Investigation and Rehabilitation of a Bridge Abutment MSE Wall Instability

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IFAI Geosynthetics Conference

1

KEY POINTS

As a designer, always evaluate if "new" geo solutions have been properly vetted before relying upon industry developed specifications.

2

KEY POINT

As a designer or builder, always consider long-term compatibility of reinforcement and retained soil materials used to construct infrastructure

3

Investigation and Rehabilitation of a Bridge Abutment MSE Wall Instability

First contacted in July 2001
Large city engineering department had an ongoing settlement problem of embankment at approach/departure bridge slab
MSE wall built in 1985

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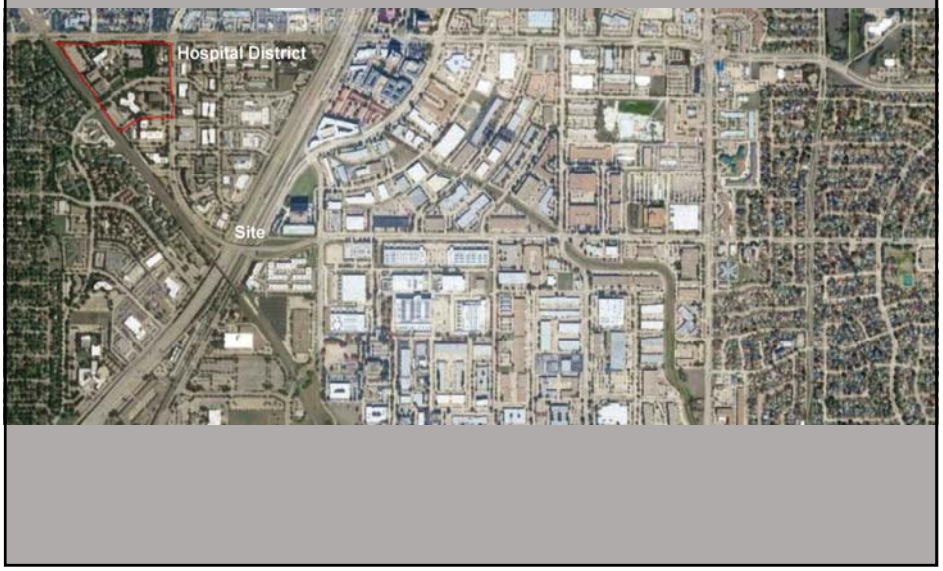

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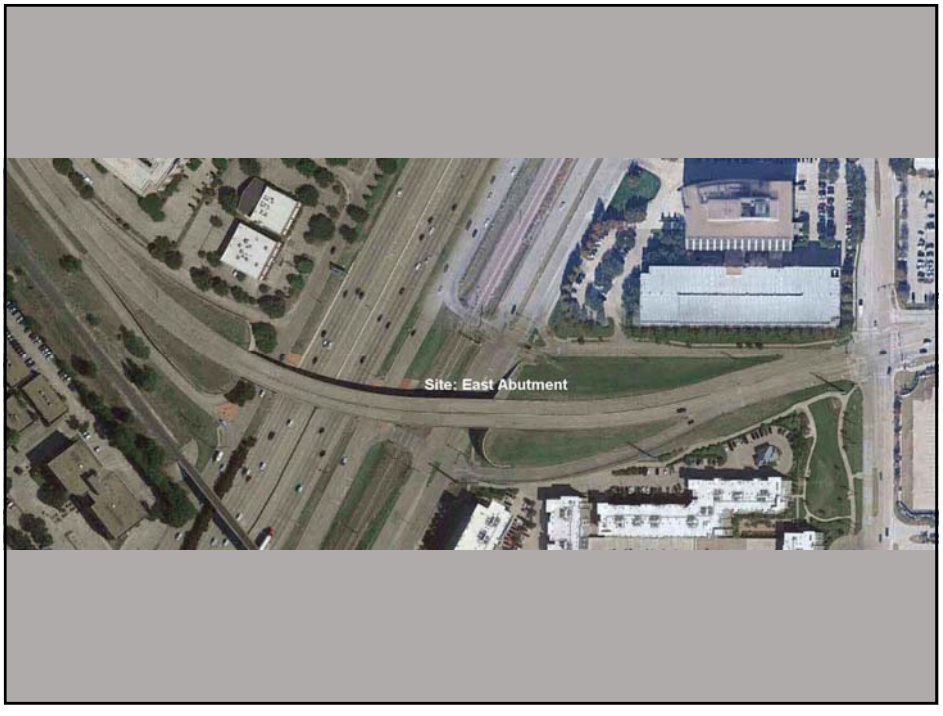

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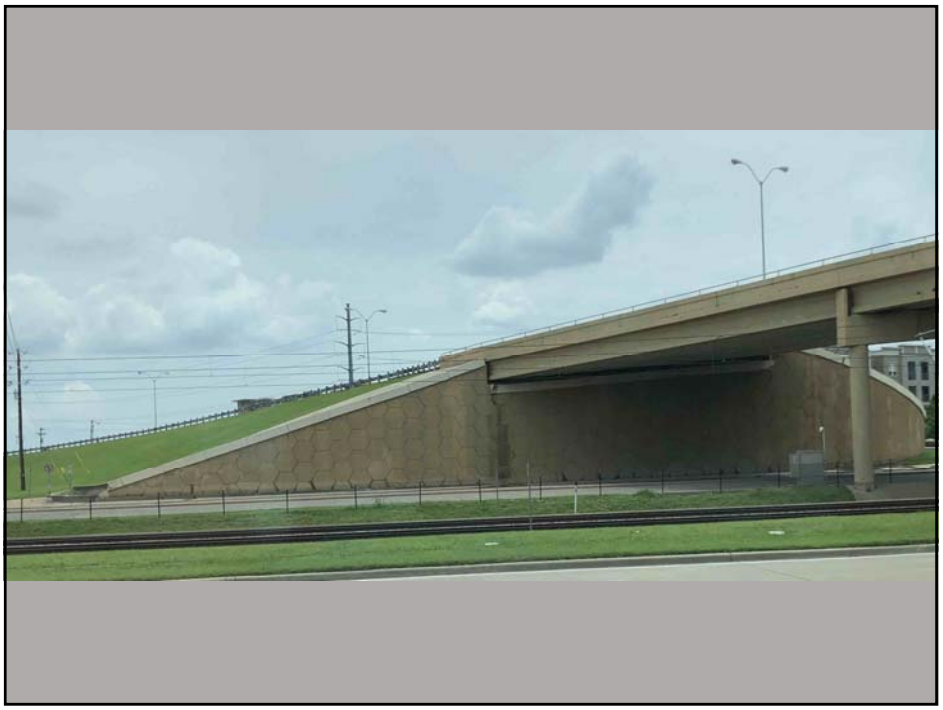

