U.S. Department of Transportation
Federal Highway Administration

Memorandum

Central Federal Lands Highway Division
12300 West Dakota Avenue
Lakewood, CO 80228

Subject: TX RRP BRAZ 10(3) Brazoria
Pavement Recommendations

Date: 09/29/08

From: Mike Voth, Pavement Discipline Leader

To: Lisa Larson, Project Manager
Bob Gansauer, Project Manager

The pavement recommendations for the subject project are to follow the recommendations from the previous TX RRP BRAZ 10(2) project. The preferred alternative is again option 1 in the report:

75 mm HACP
125 mm Aggregate Base
200 mm Chemically Stabilized Subgrade

The 2 test pits completed within the project limits of the 10(3) project both had subgrade soil within the top 600 mm that classified as A-7-6 soils per AASHTO M 145. The plasticity index of the soil was 29 and 45, respectively. According to ASTM D 2487 (Unified Soil Classification System), the soils were CL (clay with low to medium PI) and CH (fat clay; high PI). Please refer to the 10(2) pavement report for additional information.

Attachment

Cc: Steve Deppmeier, Pavement Engineer
Leo Depaula, COE

BRAZORIA NATIONAL WILDLIFE REFUGE
TX RRP BRAZ 10(2) BRAZORIA TOUR LOOP ROAD

PAVEMENT RECOMMENDATION SUMMARY
August 2006
REPORT 06-01

Report by:
Michael D. Voth, Lead Pavement Engineer

Technical Services Branch
Central Federal Lands Highway Division
Federal Highway Administration
Lakewood, Colorado

Distribution:
Project Development (1)
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Materials (1)

Prepared by: ______________________________

Michael D. Voth, Lead Pavement Engineer

Reviewed by: ______________________________

Rick Marquez, Quality Assurance Engineer

Approved for distribution by:

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Michael D. Voth, Lead Pavement Engineer

9-1-06

DATE

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BACKGROUND, CLIMATE, and EXISTING CONDITIONS

Brazoria National Wildlife Refuge is located along the Gulf of Mexico about 50 miles south of Houston. The scope of the project is reconstruction of about 1.9 km of the refuge entrance road and the construction of a parking lot. Kleinfelder, Inc., the CFLHD Geotechnical IDIQ contractor, completed the field investigation and sampling.

The project area is FLAT with shallow ditches and little to no grades. Rainfall events in access of 3-4 inches may flood the roadway in areas. Tidal/Storm surges from the Gulf of Mexico can also flood parts of the roadway. After rainfall events, drainage is slow. It is estimated that the pavement structure is in a saturated condition 20-40% of the time.

Periods of heavy rainfall while the project is under construction are to be expected and can be alleviated by providing positive drainage of the subgrade and embankment. Additionally, the use of light duty equipment for construction operations may be necessary during wet and rainy periods. The average precipitation and temperatures during the period of construction are as follows:

Average Climate Conditions - Freeport, TX (~10 miles from Brazoria NWR)

Month	Precipitation	High	Low
December	3.51"	65°F	47°F
January	4.29"	63°F	45°F
February	2.84"	65°F	48°F
March	2.87"	72°F	55°F
April	2.82"	77°F	61°F
May	4.02"	83°F	69°F

The existing roadway consists of gravel with a geotextile fabric located below the gravel. Fat clays exist immediately below the gravel layer. Five borings were completed within the roadway of the 3.5-mile entrance road. The depth of the gravel ranged from 150 mm to 300 mm with an average of 212 mm. Two borings were completed within the bounds of this 10(1) project. They had gravel depths of 150 mm and 225 mm, respectively. The borings were drilled to depths between 1.5 to 1.8 m. Groundwater seepage was only encountered in borings along the Tour Loop Road and this is not a part of the current project. For more detailed information see the boring logs in attachment A.

The subgrade soil along the route is of **poor** quality. In general, the subgrade material is classified as A-7-6 (per AASHTO M 145), which is fat clay with high plasticity indexes. This material is also subject to extremely high volume change. Workability as a construction material is poor. <u>It is very common for this material to have 90% passing the #200 sieve and plasticity indexes over 40</u>. R-Values for the subgrade within this project are expected to be <10. See attachment B for the complete test reports on the soil subgrade.

TRAFFIC

The environmental and subgrade conditions will govern the pavement design, because the current traffic is well below our minimum design ESAL level of 50,000. However, the refuge is expecting an increase in traffic when a visitor center is built. Additionally, heavy trucks hauling drilling equipment for oil production will use the access road on an occasional basis. Below are rough estimates of current traffic.

- 15 to 20 vehicles per day (based on 7500 visitors per year plus refuge staff operations)
- 1 school bus per day (~180 ESALs/year)
- An occasional heavy truck hauling oil drilling equipment (~60 ESALs/year)

LOCAL (TxDOT) PAVEMENT DESIGN PRACTICE

The Texas DOT typical section in an area like Brazoria, with fat clays, is a stabilized subgrade, followed by a cement-stabilized base, followed by a hot asphalt concrete pavement (HACP) riding surface. Route 523, which is the local road from Freeport that leads to the refuge access road, has a structural section as follows: 125 mm hot asphalt concrete pavement (HACP) over a 225 mm stabilized base.

PAVEMENT RECOMENDATIONS

Because the existing conditions are not typically encountered on most CFLHD projects (i.e. very poor subgrade, annual flooding, high precipitation), numerous options for the pavement structural section were considered including a conventional partial-depth asphalt pavement section as well as the use of a stabilized subgrade. Additionally, lessons learned from the TX RRP BRAZ 10(1) and the TX RRP ANAH 10(1) projects were considered when developing the pavement recommendations. The following two pavement structural sections were considered the most efficient:

1. Partial Depth Asphalt Pavement **(preferred alternative)**
   75 mm HACP
   125 mm Aggregate Base
   200 mm Chemically Stabilized Subgrade*
   SN = 2.28

2. Full Depth Asphalt Pavement
   114 mm HACP
   200 mm Chemically Stabilized Subgrade*
   SN = 2.28

*The structural coefficient for the chemically stabilized subgrade was reduced to 0.06. No preliminary evaluation of the achievable strengths was completed. However, from the previous Brazoria project it is known the achieving standard strengths values will be difficult. SCRs will be developed with appropriate strength requirements (e.g. 200 psi for cement stabilized subgrade; note that this is a no freeze climate). Non-structural benefits of the chemically stabilized subgrade include a reduction or elimination of the soil PI, completion of a stable paving platform, and expedited construction.

Option 1 above was chosen as the preferred alternative for three primary reasons: (1) an analysis completed by CFL's roadway design section indicated that this option was more economical, (2) this option provides greater distance between the wheel load and poor subgrade (providing greater distribution of load), and (3) this option allows HACP to be placed on a conventional aggregate base as opposed to a stabilized subgrade. The material and placement costs for both options were estimated to be about equal (within 3% of each other).

The design structural number (SN) is 2.32. See attachment E for the complete pavement design calculations.

Pavement Materials Recommendations

- HACP (small quantity): Use section 403 modified as necessary to meet local standards. Place in two equal lifts. Use tack coat between lifts. Unit weight is estimated at 2325 kg/m^3.
- Aggregate Base (small quantity): Use section 308, method 2 compaction. Unit weight is estimated at 2225 kg/m^3.
- Prime coat: Contractor chooses product. Cut-back asphalts are available seasonally and are preferred, but an emulsion meeting specifications and formulated to penetrate may be allowed. Use 1.2 L/m^2 for estimating.
- Tack coat: CSS-1, CSS-1h, SS-1, or SS-1h is allowed. Use 0.45 L/m^2 for estimating.
- Unclassified Borrow: incorporate specification used in Anuhuac project.
- Stabilized Subgrade: Use section 213 modified for site conditions. For estimating purposes, use at least 6% cement by unit weight of subgrade (~2000 kg/m^3). Suggest allowing the use of cement, lime, or lime/fly ash and allowing contractor to select most economical stabilizing product that will meet CFLHD standards.

CONSTRUCTION ISSUES

Spreading or mixing the existing gravel surface material across the whole grade during the building of subgrade may be advantageous to the contractor. This may provide a more stable subgrade for construction traffic and improve compaction. Test results of a sample of this gravel material from one location indicated that the material is non-plastic, has 19% passing the #200 sieve, and classified as an A-1-b material (AASHTO M 145). During construction of the subgrade it will be important for the contractor to maintain positive drainage (i.e. crowns and superelevations) because heavy rain events are expected.

