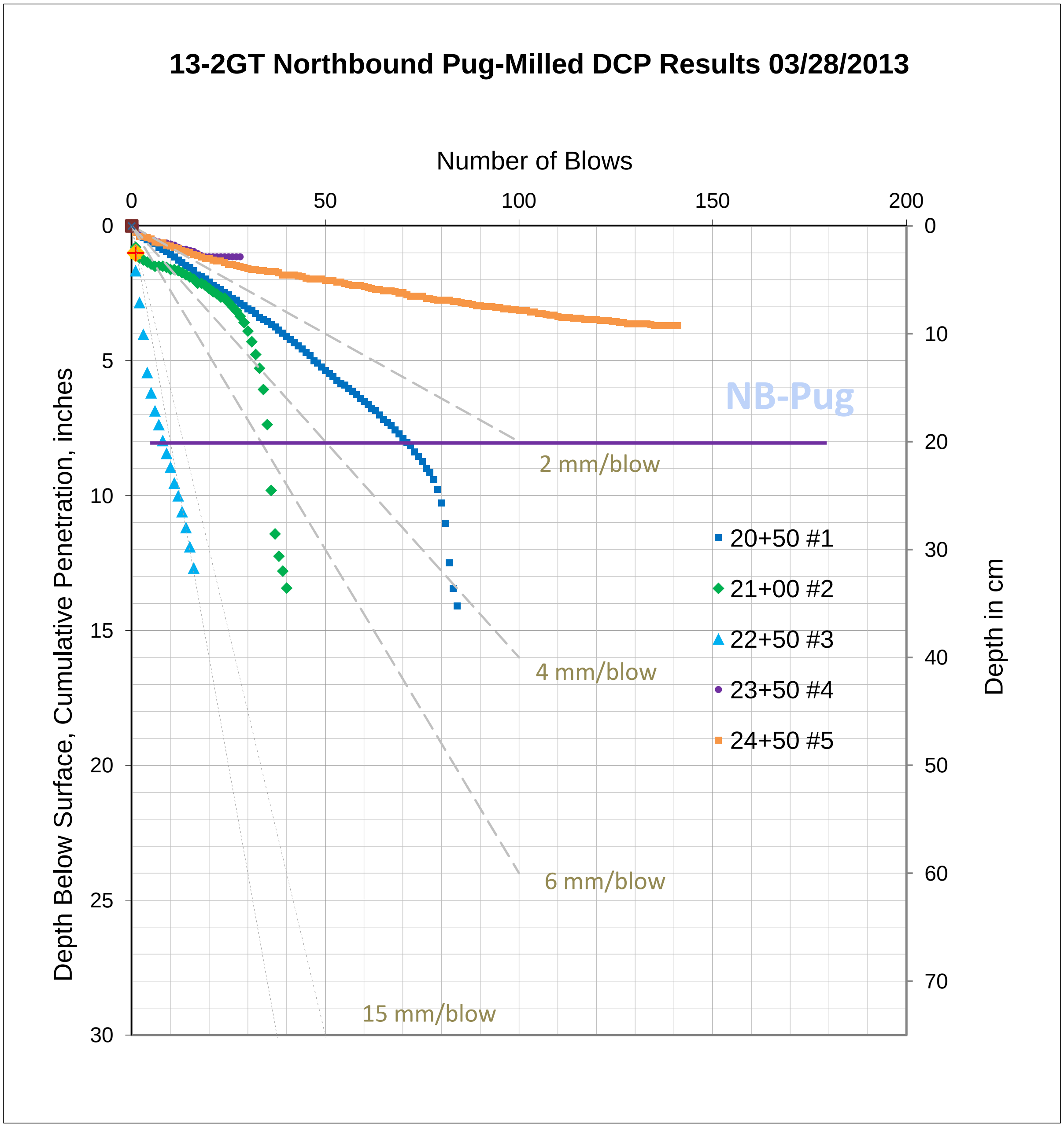


Figure 19
NB-Pug 6-month DCP results

Field Cores Compressive and Unconfined Compressive Strengths

As part of the monitoring process, field cores were obtained from all test sections. These samples were returned to the laboratory for unconfined compression testing.

Southbound Core Samples. Samples from SB-1 and SB-2 are shown in Figure 20. The samples contain some aggregate likely from the asphalt left on the job after milling operations.

Figure 20
Southbound cored samples

Southbound Core Strengths. The sample from station 12+00 obtained the highest strength of all samples from the southbound lanes, and shows evidence of the slag/BCS reaction by the green color at its bottom. All but the sample from station 20+00 achieved 300 psi or greater. The UCS results of these samples are shown in Figure 21.

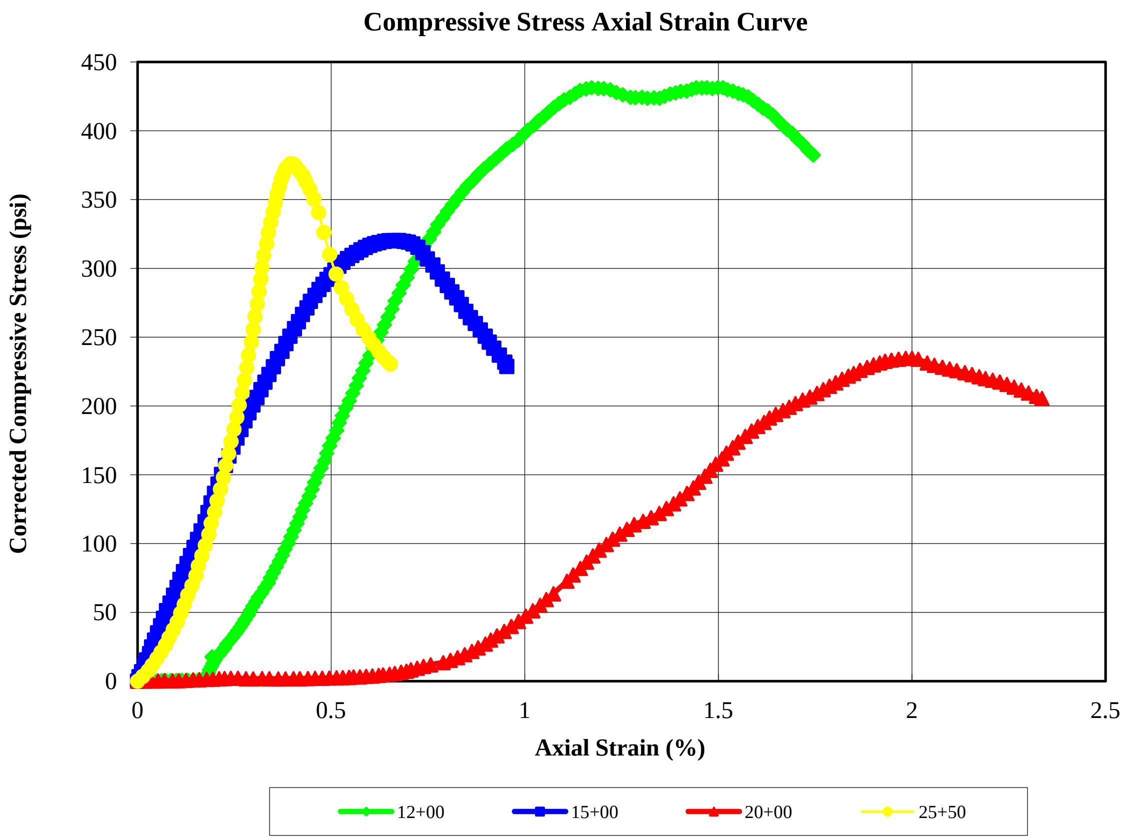


Figure 21
Southbound cored samples – UCS results

NB-Inplace Core Samples. Samples cored from NB-Inplace are shown in Figure 22. The sample from station 16+00 shows the green color (at the bottom) indicative of the slag/BCS bond.

Figure 22
NB-Inplace cored samples

NB-Inplace Core Strengths. The UCS results are shown in Figure 23. Samples from stations 16+00 and 18+00 both reached 300 psi. The strength from station 11+00 was remarkably weak with a UCS of 76 psi.

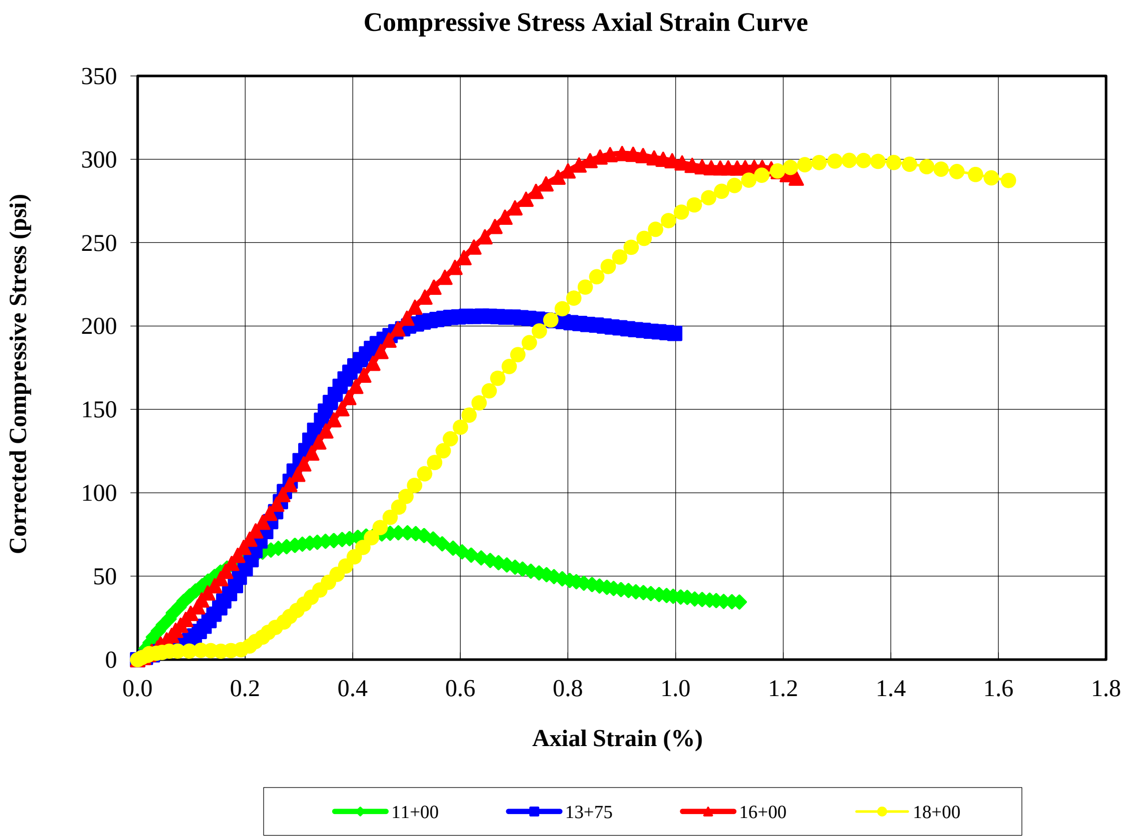


Figure 23
NB-Inplace cored samples – UCS results

NB-Pug Core Samples – Round 1. Samples were collected from the NB-Pug section for UCS testing. Photos of the samples are shown in Figure 24. Many of the samples were fractured and did not provide suitable material for the UCS test. In the pictures, however, the green areas indicative of the slag/BCS bond are apparent.

Figure 24
NB-Pug cored samples – round 1

NB-Pug Core Strengths – Round 1. UCS results of the samples tested from Round 1 are shown in Figure 25. Samples from stations 23+50 and 25+75 both exceeded 700 psi. The sample from station 22+50 was weak and may have been fractured prior to the test. Additional cores samples were collected to replace fractured samples from Round 1.

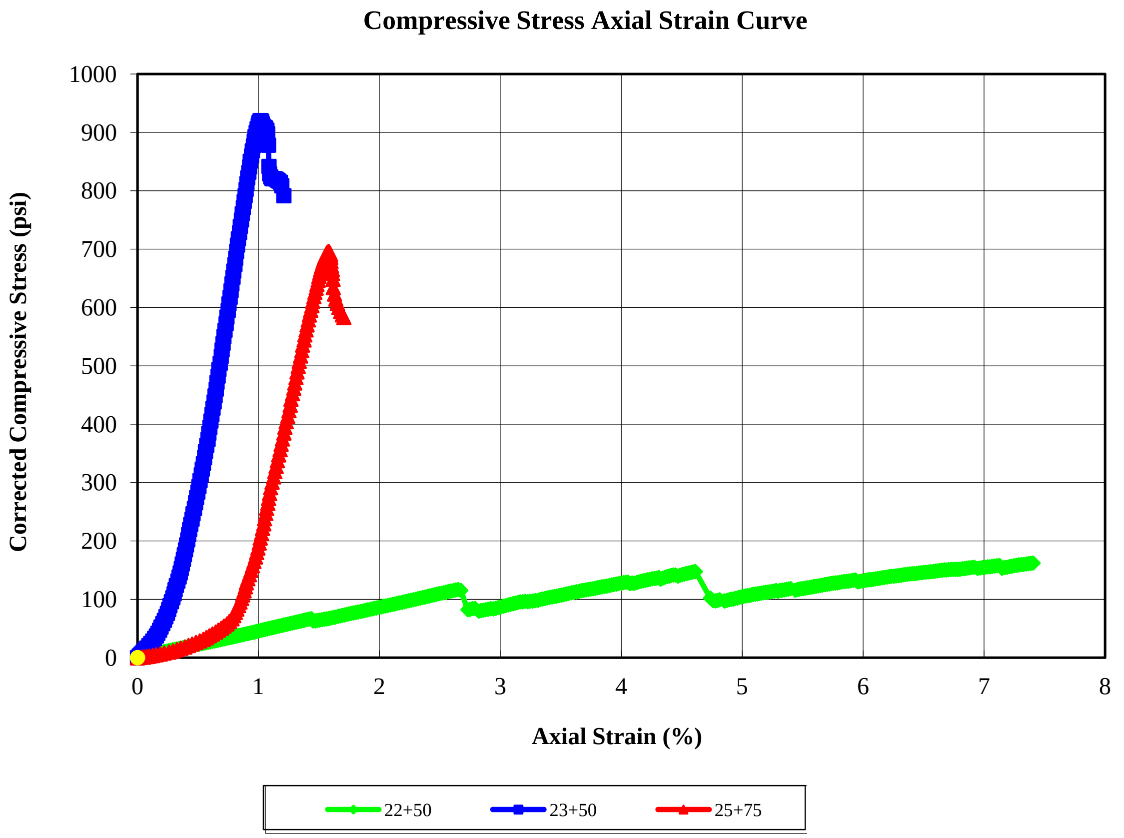


Figure 25
NB-Pug cored samples – UCS results – Round 1

NB-Pug Core Samples – Round 2. Additional samples were collected from the NB-Pug section for UCS testing on July 2, 2013. Photos of the samples are shown in Figure 26. Multiple attempts to core station 20+50 were unsuccessful due to excess fracturing. Samples from other areas did provide acceptable samples for UCS test. In the pictures, however, the green areas indicative of the slag/BCS bond are apparent.

Figure 26
NB-Pug cored samples – Round 2

NB-Pug Core Strengths – Round 2. UCS results from Round 2 are shown in Figure 27. All samples exceeded 500 psi, and samples from station 21+00 exceeded 1000 psi.

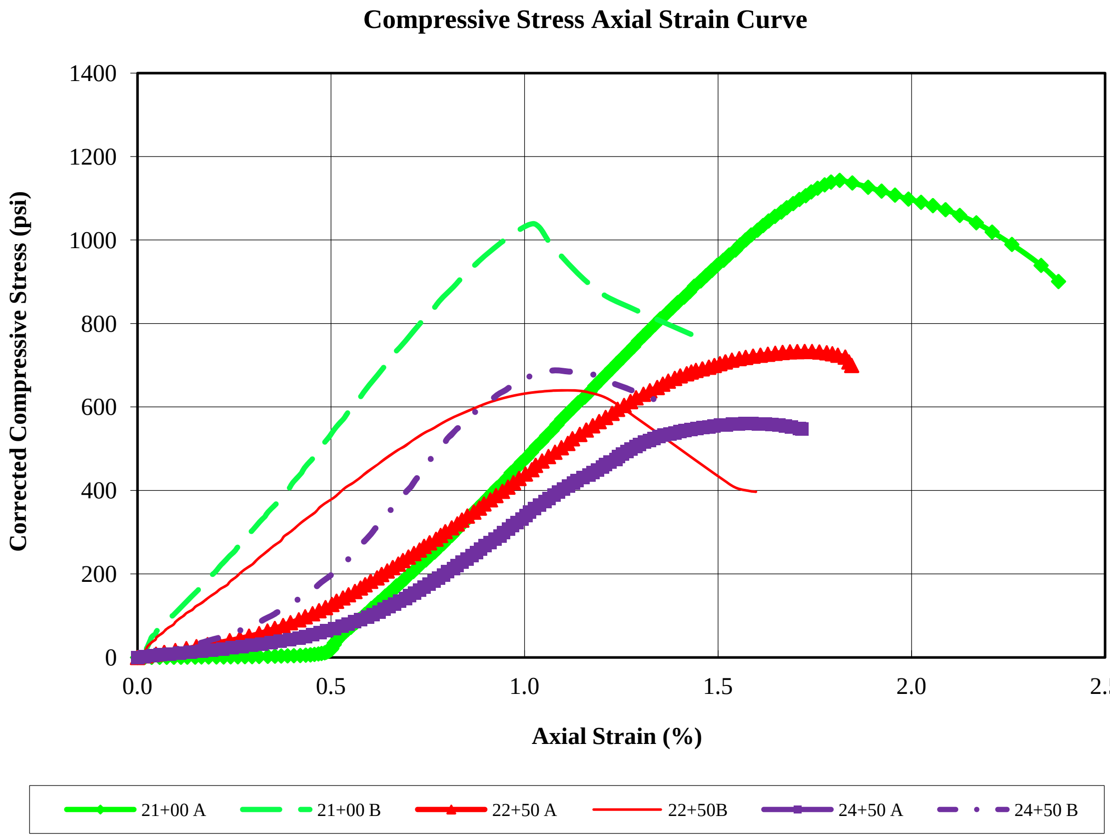


Figure 27
NB-Pug UCS results - Round 2

Terracon Report of Testing Results

Strength Testing. Terracon conducted lab remolded samples of in-place and imported calcium sulfate select with 5% by weight slag. They produced multiple samples and tested them over time to measure the strength gains. Table 16 shows the rate at which the slag/BCS reaction occurs. The reaction is slower than cement, but in the end, exceptionally high strengths were achieved. Additional testing conducted during the construction of the field sites is presented in Table 17. The full Terracon report is included as an Appendix.