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Investigation begins with no info on MSE wall design

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Built 1985
Engineering letter reports:
- **1989**
- **1991**
- **1994**

Our investigation 2001

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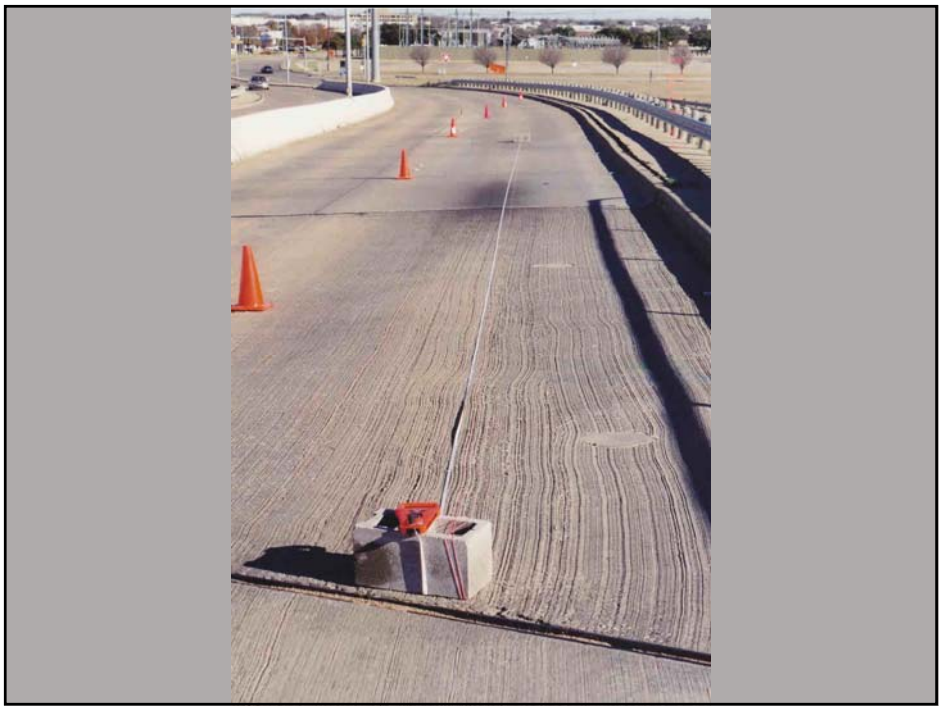

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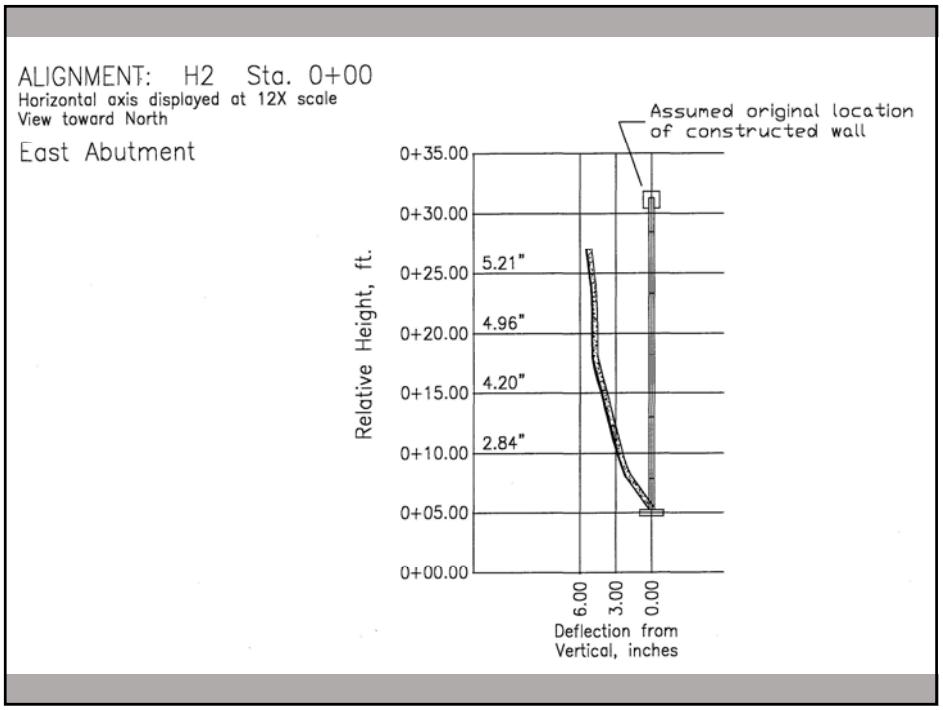
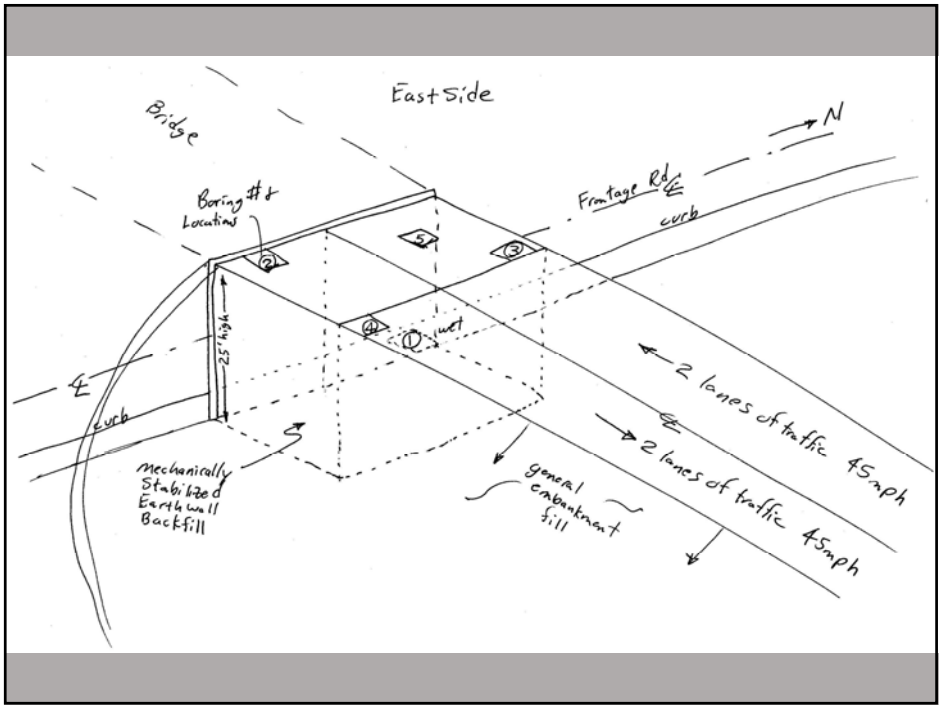