An SCR for subgrade stabilization (Section 213) will be developed. During development of the previous Brazoria 10(1) project, a lime stabilization mix design was performed on a sample of subgrade material using the ASTM C 977 (Eades and Grimm) procedure. See attachment B for the complete results. A preliminary cement stabilized mix design has not performed, but the use of cement appears to be a suitable alternative to lime. Contractors should be encouraged to use the most economical combination of stabilization agents (i.e. lime, fly ash, cement) to meet CFLHD strength and quality requirements.

Sulfate content of the subgrade soil was tested. The 4 samples tested had values of 825 ppm, 850 ppm, below the detectable limit, and 875 ppm. The TXDOT Technical Memorandum, "Guidelines for Stabilization of Soils Containing Sulfates" dated August 2000 states that soluble sulfates below 3000 ppm should not be of significant concern. However, the technical memorandum does recommend using the lime slurry method (as opposed to dry lime) if any sulfates are detected. Attachment C contains the above technical memorandum. Lime slurry was used on the previous 10(1) project.

FUTURE MAINTENANCE

This road should be maintained as any other asphalt road. Surface seals, like chip seals or slurry seals, should be applied periodically according to need throughout the life of the pavement. Typically, the first surface seal should be applied 4 to 6 years after construction has been completed. The surface seal accomplishes three goals: (1) rejuvenates the asphalt and thus slows oxidation; (2) seals small cracks, which prevents water infiltration; (3) improves skid resistance. The exact timing of the first seal depends upon local conditions. The ideal time to apply a surface seal is when cracks are very small (3 – 5 mm).

There is a potential that longitudinal cracks may develop in areas due to differential settlement of the widened areas of the roadway. If these cracks occur, they should be sealed with an asphaltic crack sealant as soon as possible. If these cracks receive timely maintenance, the long-term performance of the roadway will not be significantly affected.