Table 16
Terracon compressive strength results

Sample ID	Date Molded	Related US 61 Test Section	Compressive Strength, PSI (Days)					
			7	14	21	28	35	42
0919-1	09/19/2012	NB-Inplace	16.9	80.0	254.4	345.1	444.3	457.8
0919-2	09/19/2012	NB-Inplace	13.6	40.0	193.1	243.6	294.6	398.9
0924-1	09/24/2012	NB-Pug, Day 1	66.7	98.3	146.5	218.6	459.4	717.8
0924-2	09/24/2012	NB-Pug, Day 1	37.0	46.2	124.6	504.0	724.5	876.2
0925-1	09/25/2012	NB-Pug, Day 2	355.9	511.5	434.3	412.0	453.8	541.0
0925-2	09/25/2012	NB-Pug, Day 2	837.6	939.5	864.6	898.1	1087.6	1106.5
0926-1	09/26/2012	--	88.8	140.5	572.9	804.5	1195.1	1427.1
1003-1	10/03/2012	--	541.4	725.3	813.7	816.5	856.7	847.5
1003-2	10/03/2013	--	99.5	158.4	488.1	815.7	1015.5	1031.8

Average	228.6	304.4	432.5	562.0	725.7	823.1
Min	13.6	40.0	124.6	218.6	294.6	398.9
Max	837.6	939.5	864.6	898.1	1195.1	1427.1

Table 17
Terracon laboratory results

Laboratory Test Results

Project No.	Sample No.	Lab Number	Date Received	Material Source	ω (% as received)	γ_{wet} (pcf)	γ_{dry} (pcf)	% Compaction	COMMENTS
EH121056	0919-1	3	9/20/12	In-Place Calcium Sulfate Select w/ 5% Slag- 9/19/12	14.2%	120.1	105.1	97.8%	Lab Density- Compressive Strength Testing
EH121056	0919-2	4	9/20/12	In-Place Calcium Sulfate Select w/ 5% Slag- 9/19/12	14.9%	122.6	106.7	99.2%	Lab Density- Compressive Strength Testing
EH121056	0924-1	10	9/24/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/24/12	14.0%	117.9	103.4	97.1%	Lab Density- Compressive Strength Testing
EH121056	0924-2	11	9/24/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/24/12	14.3%	122.2	107.0	100.4%	Lab Density- Compressive Strength Testing
EH121056	0925-1	12	9/25/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/25/12	11.7%	117.1	104.8	98.4%	Lab Density- Compressive Strength Testing
EH121056	0925-2	13	9/25/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/25/12	12.3%	118.8	105.7	99.3%	Lab Density- Compressive Strength Testing
EH121056	0926-1	14	9/26/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/26/12	12.1%	120.1	107.1	100.6%	Lab Density- Compressive Strength Testing
EH121056	0927A	15	9/27/12	Gauge Moisture Check 24+00 - Tested 9/26/12	10.1%	130.0	118.0	110.8%	Field Density[1]
EH121056	0927B	16	9/27/12	Gauge Moisture Check 20+50 - Tested 9/25/12	10.2%	129.1	117.1	110.0%	Field Density[1]
EH121056	0927C	17	9/27/12	Gauge Moisture Check 22+40 - Tested 9/26/12	11.8%	129.8	116.1	109.0%	Field Density[1]
EH121056	0927D	18	9/27/12	Gauge Moisture Check 21+60 - Tested 9/25/12	10.6%	126.6	114.5	107.5%	Field Density[1]
EH121056	1003-1	19	10/3/12	Imported Clacium Sulfate Select w/ 5% Slag- 10/3/12	12.5%	119.9	106.6	100.1%	Lab Density- Compressive Strength Testing
EH121056	1003-2	20	10/3/12	Imported Clacium Sulfate Select w/ 5% Slag- 10/3/12	12.2%	119.1	106.1	99.6%	Lab Density- Compressive Strength Testing
EH121056	1003C	21	10/3/12	Gauge Moisture Check 27+00 - Tested 9/27/12	13.6%	121.1	106.6	100.1%	Field Density[1]
EH121056	1003D	22	10/3/12	Gauge Moisture Check 28+00 - Tested 9/27/12	13.1%	123.6	109.3	102.6%	Field Density[1]
EH121056	1008A	23	10/9/12	Gauge Moisture Check 30+00 - Tested 10/7/12	10.3%	130.2	118.0	110.8%	Field Density[1]
EH121056	1008B	24	10/9/12	Gauge Moisture Check 31+00 - Tested 10/7/12	8.8%	122.4	112.5	105.6%	Field Density[1]

Figure 28 shows the average unconfined compressive strengths (UCS) of the different sections over time. The chart also shows a comparison of the LTRC and Terracon laboratory data. The last set of points represents the strengths from field cores collected from the site, at roughly a year out. The data shows that each layer gained strength over time reaching the 300 psi mark with the slight exception of the NB-Inplace section which had cored strengths of 76 psi (at the wet project end described previously), 205, 304, and 299 psi.

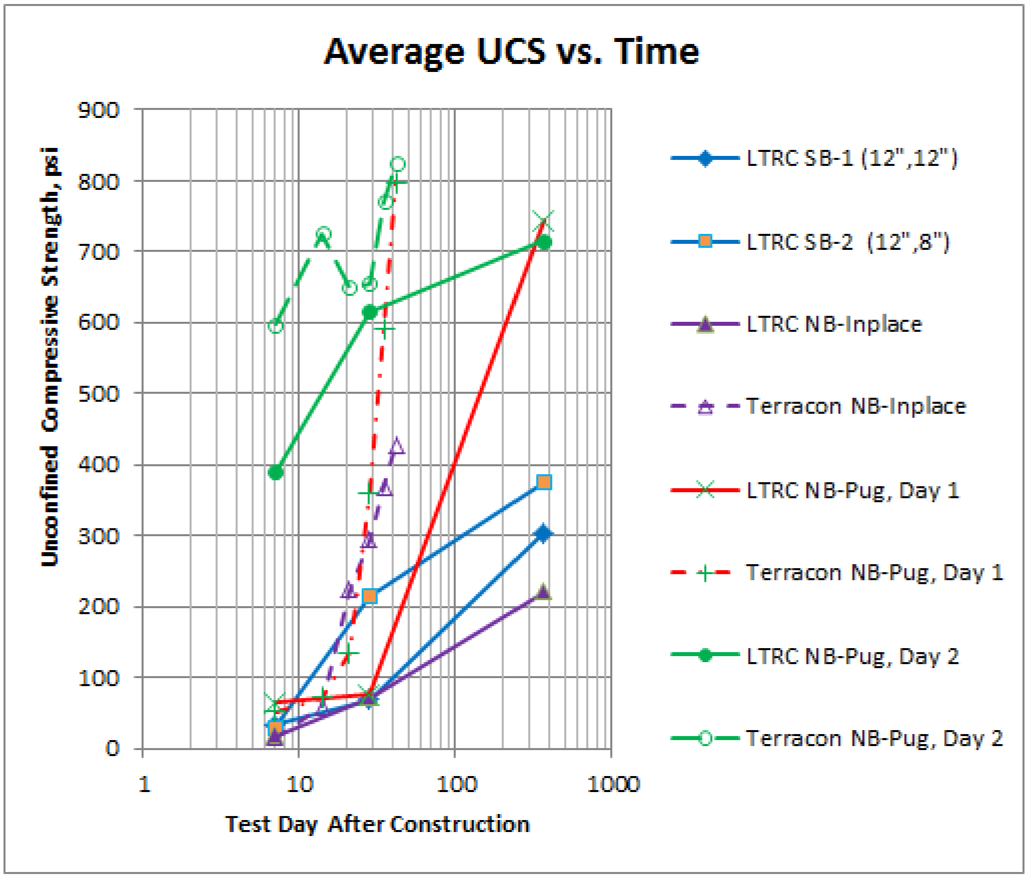


Figure 28
Average UCS over time

Benefit Cost Analysis

Shoulders on Airline Highway

The district was set to rehabilitate the section of Airline Highway, and found old, non-standard BCS in the shoulders. They planned to remove and replace the old non-standard BCS material with a stone base course—a costly option. Due to reduced funding, the District sought alternatives from LTRC. The recent LTRC research utilizing slag stabilization of BCS proved to show savings in several ways. First, by leaving the material in place, removal and haul costs are eliminated. Additionally, the BCS manufacturer, Honeywell, included additional savings and donations to the project to assist with the implementation of the innovative slag-BCS research.

Remove and replace vs. inplace slag stabilization. Per the District 61 office, the cost to remove the existing BCS and replace it with a Class II stone base course was estimated at $35/s.y. The cost to stabilize the old, non-standard BCS, in-place with slag was $19.50/s.y. per the change order. This is a saving of $15.50/s.y. The total savings realized on this project alone for implementing the test sections was over $55,000.

Pug-milled slag stabilized base vs. stone base. Transportation costs will most often dominate this evaluation. As the BCS is created and stockpiled in the Ascension Parish area, BCS and slag-BCS would likely be most cost competitive in this parish and surrounding parishes. For new base courses, recent stone base course costs (per DOTD Item Bid History Tool) are about $20/s.y. In comparison, the manufacturer estimated a base course of pugmilled slag-BCS would be roughly 18.50/s.y. Slag stabilized BCS could provide DOTD with cost comparable alternative base course material; certainly in the Ascension Parish area, but also across the state, should stone or cement cost inflate.

The slag-treated BCS test sections were well received by the District forces, so much so, they have requested funding for additional BCS stabilization projects along the same US 61 corridor for continued shoulder repair.

CONCLUSIONS

This research project was the field implementation follow-up to laboratory research conducted at LTRC. The research met a need and benefited District 61 staff by allowing an alternative to the removal and replacement of the old, non-standard BCS found on site.

The researchers used the previous research to draft, finalize, approve, and implement specifications to allow for the stabilization of BCS with slag on the shoulders of US 61 just south of LA 22 in Sorrento, LA. Two specifications were used. The first addressed the inplace stabilization of BCS with slag. The second specification addressed a market driven implementation of the research, specifically, the applicability of Honeywell's "fines" material treated with slag in a pugmill for use as base material. The researchers worked with Honeywell, District 61 staff, and the contractor to design a plan for the test sections. The partnership with Honeywell and its contractor, Brown Industries and their investment (financial and reputation) toward the project benefited the research.

The field-constructed test sections showed the benefit of the slag stabilized BCS.

- The two test sections (SB-1 and SB-2) with pulverization and mixing depth issues (too deep) initially had marginal results, but the resulting sections gained strength over time, which the FWD, Dynaflect, DCP, and field cores confirmed. This is likely due to the slower reaction of slag (as compared to cement's rate of reaction).
- Higher concentrations of slag in the BCS/ soil mixture produced higher strengths. The slag in SB-1 was diluted over a larger volume due to the mixing error, but still gained strength. SB-2 performed better, likely due to the higher (intended/desired) concentration of slag in the BCS/soil pulverized mixture.
  - Truck spreading (of the slag) may have also affected concentrations available for stabilization, and thus the strengths. For example, SB-2 station 12+00 was one of the best performing sample locations, and likely received higher application rates at the end of the section (possibly due to cleanout of the spreader truck).
- The previous research, LTRC# 03-8GT, utilized a BCS of a coarser nature (rock BCS) and based slag amounts on the percentage smaller than a number four sieve, since the larger particles have their own intergranular friction. The current project, LTRC# 13-2GT, with its old BCS was uniformly finer than the "rock" BCS, and in hindsight, the slag percentage should have been higher to account for the increase in surface area of the finer material. The additional slag would likely have also resulted in higher strengths in a shorter time period.

- Two sections were completed on the northbound lane of US 61. At NB-Inplace, the existing BCS material was stabilized inplace. At NB-Pug, the existing BCS was removed, hauled away, and replaced with pug-milled slag/BCS from offsite.

  - The NB-Inplace section showed that moisture control is important during construction. Immediately after stabilization with slag, the slag-BCS bonds have yet to form, and the material can be moisture sensitive. Though water is good for the slag/BCS reaction, too much water with BCS can cause pumping and hinder compaction and grading operations. Over time, the bonds grow and reduce the moisture susceptibility of the slag stabilized BCS. Once cured, research and field results show the strong, green-colored bond is not moisture sensitive.
  - The NB-Pug section showed variations between placement days. The consistency throughout each day was stable, but varied from day to day. This was also confirmed by the Terracon results. Further QC/QA appears necessary at the plant level.

- The inplace treatment of BCS with slag offers a solution to the choice of cement as a stabilizing agent, which can create the expansive mineral, ettringite, and lead to expansion and ride quality issues. Based on the 03-8GT research, the slow slag reaction inhibits the growth of the expansive ettringite.
- The slag reaction with BCS is slower than a standard soil cement reaction, but eventually gained suitable strength/stiffness.
  - The application of the research on the Airline Highway shoulders allowed suitable cure time, without the need to open immediately to traffic.
  - The slower slag reaction provided timing-flexibility for pugmill operations allowing slag stabilized BCS to be prepared off-site, hauled to the site, and utilized as base course material for the shoulders.
- The potential to utilize Honeywell byproduct, BCS "fines", stabilized with slag offers the Department an option to address the environmentally friendly "Green" initiatives of reducing Louisiana landfills.
- The strength data shows that each section, even with its various cross-sections, was capable of reaching 300 psi, offering a way to treat inplace BCS; and offering an alternative base course solution when remove and replace options, potential expansion exists, or the cost of stone replacement material may be too expensive.
- Stabilizing old non-standard BCS inplace, provided a cost benefit of $15.5/s.y., which realized a saving of $55,000 for the test sections.

RECOMMENDATIONS

Researchers recommend the use of slag stabilization on BCS encountered during forensic or rehabilitation operations of BCS sections. Slag stabilization of BCS provides:

- a cost effective way to deal with these areas of old, non-standard BCS, as compared to a remove and replace option.
- a strong bond, which renders the BCS less moisture sensitive compared to untreated BCS.
- a relatively slow slag-BCS reaction to reduce the likelihood of expansive reactions, an alternative to cement stabilization that may cause ettringite formation and therefore expansion issues and/or ride quality issues.
- another base course option to meet Department needs.

The draft specifications included can be used to incorporate this research into the Department's “toolbox.” The design slag percentages should be verified with laboratory testing and then increased slightly to account for spreading inconsistencies, and increased surface areas of old, non-standard BCS or the Honeywell “fines” material.

The continued use of BCS as a base course material can be supplemented with the addition of a slag stabilized BCS (inplace and pugmilled). This research offers the Department other base course alternatives, and addresses the “Green” philosophy and market need to recycle BCS. Further refinements to the pugmill plant process are necessary to ensure consistent output by the hour and by the day. The pug-mill process is, however, an excellent way to control and balance the moisture of the mixture to create the slag/BCS reaction without excess moisture that may cause pumping.

The slag-BCS reaction can realize excellent strength gains with time. The researchers recommend that care, including specific testing with onsite materials, be used in selecting sites for the application and implementation of this research.

ACRONYMS, ABBREVIATIONS, & SYMBOLS

AASHTO	American Association of State Highway and Transportation Officials
ALF	Accelerated loading Facility
ASTM	American Society of Testing and Materials
BCS	Blended Calcium Sulfate
DCP	Dynamic Cone Penetrometer
ft.	foot
FWD	Falling Weight Deflectometer
HMA	Hot Mix Asphalt
GGBFS	Grade 120, Ground Granulated Blast Furnace Slag
in.	inches
kNm	kilo newton meters
kPa	kilopascals
ksi	thousand pounds per square inch
DOTD	Louisiana Department of Transportation and Development
LTRC	Louisiana Transportation Research Center
NB	Northbound
pcf	pounds per cubic foot
PRF	Pavement Research Facility
psi	pounds per square inch
SB	Southbound
Slag	Grade 120, Ground Granulated Blast Furnace Slag (GGBFS)
UCS	Unconfined Compressive Strength

REFERENCES

1. Tao, M., Zhang, Z., “Stability of Calcium Sulfate Base Course in a Wet Environment,”, Louisiana Transportation Research Center, Report #419, LTRC Project 03-8GT, 2007, www.ltrc.lsu.edu/pdf/2007/fr_419.pdf
2. Materials Properties Evaluation, Honeywell Specialty Materials, Calcium Sulfate ‘Select’ Material, Terracon Consultants, Inc. Project Number EH116309, December 20, 2011.

APPENDIX A

NS In-Place Slag Stabilized Blended Calcium Sulfate Base Course (Roadbed)

Louisiana Department of Transportation and Development

NSINR-2 — Louisiana Department of Transportation and Development — 12/2009

Suggested Item Number NS-

Non-Standard or Standard Item Number Request

For Office Use Only Item Number: Approved _____

Type and enter all information completely. Do not refer to attachments in your responses.

Submit only one item per form. *Send a electronic specification in WORD® format with this form.*

Item Description: Non-Standard ☒ Standard ☐
NS DEV-303, In-Place Slag Stabilized Calcium Sulfate Base Course

Proposed Letting Date: 12/14/2011

Date of Request: 3-29-2012

State Project Number: H000329

Project Name and Description: Airline Hwy (US 61) Shoulders @ LA 22, Sorrento

Is a Construction detail required? Yes ☐ No ☒ Send copy if available.

Existing standard item replaced by this item:

Design Phase PP ☐ FP ☐ PS&E ☐

Construction Activity: Roadway ☒ Bridge ☐ Utility ☐

Other:

Materials:
Slag Stabilized Blended Calcium Sulfate

Recommended Primary Use:
Stabilization of In-Place BCS

Method of Construction:

Method of Measurement:

Basis of Payment: Square Yard

Estimated Cost per Unit of Application: $
Supporting Cost Documentation must be attached.

Proprietary: Yes ☐ No ☒
If yes, attach "Public Interest Finding" documentation.

Specification Numbers: List the specification number if your item meets any of the following specification requirements.

Testing: List report number if the item has been tested by any of the following organizations.

Specification	Number	Organization	Report Number
AASHTO		LTRC	03-8GT
ASTM		MATERIALS LAB	
FHWA			
LADOTD		Other:	

Manufacture/Suppliers: Is this product manufactured in the USA? Yes ☐ No ☐
If so, state by whom and if the use is routine or experimental. Attach any approval letters.

Safety: Has this item been certified according to NCHRP 350? Yes ☐ No ☐ Other:

Note: The office requires at least 30 working days to assign an item number. Failure to submit the required information may delay the issuance of the item number and the evaluation, approval and funding of your technology or product.

Additional Information:

Contact Information: DOTD Section Number & Name, or Name of Company: LTRC / SECT 19

Person furnishing information: GAVIN GAUTREAU Title: GEOTECHNICAL RESEARCH ENG

Phone number: 225 767 9110 Cell number: 225 802 7488 Fax number: 225 767 9110

Email address: GAVIN.GAUTREAU@LA.GOV

Section Head Name: MARK MORVANT Section Head Signature: Phone: 225 767 9124 Date: 4/2/12

DOTD Rev. Date 12-15-09

NS In-Place Slag Stabilized Blended Calcium Sulfate Base Course (Roadbed) (04/12)

DESCRIPTION. This work consists of blending, shaping and stabilizing in-place calcium sulfate roadbed material with ground granulated blast furnace slag (GGBFS) in accordance with the 2006 *Louisiana Standard Specifications for Roads and Bridges*, these specifications, and the lines, grades, thickness and sections established or shown on the plans.

This GGBFS stabilization is primarily for existing roadbed materials.

Quality assurance requirements shall be as specified in the latest edition of the Department's publication entitled "Application of Quality Assurance Specifications for Embankment and Base Course."

MATERIALS. Materials shall comply with the following Sections or Subsections:

Emulsified Asphalt	1002
Water	1018.01
Ground Granulated Blast Furnace Slag	1018.27

Ground Granulated Blast Furnace Slag (GGBFS): Slag shall be ground granulated blast furnace slag (GGBFS) of grade 120. The quantity of GGBFS used shall be supported by Certificate of Delivery.

Equipment necessary to produce a finished base course, which meets specification requirements shall be furnished and maintained by the contractor. Equipment shall be approved prior to use. The in-place mixer shall be equipped with a spray bar, which has the capability of applying water across the full width of the cut, and shall be adjustable to prevent overlap of water distribution on adjacent paths.

GGBFS spreaders shall be equipped with a calibrated spreader-box mechanically adjustable for various widths. The contractor shall have a back-up GGBFS spreader equipped with a calibrated spreader-box on the project. GGBFS may be distributed from transports using spreader bars approved by the engineer. The engineer may require the use of a GGBFS spreader capable of width adjustment and equipped with a calibrated spreader box if a uniform GGBFS spread cannot be achieved, or to control dust. The distribution of dry additives shall be monitored using DOTD TR 436, Method A.

Compaction equipment shall be conventional sheepsfoot type roller or a self-propelled tamping foot compactor-type roller for initial compaction. The spikes shall be sufficient in size and number to provide uniform compaction for the full width and depth of the base course. Finish rolling shall be with a pneumatic tire roller.