ALIGNMENT: H2 Sta. 0+00
Horizontal axis displayed at 12X scale
View toward North
East Abutment
Assumed original location of constructed wall
Relative Height, ft.
0+35.00
0+30.00
0+25.00
0+20.00
0+15.00
0+10.00
0+05.00
0+00.00
5.21"
4.96"
4.20"
2.84"
6.00
3.00
0.00
Deflection from Vertical, inches

19


East Side
Bridge
Boring #'s Locations
Frontage Rd
curb
N
25' High
mechanically Stabilized Earth wall Backfill
general embankment fill
2 lanes of traffic 45mph
2 lanes of traffic 45mph

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Location: Approx. 8 ft E & 4 ft N of south corner of joint between bridge and approach on East Abutment
Surface El.:

Depth, feet	Samples	Symbol USCS	MATERIAL DESCRIPTION	Hand Penetrometer, tsf	Penetration Blows / Foot	Moisture Content, %	Unit Dry Weight, pcf	Liquid Limit	Plastic Limit	Plasticity Index	% Passing No. 200 Sieve	Unc. Compressive Strength, tsf	Swell (%)
			PAVEMENT - concrete, reinforced, 9 inches thick 0.8										
			FILL consisting of silty sand, tan 2.0										
			FILL, consisting of brown & tan clay with limestone gravel	3.5	35	22.2	99.2				84	3.10	1.50
5				2.25	39	25.7 21.0	96.4	51	22	29			
				2.0	32	20.9 24.0	98.5 98.2	45	20	25	70	2.00	0.40
			9.5	3.0	31	21.6	100.2					1.50	
10			FILL, consisting of tan sand - pH = 8.58; Resistivity = 7900 ohm-cm @ 11.5 ft - pH = 9.06; Resistivity = 13500 ohm-cm @ 21.5 ft - pH = 9.24; Resistivity = 14000 ohm-cm @ 31.5 ft		19	20.6							
					16	6.3							
15					32								
					12	7.8					15		
20					47								
					26	6.6					10		
25													

Completion Depth: 50 ft
Date: 10/16/01

Remarks: Boring terminated at 50.0 ft due to City time constraints. Boring dry at completion. Boring backfilled upon completion due to City requirements.

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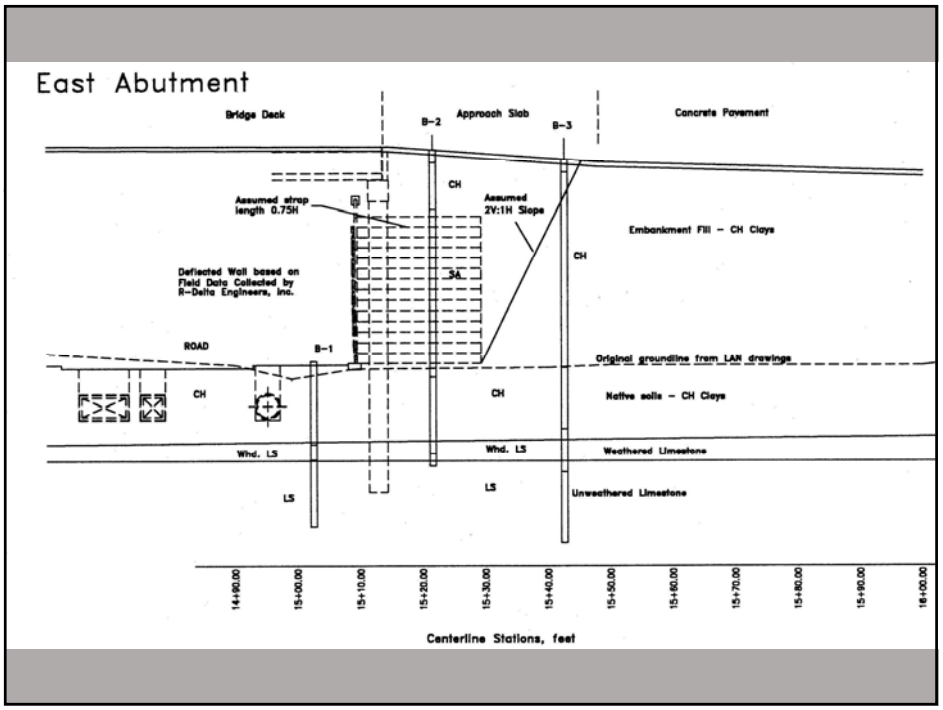
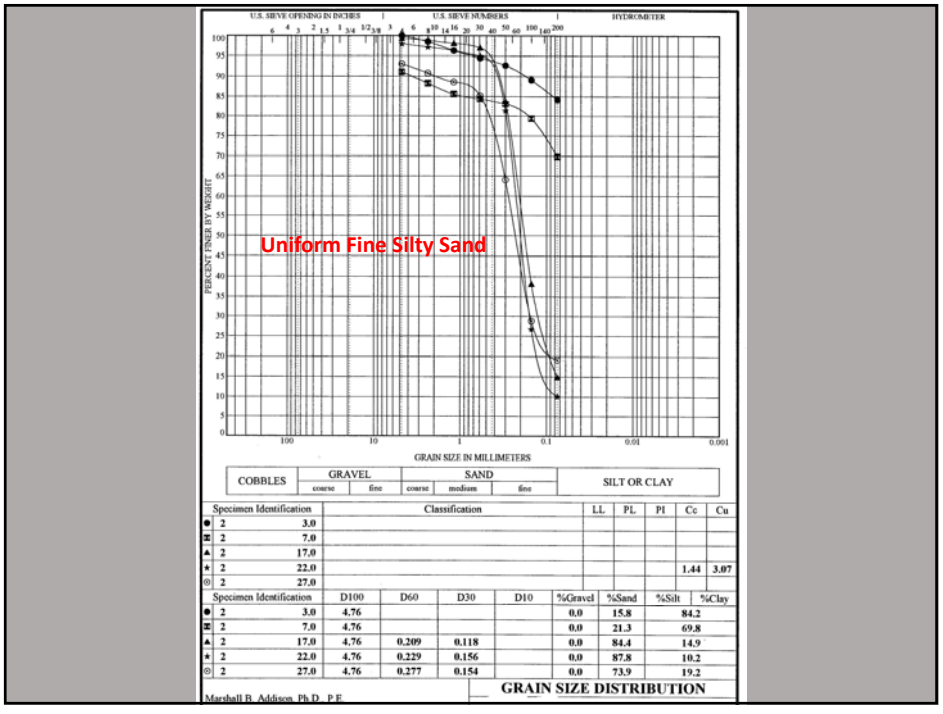