ATTACHMENTS

A – Boring Logs & Maps

B – Laboratory Test Results

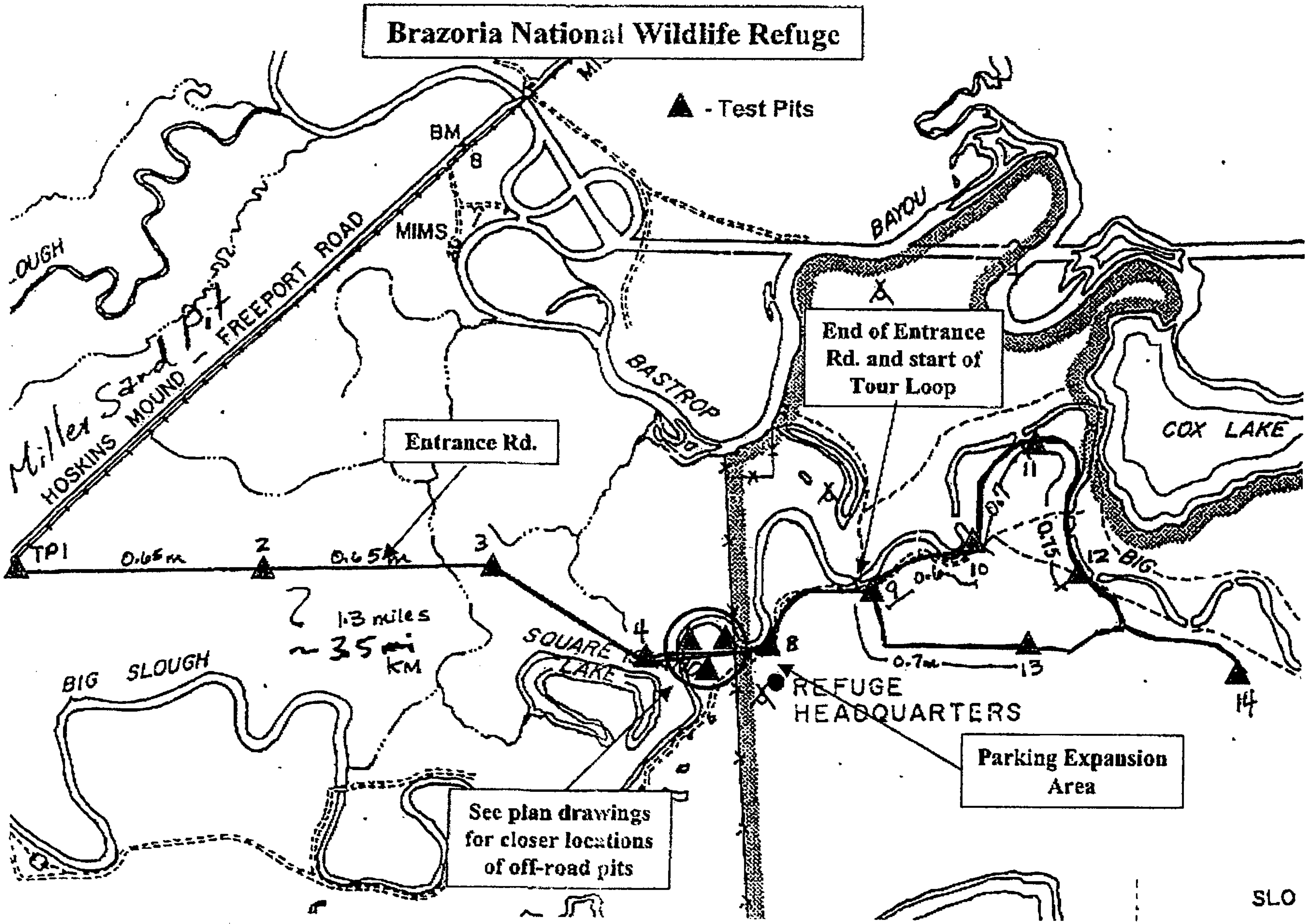
C – Technical Memorandum

D – Photographs

E – Pavement Design Calculations

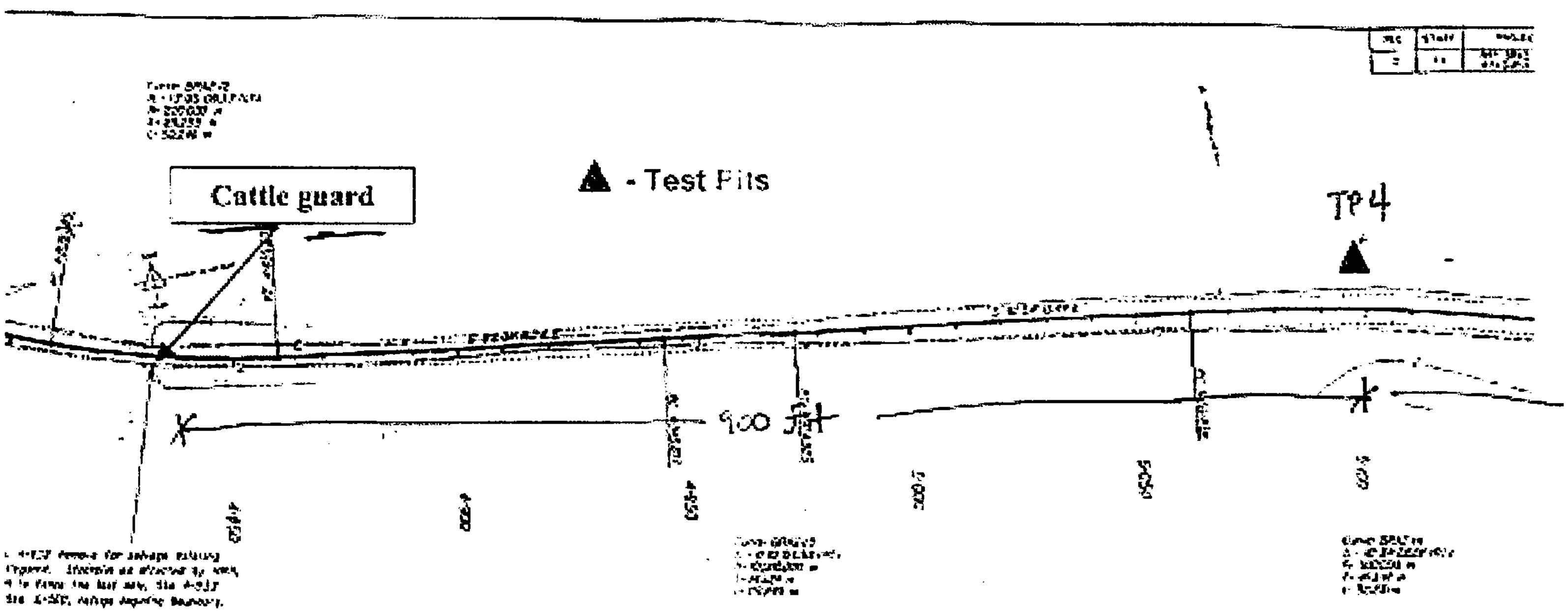
ATTACHMENT A

Boring Logs and Maps

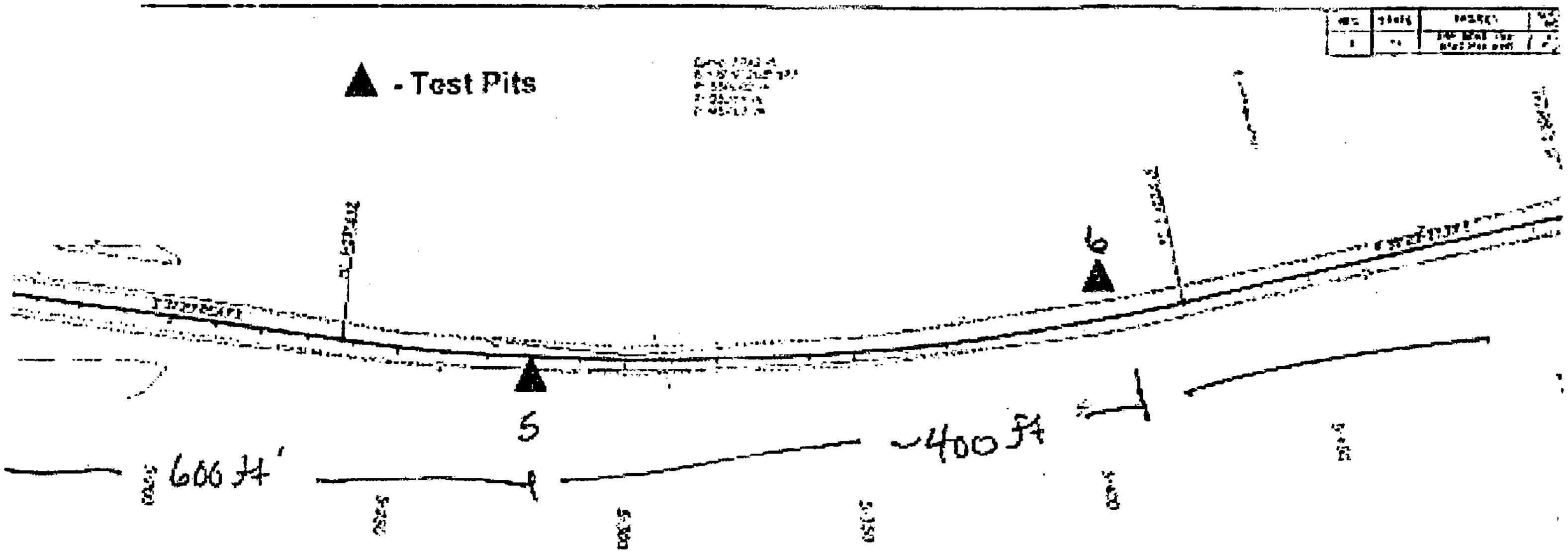


Brazoria National Wildlife Refuge
- Test Pits
BM
MIMS
HOSKINS MOUND - FREEPORT ROAD
Miller Sand Pit
SLOUGH
BAYOU
BASTROP
End of Entrance Rd. and start of Tour Loop
COX LAKE
Entrance Rd.
TP1
0.65m
2
0.65m
3
1.3 miles
~35 km
SQUARE LAKE
BIG SLOUGH
4
8
9
10
11
12
13
14
0.7m
BIG
REFUGE HEADQUARTERS
Parking Expansion Area
See plan drawings for closer locations of off-road pits
SLO

Brazoria National Wildlife Refuge

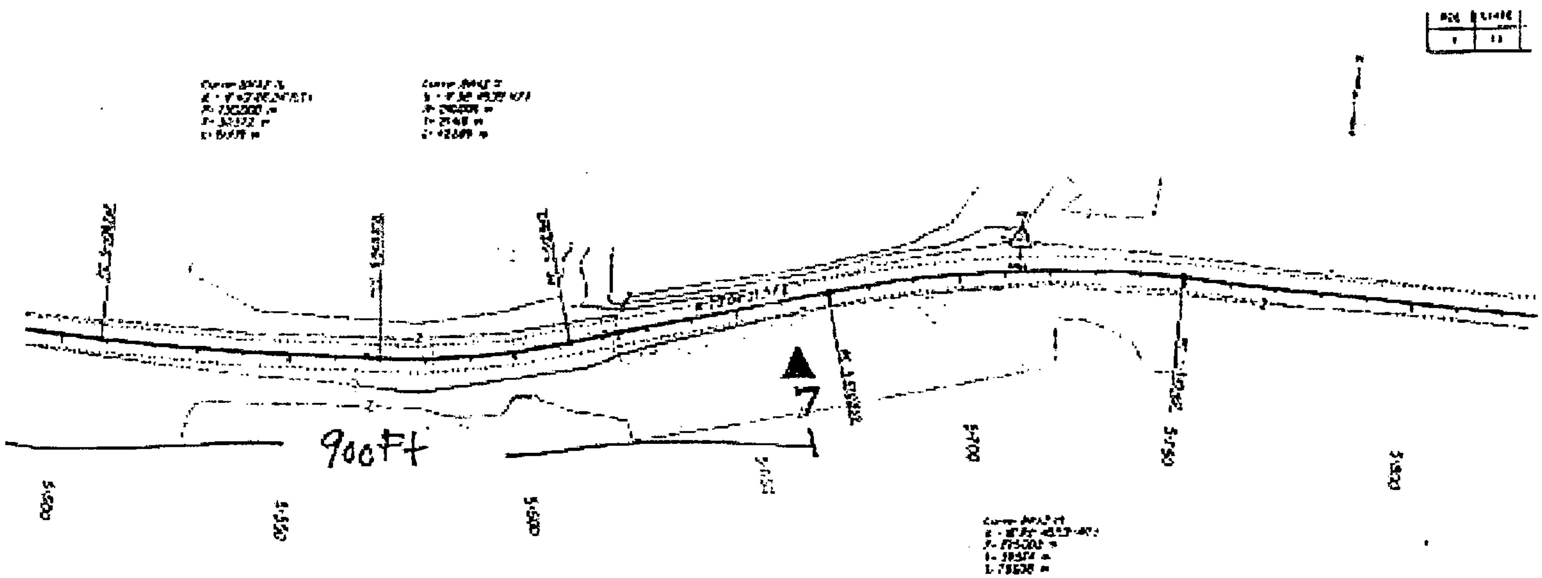


Brazoria National Wildlife Refuge



Brazoria National Wildlife Refuge

▲ - Test Pits



LOG OF TEST PIT

Project: FHWA - Brazoria NWR
Project No.: 15215, Task 2
Location: Brazoria NWR
Date: 5-20-02
Type: Backhoe
Boring No.: TP- 1

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	ROCK CORE REC / RQD %	DEPTH	DEPTH
				6" Gravel Base*		0.5	
				FAT CLAY (CH), dark gray, lightens with depth		[illegible]	
5				SAND (SP) with SILT to SILTY SAND (SM), reddish brown		5.3	
10				*Total Depth of Boring = 5.3 Feet* *Groundwater seepage was not encountered* *Geotextile fabric located below gravel road base			

Kleinfelder, Inc.

LOG OF TEST PIT

Project: FHWA - Brazoria NWR
Project No.: 16215, Task 2
Location: Brazoria NWR

Date: 6-29-02 **Type:** Backhoe **Boring No.:** TP- 2

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	ROCK CORE REC / RQD %	DEPTH	DEPTH
				10" Gravel Base*		1.0	
				FAT CLAY (CH), dark gray, lightens with depth		3.4	
5				FAT CLAY (CH), reddish-brown with gray seams		5.7	
10				*Total Depth of Boring = 5.7 Feet* *Groundwater seepage was not encountered* *Geotextile fabric located below gravel road base			

Kleinfelder, Inc.

LOG OF TEST PIT

Project: FHWA - Brazoria NWR
Project No.: 15215, Task 7
Location: Brazoria NWR
Date: 5-29-02 **Type:** Backhoe **Boring No.:** TP- 3

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	ROCK CORE REC / RQD %	DEPTH	DEPTH
				9" Gravel Base*		0.8	
				FAT CLAY (CH), dark gray, lightens with depth		4.7	
5				FAT CLAY (CH), gray with olive seams		6	
10				*Total Depth of Boring = 6.0 Feet* *Groundwater seepage was not encountered* *Geotextile fabric located below gravel road base			

Kleinfelder, Inc.