Preparation Of Roadbed**.** Remove all asphalt pavement prior to GGBFS stabilization of the BCS.

Mixing**.** The percent of GGBFS to be used will be 5 percent by weight (8 percent by volume).

The method of spread shall be such that the amount of GGBFS used can be readily determined when tested in accordance with DOTD TR 436. GGBFS shall be uniformly spread and mixed with the material. A minimum of two passes with the mixer (stabilizer) will be required. The mixture shall be shaped to the required section.

During the mixing process, water shall be added only through the spray bar of the in-place mixer, which is adjusted to provide uniform coverage across the completed width of the roadway for the full depth of the base. Wet streaks or spots will not be allowed.

Optimum moisture of the mixture will be determined in accordance with DOTD TR 415 or TR 418. The percentage of moisture determined in accordance with DOTD TR 403 [modified to include a maximum drying temperature of 140°F (60°C)] in the mixture by dry weight shall not vary from optimum moisture by more than +4 percent at the time of compaction.

Compacting and Finishing**.** The mixture shall be uniformly compacted immediately upon completion of mixing. Initial compaction shall be completed with an approved sheepsfoot-type roller or a self-propelled tamping foot compactor-type roller in such a manner that no internal laminations occur in the completed base course. Final compaction shall be with a pneumatic tire roller.

The surface shall be kept uniformly moist during compacting and final finishing. Compaction shall continue until each lift of base course has met the requirements of the Acceptance Requirements Subsection of this specification.

Compaction and finishing operations shall be completed within 3 hours after initial placement of GGBFS on base course materials. Upon expiration of the 3-hour period after initial placement, only tight blading of the base course surface will be allowed. Bladed material shall not be drifted along the base, but shall be wasted. Stabilized material shall be utilized in the base course except that small amount necessary for tight blading. Excessive blading to achieve plan depth will not be allowed. The contractor shall complete operations, including tight blading, before the end of the day. The finished base course shall have a smooth, uniform, closely knit surface, free from ridges, waves, laminations, or loose material. No GGBFS shall be spread within two hours of sunset, unless otherwise approved by the project engineer.

Quality Control**.** The contractor shall control the preparation of roadbed, selection and placement of materials, GGBFS spread, mixing, compaction, moisture content, density, thickness, width, surface finish, grade, and cross slope so that the completed base course is uniform and conforms to plan dimensions and other acceptance requirements as provided herein. The contractor shall control his operations so that contamination, segregation, soft spots, wet spots, laminations and other deficiencies are prevented. The contractor shall be responsible for taking such tests as necessary to adequately control the work.

Protection and Curing**.** Upon completion of final finishing, the base shall be immediately protected against rapid drying by applying an asphalt curing membrane in accordance with Section 506. Asphalt curing membrane shall be placed on the same day as stabilizing. Complete coverage of curing membrane shall be maintained from initial application until the placement of the next course. When traffic, including construction equipment, is allowed on the base course, at least the first lift of surfacing shall be placed within 30 calendar days unless otherwise directed.

Maintenance**.** The contractor shall protect the completed base course from damage due to either public traffic or the contractor's operations, and shall satisfactorily maintain the completed base course including asphalt curing membrane. Damaged base course shall be repaired by the contractor at no direct pay. When patching of the base course is required, in addition to removing damaged or unsound base course, the contractor shall remove a sufficient width and depth of base course to ensure satisfactory placement of patching material. The engineer will approve the type of patching materials before use. Patching or other repair of the base course shall be made in such manner as to restore a uniform surface, shall conform to the requirements of the material being used and shall be completed prior to surfacing operations.

Public traffic or construction traffic shall not be allowed on the completed base course for a 72-hour curing period.

When traffic is permitted to use the completed base after a 72-hour curing period and prior to the construction of the surface course, the base shall be further protected by additional applications of asphalt curing membrane as directed at no direct pay in accordance with Subsection 302.10.

Prior to surface course construction, the contractor shall clean the base course and apply and maintain additional asphalt curing membrane as directed at no direct pay.

Any weak spots that develop shall be satisfactorily corrected and the base kept free from deficiencies and true to grade and cross section at no direct pay. When the surfacing is asphaltic concrete the first lift of surfacing shall be placed within 30 calendar days.

Weather Limitations**.** Mixing will not be permitted when the base course material is frozen, when raining, when the ambient air temperature is below 35°F (2°C), or the temperature forecasted by the U.S. Weather Service is to be 25°F (-3°C) or less within the 24 hour period following placement.

Acceptance Requirements**.** GGBFS spread rate will be tested in accordance with DOTD TR 436. The moisture content of the SSBCS will be tested for compliance with optimum moisture content in accordance with DOTD TR 403 at placement at least twice per day.

The completed base course will be checked for determining acceptance in increments of 1,500 linear feet (457 lin m).

(a) Density Requirements**:** Upon completion of compaction operations, the density will be determined in accordance with DOTD TR 401 except that all moisture content determinations for density calculations shall be conducted by oven drying the material for 24 hours at 140°F (60°C). A forced draft type oven capable of maintaining the temperature shall be provided by the contractor for field moisture content determination for density control.

The density requirement as based on DOTD TR 415 or TR 418 will be 95.0 percent of maximum dry density.

When the density test value for the section is below 95.0 percent, a payment adjustment will be applied in accordance with Table 1 below.

Table 1
Density Acceptance and Payment Schedule

Density Test Value	Percent of Contract Unit Price
95.0 & Above	100
93.0 to 94.9	90
90.0 to 92.9	75
Below 90.0	50 or Remove[1]

[1]At the option of the Chief Engineer after investigation.

(b) Thickness Requirements**:** The thickness of the completed base course will be determined in accordance with DOTD TR 602.

The completed base course shall not vary from plan thickness in excess of the tolerances in Table 2 as follows. Base course thickness deficiencies in excess of these tolerances shall be corrected as specified herein at no direct pay.

Table 2
Base Course Thickness Tolerance

Underthickness, Inches (mm)	Overthickness, Inches (mm)
3/4 (20)	1 1/2 (40)

Any failing area will be isolated for purposes of correction. Base course thickness deficiencies in excess of the foregoing tolerances shall be corrected as follows.

When no grade adjustments are permitted, thickness deficiencies shall be corrected by restabilizing with GGBFS.

When grade adjustments are permitted, the contractor shall have the option of correcting deficiencies by furnishing and placing a supplemental layer of asphaltic concrete complying with Section 502 for the full width of base course in lieu of removing and replacing deficient base course. When approved, corrections may be made by restabilizing the existing material in accordance with this section. Thickness of the supplemental layer of asphaltic concrete shall be in accordance with Table 3 as follows.

Table 3
Supplemental Asphaltic Concrete Layer Thickness

Underthickness, Inches (mm)	Overthickness, Inches (mm)	Minimum Thickness of Supplemental Asphaltic Concrete[1], Inches (mm)
1 to 1 1/2 (30 to 40)	1 3/4 to 2 (45 to 50)	1 1/4 (35)
1 3/4 to 2 (45 to 50)	2 1/4 to 2 1/2 (60 to 65)	1 1/2 (40)
2 1/4 to 2 1/2 (60 to 65)	2 3/4 to 3 (70 to 80)	2 (50)
Over 2 1/2 (Over 65)	Over 3 (Over 80)	Remove and Replace[2]

[1]May be placed with subsequent lift of asphaltic concrete.
[2]At the option of the Chief Engineer after investigation

(c) Width Requirements**:** The width of the completed base course will be determined in accordance with DOTD TR 602. Roadway base course width shall not vary from plan width in excess of +6 inches (+150 mm). Shoulder base course width shall not vary from plan width in excess of +3 inches (+75 mm). No tolerances are provided for underwidths of shoulder or roadway bases. When the base course for roadway and shoulders are constructed at the same time, the 6-inch (150 mm) width tolerance will be applied. Base course width deficiencies in excess of foregoing tolerances shall be corrected as follows at the contractor's expense.

(1) Overwidth**:** When no grade adjustments are permitted, the full depth and width of base course in isolated areas having overwidths in excess of the foregoing tolerances shall be restabilized full width with GGBFS or removed and replaced to the plan width with asphaltic concrete complying with Section 502 or concrete complying with Section 901.

In lieu of removing and replacing overwidth base course, areas of the deficient base course will be allowed to remain in place at a payment adjustment of 90 percent of the contract unit price for the entire lot.

When grade adjustments are permitted, the contractor shall correct base course width deficiencies by removing and replacing as specified above, or by furnishing and placing a 1 1/4 inch (35 mm) thick supplemental layer of asphaltic concrete complying with Section 502 for the full width of the roadway.

(2) Underwidth**:** Underwidths of base course in excess of the foregoing tolerances shall be corrected to plan width by restabilizing the full width with GGBFS or by furnishing and placing additional materials; however, the width and thickness of the widening materials shall be not less than 12 inches (300 mm). Materials used for widening the deficient base course shall be the same as specified for overwidth correction in Heading (1).

(d) Grade and Cross-slope: The finished grade shall be within ±1/2 inch (±15 mm) of the established grade. The cross-slope shall not vary by more than ±0.003 ft./ft. (±3 mm/m).

(e) Correction of Deficiencies: The contractor shall correct deficiencies in surface finish, grade, contamination, segregation, soft spots, wet spots, laminations and other deficiencies at no direct pay. Deficiencies shall be corrected by removing and replacing or as directed.

MEASUREMENT. The quantity of In-Place GGBFS Stabilized BCS Base Course for payment will be the design areas as specified in the plans and adjustments thereto. The design quantity is based on the horizontal dimensions of the completed base course shown on the plans. The design quantity will be adjusted if the engineer makes changes to adjust to field conditions, if design errors are proven, or if design changes are necessary.

PAYMENT. Payment for In-Place GGBFS Stabilized BCS Base Course will be made at the contract unit price per square yard (sq m), adjusted as specified in the Acceptance Subsection of this specification Payment includes furnishing all labor, materials, equipment, and incidentals required including GGBFS, water, and asphalt curing membrane, and performing necessary roadbed preparation. Payment for removing all existing asphaltic concrete surfacing will be made under Section 509.

If the actual required percent of GGBFS differs from that required by the contract documents, payment will be increased or decreased based on the difference in required quantity of GGBFS at the price of GGBFS shown on paid invoices (total of all charges). The contractor shall provide copies of paid invoices for this determination.

Removal of existing patches will be paid at the contract unit price or if no item is provided, in accordance with Subsection 109.04. However, no payment will be made unless the contractor identifies the patches and participates in the measurement and documentation.

Payment will be made under:

Item No.	**Pay Item**	**Pay Unit**
NS DEV-30801	In-Place Slag Stabilized BCS Base Course 8.0 in (mm) Thick	Sq Yd (Sq m)

NS Slag Stabilized Blended Calcium Sulfate Base Course (Shoulder)

Louisiana Department of Transportation and Development

NSINR-2
Suggested Item Number
NS-

Louisiana Department of Transportation and Development

Non-Standard or Standard Item Number Request

12/2009

For Office Use Only
Item Number: Approved ____

Type and enter all information completely.
Do not refer to attachments in your responses.
Submit only one item per form.
Send a electronic specification in WORD® format with this form.

Item Description: Non-Standard ☒ Standard ☐
NS DBV-302, Slag Stabilized Blended Calcium Sulfate Base Course

Proposed Letting Date: 12/14/2011

Date of Request: 3-29-2012

State Project Number: H.000329

Project Name and Description: Airline Hwy (US 61) Shoulders @ LA 22, Sorrento

Is a Construction detail required? Yes ☐ No ☒ Send copy if available.

Existing standard item replaced by this item:

Design Phase PP ☐ FP ☐ PS&E ☐
Other:

Construction Activity: Roadway ☒ Bridge ☐ Utility ☐

Materials:
Slag Stabilized Blended Calcium Sulfate

Recommended Primary Use:
Stabilization of BCS for shoulder application

Method of Construction:

Method of Measurement:

Basis of Payment: Square Yard

Estimated Cost per Unit of Application: $
Supporting Cost Documentation must be attached.

Proprietary: Yes ☐ No ☒
If yes, attach "Public Interest Finding" documentation.

Specification Numbers: List the specification number if your item meets any of the following specification requirements.

Specification	Number
AASHTO	
ASTM	
FHWA	
LADOTD	

Testing: List report number if the item has been tested by any of the following organizations.

Organization	Report Number
LTRC	03-8GT
MATERIALS LAB	
Other:	

Manufacture/Suppliers: Is this product manufactured in the USA? Yes ☐ No ☐
If so, state by whom and if the use is routine or experimental. Attach any approval letters.

Safety: Has this item been certified according to NCHRP 350? Yes ☐ No ☐ Other:

Note: The office requires at least 30 working days to assign an item number. Failure to submit the required information may delay the issuance of the item number and the evaluation, approval and funding of your technology or product.

Additional Information:

Contact Information: DOTD Section Number & Name, or Name of Company:
LTRC/SECT 19

Person furnishing information: GAVIN GAUTREAU Title: GEOTECHNICAL RESEARCH ENG.

Phone number: 225 7679110 Cell number: 225 802 7488 Fax number: 225 767 9110

Email address: GAVIN.GAUTREAU@LA.GOV

Section Head Name: MARK MORVANT

Section Head Signature:

Phone: 225 7679124

Date: 4/2/12

DOTD Rev. Date 12-15-09

NS Slag Stabilized Blended Calcium Sulfate Base Course (Shoulder) (04/12)

DESCRIPTION. This work consists of furnishing slag stabilized blended calcium sulfate (SSBCS) and placing it as shoulder base course on a prepared surface in accordance with the 2006 Louisiana Standard Specifications for Roads and Bridges, these specifications, and in conformity with the lines, grades, thickness, and typical sections shown on the plans or established. The contractor shall control the selection, placement, mixing and compaction of materials so that the completed base course is uniform and conforms to plan dimensions and other acceptance requirements.

Quality assurance requirements shall be as specified in the latest edition of the Department's publication entitled "Application of Quality Assurance Specifications for Embankment and Base Course."

MATERIALS. Materials shall comply with the following Sections or Subsections and requirements.

Water	1018.01
Ground Granulated Blast Furnace Slag	1018.27
Blended Calcium Sulfate (BCS)	

(a) Ground Granulated Blast Furnace Slag: Slag shall be ground granulated blast furnace slag (GGBFS) of grade 120. The quantity of GGBFS used shall be supported by Certificate of Delivery.

(b) BCS for Slag Treatment: The BCS shall consist of calcium sulfate from a source approved by the Materials and Testing Section and be blended with an approved aggregate or lime. The source shall have a quality control program approved by the Materials and Testing Section. The source shall have been given environmental clearance by the Department of Environmental Quality for the intended use, and written evidence of such environmental clearance shall be on file at the Materials and Testing Section. DOTD monitoring for compliance with environmental regulations will be limited to the pH testing stated herein below. The blended material shall be non-plastic and reasonably free from organic and foreign matter. The pH shall be a minimum of 5.0 when tested in accordance with DOTD TR 430. Re-evaluation will be required if the source of the aggregate or lime that is blended with the calcium sulfate changes.

Blended calcium sulfate material used as base course shall comply with the following gradation requirements when tested in accordance with DOTD TR 113, modified to include a maximum drying temperature of 140°F (60°C). Samples shall be taken from an approved stockpile at the point of origin. Blended calcium sulfate shall be sampled in accordance with the requirements for stone in Section 302 of the Materials Sampling Manual. BCS shall classify as an A-4 according to AASHTO, and a sandy silt according to the Unified Soil Classification System. BCS with a Liquid Limit (LL) greater than 35 or a Plasticity Index (PI) greater than 15 percent shall not be used. Determine LL and PI in accordance with DOTD TR 428. BCS containing greater than 79 percent sand or 80 percent silt when tested in accordance with DOTD TR 407 shall not be used.

Equipment. Equipment shall be furnished and maintained by the contractor and shall be subject to approval prior to use. Central mixing equipment shall conform to Subsection 301.03(a). Compaction equipment shall conform to Subsection 301.03(a)(5).

CONSTRUCTION REQUIREMENTS. Base course material shall be placed on a subgrade prepared in accordance with Sections 203, 304, 305 or 306 as specified. Asphaltic concrete base course shall be constructed in accordance with Section 502.

Mixing.

a. Slag Stabilized BCS**:** BCS shall be combined with GGBFS and water in a central plant and shaped on the subgrade.

The optimum moisture of the mixture will be determined in accordance with DOTD TR 415 or TR 418. The percentage of moisture in the mixture, by dry weight, shall not vary from the optimum moisture by more than +4.0 percent at the time of compaction when tested in accordance with DOTD TR 403 modified to include a maximum drying temperature of 140°F (60°C). .

(1) Central Plant Mixing**:** Mixing in a central mix plant shall conform to Section 301. The required moisture content of the slag stabilized BCS shall be between optimum and +4.0 percent of optimum.

Transporting and Placing on Subgrade**.** Transportation and spreading methods shall not damage the subgrade. The contractor shall place and spread sufficient base course material to obtain required width and compacted thickness within the tolerances set forth in the Acceptance Subsection of this specification. Subgrade material shall not contaminate the base course. Any contamination will require retesting and correction of deficiencies. Base course material shall not be placed, spread or mixed on portland cement concrete or asphaltic concrete pavements. Base course construction operations shall not damage adjacent pavement surfaces, edges and joints.

Compacting and Finishing**.**

(a) General**:** The finished base course shall have a smooth, uniform, closely knit surface, free from ridges, waves, laminations or loose material. The surface shall be thoroughly rolled and finished to grade. The cross-slope shall not vary by more than ±0.003 ft/ft (±3 mm/m). Density requirement shall be in accordance with the Acceptance Subsection of this specification.

(b) Slag Stabilized BCS**:** Compact and finish in accordance with Subsection 301.10, except that the automatic grade machine will not be required.

Compaction and finishing operations shall be completed within 3 hours after initial placement of SSBCS base course materials. Upon expiration of the 3-hour period after initial placement, only tight blading of the base course surface will be allowed. Bladed material shall not be drifted along the base, but shall be wasted. Stabilized material shall be utilized in the base course except for that small amount necessary for tight blading. Excessive blading to achieve plan depth will not be allowed. The contractor shall complete operations, including tight blading, before beginning the next day's operations. The finished base course shall have a smooth, uniform, closely knit surface, free from ridges, waves, laminations, or loose materials. No SSBCS shall be spread within 2 hours of sunset, unless otherwise approved by the project engineer.

Optimum moisture and maximum density shall be determined in accordance with DOTD TR 418 Method G modified to include a maximum drying temperature of 140°F (60°C).

Quality Control of Roadway Operations**.** The contractor shall control the SSBCS mixing, placement, compaction, moisture content, density, thickness, width, surface finish, cross-slope and grade to produce a completed base course that is uniform and conforms to plan dimensions and other acceptance requirements as provided herein. The contractor shall control his operations to prevent contamination, segregation, soft spots, wet spots, laminations and other deficiencies. The contractor shall be responsible for taking tests necessary to adequately control the work.

Protection and Curing**.**

(a) Slag Stabilized BCS**:** Upon completion of intermediate finishing, the base course shall immediately be protected against drying by applying an asphalt curing membrane in accordance with Section 506. Asphalt curing membrane shall be placed on the same day as treatment. Complete coverage of curing membrane shall be maintained from initial application until the placement of the next course. When traffic, including construction equipment, is allowed on the base course, at least the first lift of surfacing shall be placed within 30 calendar days unless otherwise directed.