East Abutment
Bridge Deck
B-2
Approach Slab
B-3
Concrete Pavement
CH
Assumed strap length 0.75H
Assumed 2V:1H Slope
Embankment Fill – CH Clays
CH
Deflected Wall based on Field Data Collected by R-Delta Engineers, Inc.
SA
ROAD
B-1
Original groundline from LAN drawings
CH
CH
Native soils – CH Clays
Whd. LS
Whd. LS
Weathered Limestone
LS
LS
Unweathered Limestone
14+90.00
15+00.00
15+10.00
15+20.00
15+30.00
15+40.00
15+50.00
15+60.00
15+70.00
15+80.00
15+90.00
16+00.00
Centerline Stations, feet

25


U.S. SIEVE OPENING IN INCHES
U.S. SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
Uniform Fine Silty Sand
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
coarse
fine
SAND
coarse
medium
fine
SILT OR CLAY
Specimen Identification
Classification
LL
PL
PI
Cc
Cu
● 2 3.0
■ 2 7.0
▲ 2 17.0
★ 2 22.0
◎ 2 27.0
1.44
3.07
Specimen Identification
D100
D60
D30
D10
%Gravel
%Sand
%Silt
%Clay
● 2 3.0 4.76 0.0 15.8 84.2
■ 2 7.0 4.76 0.0 21.3 69.8
▲ 2 17.0 4.76 0.209 0.118 0.0 84.4 14.9
★ 2 22.0 4.76 0.229 0.156 0.0 87.8 10.2
◎ 2 27.0 4.76 0.277 0.154 0.0 73.9 19.2
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GRAIN SIZE DISTRIBUTION

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Literature review and engineering analysis

Some details of MSE wall are found in Public Works Dept.

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Built 1985
Pressure grouting to lift settled approach slabs:
- **1989**
- **1991**
- **1994**

Our investigation 2001

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STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

SPECIAL SPECIFICATION 3

ITEM 4002

RETAINED EARTH WALLS

.1. Description. This item shall govern for the construction of Retained Earth Walls in accordance with these specifications and with the lines, grades and dimensions shown on the plans.

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All backfill material used in the structure volume shall be free from organic or otherwise deleterious materials and shall conform to the following gradation limits as determined by Test Method Tex-110-E.

Sieve Size	Percent Passing
6 inches	100
3 inches	75 - 100
No. 200	0 - 15

The Resistivity shall be 1,500 ohms-cm or greater as determined by Test Method Tex-129-E.

The pH range shall be from 5.5 to 9.0 as determined by Test Method Tex-128-E.

Materials not meeting these gradation limits may be used if they conform to the following additional requirements:

1. The fraction finer than the No. 200 sieve as determined by Test Method Tex-100-E shall not exceed 25 percent.
2. The Plasticity Index (P.I.) as determined by Test Method Tex-106 shall not exceed 6.
3. The material, when compacted to 95% density as determined by Test Method Tex-114-E at optimum moisture content, shall exhibit an angle of internal friction of not less than 34 degrees as determined by Test Method Tex-117-E.

SS 3 2-7

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U. S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-NHI-10-024
FHWA GEC 011 – Volume I
November 2009

NHI Courses No. 132042 and 132043

Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I

Developed following:
AASHTO LRFD Bridge Design Specifications, 4th Edition, 2007, with 2008 and 2009 Interims. and *AASHTO LRFD Bridge Construction Specifications, 2nd Edition, 2004, with 2006, 2007, 2008, and 2009 Interims.*

NHI
NATIONAL HIGHWAY INSTITUTE

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Select Granular Fill Material for the Reinforced Zone of Walls. All fill material used in the structure volume for MSE wall structures should be reasonably free from organic or other deleterious materials and should conform to the gradation limits, PI and soundness criteria listed in Table 3-1. Note that Table 3-1 presents a broad gradation range that is applicable across the United States. Individual DOTs may adjust this range based upon locally available and economical select granular fill. The reinforced fill should be well-graded in accordance with the Unified Soil Classification System (USCS) in ASTM D2487. Unstable broadly graded soils (i.e., $C_u > 20$ with concave upward grain size distributions) and gap-graded soils should be avoided (see Kenney and Lau, 1985, 1986 for a method to identify unstable soils). These soils tend to pipe and erode internally, creating problems with both loss of materials and clogging of drainage systems.

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Table 3-1. MSE Wall Select Granular Reinforced Fill Requirements.

Gradation: (AASHTO T-27)	U.S. Sieve Size	Percent Passing[(a)]
	4 in. (102 mm)[(a,b)]	100
	No. 40 (0.425 mm)	0-60
	No. 200 (0.075 mm)	0-15
Plasticity Index, PI (AASHTO T-90)	PI $\leq$ 6	
Soundness: (AASHTO T-104)	The materials shall be substantially free of shale or other soft, poor durability particles. The material shall have a magnesium sulfate soundness loss of less than 30 percent after four cycles (or a sodium sulfate value less than 15 percent after five cycles).	