LOG OF TEST PIT

Project: FEMA - Brazoria NWR
Project No.: 15215, Task 2
Location: Brazoria NWR
Date: 5-29-02 **Type:** Backhoe **Boring No.:** TP-4

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	ROCK CORE REC / RQD %	DEPTH	DEPTH
				FAT CLAY (CH), dark gray, lightens with depth		1.5	
				FAT CLAY (CH), reddish brown with gray seams		4	
5				*Total Depth of Boring = 4.0 Feet* *Groundwater seepage was not encountered.* Test pit excavated in ditch adjacent to gravel road.			
10							

Kleinfelder, Inc.

LOG OF TEST PIT

Project: FHWA - Brazoria NWR
Project No.: 15215, Task 7
Location: Brazoria NWR **Date:** 5-29-07 **Type:** Backhoe **Boring No.:** TP - 5

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	ROCK CORE REC / RQD %	DEPTH	DEPTH
				6" Gravel Base Fines (SILT), tan and gray		0.5	
				FAT CLAY (CH), dark gray, lightens with depth		3	
5				FAT CLAY (CH), reddish-brown with silty sand seams		5	
10				*Total Depth of Boring = 5.0 Feet* *Groundwater seepage was not encountered.* Test pit excavated in ditch adjacent to gravel road			

Kleinfelder, Inc.

LOG OF TEST PIT

Project: FHWA - Brazoria NWR
Project No.: 15215, Task 2
Location: Brazoria NWR **Date:** 6-29-02 **Type:** Backhoe **Boring No.:** TP- 6

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	ROCK CORE REC / RQD %	DEPTH	DEPTH
				FAT CLAY (CH), dark gray, lightens with depth		1	
				FAT CLAY (CH), reddish-brown with gray seams		2	
5				SAND (SP) with SILT to SILTY SAND (SM), reddish brown		5	
10				*Total Depth of Boring = 5.0 Feet* *Groundwater seepage was not encountered* Test pit excavated in ditch adjacent to gravel road			

HOUSTON TEST PIT 15215.GPJ HOUSTON_AU.GDT 8/7/02

Kleinfelder, Inc.

LOG OF TEST PIT

Project: FHWA - Brazoria NWR
Project No.: 15215, Task 2
Location: Brazoria NWR

Date: 5-29-02 **Type:** Backhoe **Boring No.:** TP-7

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	ROCK CORE REC / RQD %	DEPTH	DEPTH
				FAT CLAY (CH), dark gray, lightens with depth		1.5	
				FAT CLAY (CH), reddish-brown with gray seams		3	
5				SAND (SP) with SILT to SILTY SAND (SM), reddish-brown		5.5	
15				*Total Depth of Boring = 5.5 Feet* *Groundwater seepage was encountered at 5.3 feet* Test pit excavated in ditch adjacent to gravel road.			

HOUSTON TEST PIT 15215GPJ HOUSTON AU.GDT 6/4/02

ATTACHMENT B

Laboratory Test Results

Federal Highway Administration – Central Federal Lands Highway Division

Request for Laboratory Testing

PROJECT: Brazoria Wildlife Refuge - TX RRP BRAZ 10(1)
ACCOUNT NO.: X601-D50-16-0-601051-164800-D2484721901AG (Anahuac Acct.)
DATE: 6/4/02
SUBMITTED BY: Matt DeMarco
SAMPLED BY: Kleinfelder, Inc.

Sample Location	Sample Number	Approx. Station[1]	Offset (ft)	Interval (ft)	Date Sampled	Container Type	Material Type	Tests to be Conducted
Test Pit 1 Entrance Rd.	BRAZ-TP1-R1	180 ft from Entrance Gate	In road	1-2	5-29-02	Bucket (2)	Dk gray/brown fat clay w/silt and minor organics	*Lime treatment, classification
Test Pit 1 Entrance Rd.	BRAZ-TP1-R2	180 ft from Entrance Gate	In road	4-5	5-29-02	Bucket (2)	Reddish brown silty clay with minor sand	Classification, R-value
Test Pit 2 Entrance Rd.	BRAZ-TP 2-R3	0.65 mi. from Entrance Gate	In road	1-2	5-29-02	Plastic bag	Dk gray/brown fat clay w/silt and minor organics	*Classification
Test Pit 3 Entrance Rd.	BRAZ-TP3-R4	1.3 mi. from Entrance Gate	In road	0-1	5-29-02	Bucket	Crushed limestone base material	Classification
Test Pit 3 Entrance Rd.	BRAZ-TP3-R5	1.3 mi. from Entrance Gate	In road	1-2	5-29-02	Plastic Bag	Dk gray/brown fat clay w/silt and minor organics	*Classification, moisture content
Test Pit 3 Entrance Rd.	BRAZ-TP3-R6	1.3 mi. from Entrance Gate	In road	5-6	5-29-02	Plastic Bag	Lt gray fat clay w/silt	Classification
Test Pit 4 Entrance Rd.	BRAZ-TP4-R7	900 ft. from cattle guard (4+830)	20 ft L	0-1	5-29-02	Bucket	Dk gray/brown fat clay w/silt and minor organics	*Classification, R-value
Test Pit 4 Entrance Rd.	BRAZ-TP4-R8	900 ft. from cattle guard (4+830)	20 ft L	3-4	5-29-02	Bucket	Reddish brown silty clay with minor sand	Classification
Test Pit 5 Entrance Rd.	BRAZ-TP5-R9	600 ft from TP 4	20 ft R	2.5-5	5-29-02	Bucket (2)	Reddish brown silty clay with minor sand and gravel lenses	Classification
Test Pit 6 Entrance Rd.	BRAZ-TP6-R10	400 ft from TP 5	20 ft L	1-2	5-29-02	Plastic Bag	Reddish brown silty clay with minor sand and gravel lenses	Classification, moisture content
Test Pit 6 Entrance Rd.	BRAZ-TP6-R11	400 ft from TP 5	20 ft L	2-3	5-29-02	Plastic Bag	Reddish brown silty clay	Classification, moisture content
Test Pit 6 Entrance Rd.	BRAZ-TP6-R12	400 ft from TP 5	20 ft L	4-5	5-29-02	Plastic Bag	Reddish brown silty clay	Extra sample
Test Pit 7 Entrance Rd.	BRAZ-TP7-R13	900 ft from TP 6	20 ft R	0.5-1.5	5-29-02	Plastic Bag	Dk gray/brown fat clay w/silt and minor organics	*Classification, moisture content
Test Pit 7 Entrance Rd.	BRAZ-TP7-R14	900 ft from TP 6	20 ft R	1.5-3	5-29-02	Plastic Bag	Reddish brown silty clay with minor sand	Classification, moisture content

Electrochemical Properties

Electrochemical standards per the FP-96, Section 704.10 Select Granular Fill, subsection (b) Electrochemical Requirements:

(1) Resistivity, AASHTO T 288	3000 ohm-cm minimum
(2) pH, AASHTO T 289	5.0 to 10.0
(3) Sulfate content, AASHTO T 290	1000 ppm maximum
(4) Chloride content, AASHTO T 291	200 ppm maximum

Electrochemical standards per publication FHWA-HI 97-013 Design and Construction of Driven Pile Foundations:

"Whenever the pH is 4.5 or less, the foundation design should be based on aggressive subsurface environment. Alternatively, if the resistivity is less than 2,000 ohm-cm the site should also be treated as aggressive. When the soil resistivity test results are between 2,000 and 5,000 ohm-cm, chloride ion content and sulfate ion content tests should be performed. If these tests indicate chloride ion content greater than 100 ppm or sulfate ion content greater than 200 ppm, then the foundation design should be based on an aggressive subsurface environment. Resistivity values greater than 5,000 ohm-cm are considered non-aggressive environments."

Table 1. pH and resistivity data for select material types along the Entrance Road and Tour Loop Road at the Brazoria NWR.

Test Pit Number	Station	Offset (m)	Sample Depth (m)	Material Type	pH	Resistivity (ohm-cm)	Sulfates (ppm)	Chlorides (ppm)
6	6+730	6.1 m L	1.2 – 1.5	Red-brown silty clay (CL/ML)	8.0	138	825	2375
11	5+230	In road	0.0 – 0.3	Dk gray-brown fat clay (CL)	7.7	97	850	4000
11	7+200	In road	0.0 – 0.3	Dk gray-brown fat clay (CL)	8.0	726	BDL*	188
11	7+200	In road	1.0 – 1.2	Red-brown silty clay (CL/ML)	8.2	154	875	625

* Below detectable limit.

The results indicate a very aggressive environment for both chloride corrosion and sulfate attack. Culverts and long-term structures should be designed accordingly.