Maintenance of Base Course**.** The contractor shall protect the base course from damage from public traffic or the contractor's operations, and shall satisfactorily maintain the base course including the asphalt curing membrane or prime coat. Damaged base course shall be repaired by the contractor at no direct pay. When patching of the base course is required, in addition to removing damaged or unsound base course, the contractor shall remove a sufficient width and depth of base course to ensure satisfactory placement of patching material. The engineer will approve the type of patching material before use. Patching or other base course repair shall restore a uniform surface, shall conform to the requirements of the material being used, and shall be completed before paving operations begin. Failures detected during paving may be patched as detected.

Public traffic or construction traffic shall not be allowed on the completed base course during the 72-hour curing period.

Prior to surface course construction, the contractor shall correct deficiencies, clean the base course surface, repair any damages caused by traffic, and apply and maintain additional asphalt curing membrane or prime coat as directed at no direct pay.

Any weak spots that develop shall be satisfactorily corrected and the base kept free from deficiencies and true to grade and cross section at no direct pay.

When the surfacing is asphaltic concrete, the first lift of surfacing shall be placed within 30 calendar days.

Weather Limitations**.** Construction of base course will not be permitted when the subgrade or stockpiles are frozen, when raining, or, in the case of slag stabilized BCS, when the ambient air temperature is below 35°F (2°C), or the temperature forecasted by the U.S. Weather Service is to be 25°F (-3°C) or less within the 24 hour period following placement.

Acceptance Requirements**.** Soils and aggregates will be sampled for acceptance by the Department in accordance with the Materials Sampling Manual.

Central plant mixing operations will be checked for uniformity and the proportioning of the components. The percent GGBFS will be checked at least twice per day in accordance with DOTD TR 436. The percent GGBFS being incorporated into the mixture shall not be more than 0.1 percent by weight (mass) of the total material below the approved percent GGBFS, or operations shall be discontinued until corrections have been made.

The moisture content of the SSBCS will be tested for conformance to optimum moisture content in accordance with DOTD TR 403 modified to include a maximum drying temperature of 140°F (60°C).

The SSBCS will be tested in accordance with DOTD TR 431 and shall be sampled at the plant prior to shipping.

Base course will be checked for determining acceptance in increments of 1,500 linear feet (457 lin m) per shoulder.

(a) Density Requirements**:** Upon completion of compaction operations, the density will be determined in accordance with DOTD TR 401 except that all moisture content determinations for density calculations shall be conducted by oven drying the material for 24 hours at 140°F (60°C). A forced draft type oven capable of maintaining the temperature shall be provided by the contractor for field moisture content determination for density control. The density requirements shall be 95.0 percent of Maximum Dry Density in accordance with DOTD TR 418.

(1) Slag Stabilized BCS**:** When the density test value for the section is below 95.0 percent, a payment adjustment will be applied in accordance with Table 1 as follows.

Table 1
Density Acceptance and Payment Schedule

Density Test Value	Percent of Contract Unit Price
95.0 & Above	100
94.0 to 94.9	90
93.0 to 93.9	75
Below 93.0	50 or Remove[1]

[1]At the option of the Chief Engineer after investigation.

(b) Thickness Requirements**:** The thickness of the completed base course will be determined in accordance with DOTD TR 602.

The completed base course shall not vary from plan thickness in excess of the tolerances in Table 2 below. Base course thickness deficiencies in excess of these tolerances shall be corrected as specified herein at no direct pay.

Table 2
Base Course Thickness Tolerance

(All Bases Except Asphaltic Concrete) Underthickness, Inches (mm)	(Stabilized & Treated Bases) Overthickness, Inches (mm)
3/4 (20)	1 1/2 (40)

Any failing area will be isolated for purposes of correction.

Asphaltic concrete base thickness will be determined in accordance with Section 502.

Overthickness may be waived at no direct pay.

(1) Slag Stabilized BCS**:** When no grade adjustments are permitted, underthickness deficiencies in excess of tolerance shall be corrected by removing and replacing the full depth of base course in deficient areas with the same type of base course.

When grade adjustments are permitted, the contractor shall have the option of correcting thickness deficiencies by furnishing and placing a supplemental layer of asphaltic concrete complying with Section 502 for the full width of base course in lieu of removing and replacing deficient base course. When approved, corrections may be made by restabilizing the existing material in accordance with this section. Thickness of the supplemental layer of asphaltic concrete shall be in accordance with Table 3 as follows.

Table 3
Supplemental Asphaltic Concrete Layer Thickness

Underthickness, Inches (mm)	Overthickness, Inches (mm)	Minimum Thickness of Supplemental Asphaltic Concrete, Inches (mm)[1]
1 to 1 1/4 (30 to 35)	1 3/4 to 2 (45 to 50)	1 1/4 (35)
1 1/2 to 1 3/4 (40 to 45)	2 1/4 to 2 1/2 (60 to 65)	1 1/2 (40)
2 to 2 1/2 (50 to 65)	2 3/4 to 3 (70 to 80)	2 (50)
Over 2 1/2 (Over 65)	Over 3 (Over 80)	Remove and Replace[2]

[1] May be included in the subsequent lift
[2] At the option of Chief Engineer after investigation.

When reconstruction is the method of correction, the above tolerances shall apply.

(c)Width Requirements**:** The width of the completed base course will be determined in accordance with DOTD TR 602. Roadway base course width shall not vary from plan width in excess of +6 inches (+150 mm). Shoulder base course width shall not vary from plan width in excess of +3 inches (+75 mm). No tolerances are provided for underwidths of shoulder or roadway bases. When the base course for both roadway and shoulders are constructed at the same time, the 6-inch (150 mm) tolerance will be applied. Base course width deficiencies in excess of the above tolerances shall be corrected as follows at the contractor's expense:

(1) Overwidth**:** Overwidths of asphaltic concrete and treated base courses mixed in a central plant may be waived at no additional cost to the Department. When no grade adjustments are allowed, the full depth and width of base course in areas having overwidths in excess of the foregoing tolerances shall be removed and replaced to the plan width the same type of base course.

In lieu of removing and replacing the overwidth areas of base course, at the Department's option, any base course less than 12 inches (300 mm) overwidth will be allowed to remain in place at an adjusted payment of 90 percent of the contract unit price for the complete section. Overwidth in excess of 12 inches (300 mm) shall be removed and replaced as indicated above. When approved, corrections may be made by restabilizing the existing material in accordance with this subsection.

When grade adjustments are permitted, the contractor shall correct base course width deficiencies by removing and replacing as specified above, or by furnishing and placing a 1 1/4 inch (35 mm) thick supplemental layer of asphaltic concrete complying with Section 502 on the 1,000-foot (300 m) section for the full width of the base course.

(2) Underwidth**:** Underwidths of base course in excess of the foregoing tolerances shall be corrected to plan width and thickness by furnishing and placing additional materials; however, the width of widening materials shall be not less than 12 inches (300 mm). When approved, corrections may be made by restabilizing the existing material in accordance with this section. Materials for widening deficient base course shall be either asphaltic concrete complying with Section 502 or concrete

complying with Section 901, at the option of the contractor.

(d) Grade and Cross-slope**:** The finished grade shall be within ±1/2 inch (±15 mm) of the established grade. The cross-slope shall not vary by more than ±0.003 ft./ft. (±3 mm/m).

(e) Correction of Deficiencies**:** The contractor shall correct deficiencies in surface finish, cross-slope, grade, contamination, segregation, soft spots, wet spots, laminations and other deficiencies at no direct pay. Deficiencies shall be corrected by removing and replacing or as directed.

MEASUREMENT. The quantities of base course for payment will be the design volumes or areas specified in the plans and adjustments thereto. Design quantities are based on the horizontal dimensions and compacted thickness of the completed base course shown on the plans. Design quantities will be adjusted if the engineer makes changes to adjust to field conditions, if plan errors are proven, or if design changes are necessary.

PAYMENT. Payment for base course will be made at the contract unit price per square yard (sq m), adjusted as specified in the Acceptance Subsection of this specification and the following provisions, which includes furnishing all labor, materials, equipment, and incidentals and placing required base course materials, SSBCS, water, asphaltic curing membrane and prime coat.

Payment adjustments will be applied for specification deviations of asphalt materials in accordance with Section 1002.

When payment adjustments are made for more than one deficiency, they shall be cumulative.

Payment will be made under:

Item No.	**Pay Item**	**Pay Unit**
NS DEV-30800	Class II Base Course – Slag Stabilized BCS 8.5 in(mm)Thick	Sq Yd (Sq m)

APPENDIX B

Terracon Report on Honeywell Fines

Materials Properties Evaluation

Honeywell Specialty Materials
Calcium Sulfate 'Select' Material

December 20, 2011
Terracon Project Number: EH116309

Prepared for:
Honeywell Specialty Materials
Geismar, Louisiana

Prepared by:
Terracon Consultants, Inc.
Baton Rouge, Louisiana

Offices Nationwide
Employee-Owned
Established in 1965
terracon.com

Terracon

Geotechnical ■ Environmental ■ Construction Materials ■ Facilities

December 20, 2011

Terracon

Honeywell Specialty Materials
5525 Highway 3115
Geismar, Louisiana 70734

Attn: Mr. Travis Williams
Marketing Manager-Fluorine Products
P: [225] 642-3589
Travis.Williams2@honeywell.com

Re: Materials Properties Evaluation
Calcium Sulfate – Select Material
Terracon Project Number: EH116309

Dear Mr. Williams:

Terracon Consultants, Inc. (Terracon) has completed the engineering testing services for the above-referenced project. This study was performed in general accordance with our proposal number PEH110340 dated July 25, 2011 which was approved by Mr. Travis Williams on August 1, 2011.

This report presents the results of various test procedures performed on both raw select grade calcium sulfate and compacted/molded samples. In addition to the presentation of test results, a preliminary discussion of the apparent engineering properties of the material is provided.

We appreciate the opportunity to be of service on this project. We look forward to providing additional assistance in evaluating potential uses of the calcium sulfate materials in the construction marketplace. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.

Lynne E. Roussel

Lynne E. Roussel, P.E.
Project Engineer

Stephen E. Greaber

Stephen E. Greaber, PE
Principal – Office Manager
LA #26107

Enclosure

Terracon Consultants, Inc. 2822 O'Neal Lane Building B Baton Rouge, Louisiana 70816
P [225] 344 6052 F [225] 344 6346 terracon.com

Geotechnical ■ Environmental ■ Construction Materials ■ Facilities

TABLE OF CONTENTS

MATERIALS PROPERTIES EVALUATION
HONEYWELL SPECIALTY MATERIALS
CALCIUM SULFATE – SELECT MATERIAL
Terracon Project Number EH116309
December 20, 2011

1.0 INTRODUCTION

Terracon Consultants, Inc. (Terracon) was retained by Honeywell Specialty Materials (Honeywell) to conduct geotechnical laboratory testing of their calcium sulfate "select" material.

Terracon performed various engineering laboratory tests on the raw material and on molded/compacted samples of the Calcium Sulfate 'select' material to aid in development of an understanding of the engineering properties of the material. In particular, the evaluation focused on the strength and compressibility of the material. Initial testing of the material to evaluate its potential use as select fill for construction of a soil cement pavement base was also conducted.

Laboratory services for this project included those that will assist in evaluating the general strength and compressibility properties of the material as it applies to typical commercial and industrial applications. This laboratory program is not intended to be an exhaustive research based program, but more of an initial cursory evaluation for basic low risk applications. The following tests were performed for this initial evaluation:

- Grain Size Analysis with Hydrometer (ASTM D422)
- Standard Proctor (ASTM D698)
- Consolidated Undrained Triaxial Test (Molded Sample at 95% of Standard Proctor and +2% of optimum) (ASTM D4767)
- Unconfined Compression Tests (Various Density/Moisture Conditions and days of aging) (ASTM D2166)
- Constant Rate of Strain Consolidation (Remold Sample at 95% or Standard Proctor) (ASTM D4186)
- CBR/Swell Test at 96 hours and 30 day soak (Molded Sample at 95% of Standard Proctor) (ASTM D1883)
- LADOTD Soil Cement Series (DOTD Method TR432)
- CBR/Swell Test of select material with 9% cement addition at 33 day soak (Molded Sample at 95% of Standard Proctor) (ASTM D1883)

2.0 BACKGROUND INFORMATION

The Calcium Sulfate 'select' material is derived from Honeywell Specialty Materials production of hydrofluoric acid. The process results in a by-product material that is termed fluorogypsum.

This material is currently recognized by the Louisiana Department of Environmental Quality for beneficial reuse as a road bed construction material. The Louisiana Department of Transportation and Development (LADOTD) provides specifications for the use of blended calcium sulfate as nonplastic embankment material in Section 203.09 (d) and as a Class II Base as outlined in Section 302 of the 2006 Louisiana Standard Specification for Roads and Bridges (LSSRB) as amended by LADOTD Supplemental Specifications dated May 2009, The 2006 LSSRB also provides for use of calcium sulfate blended with approved aggregate to aid in establishment of a subgrade as described in Section 305.04(d).

The calcium sulfate 'select' is generated from the screening process used to produce the 610 graded Calcium Sulfate materials. In particular, the 'select' material represents the fines from this process which is material finer than the No. 8 screen.

3.0 LABORATORY TESTING

The following section provides a general description of the testing procedures implemented and a brief discussion of the results. It is noted that the material in all procedures requiring moisture testing was dried back at 140° F, a requirement for this material.

3.1 Grain Size Analysis and Classification

A representative sample of the material was subjected to grain size analysis using ASTM Method D422. The material had 78% passing the No. 200 sieve. Atterberg limits testing was performed on the material and indicated a Liquid Limit of 22, but no plastic limit test was possible and the material was classified as non-plastic. The hydrometer analysis indicated the material contains approximately 22% sand, 73% silt, and 5% clay sized particles. According to the Unified Soil Classification system, this material would be classified as sandy silt (USCS: ML). The material would classify as an A-4 material in accordance with the AASHTO Classification System. The grain size curve is provided in the Appendix.

3.2 Compaction Test

A bulk sample of the material was subjected to a compaction test to determine the moisture/density relationship in accordance with ASTM Method D698. The test results indicated a maximum dry density of 95.7 pounds per cubic foot (pcf) at optimum moisture of 15.4%. It is noted that the moisture samples were dried back at 140° F, which is a requirement for testing of this material. The compaction curve is provided in the Appendix.

3.3 Strength Testing

Strength testing was performed on a series of remolded samples to develop an understanding of the expected performance of the material as an engineered fill.

3.3.1 Consolidated-Undrained (CU) Triaxial Compression Testing

A series of sample specimens were molded to approximately 95% of the maximum dry density at 2% above optimum moisture and tested in triaxial shear using the Consolidated-Undrained test procedure in accordance with ASTM Method D4767.

The total stress parameters derived from the test results indicated a phi angle of 41.1° with cohesion of 5.2 pounds per square inch (psi). The effective stress parameters derived from the test results indicated an effective phi angle of 45.9° with a nominal 0.5 psi effective cohesion. The results of the testing are provided in the Appendix.

3.3.2 Unconfined Compression (UC) Testing

A series of sample specimens were molded at varying compaction percentage and moisture content to develop an understanding of relative strength vs. compaction. In addition, a set of samples was molded to near 93% compaction at moisture 3% above optimum and tested over a period of 30 days to evaluate strength gain over time. The undrained shear strength of the molded samples was determined by means of unconfined compression tests (ASTM D 2166). In an unconfined compression test, a cylindrical sample of soil is subjected to a uniformly increasing axial strain until failure develops. For cohesive soils, the undrained shear strength, or cohesion, is taken to be equal to one-half of the maximum observed normal stress on the sample during the test. The results of the unconfined compression tests are provided as undrained shear strength values in the tables below.

Table 1 – Unconfined Compression Testing – Molded Samples – Various Compaction and Moisture Levels

Relative Moisture Condition	% Compaction (compared to ASTM D698)	Moisture Content w (%)	$w - w_{opt}$	Undrained Shear Strength (psf)
Dry of Optimum (-2 to -6%)	91.4	11.9	-3.5	570
	91.9	10.2	-5.2	805
	95.6	9.3	-6.1	1109
	96.0	11.7	-3.7	992
Near Optimum -2 to +2%	92.0	15	-0.4	691
	92.6	14.7	-0.7	631
	93.7	17.5	2.1	704

Relative Moisture Condition	% Compaction (compared to ASTM D698)	Moisture Content w (%)	$w - w_{opt}$	Undrained Shear Strength (psf)
Wet of Optimum +2 to +5	93.7	20	4.6	241
	94.2	18.6	3.2	257
	92.2	18.3	2.9	478
	93.0	18.3	2.9	360
	96.5	20.3	4.9	528

Table 2 – Unconfined Compression Testing – Molded Samples – Strength vs. Time

Compaction and Moisture Condition	% Compaction[1] (compared to ASTM D698)	Moisture Content[1] w (%)	Compaction Age (days)	Undrained Shear Strength – Avg. (psf)
93 to 94% +3% Moisture	93.2	18.5	0	367
	93.2	18.6	7	754
	94.0	18.2	14	950
	94.3	18.4	28	840

Notes: 1. Average of two samples.

3.4 California Bearing Ratio (CBR) Testing

A sample of select material was compacted into a CBR mold at approximately 95% compaction and at near +2% of optimum moisture for CBR testing in accordance with ASTM Test Method D1883-07. A 10-lb surcharge weight was used for the test. The sample/mold was soaked in water for 96 hours prior to implementing the penetration test. During the 96-hour soak period a swell of 0.6% was recorded. A CBR (%) of 18.4 and 24.6 was obtained from the 0.1 and 0.2 penetration, respectively. A plot of the penetration test results is provided in the Appendix.

The second sample was compacted at approximately 90% compaction and at near +2% of optimum moisture and soaked in water. A 10-lb surcharge weight was used for the test. The sample/mold was soaked in water for 30 days prior to implementing the penetration test. During the 30-day soak period, the sample consolidated slightly (swell of 0%). A CBR (%) of 9.3 and 9.5 was obtained from the 0.1 and 0.2 penetration, respectively. A plot of the penetration test results is provided in the Appendix.

3.5 Consolidation Characteristics

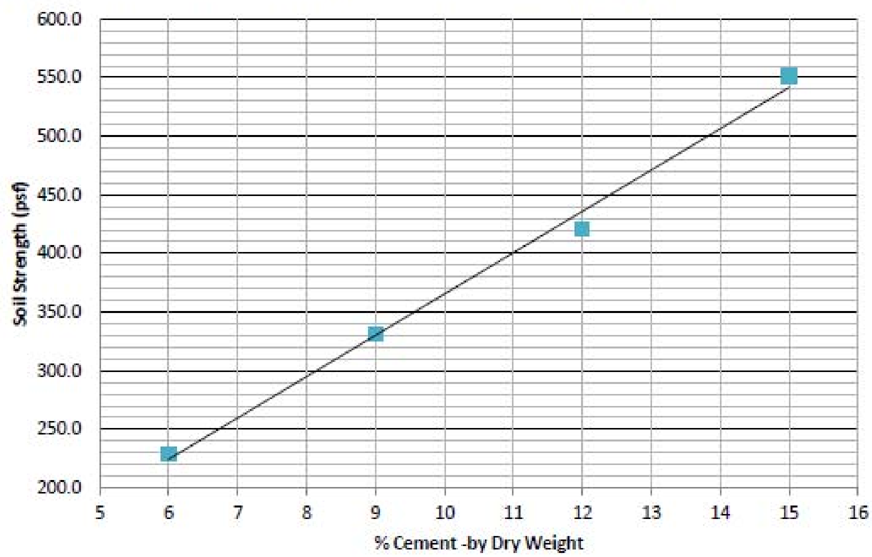
A constant rate of strain consolidation test (ASTM D4186) was performed on a sample molded to around 95% of Standard Proctor. The results of this test can be used for calculating settlement for foundation loads placed upon the select material. The test results are included in the Appendix.

3.6 Soil Cement Study – LADOTD TR-432

An evaluation of the material for potential use as select material for construction of a soil cement pavement base was performed in general accordance with LADOTD Method TR-432. In addition a CBR test was performed on a select/cement sample to evaluate bearing and swell.