Notes:
(a) To apply default F* values, C_u, should be greater than or equal to 4.
(b) As a result of recent research on construction survivability of geosynthetics and epoxy coated reinforcements, it is recommended that the maximum particle size for these materials be reduced to ¾-in. (19 mm) for geosynthetics, and epoxy and PVC coated steel reinforcements unless construction damage assessment tests are or have been performed on the reinforcement

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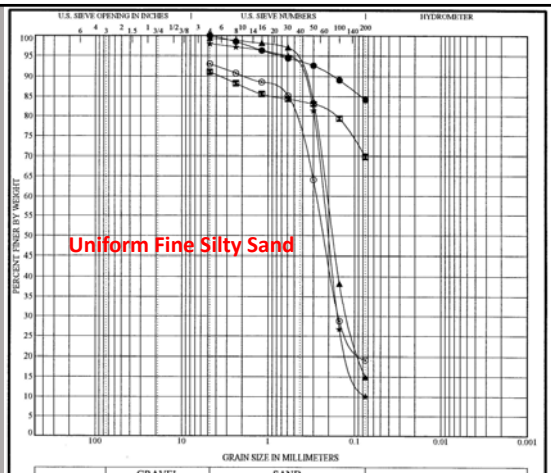

Specimen Identification			Classification				LL	PL	PI	Cc	Cu
●	2	3.0									
■	2	7.0									
▲	2	17.0									
★	2	22.0								1.44	3.07
◎	2	27.0									

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	2	3.0	4.76				0.0	15.8	84.2	
■	2	7.0	4.76				0.0	21.3	69.8	
▲	2	17.0	4.76	0.209	0.118		0.0	84.4	14.9	
★	2	22.0	4.76	0.229	0.156		0.0	87.8	10.2	
◎	2	27.0	4.76	0.277	0.154		0.0	73.9	19.2	

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GRAIN SIZE DISTRIBUTION

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Performance and calculations revealed pullout failure of bar mat reinforcement

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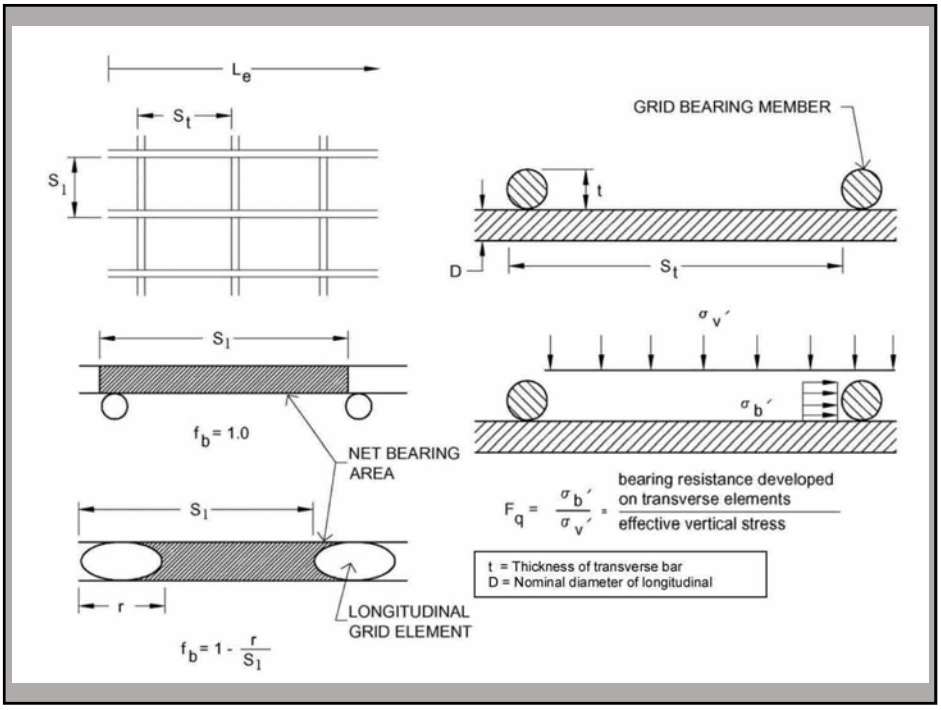

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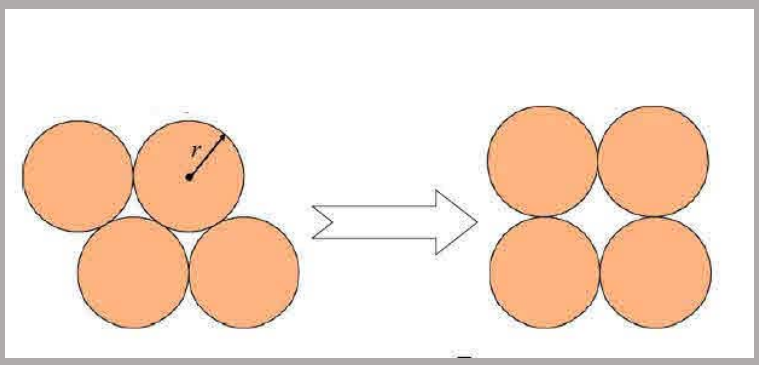

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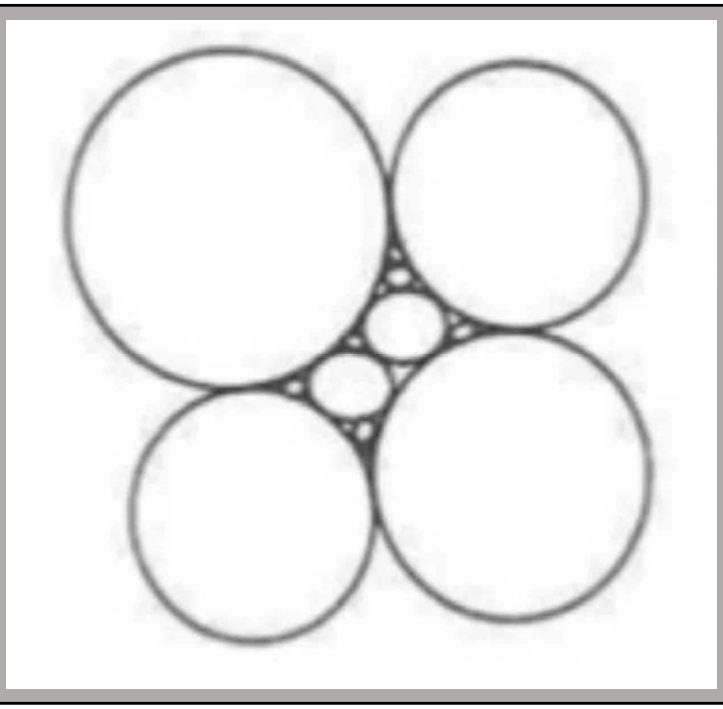