U.S. Department of Transportation
Federal Highway Administration

Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

Report of Soil or Aggregate Tests

AASHTO R18 ISO/IEC 17025

Project: Texas ANAH 10 (1) Brazoria National Wildlife Refuge
Submitted By: Matt DeMarco
Date Reported: 6/21/2002

Sample Number	Lab Number		02-477-S	02-478-RV	02-479-SB	02-480-AGG	02-481-SB
	Hole Number		--	--	--	--	--
	Field Number BRAZ		TP1-R1	TP1-R2	TP2-R3	TP3-R4	TP3-R5
Sample Location	Station or Location		Entrance Rd.	Entrance Rd.	Entrance Rd.	Entrance Rd.	Entrance Rd.
	Test Pit	Number	1	1	2	3	3
	Depth	Feet	1 - 2	4 - 5	1 - 2	0 - 1	1 - 2
AASHTO T 11, T 27 & T 88 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm				100	
	1"	25.0 mm				91	
	3/4"	19.0 mm				83	
	1/2"	12.5 mm				74	
	3/8"	9.5 mm				67	
	#4	4.75 mm		100		54	
	#8	2.36 mm				47	
	#10	2.00 mm		99		45	
	#16	1.18 mm		99			
	#30	600 μm				35	
	#40	425 μm	100	99		32	100
	#50	300 μm				29	
	#100	150 μm	99	98	100		99
	#200	75 μm	95	89	93	19	90
		20 μm					
		2 μm					
		1 μm					
AASHTO T 255	Moisture %						26.2
AASHTO T 89 & T 90	Liquid Limit		47 *	25	69	NV	48
	Plasticity Index		29 *	5	45	NP	31
Soil Classification	AASHTO M 145		A-7-6 (29)	A-4 (3)	A-7-6 (47)	A-1-b (0)	A-7-6 (29)
	ASTM D 2487		CL	CL-ML	CH	GM	CL
AASHTO T 190	R –Value			16			
AASHTO T 288	Min. Resistivity, ohm-cm						
AASHTO T 289	pH						
AASHTO T 99 Method C	Optimum Moisture, %			16			
	Maximum Dry Density, pcf			110			

Distribution:

Laboratory	Num. / Project File
	Darrell Harding
Geotechnical	Matt DeMarco
Pavements	Mike Voth

Remarks: Moisture samples are from sealed plastic bags.
* This material, when treated with 3% or 6% lime, produces liquid limit and plasticity index values that cannot be determined.

Reported By:
For
Darrell Harding

U.S. Department of Transportation
Federal Highway Administration

AASHTO R18 ISO/IEC 17025

Report of Soil or Aggregate Tests

Project: Texas ANAH 10 (1) Brazoria National Wildlife Refuge
Submitted By: Matt DeMarco
Date Reported: 6/21/2002

Sample Number	Lab Number		02-482-S	02-483-RV	02-484-S	02-485-S	02-486-S
	Hole Number		--	--	--	--	--
	Field Number BRAZ		TP3-R6	TP4-R7	TP4-R8	TP5-R9	TP6-R10
Sample Location	Station or Location		Entrance Rd.	Entrance Rd.	Entrance Rd.	Entrance Rd.	Entrance Rd.
	Test Pit	Number	3	4	4	5	6
	Depth	Feet	5 – 6	0 - 1	3 - 4	2.5 - 5	1 - 2
AASHTO T 11, T 27 & T 88 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm					
	1"	25.0 mm					
	3/4"	19.0 mm					
	1/2"	12.5 mm					
	3/8"	9.5 mm				100	
	#4	4.75 mm			100	99	100
	#8	2.36 mm					
	#10	2.00 mm			99	97	98
	#16	1.18 mm			98	96	97
	#30	600 µm					
	#40	425 µm	100		98	95	96
	#50	300 µm					
	#100	150 µm	99	100	97	95	96
	#200	75 µm	91	99	97	92	94
		20 µm					
		2 µm					
		1 µm					
AASHTO T 255	Moisture, %						19.4
AASHTO T 89 & T 90	Liquid Limit		60	64	42	35	41
	Plasticity Index		41	41	24	17	24
Soil Classification	AASHTO M 145		A-7-6 (40)	A-7-6 (47)	A-7-6 (25)	A-6 (15)	A-7-6 (23)
	ASTM D 2487		CH	CH	CL	CL	CL
AASHTO T 190	R –Value			< 5			
AASHTO T 288	Min. Resistivity, ohm-cm						
AASHTO T 289	pH						
AASHTO Method	Optimum Moisture, %						
	Maximum Dry Density, pcf						

Distribution:

	Num. / Project File
Laboratory	Darrell Harding
Geotechnical	Matt DeMarco
Pavements	Mike Voth

Remarks: Moisture samples are from sealed plastic bags.

Reported By:

For

Darrell Harding

U.S. Department of Transportation
Federal Highway Administration

Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

AASHTO R18 ISO/IEC 17025

Report of Miscellaneous Tests

Laboratory Number: 02-477-S

Date Reported: 6/21/2002

Project: Texas ANAH 10 (1) Brazoria National Wildlife Refuge

Submitted By: Matt DeMarco

Material Type: Subgrade

Material Source: Entrance Road Test Pit 1

Tested For: ASTM D 5102 Unconfined Compressive Strength of Compacted Soil-Lime Mixtures, Method B

Field Sample Number: BRAZ TP1-R1

Test Results

Lime Content (%)	Plain			Three		
Specimen Age	7 Days			7 Days		
Length (in)	4.60	4.60	4.60	4.60	4.60	4.60
Diameter (in)	3.98	3.97	3.99	3.99	3.99	3.99
Corrected Area (in^2)	13.377	13.099	13.302	12.958	12.825	12.825
Strain at Failure (%)	7.0	5.5	6.0	3.5	2.5	2.5
Maximum Load (lbs)	582	558	647	796	802	873
Compressive Strength (psi)	44	43	49	61	63	68
Average Maximum Load (psi)	45			64		

Lime Content (%)	Six		
Specimen Age	7 Days		
Length (in)	4.60	4.60	4.60
Diameter (in)	3.99	3.98	3.99
Corrected Area (in^2)	13.302	12.895	12.891
Strain at Failure (%)	3.5	4.0	3.0
Maximum Load (lbs)	719	712	774
Compressive Strength (psi)	54	55	60
Average Maximum Load (psi)	56		

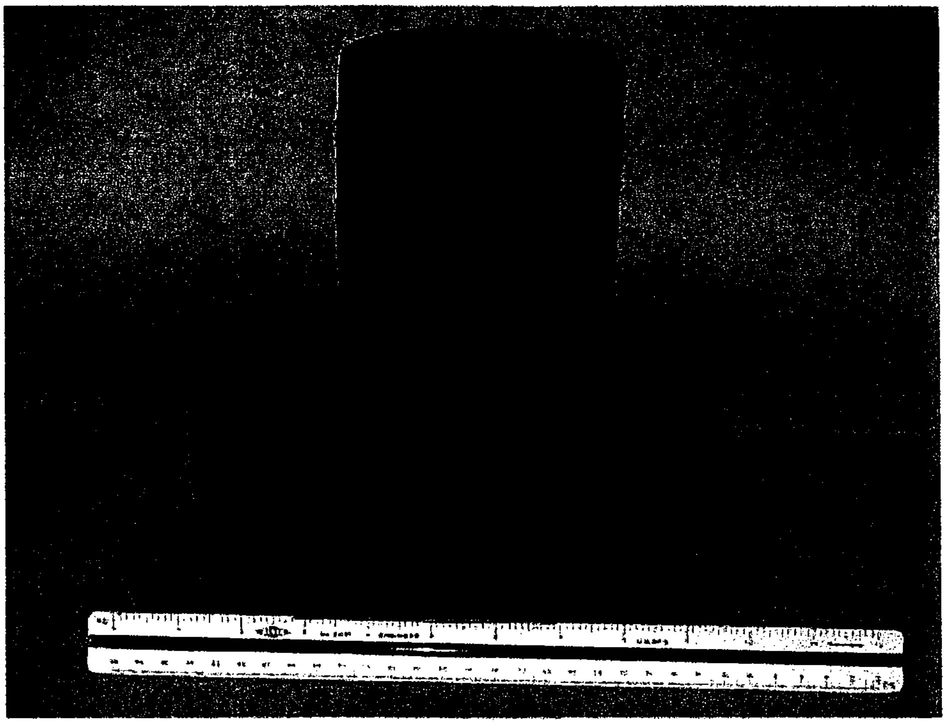
Distribution:
Laboratory
Geotechnical
Pavements