In summary, subsamples of the material were prepared and varying percentages of cement were added on a dry weight basis, mixed, and then compacted into a proctor mold as outlined in the TR432 Method. Five subsamples were prepared for each cement percentage of 6%, 9%, 12% and 15% on a dry weight basis. After extruding the samples from the mold, they were placed in plastic and cured in a temperature controlled room for 7 days. On day 7, the samples were tested for compressive strength. The test results are included in the Appendix. A plot of the average compressive strength vs. percent cement by dry weight is provided below:

Figure 1 – Plot of Compressive Strength vs. % Cement (by dry weight)



Upon completion of the soil cement series, a sample of select material was mixed with 9% cement by dry weight and compacted into a CBR mold using 25 blows/layer. A 10-lb surcharge weight was applied. The sample/mold was soaked in water for 33 days prior to implementing the penetration test. During the 33-day soak, periodic swell measurements were obtained and showed that the sample consolidated slightly (e.g., no swell). A CBR (%) of 144 and 133.9 was obtained from the 0.1 and 0.2 penetration, respectively. A plot of the penetration test results is provided in the Appendix.

4.0 DISCUSSION OF RESULTS

As outlined, the purpose of this cursory laboratory testing program was to provide an understanding of the Calcium Sulfate 'select' materials engineering properties to allow for a generalized evaluation of potential uses as a construction material. This study was not intended to be an exhaustive research based program, but more of an initial cursory evaluation for perhaps low risk applications. This report should not be construed as providing an evaluation of all aspects of the expected performance of the material. Further evaluation and/or testing may be required depending upon the intended application and project specific requirements.

4.1 Compacted Engineered Fill

The testing indicates the material is classified as sandy silt (ML) per the USCS. In general, soils that are classified as silt are normally not considered conducive for use as engineering fill due to moisture sensitivity and potential difficulties in achieving compaction with stability. The results of the strength testing suggest that this material would be expected to perform better than a similarly graded soil material. The materials effective angle of friction of 45.9 degrees is perhaps 1.5 to 2 times that which might be expected from a similarly graded sandy silt soil. This relative high friction angle and moderate compacted unit weight provides some advantages in applications where reduced lateral earth pressures are desired.

The results of the unconfined compression testing at various degrees of compaction and moisture levels were performed to provide an understanding of expected compaction stability at varying moisture conditions. The results indicate that materials compacted to within -2 to +2% moisture and at least 95% yield undrained shear strengths generally above 600 psf. The strength dropped to around 250 psf for the samples at a moisture of about 3% above optimum; however, even at a moisture of +5%, a nominal 500 psf undrained shear strength was obtained for a sample at 96.5% compaction.

The results of the unconfined compression vs. time showed the strength of the compacted material molded at +3% moisture and around 93% compaction increased from near 360 psf to around 750 psf after 7 days. The material strength increased to around 900 psf after 14 days, with similar results at the 28-day age. These results suggest the material exhibits a relatively short period strength gain over time; although the mechanism governing the strength gain is not known.

The results suggest that this material would not behave substantially different from a compaction and stability perspective than the conventional lean clay (CL) fill used in the local market. Conventional moisture control (e.g., maintaining moisture to within +/- 2% of optimum) would be considered applicable for compaction of this material.

4.2 Pavement Subgrade Characteristics

The results of CBR testing of the material compacted to around 95% of standard Proctor (D698) revealed a CBR (%) of 18.4. This CBR is considered to be on the order of 3 to 4 times higher than a CBR typically achieved with conventional lean clay (CL) fill normally used in the local market. The CBR test of the material compacted to around 90% and soaked for 30 days revealed a CBR (%) of 9. Although this test was performed at a relatively low compaction level and an extended soak period, it still exhibited a CBR on the order of 2 times that expected from typical locally available CL fill material.

The results of swell testing performed as part of the CBR test indicated 0.6% swell during the 96 hour soak. The 30-day CBR test exhibited no swell. Typically materials with swell less than 1 percent are considered to be non-swelling. These results and the general evaluation of compaction stability suggest that the 'select' calcium sulfate may provide for good support characteristics when used as an engineering fill for support of pavements.

4.3 Soil Cement Pavement Base

The results of the soil cement evaluation performed in general accordance with LADOTD Method TR432 revealed results that are typically obtained using conventional select material as defined in Section 302.02(a) of the 2006 LSSRB. Select material for this application requires a material with a Liquid Limit less than 35, a Plasticity Index less than 15, silt content less than 60%, sand content less than 79%, and organics of 2% or less. The calcium sulfate 'select' material would not meet the criteria due to the silt content being at around 73%.

According to TR432, sufficient cement must be added to the select soil to achieve a minimum compressive strength of 300 psi at 7 days to be considered as Class II Soil Cement Base. From a performance basis, the calcium sulfate 'select' material achieved the minimum 300 psi strength at slightly over 8% cement by dry weight, despite the apparent higher than specified silt percentage. Using a maximum dry density of around 95 pcf for this material, a volumetric cement addition rate of 7.6% is calculated. This addition rate is similar, if not slightly lower, to what typically is prescribed with conventional locally available select soil. The results of the CBR swell test on a compacted sample set at 9% cement did not exhibit any swell (it actually consolidated slightly) over a 30-day period, providing at least anecdotal evidence of the volumetric stability of the select/cement material.

One apparent advantage of the 'select' calcium sulfate as a source of select material is consistency. Since this material is derived from a process, it could be argued that only minor deviations in material properties would be expected compared to select soils that are derived from natural deposits from a borrow source.

5.0 LIMITATIONS AND CONSIDERATIONS

The information presented in this report is based upon data obtained from a limited laboratory program as discussed in this report. This laboratory scope is not intended to be an exhaustive research based program, but more of an initial cursory evaluation of the material for consideration of its use in basic low risk applications.

The scope of services for this project does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the material or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either expressed or implied, are intended or made.

APPENDIX A
LABORATORY TEST RESULTS

Terracon

Grain Size Curve

Honeywell Calcium Sulfate Evaluation

EH116309

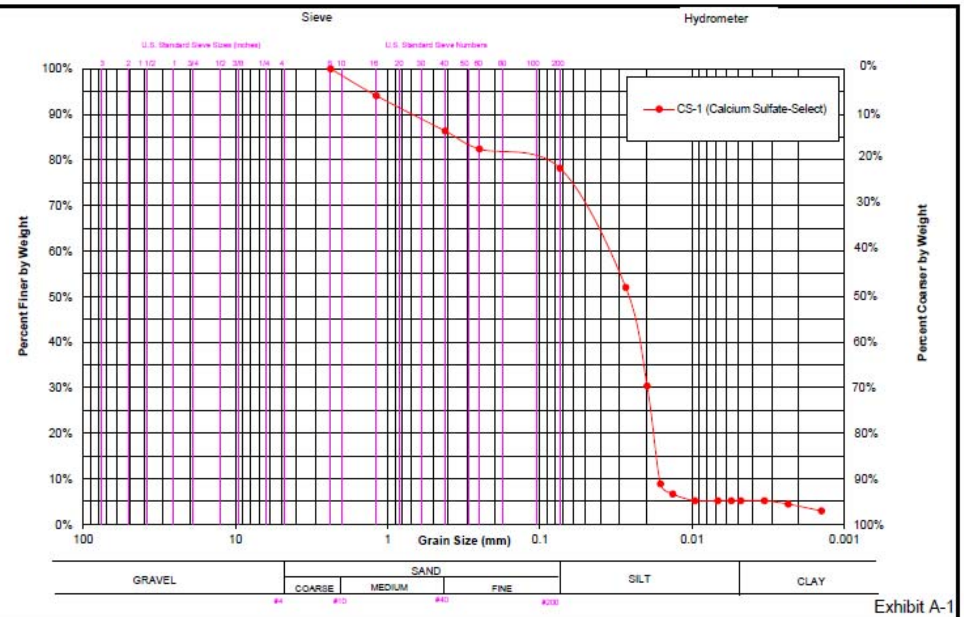
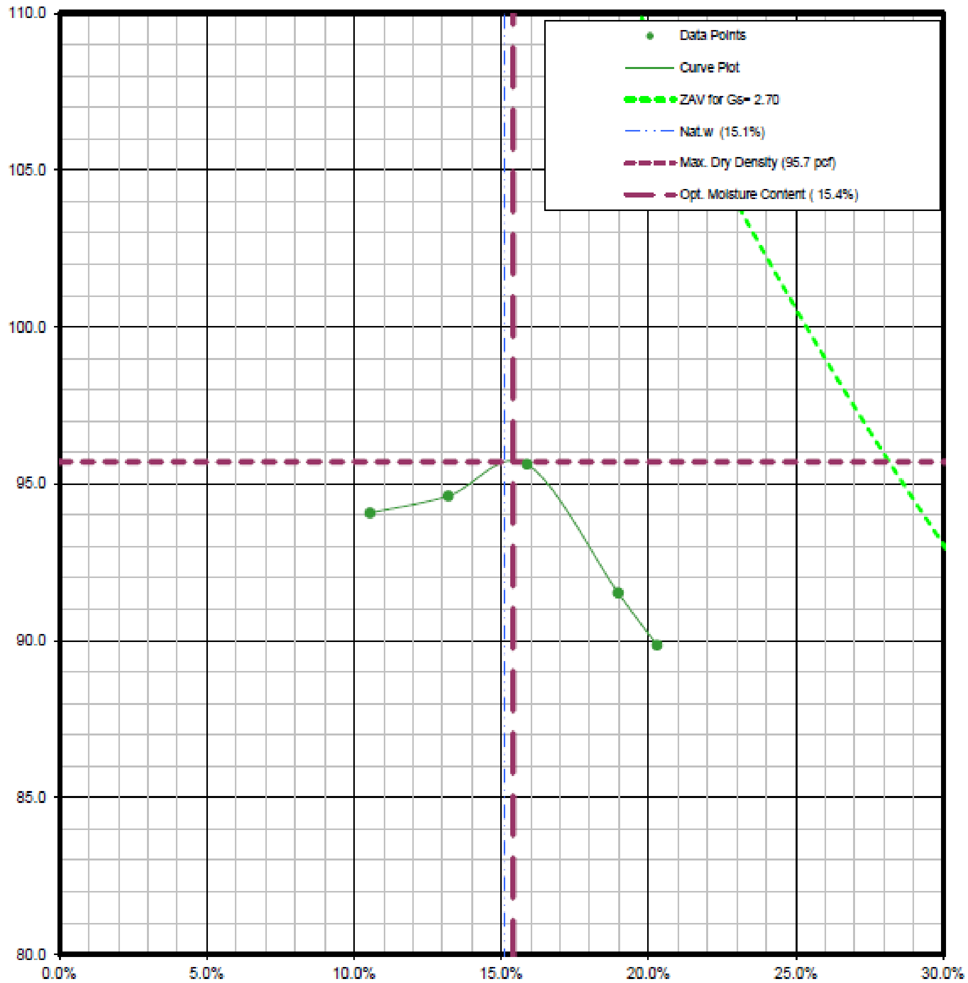


Exhibit A-1



Test Information

Type Test: Standard Proctor

Method: ASTM D 698

Performed By: BF

Date Performed: 08/08/11

Test Results

Maximum Dry Density = 95.7 pcf

Optimum Water Content = 15.4%

Sample Information

Sample Number: CS-1

Source: Honeywell - Geismar Plant

Natural Water Content = 15.1%

Atterberg Limits: LL = 22 PL = NP

Fines Content = 78.2%

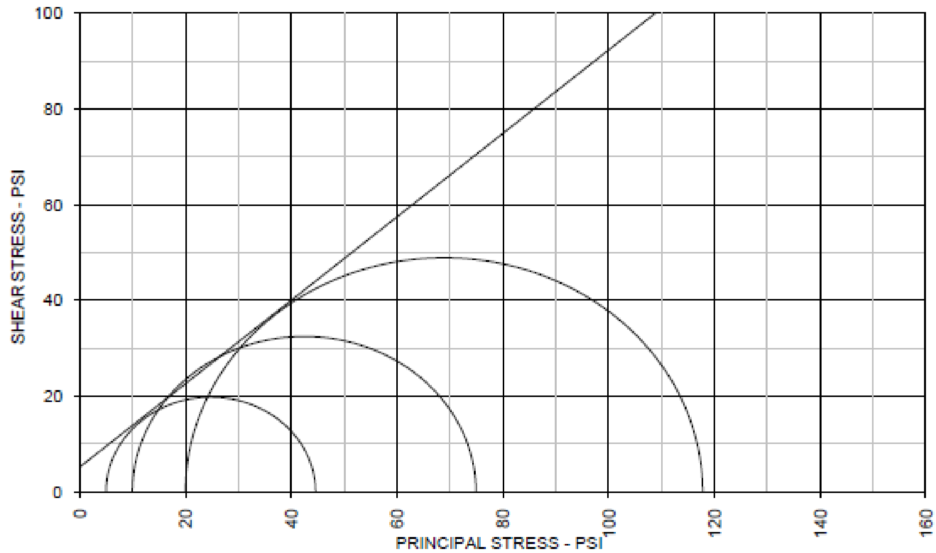
Classification: Calcium Sulfate- Select

Moisture/Density Relationship		
Honeywell Lab Testing Baton Rouge, LA		
Engr: SEG EH116309	Terracon	Exhibit A-2

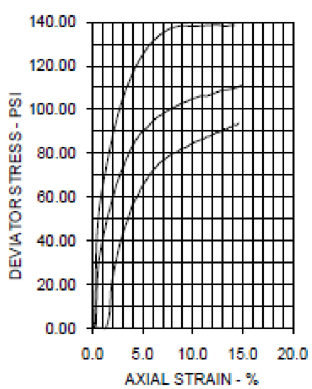
TRIAXIAL SHEAR TEST REPORT

Terracon

P.O. Box 5010, 51 Lost Mound Drive, Suite 135 Chattanooga, TN 37406



TOTAL STRESS PARAMETERS	ϕ = 41.1 deg	c = 5.2 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	17.4	17.4	17.4	
Dry Density - pcf	90.9	90.9	90.9	
Diameter - inches	2.80	2.80	2.80	
Height - inches	6.00	6.00	6.00	
AT TEST				
Final Moisture - %				
Dry Density - pcf	90.9	91.1	91.5	
Calculated Diameter (in.)	2.79	2.78	2.78	
Height - inches	5.97	5.95	5.93	
Effect. Cell Pressure - psi	5.0	10.0	20.0	
Failure Stress - psi	39.62	64.96	97.82	
Total Pore Pressure - psi	47.5	48.0	51.1	
Strain Rate - inches/min.	0.00060	0.00060	0.00060	
Failure Strain - %	2.8	2.3	2.6	
σ_1 Failure - psi	44.62	74.96	117.82	
σ_3 Failure - psi	5.00	10.00	20.00	

TEST DESCRIPTION

TYPE OF TEST & NO: CU with Pore Pressure Measurements
SAMPLE TYPE: Remolded Specimens
DESCRIPTION: Calcium Sulfate Select (USCS: ML)
SAMPLE LOCATION: CS-1
ASSUMED SPECIFIC GRAVITY: 2.7
LL: 22 PL: NP PI: NP Percent -200: 78%
REMARKS: Samples remolded to 95% +2 omc.

PROJECT INFORMATION

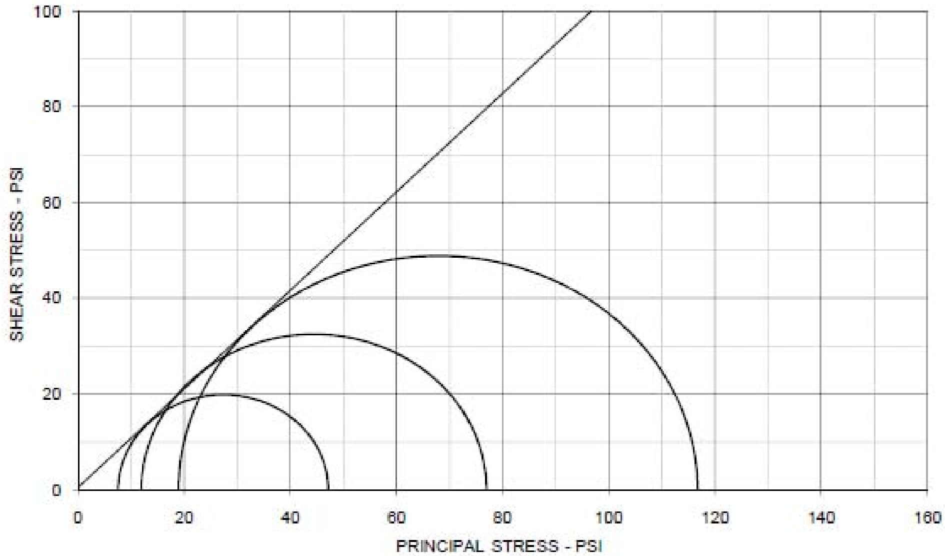
PROJECT: Honeywell Lab Testing
LOCATION: Baton Rouge, LA
PROJECT NO: EH116309
CLIENT: Honeywell Specialty Materials
DATE: 8/26/11

TERRACON | Exhibit A-3

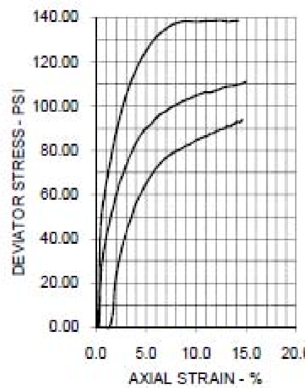
CS-1 TRIAX_Terracon-1.xls

TRIAXIAL SHEAR TEST REPORT

Terracon



EFFECTIVE STRESS PARAMETERS	ϕ ' =	45.9 deg	c' =	0.5 psi



SPECIMEN NO.	1	2	3	4
INITIAL				
Moisture Content - %	17.4	17.4	17.4	
Dry Density - pcf	90.9	90.9	90.9	
Diameter - inches	2.80	2.80	2.80	
Height - inches	6.00	6.00	6.00	
AT TEST				
Final Moisture - %				
Dry Density - pcf	90.9	91.1	91.5	
Calculated Diameter (in.)	2.79	2.78	2.78	
Height - inches	5.97	5.95	5.93	
Effect. Cell Pressure - psi	5.0	10.0	20.0	
Failure Stress - psi	39.62	64.96	97.82	
Total Pore Pressure - psi	47.5	48.0	51.1	
Strain Rate - inches/min.	0.00060	0.00060	0.00060	
Failure Strain - %	2.8	2.3	2.6	
σ_1' Failure - psi	47.14	76.92	116.74	
σ_3' Failure - psi	7.52	11.96	18.92	

TEST DESCRIPTION

TYPE OF TEST & NO: CU with Pore Pressure Measurements
SAMPLE TYPE: Remolded Specimens
DESCRIPTION: Calcium Sulfate Select (USCS: ML)
SAMPLE LOCATION: CS-1
ASSUMED SPECIFIC GRAVITY: 2.7
LL: 22 PL: NP PI: NP Percent -200: 78%
REMARKS: Samples remolded to 95% +2 omc.