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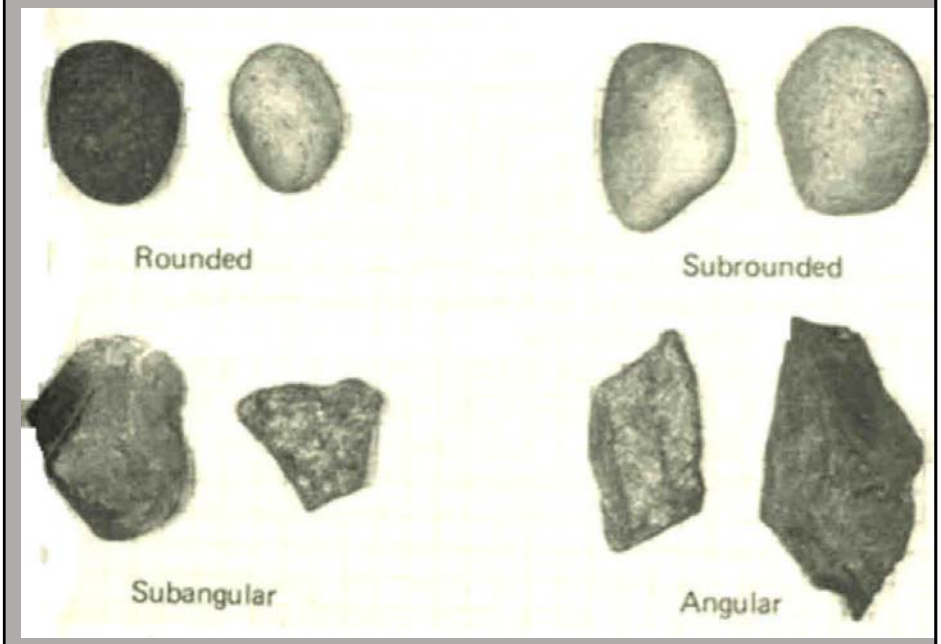

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Options to consider for remediation

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Phase II investigation recommended sodium silicate permeation grouting program to increase passive resistance of in-place reinforcement to keep route open to hospital district

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Interviewed and selected a Geotechnical specialty contractor

Determined DCP with extensions would be an economical means on the slopes to evaluate current and after grouting in-place stiffness

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Statistical analysis of Deep DCP testing revealed, on this project, that injections spaced greater than 54” (1.4m) encountered significant deterioration in after grouting stiffness.

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Closer spacings of DDCP probes Found uniform resistance that was approximately 3.5 X stiffer than pre permeation grouting results and resulted in F.S. exceeding 1.5 at all locations

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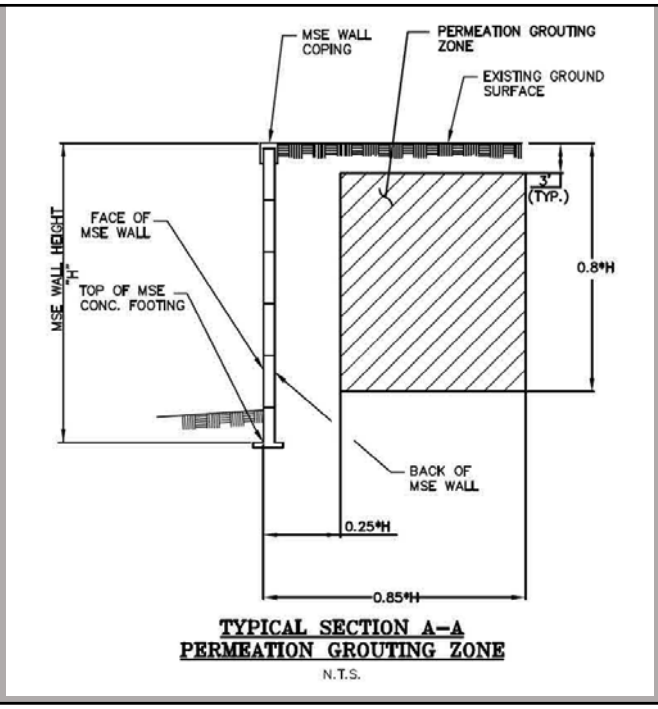

54

Specifications were developed

The grouting sequence did not allow injections next to fresh grout

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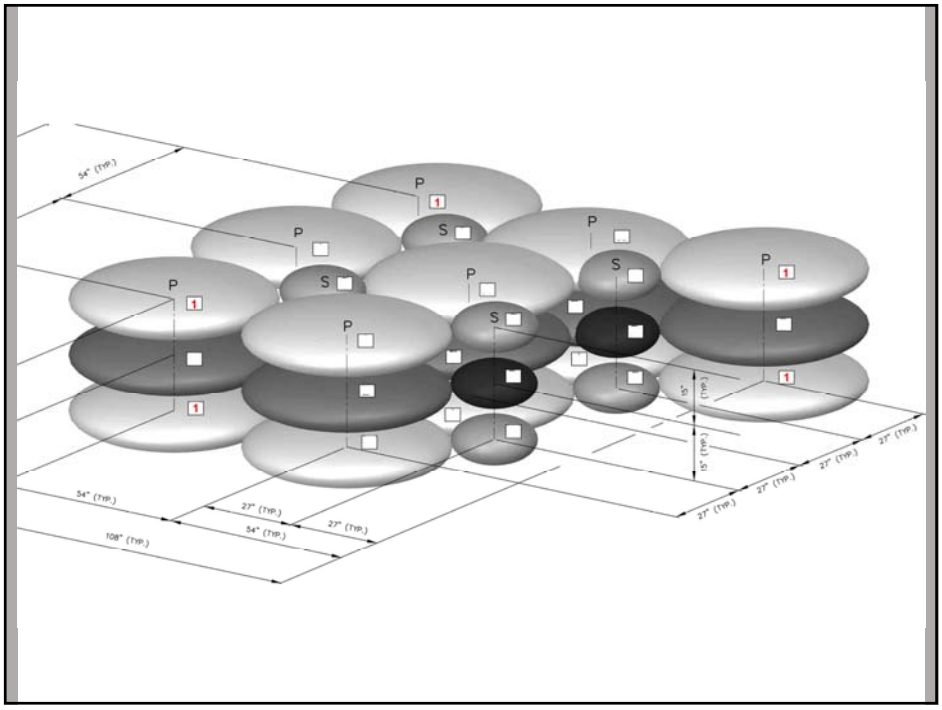