Num. / Project File
Darrell Harding
Matt DeMarco
Mike Voth

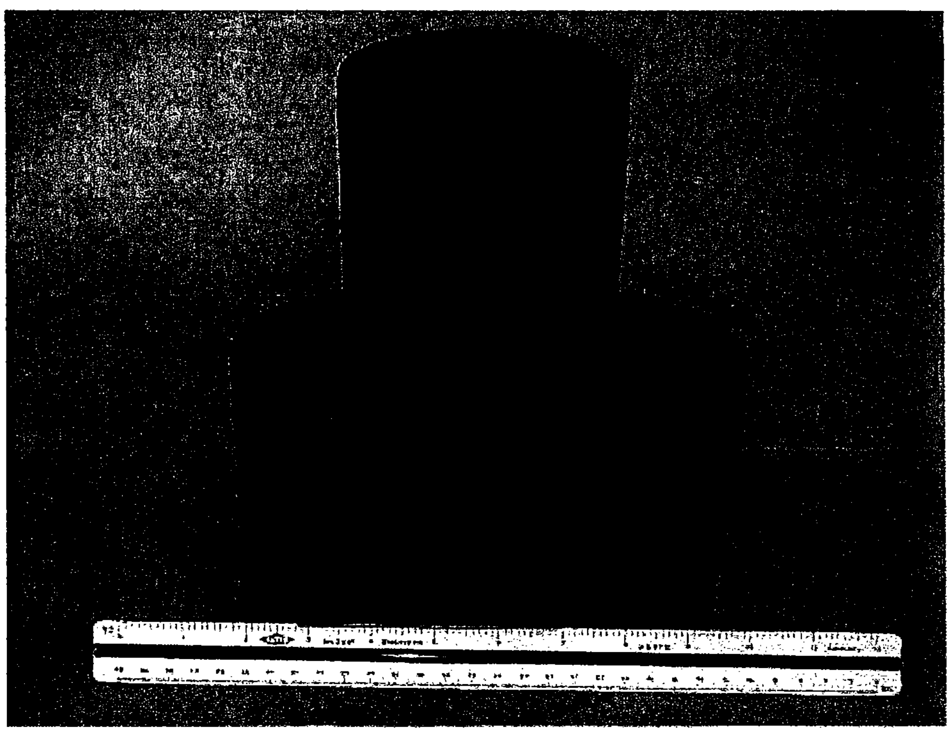
Reported By:

For
Darrell Harding

Lime-Treated Unconfined Compressive Strength Specimens 02-477-S For Brazoria N.W.R.

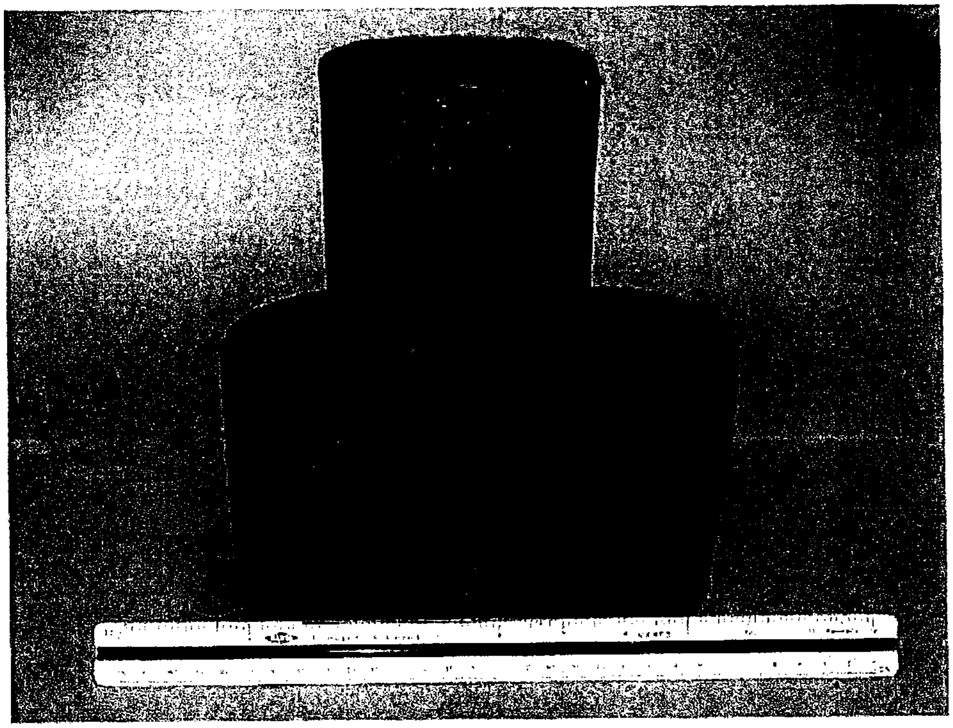


Untreated



3 Percent Lime

Lime-Treated Unconfined Compressive Strength Specimens 02-477-S For Brazoria N.W.R.



6 Percent Lime

ATTACHMENT C

Technical Memorandum, "Guidelines for Stabilization of Soils Containing Sulfates"

August 2000

TECHNICAL MEMORANDUM

GUIDELINES FOR STABILIZATION OF SOILS CONTAINING SULFATES

AUSTIN WHITE LIME, CHEMICAL LIME, TEXAS LIME

Purpose of This Technical Memorandum

This memorandum is prepared for members of the engineering and construction communities to establish a protocol for lime stabilization of clay soils containing soluble sulfates. It is critical to perform a thorough investigation of a site where sulfates have been identified so that a program can be devised to produce a strong, stabilized structural layer that will perform as expected for its entire design life. Any additional testing and analysis that is required can easily be justified considering the enormous expense of alternatives to lime stabilization which commonly include removal and replacement of the expansive clays or full-depth paving with an unnecessarily thick asphalt or concrete pavement section.

The memorandum presents a brief background explaining the scope of the problems associated with sulfate bearing soils when stabilized. This is followed by a practical explanation of the reactions which result in distress in sulfate soils stabilized with lime or with other calcium-based stabilizers. This practical discussion provides a basic level of understanding of the complex causes of sulfate-induced distress. This is necessary so that designers and builders will understand the reason for the protocol used in the stabilization of sulfate-bearing soils. Furthermore, this background will help to address questions posed regarding the need for more careful attention to testing, mix design, construction and quality control required when dealing with sulfate-bearing soils.

Background

In 1986 Jim Mitchell, professor of civil engineering at the University of California at Berkeley, presented a paper in the Terzaghi Lecture Series published by the American Society of Civil Engineers (ASCE). This paper addressed several interesting and rather unique geotechnical engineering problems. One of these problems was the Stewart Avenue pavement failure in Las Vegas, Nevada. The paper gained widespread notoriety because it was published by ASCE under the prestigious Terzaghi Lecture series and because it addressed unconventional and distinctive geotechnical engineering failures.

The Mitchell paper was followed by a paper by Dal Hunter also addressing the Stewart Avenue failure but with a more complete description of the chemical and mineralogical aspects. Sulfate induced problems in soils stabilized with calcium-based stabilizers such as lime, Portland cement and fly ash have been documented since the late 1950's. The mechanism has been studied by a number of highly qualified cement chemists in an effort to understand and control sulfate attack on Portland cement concrete structures.

Basic Mechanisms of Reactions

An in-depth discussion of the complex reactions of sulfate-induced distress in stabilized soils is not within the scope of this technical memorandum. However, it is important for engineering and construction professionals to understand the fundamentals of sulfate-induced distress.

Basically four components are the culprits in sulfate-induced distress in stabilized soils: calcium, aluminum, water and sulfates. Together in the right combination these components will produce calcium-aluminate-sulfate-hydrate minerals with very large expansion potential, in some cases as high as 250%. One of these minerals is called ettringite. This mineral holds very large quantities of water within its structure. During the formation of ettringite very high swell pressures can develop, and very large volume increases can and do occur.

The formation of ettringite and similar troublesome minerals can be prevented by interrupting the supply of any one of the four components: calcium, aluminum, water or sulfate. When lime and water for construction are added to clay, the calcium is supplied by the lime, and the aluminum is released from the clay in the high pH system produced by lime and water. If the soil contains a high sulfate concentration in the form of gypsum, for example, all the ingredients with the exception of water are present for the formation of the expansive minerals. Using a low aluminate Portland cement (such as type V, sulfate-resistant cement) does not solve the problem because the source of the aluminum is not entirely the Portland cement but the soil.