PROJECT INFORMATION

PROJECT: Honeywell Lab Testing
LOCATION: Baton Rouge, LA
PROJECT NO: EH116309
CLIENT: Honeywell Specialty Materials
DATE: 8/26/11

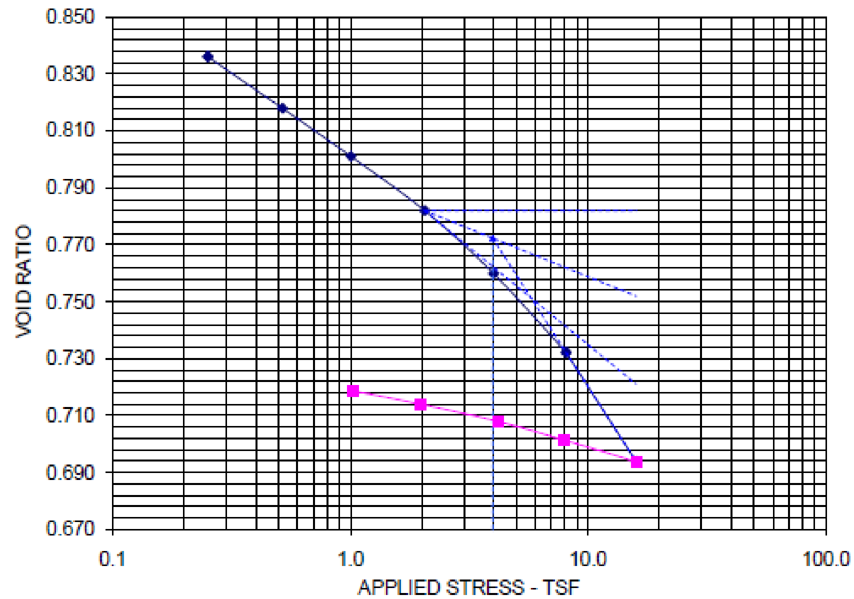
TERRACON | Exhibit A-4

CS-1 TRIAX_Terracon-1.xls

CONSOLIDATION TEST REPORT

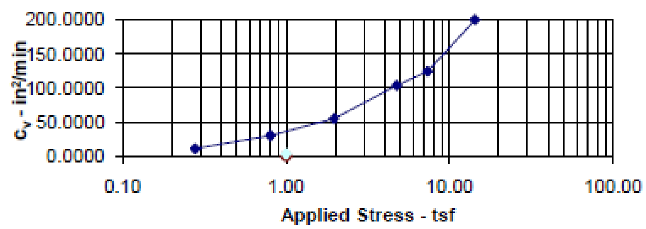
CRS - ASTM D 4186

Terracon



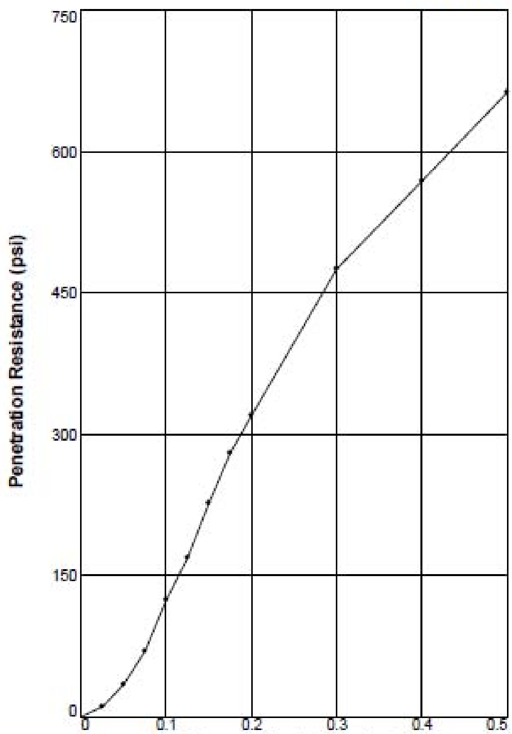
C_c = 0.130	C_r = 0.021	e_0 = 0.8526	Preconsolidation Pressure (tsf) = 3.97

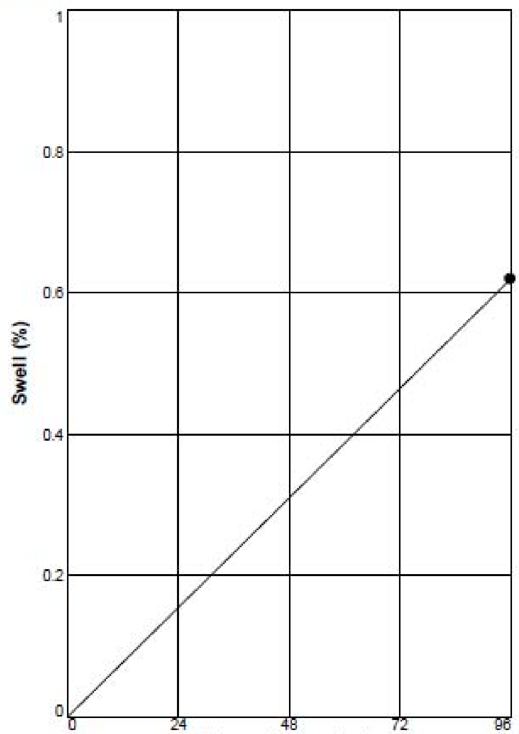
LOAD tsf	c_v in^2/min
Seating	NA
0.28	11.5502
0.80	30.6242
1.96	55.3750
4.74	103.6029
7.34	124.2492
14.31	199.6080
0.00	0.0000
0.00	0.0000



SAMPLE AND TEST DATA	PROJECT INFORMATION
SAMPLE LOCATION: CS-1	PROJECT: Honeywell Lab Testing
DESCRIPTION: Calcium Sulfate Select (USCS:ML)	LOCATION: Baton Rouge, LA
	PROJECT NO.: EH116309
LL: 22 PL: NP PI: NP -200: 78%	CLIENT: Honeywell Specialty Materials
ASSUMED SPECIFIC GRAVITY: 2.70	CLIENT NO.: 001
MC Initial: 17.4% MC Final: 26.6%	DATE: 8/25/2011
Initial Sat %: 55.1 Final Sat %: 100.0	TERRACON
DRY DENSITY (pcf): 90.7	Exhibit A-5

BEARING RATIO TEST REPORT
ASTM D 1883-07





	Molded			Soaked			CBR (%)		Linearity Correction (in.)	Surcharge (lbs.)	Max. Swell (%)
	Density (pcf)	Percent of Max. Dens.	Moisture (%)	Density (pcf)	Percent of Max. Dens.	Moisture (%)	0.10 in.	0.20 in.			
1 ○	91.3	95.4	17.4	90.7	94.8	21.9	18.4	24.6	0.032	10	0.6
2 △											
3 □											

Material Description	USCS	Max. Dens. (pcf)	Optimum Moisture (%)	LL	PI
Calcium Sulfate		95.7	15.4	22	0

Project No: EH116309

Project: Honeywell Lab Testing

Source of Sample: Honeywell- Geismar Plant **Depth:** Bulk

Sample Number: CS-1

Date: 8/25/11

Test Description/Remarks:

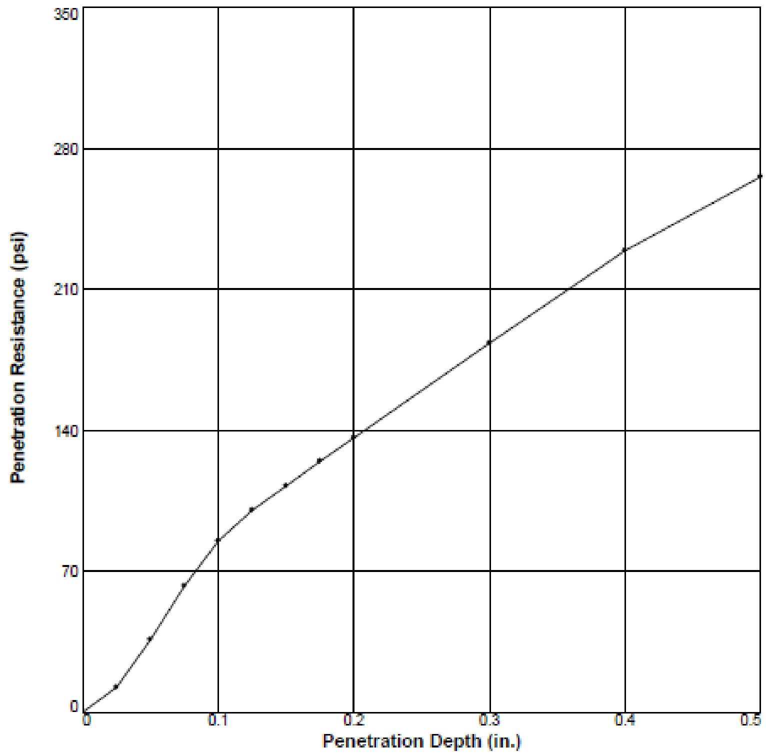
Sample Remolded To Approximately 95% +2omc.

BEARING RATIO TEST REPORT

Terracon Consultants, Inc.

Exhibit A-6

BEARING RATIO TEST REPORT
ASTM D 1883-07



	Molded			Soaked			CBR (%)		Linearity Correction (in.)	Surcharge (lbs.)	Max. Swell (%)
	Density (pcf)	Percent of Max. Dens.	Moisture (%)	Density (pcf)	Percent of Max. Dens.	Moisture (%)	0.10 in.	0.20 in.			
1 ○	86.4	90.3	17.4	86.4	90.3	30.7	9.3	9.5	0.013	10	0
2 △											
3 □											

Material Description	USCS	Max. Dens. (pcf)	Optimum Moisture (%)	LL	PI
Calcium Sulfate- 30 Day		95.7	15.4	22	0

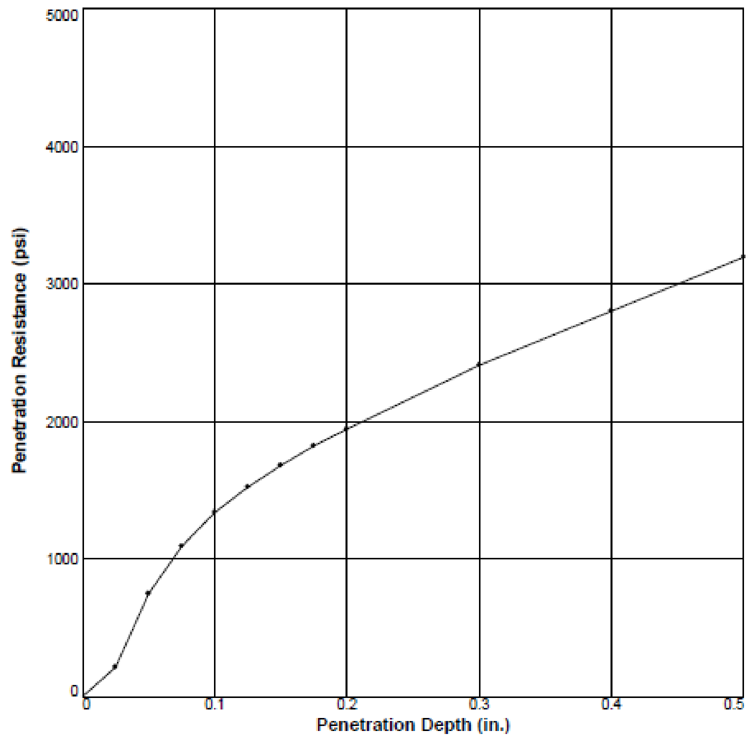
Project No: EH116309
Project: Honeywell Lab Testing
Source of Sample: Honeywell- Geismar Plant **Depth:** Bulk
Sample Number: CS-1
Date: 11/28/11

Test Description/Remarks:
25 Blows Per Layer

BEARING RATIO TEST REPORT
Terracon Consultants, Inc.

Exhibit A-7

BEARING RATIO TEST REPORT
ASTM D 1883-07



	Molded			Soaked			CBR (%)		Linearity Correction (in.)	Surcharge (lbs.)	Max. Swell (%)
	Density (pcf)	Percent of Max. Dens.	Moisture (%)	Density (pcf)	Percent of Max. Dens.	Moisture (%)	0.10 in.	0.20 in.			
1 ○	85.7	89.6	17.4	85.7	89.5	35.9	144.0	133.9	0.014	10	0
2 △											
3 □											

Material Description	USCS	Max. Dens. (pcf)	Optimum Moisture (%)	LL	PI
Calcium Sulfate- 30 Day, 9% Cement		95.7	15.4	22	0

Project No: EH116309
Project: Honeywell Lab Testing
Source of Sample: Honeywell- Geismar Plant **Depth:** Bulk
Sample Number: CS-1
Date: 11/28/11

Test Description/Remarks:
25 Blows Per Layer

BEARING RATIO TEST REPORT
Terracon Consultants, Inc.

Exhibit A-8

APPENDIX - Honeywell BCS Fines Gradation and pH

TRANSMITTAL

AAI
Ardaman & Associates, Inc.

To:	**Honeywell Specialty Materials**	**Date: January 6, 2011**
	P O Box 226	**Job No.: 113-10-81-3676**
	Geismar, LA 70734	**Project: Honeywell /BCS R & D Test Pads**
Attention:	**Travis Williams**	**From: Eric A. Paille**

COPIES	DESCRIPTION
1	Laboratory Test Results
	Brown Select BCS-Hydrometer
	Brown Select BCS-PH
	Brown 610 PH

THESE ARE TRANSMITTED:

■ **FOR YOUR USE** ☐ **FOR REVIEW & COMMENT** ■ **AS REQUESTED**

☐ **REVISE AS NOTED** ☐ **TO BE DISTRIBUTED**

REMARKS: Travis Williams travis.williams2@honeywell.com

Scott Brown scott@brown-ind.com

Page 1 of 3

AASHTO Accredited Laboratory
LELAP Certificate No. 02052

316 HIGHLANDIA DRIVE
BATON ROUGE, LA 7 0810
PHONE: (225) 752-4790
FAX: (225) 752-4878

Louisiana Department of Transporation and Development

SOILS/SOIL-AGGREGATE

Project No.	10-81-3676	Material Code	Brown Ind.	AAI Lab No.	10-81-3676
Date Sampled		Submitted By	Honeywell	Quantity	
Purp. Code		Pit No.	Select BCS	Spec Code	
Date Tested	1/6/2011	Ident.	SF-1	Parish No.	
From Station		To Station		Location	
Hole No.		Depth (ft)		Log Distance (mi)	
Item No.				Sampled by	Brown Ind.

Remarks 1

Hydrometer Analysis (DOTD TR 407)			Graduate No.	Dry Mass of Sample (W), g (1 = 50.0. 2 = 100.0) 1			
Time	(T) Elapsed Time	Temp°C (0.5° increments)	(h) Hydro Reading (0.5 increments)	(C) Correction (0.5 increments)	Corrected Reading H = h + C	% Finer P = H/W x 100	Eff. Grain Size D = KSL\T (mm)
10:40	60 Minutes	23.3	10.5	-4.9	5.6	7	0.0064
11:40	120 Minutes	23.3	9.0	-4.9	4.1	5	0.0046

RETAINED ON 2.00 um (10)		**Size**	**Mass Retained (Wx)**		(DOTD TR 407)	
Mass Cup + Soil, g	0.0		**Gram**	%	% Ret. 25.0 mm (1)	0
Cup No.		Total Mass, g	76		% Ret. 19.0 mm (3/4)	0
Mass Cup, g		25.0 mm (1)	0	0	% Ret. 12.5 mm (1/2)	0
Mass Soil, g	0.0	19.0 mm (3/4)	0	0	% Ret. 4.75 mm (4)	0
RETAINED ON 425 um (40)		12.5 mm (1/2)			% Ret. 2.00 mm (10)	0
Mass Cup + Soil, g		4.75 mm (4)	0	0	% Ret. 425 µm (40)	
Cup No.		2.00 mm (10)	0	0	% Ret. 75 µm (200)	34
Mass Cup, g		425 µm (40)			% Silt	60
Mass Soil, g	0.0	75 µm (200)	26	34	% Clay & Colloids	6
RETAINED ON 75 um (200)		% Silt		60	% Pass 2.00 mm (#10)	100
Mass Cup + "Soil, g	0.0	% Clay & Colloids		6	% Pass 425 µm (40)	100
Cup No.		Pass 4.75 mm (#4)	76	100	% Pass 75 µm (200)	66
Mass Cup, g		Pass 2.00 mm (#10)	76	100	% Sand (Tot. Material)	34
Mass Soil, g					% Unadjusted Silt	60
					% Unadjusted Sand	34
					% Unadjusted Clay	6

LIQUID LIMIT		% Organic Matter (TR 413)	
No. Blows		Liquid Limit (TR 428)	0
Mass Cup + Wet Soil, g		Plasticity Index (TR 428)	0
Mass Cup + Dry Soil, g		Natural Moisture Content, % (TR 403)	
Mass Water, g		Optimum Moisture Content, % (TR 418)	
Factor		Maximum Density, kg/m³ (lb/ft³) (TR 418)	
Cup No.		Laboratory Compaction Method (TR 418)	
Mass Cup, g		% Cement (TR 432 or Plans)	
Mass Dry Soil, g		% Lime (TR 416)	
% Moisture		% Fly Ash	
PLASTIC LIMIT		% Other (Additive) Material Code Percent	
Mass Cup + Wet Soil, g		Soil Group (TR 423)	
Mass Cup + Dry Soil, g		Classification (TR 423)	
Mass Water, g		pH (TR 430)	
Cup No.		Resistivity, ohm-cm (TR 429)	
Mass Cup, g		Classification Prefix (TR 423)	
Mass Dry Soil, g		(G = Siliceous Aggr. N = Non-Siliceous S = Shell	
% Moisture		*(Required only if +2.00 mm (No. 10) material equals or exceeds 5%)*	

Remarks 2

Tested by		Checked by		APPROVED BY	
Date		Date		DATE	

Honeywell Test Sections
113-10-81-3676

Location	*PH (Raw BCS)*
Brown Select BCS	**7.7**
Brown 610 BCS	**7.63**

APPENDIX C

Terracon Report – Field Samples/Testing

Terracon

2822-B O'Neal Lane
Baton Rouge, LA 70816
Tel: 225-344-6052

Laboratory Testing Summary Report

Project
LA Recycled Aggregate Lab Testing
Terracon Project #: EH121056

Report Date
March 15, 2013

Report No. 1

Information Included
The following report includes laboratory test data of selected soil samples for LA Recycled Aggregate, LLC. The information has been reviewed by the Quality Assurance Project Manager as noted. Lab remolded samples of in-place and imported calcium sulfate select with 5% by weight slag were tested to determine compressive strengths over time. The following tables and graphs provide the information developed for this laboratory test report.

Distribution
Scott Brown
LA Recycled Aggregate, LLC
SCOTT@BROWN-IND.COM

Lab Tests Pending
None

Total Number Pages: 17

Comments
This report pertains only to the samples listed in the Laboratory Test Summary and should be retained as a permanent record thereof. The results contained in this report relate only to the samples reported. The documented results are presented in this report. The results contained in this report are intended for the use of the client. Any unauthorized use of the information contained in this report is prohibited.
Any deviations, additions to, or exclusions from the test method and any other information relevant to a specific test will be noted as needed.