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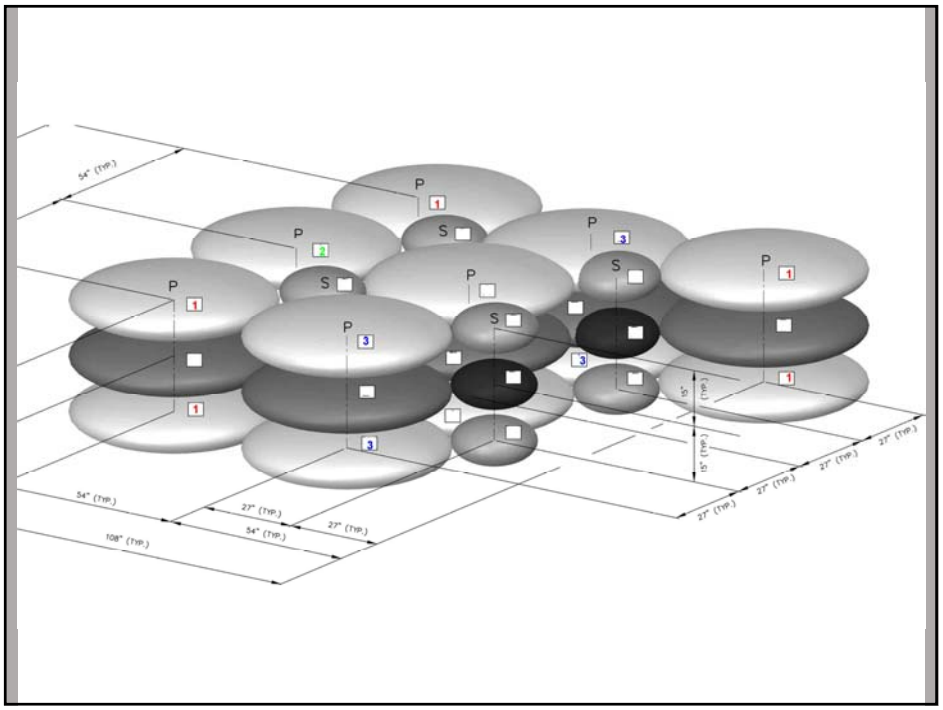
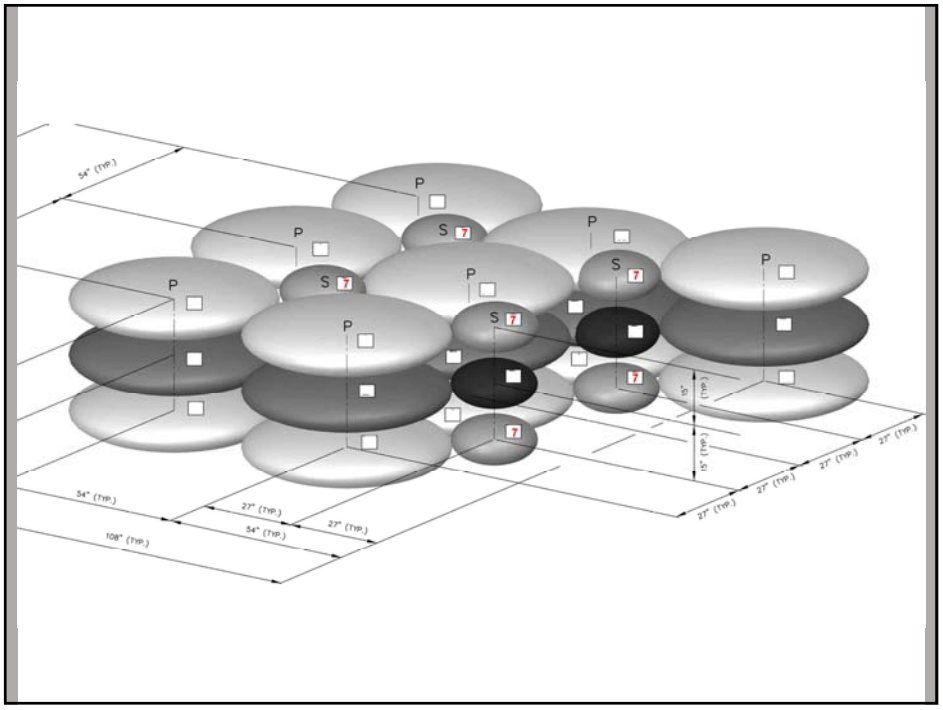
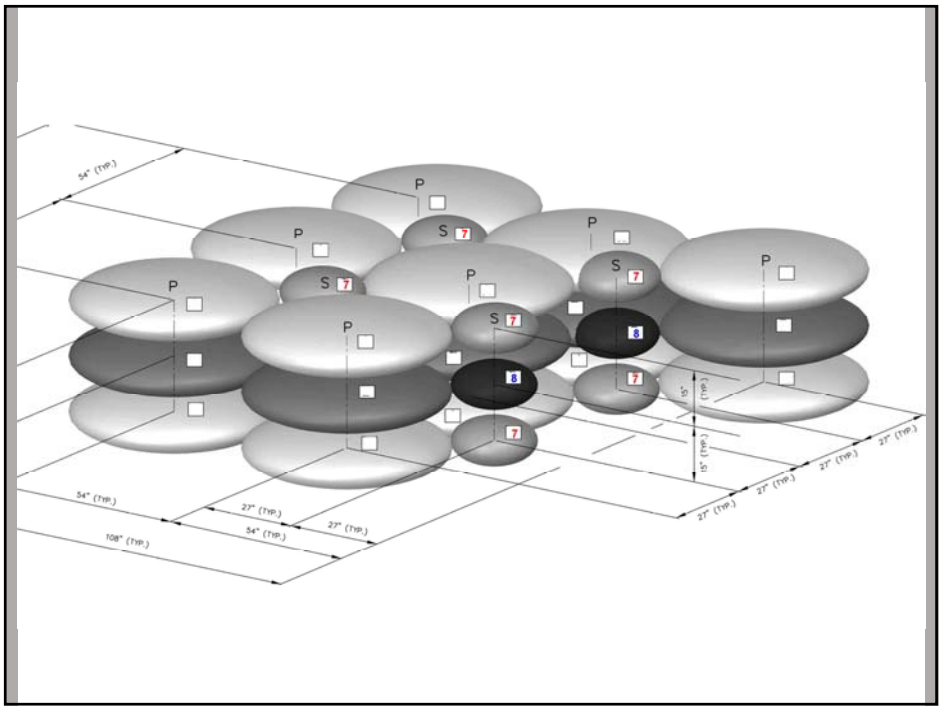