There is no easy answer to the problem. Calcium is present when either lime or Portland cement are used for soil stabilization. Soils containing clay are rich with aluminum, a basic structural unit of clay. Water is necessary for compaction and for stabilization reactions and is present within pavement structures during their service life. Unfortunately, the sulfates usually cannot be efficiently or economically removed from the soil.

Factors Affecting the Reactions

A number of efforts have been made to control the reactions that result in the formation of the problematic expansive minerals. Some of these efforts have been successful, but others have not. Some are successful but economically impractical.

Presently, the best approach when dealing with lime stabilization of clay with a significant soluble sulfate content is to force the formation of the deleterious minerals prior to compaction. If these minerals form during the mellowing period before placement and compaction, no damage will be done to the pavement. Fortunately, the expansive minerals do form relatively rapidly as long as the sulfates are soluble, the aluminum is released from the clay and adequate water is available for the formation of the minerals. The keys to success are to force the expansive mineral ettringite to form prior to placement and compaction of the pavement layer by providing adequate mellowing time (time delay between application of the stabilizer and compaction of the stabilized soil) and adequate water.

Adequate mellowing time may (practically) be as little as 24 hours or as much as 7-days, depending on the level of soluble sulfates in the soil. An adequate amount of water is typically 3 to 5 percentage points above the optimum needed to achieve maximum density during compaction. Excess water should be applied during the mellowing period, and plentiful amounts of water should be applied to the surface of the stabilized layer during curing.

Water is ***the*** most important component of the equation. Adequate water must be supplied throughout the stabilization construction process to force formation of the ettringite prior to compaction. The worst scenario would be to compact a lime-treated, sulfate-bearing clay with too little water. This is especially a problem if quicklime is used, and too little water is used to completely hydrate the quicklime. If this were the case, water entering the soil subsequent to compaction would cause development of expansive minerals in the compacted layer and produce very high and very disruptive expansive pressures. For this reason use of lime slurry is always recommended in stabilization of sulfate-bearing clays. Lime slurry provides the abundance of water and uniformity of hydration required to lower risk. In the event that slurry is unavailable, the soil should be kept at 5% over optimum during the mellowing period to solubilize the sulfates. Remember, quicklime was used at Stewart Avenue, and forensic studies showed inadequate water and poor construction techniques in many areas. The result was post-construction heave when water ultimately reached the quicklime causing hydration of the quicklime and the ensuing expansive chemical reactions.

Guidelines for Using Lime in Sulfate Bearing Soils

In an effort to assist you in recommending lime stabilization in sulfate-bearing clays, the following general recommendations are made.

Sulfate Levels Too Low to be of Concern

If the total level of soluble sulfates is below 0.3%, or 3,000 parts per million (ppm), by weight of soil, then lime stabilization should not be of significant concern. The potential for a harmful reaction is low. However, good mix design and construction practices should be followed as usual. If soluble sulfates are detectable at all, lime slurry should be used, if possible, in lieu of dry lime and adequate water (optimum for compaction plus at least 3%) should be used for mixing.

Sulfate Levels of Moderate Risk

Total soluble sulfate levels of between 0.3% (3,000 ppm) and 0.5% (5,000 ppm) are of moderate concern. Generally, these sulfate levels do not result in harmful disruption, but on occasions have caused localized distress. Localized distress is often due to seams of higher sulfate concentration not detected in testing. The potential for some localized distress is a "fact of life" with sulfate levels in this range.

When encountering sulfate levels in the range of 0.3% to 0.5%, it is imperative to follow good mix design and good construction techniques explicitly. Special attention must be given to using excess water during mixing, mellowing and curing. Mixing water should be at least 3% to 5% above optimum for compaction. Lime slurry should be used in lieu of dry quicklime or hydrated lime.

The mellowing period should typically be at least 72-hours, but may need to be longer depending upon experience.

Sulfate Levels of Moderate to High Risk

Total soluble sulfate levels between 0.5% (5,000 ppm) and 0.8% (8,000 ppm) represent moderate to high risk. These soils can and have been successfully treated but require very close attention to construction technique. Generally, the same mix design and construction guidelines as described for soils containing sulfate levels between 0.3% and 0.5% should be followed. However, before treating these soils with lime laboratory testing to determine swell potential is recommended. This testing will not only establish the approximate amount of swell but also will help establish the required period of mellowing between mixing and compaction.

Sulfate Levels of High and Unacceptable Risk

Total soluble sulfate levels of greater than 0.8% (8,000 ppm) are generally of high risk to stabilize with lime. In certain situations, such soils have been successfully treated. However, the risk is generally too high for routine work. If such soils are to be treated, it should only be done following laboratory testing and by an experienced contractor, well-schooled in lime stabilization of high sulfate soils.

Treatment of such high sulfate soils requires lime slurry, mixing, mellowing, curing water contents of 3% to 5% above optimum for compaction and may require an extended mellowing period of longer than 72-hours. The required mellowing period may be as long as 7-days during which monitoring of density is recommended. Double application techniques (discussed below) may be effective in successfully treating high sulfate soils.

Soils with total soluble sulfate contents greater than 1.0% (10,000 ppm) generally are not suitable for lime stabilization because of the high risk of sulfate-induced disruption and failure. However, such concentrations often exist as seams on a project as opposed to being evenly distributed throughout a site. If the seams can be characterized using tools such as the field electrical conductivity test, detailed in Appendix C, then strategies such as removal or blending may be employed to diminish the sulfate concentrations.

Reducing Sulfates to an Acceptable Level

Evaluation of several projects that have experienced swelling problems related to elevated levels of sulfates suggests that it is seams of especially high concentration that contribute the most to pavement failures. If consistent (homogeneous) levels of sulfates exist throughout a project they can be dealt with using a variety of strategies. If, on the other hand, seams of unusually high concentrations are present they may migrate laterally as water enters the subgrade over the project's life to stable areas where, in the presence of water, calcium, and alumina ettringite may form. A practical difficulty in the field has been to identify the locations of sulfate seams so that they can be removed or diluted. A quick and easy test has been developed at the Texas Transportation Institute to reduce that problem by measuring the electrical conductivity of the soil. That test is described in more detail in Appendix C of this memorandum.

Seams containing high concentrations of sulfates are often localized on a project site. If they can be accurately characterized they may either be removed or dispersed throughout the project, diluting the total sulfate concentration to an acceptable level and homogeneity. An excellent example of sulfates being blended to a benign level occurred during the construction of the Denver International Airport. The sulfates on that project ranged higher than 3% in several areas. The high sulfates at the Denver International Airport were blended into lower sulfate areas to create a homogeneous soil throughout the project. The soil was then treated by pre-wetting and a progressive, or double, application of lime that included a mellowing period to allow ettringite to form prior to the final application of lime. The lime stabilization strategy was successful and stands as a testimonial to the marriage of sound engineering and quality construction practices.

Progressive (Double) Application of Lime

In certain situations a progressive (double) application of lime is effective in reducing heave potential and in providing successful long-term stabilization. Double mixing is obviously more expensive and, therefore, must be cost effective. Double mixing uses one-half the required lime initially. The soil, excess water and lime are then mixed followed by a mellowing period of from 72-hours to about 7-days. The purpose of the long mellowing period is to allow time for expansive reactions prior to compaction. Then the second lime treatment is applied (the other half of the required lime is used). The lime-soil mixture is then compacted. Double treatment does not mean twice the amount of lime. It means that the same amount of lime is added in two increments. This technique should be thoroughly evaluated through laboratory testing of site-specific soils to establish appropriate lime application amounts, mellowing times, etc. before proceeding with field construction.

How to Get a "Handle" on Whether or Not Sulfates May Be of Concern

The only "fool proof" way to know whether or not sulfates will be a problem is to test the soil for sulfates. This is done by sampling the soil at enough locations and at the appropriate depths to reasonably assess the level and extent of sulfates.

Quantitative sulfate testing requires the extraction of sulfates from the soil. This is done by solubilizing the sulfates in water, followed by quantitative measurement. Since sulfate salts, such as gypsum (calcium sulfate), have specific levels of solubility, the amount of sulfate extracted from the soil is determined by the type of sulfates present and amount of water added. Therefore, 10 parts water to 1 part soil will result in more solubilized sulfates than 3 parts water to 1 part soil, especially at higher sulfate contents. Experience has shown that an extraction protocol using 10 parts water to 1 part soil is the best for evaluating potential problems resulting from sulfate reactions. This also allows better comparison with most of the test data developed in related research efforts to date. ***Note that the sulfate levels and associated treatment guidelines provided in this document are based on the 10 parts water to 1 part soil testing ratio and may not be applicable to other water:soil ratios.***

Sulfates soluble in water are measured in parts per million (ppm) and often expressed either in ppm or percent. 10,000 ppm are equivalent to 1.0%. Therefore, 3,000 ppm are equivalent to 0.3% and 5,000 ppm to 0.5%, etc. The soluble sulfate content should be reported on a ***dry soil basis*** to insure consistency of test results. Soluble sulfates should be extracted from the soil using 10 parts distilled water to 1 part soil. Test method Tex-620-J (appendix A) prepared by the Texas Department of Transportation is recommended. Any of several quantitative methods (barium precipitation, ion chromatography, etc.) may be effectively used to measure the water solubilized sulfates. Again, the important thing to remember is that the water:soil ratio used in preparation of the solution will control the amount of sulfates solubilized and measured by any of these methods, and that guidelines presented here are based on 10:1 extractions.