Matthew C. Minton

Matthew C. Minton
Laboratory Manager

Terracon

Laboratory Test Results

Project No.	Sample No.	Lab Number	Date Received	Material Source	ω (% as received)	γ_{wet} (pcf)	γ_{dry} (pcf)	% Compaction	COMMENTS
EH121056	0919-1	3	9/20/12	In-Place Calcium Sulfate Select w/ 5% Slag- 9/19/12	14.2%	120.1	105.1	97.8%	Lab Density- Compressive Strength Testing
EH121056	0919-2	4	9/20/12	In-Place Calcium Sulfate Select w/ 5% Slag- 9/19/12	14.9%	122.6	106.7	99.2%	Lab Density- Compressive Strength Testing
EH121056	0924-1	10	9/24/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/24/12	14.0%	117.9	103.4	97.1%	Lab Density- Compressive Strength Testing
EH121056	0924-2	11	9/24/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/24/12	14.3%	122.2	107.0	100.4%	Lab Density- Compressive Strength Testing
EH121056	0925-1	12	9/25/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/25/12	11.7%	117.1	104.8	98.4%	Lab Density- Compressive Strength Testing
EH121056	0925-2	13	9/25/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/25/12	12.3%	118.8	105.7	99.3%	Lab Density- Compressive Strength Testing
EH121056	0926-1	14	9/26/12	Imported Clacium Sulfate Select w/ 5% Slag- 9/26/12	12.1%	120.1	107.1	100.6%	Lab Density- Compressive Strength Testing
EH121056	0927A	15	9/27/12	Gauge Moisture Check 24+00 - Tested 9/26/12	10.1%	130.0	118.0	110.8%	Field Density[1]
EH121056	0927B	16	9/27/12	Gauge Moisture Check 20+50 - Tested 9/25/12	10.2%	129.1	117.1	110.0%	Field Density[1]
EH121056	0927C	17	9/27/12	Gauge Moisture Check 22+40 - Tested 9/26/12	11.8%	129.8	116.1	109.0%	Field Density[1]
EH121056	0927D	18	9/27/12	Gauge Moisture Check 21+60 - Tested 9/25/12	10.6%	126.6	114.5	107.5%	Field Density[1]
EH121056	1003-1	19	10/3/12	Imported Clacium Sulfate Select w/ 5% Slag- 10/3/12	12.5%	119.9	106.6	100.1%	Lab Density- Compressive Strength Testing
EH121056	1003-2	20	10/3/12	Imported Clacium Sulfate Select w/ 5% Slag- 10/3/12	12.2%	119.1	106.1	99.6%	Lab Density- Compressive Strength Testing
EH121056	1003C	21	10/3/12	Gauge Moisture Check 27+00 - Tested 9/27/12	13.6%	121.1	106.6	100.1%	Field Density[1]
EH121056	1003D	22	10/3/12	Gauge Moisture Check 28+00 - Tested 9/27/12	13.1%	123.6	109.3	102.6%	Field Density[1]
EH121056	1008A	23	10/9/12	Gauge Moisture Check 30+00 - Tested 10/7/12	10.3%	130.2	118.0	110.8%	Field Density[1]
EH121056	1008B	24	10/9/12	Gauge Moisture Check 31+00 - Tested 10/7/12	8.8%	122.4	112.5	105.6%	Field Density[1]

[1] - Wet Unit Weight provided by Louisiana Recycled Aggregates

Compressive Strength Table

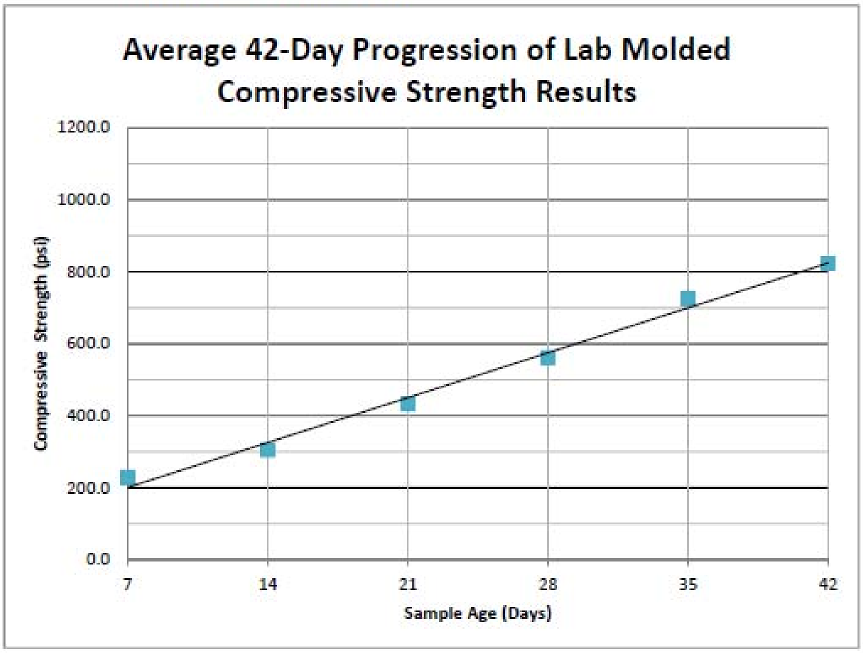
Sample ID	Date Molded	PSI (Days)					
		7	14	21	28	35	42
0919-1	9/19/2012	16.9	80.0	254.4	345.1	444.3	457.8
0919-2	9/19/2012	13.6	40.0	193.1	243.6	294.6	398.9
0924-1	9/24/2012	66.7	98.3	146.5	218.6	459.4	717.8
0924-2	9/24/2012	37.0	46.2	124.6	504.0	724.5	876.2
0925-1	9/25/2012	355.9	511.5	434.3	412.0	453.8	541.0
0925-2	9/25/2012	837.6	939.5	864.6	898.1	1087.6	1109.5
0926-1	9/26/2012	88.8	140.5	572.9	804.5	1195.1	1427.1
1003-1	10/3/2012	541.4	725.3	813.7	816.5	856.7	847.5
1003-2	10/3/2012	99.5	158.4	488.1	815.7	1015.5	1031.8
	Average	228.6	304.4	432.5	562.0	725.7	823.1
	Min	13.6	40.0	124.6	218.6	294.6	398.9
	Max	837.6	939.5	864.6	898.1	1195.1	1427.1

PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon

2822 O'Neal Lane Baton Rouge, LA 70816

42-Day Progression of Lab Molded Compressive Strength Results
Calcium Sulfate Select w/ 5% Slag

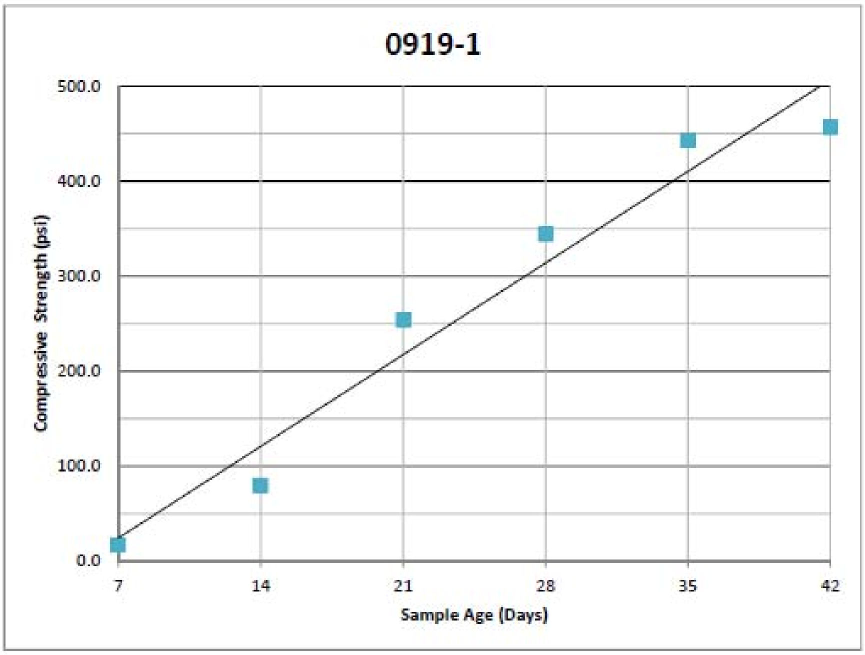


PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon

2822 O'Neal Lane Baton Rouge, LA 70816

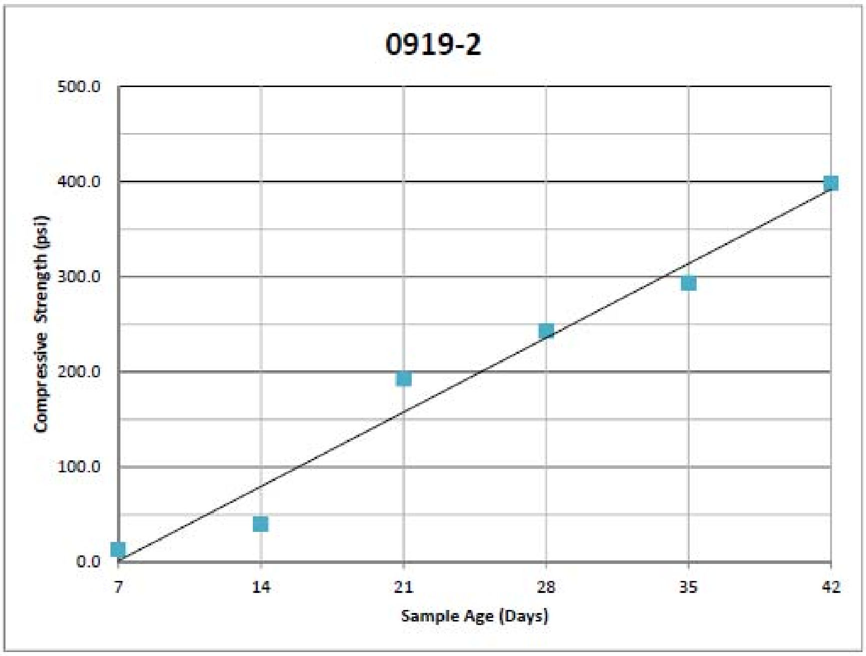
42-Day Progression of Lab Molded Compressive Strength Results
In-Place Calcium Sulfate w/ 5% by Weight Slag
Molded 9/19/12



PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon
2822 O'Neal Lane Baton Rouge, LA 70816

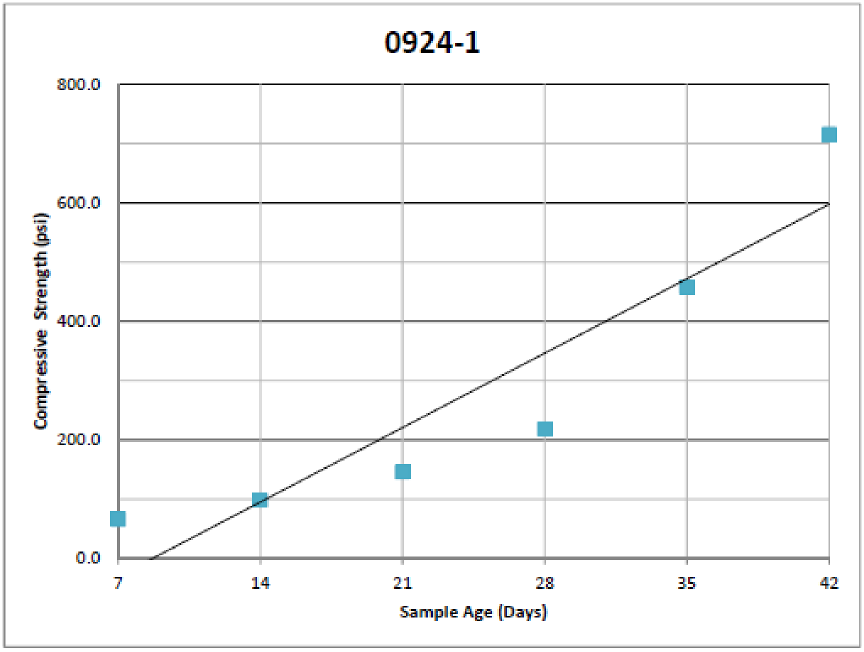
42-Day Progression of Lab Molded Compressive Strength Results
In-Place Calcium Sulfate w/ 5% by Weight Slag
Molded 9/19/12



PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon
2822 O'Neal Lane Baton Rouge, LA 70816

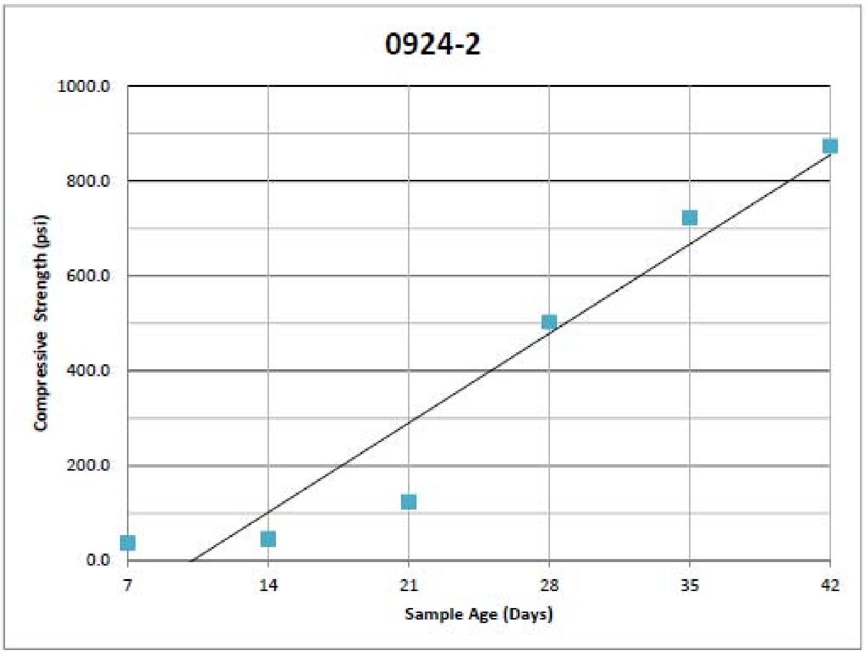
42-Day Progression of Lab Molded Compressive Strength Results
Imported Calcium Sulfate Select w/ 5% Slag
Molded 9/24/12



PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon
2822 O'Neal Lane Baton Rouge, LA 70816

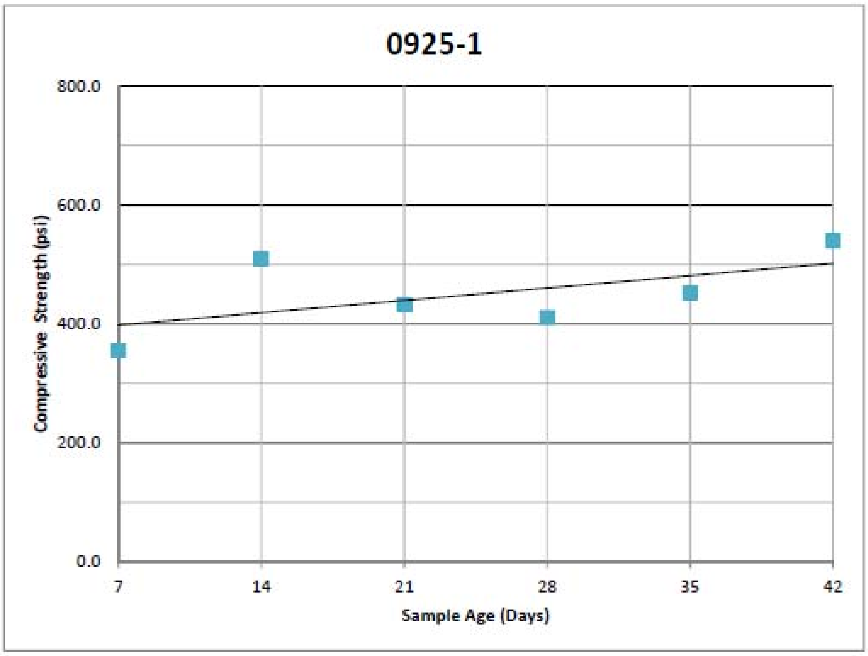
42-Day Progression of Lab Molded Compressive Strength Results
Imported Calcium Sulfate Select w/ 5% Slag
Molded 9/24/12



PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon
2822 O'Neal Lane Baton Rouge, LA 70816

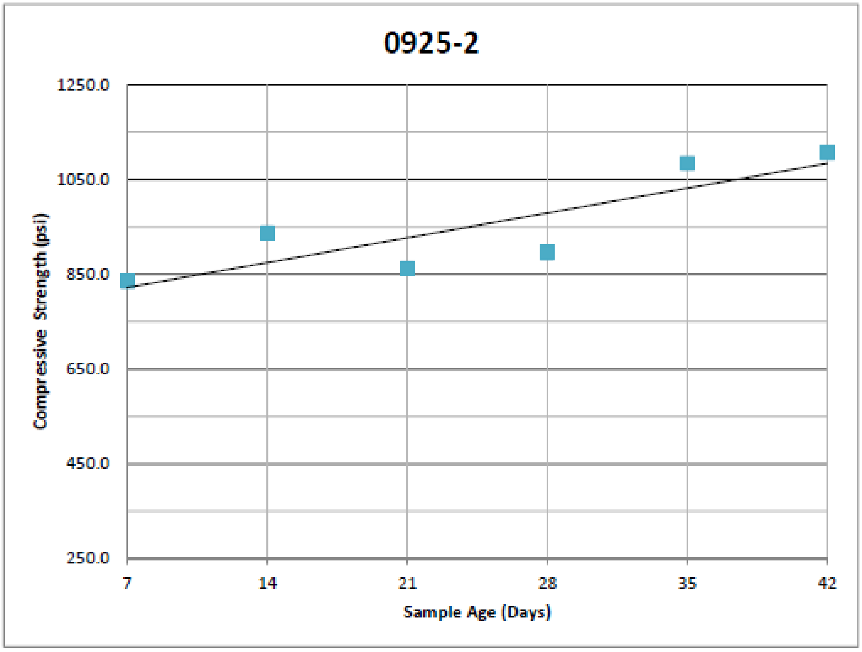
42-Day Progression of Lab Molded Compressive Strength Results
Imported Calcium Sulfate Select w/ 5% Slag
Molded 9/25/12



PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon
2822 O'Neal Lane Baton Rouge, LA 70816

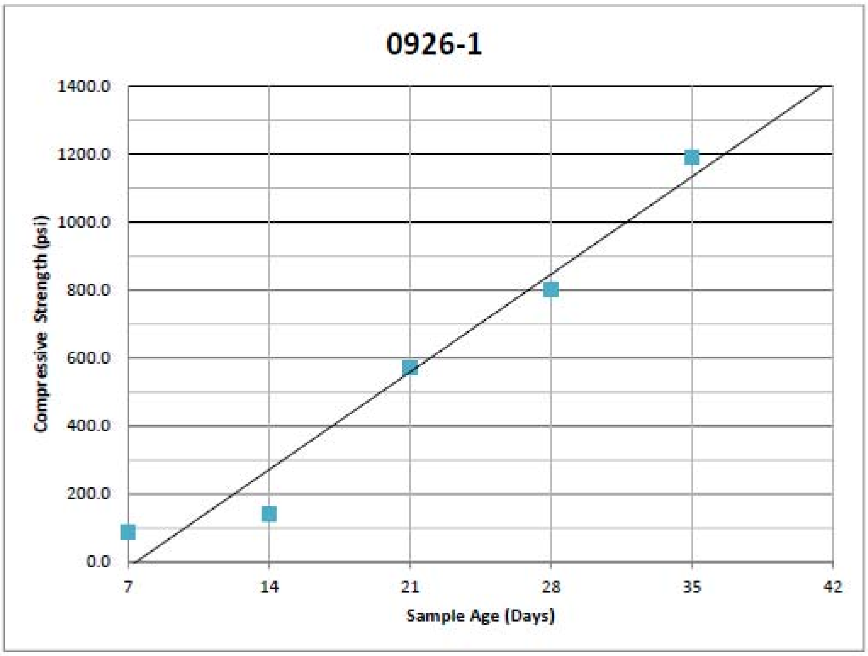
42-Day Progression of Lab Molded Compressive Strength Results
Imported Calcium Sulfate Select w/ 5% Slag
Molded 9/25/12



PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon
2822 O'Neal Lane Baton Rouge, LA 70816