54" (TYP.)
P
S
1
2
3
27" (TYP.)
15" (TYP.)
108" (TYP.)

57


54" (TYP.)
P
S
7
27" (TYP.)
15" (TYP.)
108" (TYP.)

58



59

The wall was surveyed during initial injections to monitor wall movements as the fluid grout initially reduced pullout resistance before setting up.

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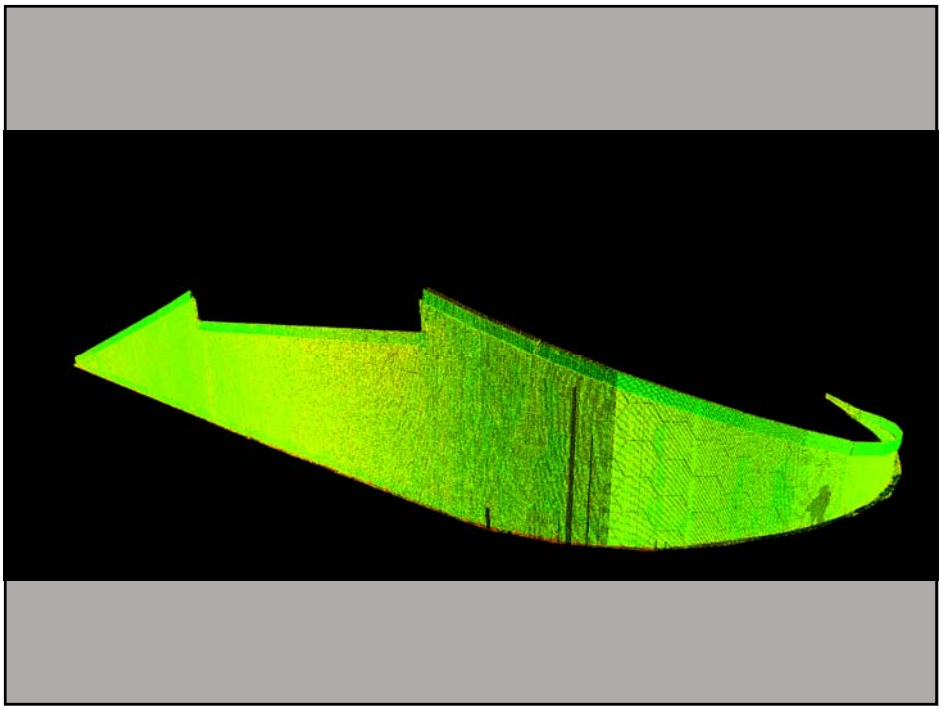

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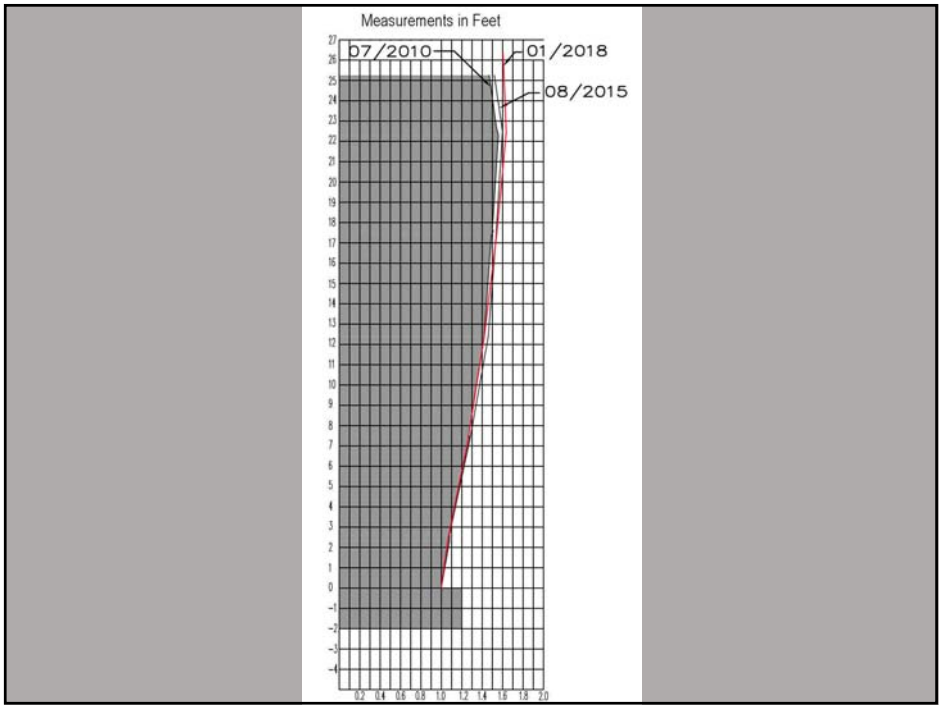

62

LESSONS LEARNED

As a designer, always evaluate if "new" geo solutions have been properly vetted before relying upon industry developed specifications.

63

LESSONS LEARNED

As a wall designer, always consider long-term compatibility of reinforcement and retained soil materials used to construct infrastructure

64

65