In testing for sulfates, it is important to remember that sulfates often are present in concentrated areas and may not be uniformly distributed. Seams or veins of sulfates are common. It is also important to realize that sulfates tend to concentrate at a certain depth below the surface of the soil. This depth of concentration is dependent on the climatic conditions of the area or region. In Texas, this depth is often three to six feet (about one to two meters) below the surface.

Sulfates typically are concentrated nearer the surface in drier, western regions. As we move eastward into wetter and more humid climates, the general rule is that sulfates, if present, tend to concentrate at lower depths.

Probably the most beneficial and reliable preliminary tool for assessing the presence and significance of sulfates within an area is the United States Department of Agriculture's County Soils Report. A report is available for every county in the United States and can be obtained from the Soil Conservation Service, a County Agent or the State land grant university. The soils report provides an abundance of engineering information conveniently tabulated. There is also a discussion of each soil series within the county and a discussion of the soil profile. This discussion will generally identify the presence of gypsum and other sulfate salts and the depth of significant concentrations, if any. This is an extremely valuable reconnaissance tool. Keep in mind that it is very important not only to identify the presence of sulfates but also the depth of occurrence. For example, a soil may be essentially sulfate free in the upper two or three feet (0.67 to 1.0 meters) but have sulfate concentrations at a depth of 6 feet (approximately 2 meters). In this case, sulfates would not be of concern during normal surface stabilization operations but could be of concern in cut and fill areas.

Required Testing and Frequency of Testing

The best approach in checking for sulfates is to ask the county agent where sulfates typically occur and at what depth to expect significant concentrations. It is also wise to buy or check out a County Soil Report. You can locate the construction job of interest to you on the aerial photographs of the county in the back of the report. From these photos the soil series in the area can be identified. Pertinent information on each soil series in presented in the discussion section and in the tabulated agricultural and engineering data for each soil.

If sulfates are present and identified in the County Soils Report, a field testing plan should be established with the geotechnical engineer. The frequency of testing depends on the level of sulfates present and the geological information for the region. If initial testing confirms the presence of sulfates in concentrations that may present problems, additional testing using the conductivity process may be warranted. The conductivity procedure and equipment are described in Appendix C.

If total soluble sulfate levels are above 0.5%, tests to determine the degree of expansion that may occur should be performed. These tests require monitoring the vertical and circumferential swell on compacted lime-soil cylinders (see appendix B). The cylinders are subjected to water by placing them on porous stones, surrounding them with absorptive towels and allowing the samples to take on water for at least 30 days or until swell levels off. The measured circumferential and vertical swells are then compared to criteria established by the engineer. If total soluble sulfate levels exceed 0.8%, this type of testing should be mandatory.

Addressing and Countering Inaccurate and Misleading Assertions

Probably the most common misconception is that ***lime is the only stabilizer that causes sulfate-induced heave.*** The fact is that any calcium-based stabilizer has the potential to cause heave in sulfate-bearing soils. Not only lime but also Portland cement and type C fly ash are sources of calcium. In fact the Portland Cement Association (PCA) promotes the concept that lime results from the hydration of Portland cement and is available for soil stabilization. Many cases have been documented of sulfate-induced heave or damage in cement- and fly ash-stabilized soils. Indeed some fly ashes high in sulfates have been the source of the distress.

Another common assertion is that ***sulfate resistant Portland cement can be used to effectively stabilize sulfate-bearing clays without the fear of deleterious reactions.*** This claim is not true. Sulfate resistant Portland cement was developed to resist the attack of sulfate-bearing water on concrete. Sulfate-bearing water will react with calcium and aluminum in the concrete to form the expansive ettringite mineral in the hardened concrete causing cracking and degradation of the concrete. Cement chemistry researchers found low-aluminum cement to be effective in reducing the expansive reaction. This is logical as one of the components of ettringite has been reduced - aluminum.

However, this approach does not work in soil stabilization because clay is a source of abundant quantities of aluminum. Therefore, using a low aluminum cement is a moot point.

An assertion of some credibility is that ***low calcium fly ashes will minimize heave potential.*** The problem with this statement is that low calcium ashes are low in the component that is the key to stabilization of clay soils - available calcium. Low calcium fly ash is primarily a pozzolan - a finely divided source of silicates and aluminates that has the potential to develop cementitious properties in the presence of water and lime. Clay is also a pozzolan. Therefore, adding pozzolans to pozzolans without the key ingredient, calcium, is poor engineering judgement. In other words, adding low calcium ash to a clay may not induce heave, but neither is it an effective stabilizer of the clay.

ATTACHMENT D

Photographs

Kleinfelder, Inc. Photo Log

Photos taken at each Test Pit Location (as labeled)

TESTPIT 1a

TESTPIT 1b

TESTPIT 2a

TESTPIT 2b

TESTPIT 3

TESTPIT 3b

TESTPIT 4a

TESTPIT 4b

TESTPIT 5a


TESTPIT 5b


TESTPIT 6a


TESTPIT 6b

TESTPIT 7a

TESTPIT 7b

TESTPIT 8a


TESTPIT 8b


TESTPIT 9a


TESTPIT 9b

TESTPIT 10a

TESTPIT 10b

TESTPIT 11a

TESTPIT 11b

TESTPIT 12a

TESTPIT 12b

TESTPIT 13a

TESTPIT 13b

TESTPIT 14a

TESTPIT 14b

ATTACHMENT E

Pavement Design Calculations

TX RRP BRAZ 10(2) Brazoria
Pavement Design Alternatives

Parameters: Design subgrade strength = R-value of 5 (M_r = 3800 psi); ESALs < 35,000. SN required = 2.22 from the first BRAZ project.

<u>Option 1</u>. Full depth asphalt pavement

Layer design:

HACP	4.5"
Cement Stabilized Subgrade	8"

SN = 2.28

<u>Option 2</u>. Partial depth asphalt pavement

Layer design:

HACP	3"
Aggregate Base	5"
Cement Stabilized Subgrade	8"

SN = 2.28

<u>Quick Cost Analysis (materials and placement only)</u>
Assumptions:

HACP = $100/ton
Aggregate Base = $35/ton
Cement Stabilized Subgrade (@ 7% cement; $220/ton for cement and $2.50/yd^2 for mixing/processing) = $8.50/yd^2

Option 1	3200 tons/mi HACP	= $320,000
	14,080 yd^2 stabilized subgrade	= <u>$119,900</u>
	Total	= $439,900
Option 2	2100 tons/mi HACP	= $210,000
	3400 tons/mi CAB	= $119,000
	14080 yd^2 stabilized subgrade	= <u>$119,900</u>
	Total	= $448,900

The costs of options 1 & 2 appear about equivalent (the costs are within 3% of each other). Option 1 has a smaller grade raise and may be completed faster, which may provide additional savings. Option 2 provides greater distance between vehicle wheel loads and the top of the very weak subgrade soil, which can improve long-term performance.

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

FHWA
12300 Dakota Avenue
Lakewood, Colorado
United States of America

Flexible Structural Design Module

Full Depth Asphalt Design Alternative

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	35,000
Initial Serviceability	4.2
Terminal Serviceability	2
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	3,800 psi
Stage Construction	1
Calculated Design Structural Number	2.32 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	HACP	0.4	1	4.5	-	1.80
2	Stabilized Subgrade	0.06	1	8	-	0.48
Total	-	-	-	12.50	-	2.28

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

FHWA
12300 Dakota Avenue
Lakewood, Colorado
United States of America

Flexible Structural Design Module

Partial Depth Asphalt Design Option

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	35,000
Initial Serviceability	4.2
Terminal Serviceability	2
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	3,800 psi
Stage Construction	1
Calculated Design Structural Number	2.32 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	HACP	0.4	1	3	-	1.20
2	CAB	0.12	1	5	-	0.60
3	Stabilized Subgrade	0.06	1	8	-	0.48
Total	-	-	-	16.00	-	2.28