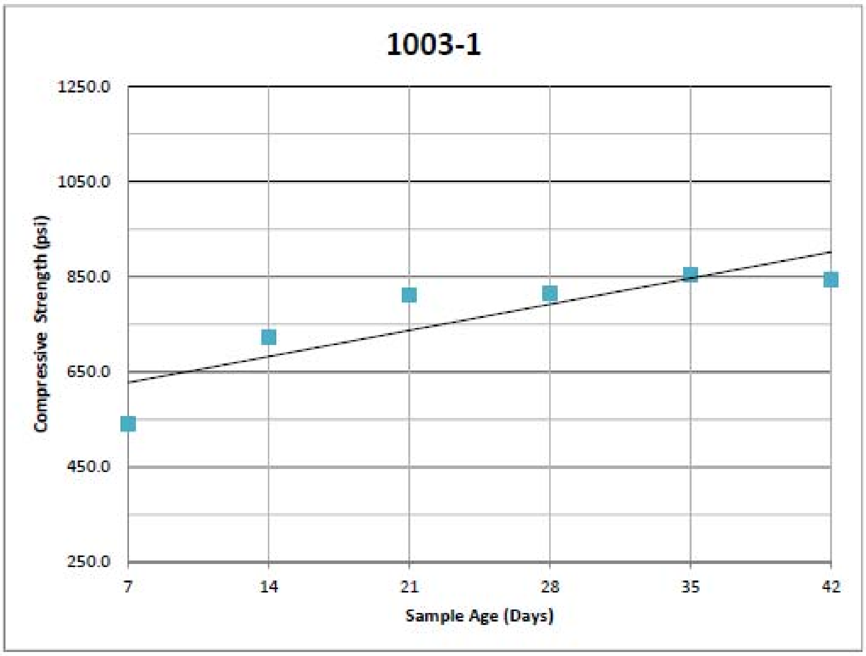
42-Day Progression of Lab Molded Compressive Strength Results
Imported Calcium Sulfate Select w/ 5% Slag
Molded 9/26/12



PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon
2822 O'Neal Lane Baton Rouge, LA 70816

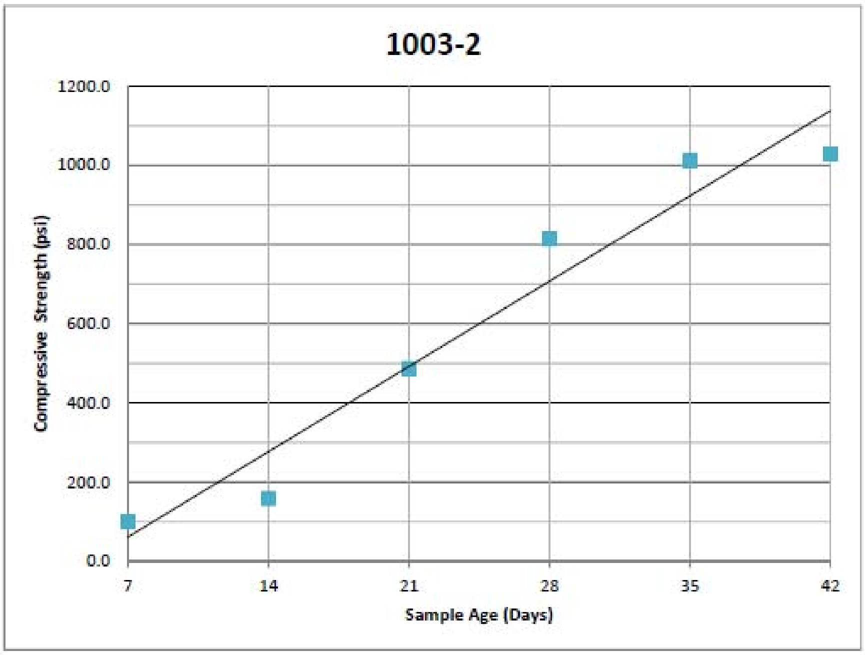
42-Day Progression of Lab Molded Compressive Strength Results
Imported Calcium Sulfate Select w/ 5% Slag
Molded 10/03/12



PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

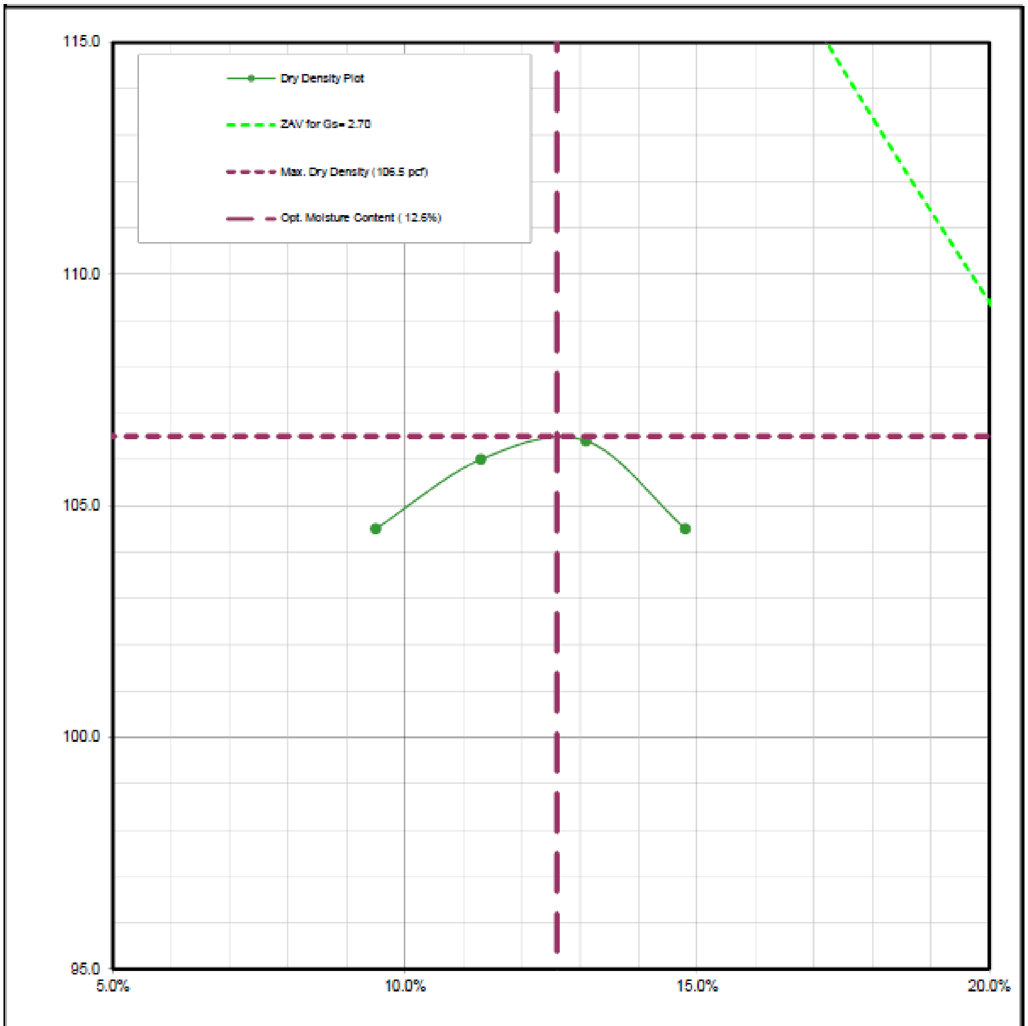
Terracon
2822 O'Neal Lane Baton Rouge, LA 70816

42-Day Progression of Lab Molded Compressive Strength Results
Imported Calcium Sulfate Select w/ 5% Slag
Molded 10/03/12



PROJECT NAME:	Louisiana Recycled Aggregates Laboratory Testing
LOCATION:	Baton Rouge, Louisiana
PROJECT NO.:	EH121056
CLIENT:	Louisiana Recycled Aggregates, LLC
PERFORMED BY:	M. Minton
REVIEWED BY:	S. Greaber

Terracon
2822 O'Neal Lane Baton Rouge, LA 70816



Test Information

Type Test: Standard Proctor

Method: ASTM D 698

Performed By: MM

Date Performed: 08/23/12

Sample Information

Sample Number: Bulk 1

Source: Imported Select Calcium Sulfate Select w/ 5% Slag

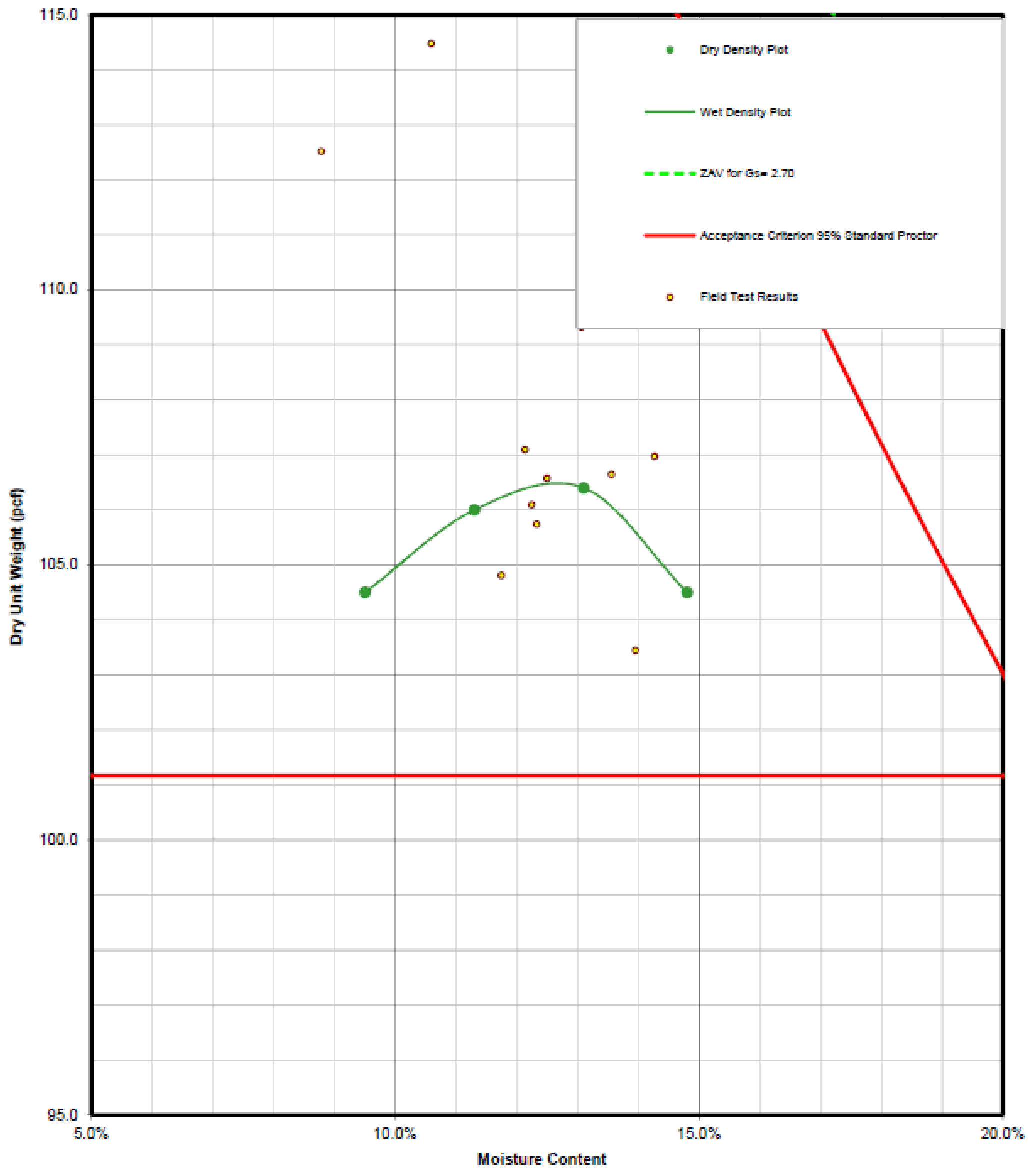
Test Results

Maximum Dry Density = 106.5 pcf

Optimum Water Content = 12.6%

Classification: Calcium Sulfate Select

Moisture/Density Relationship		
Louisiana Recycled Aggregates Laboratory Testing Baton Rouge, LA		
Engr: SEG EH121056	Terracon	Fig. No. 1

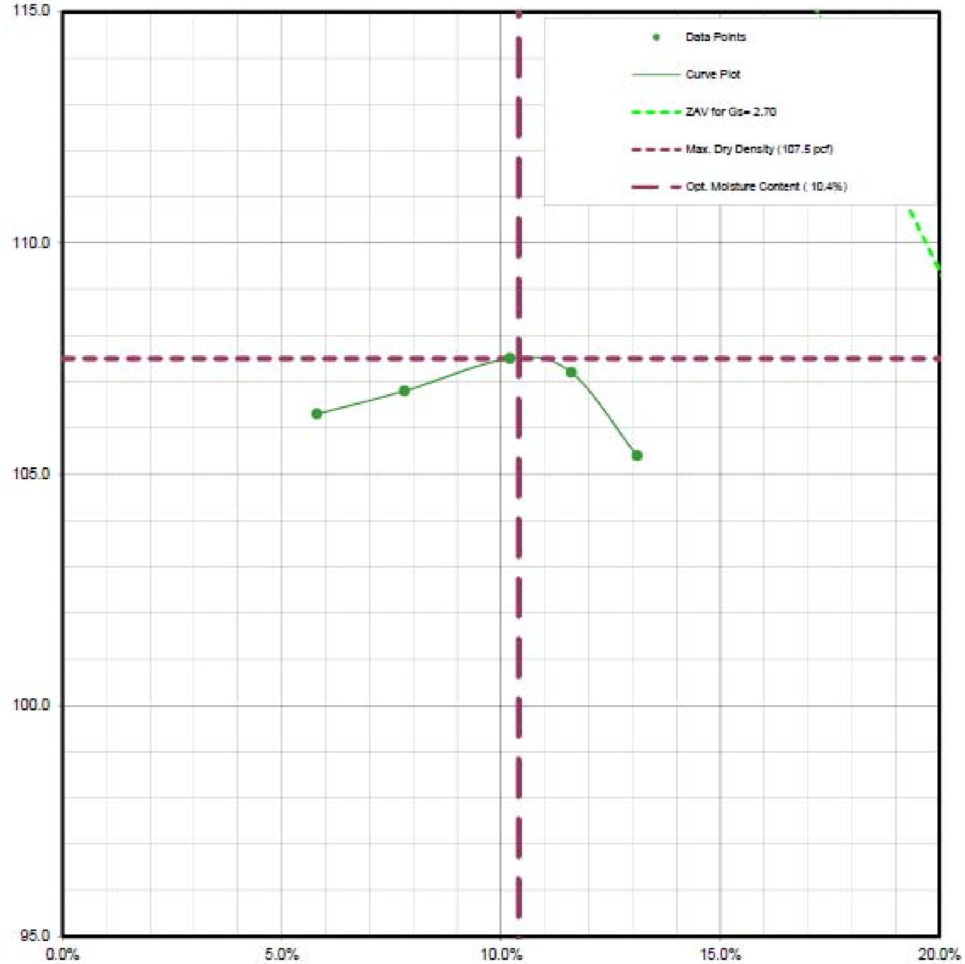


Sample Number: Bulk 1

Source: Imported Select Calcium Sulfate Select w/ 5% Slag
Maximum Dry Density (pcf): 106.5
Optimum Water Content (%): 12.6

Field Test Results
Louisiana Recycled Aggregates
Laboratory Testing
Baton Rouge, LA

Engr. SEG
EH121056
Terracon
Fig. No.
2



Test Information
Type Test: Standard Proctor
Method: ASTM D 698
Performed By: MM
Date Performed: 10/11/12

Sample Information
Sample Number: Bulk 2
Source: In-Place Calcium Sulfate Select

Test Results
Maximum Dry Density = 107.5 pcf
Optimum Water Content = 10.4%

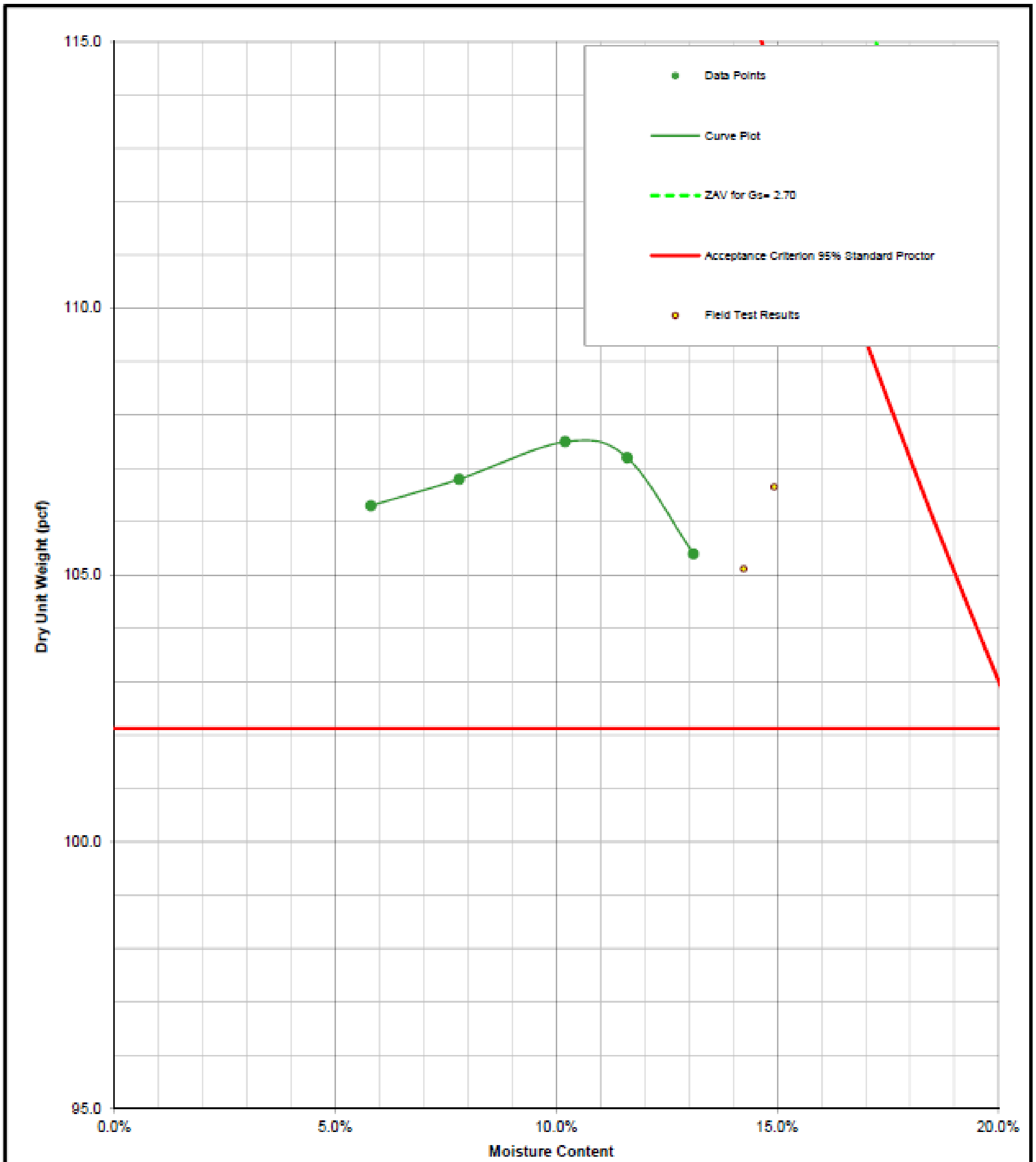
Classification: Calcium Sulfate Select

Moisture/Density Relationship
Louisiana Recycled Aggregates Laboratory Testing
Baton Rouge, LA

Engr: SEG
EH121056

Terracon

Fig. No. 3



Sample Number: Bulk 2

Source: In-Place Calcium Sulfate Select
Maximum Dry Density (pcf): 107.5
Optimum Water Content (%): 10.4

Field Test Results
Louisiana Recycled Aggregates
Laboratory Testing
Baton Rouge, LA

Engr. SEG
EH121056

Fig. No. 4