NOISE WALLS

2013 Design Training Expo

SOUND BARRIERS

ABBREVIATIONS DEFINED:

In no apparent order; but should keep me out of trouble….

- **AASHTO or LRFD:** AASHTO LRFD Bridge Design Specifications
- **SDG:** Structures Design Guidelines (Volume one of the Structures Manual)
- **QPL:** Qualified Products List
- **BOE:** Basis of Estimates
- **MASH:** AASHTO Manual for Assessing Safety Hardware
- **TL-4:** Test Level 4
- **PD&E:** Project Development and Engineering
- **ACP:** Auger Cast Piles
- **DSDE:** District Structures Design Engineer

Non-Structural Criteria

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Design Issues to Address in the Plans

Aesthetics

Color, Texture, Anti-Graffiti Coatings

Enhanced Aesthetics

Post Caps, Additional Details

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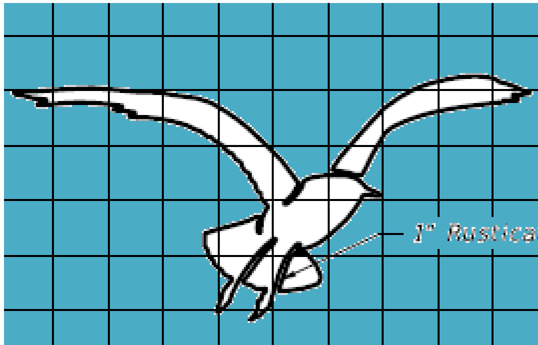
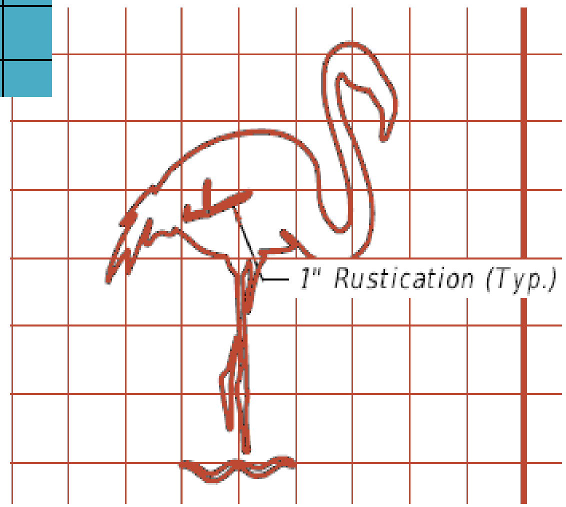
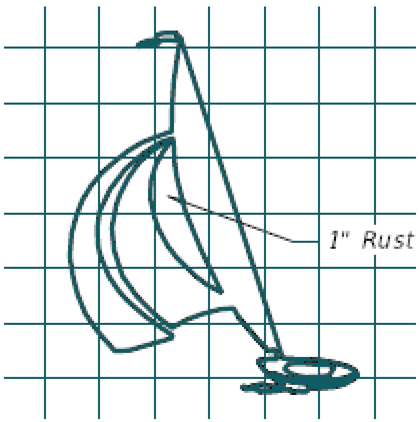
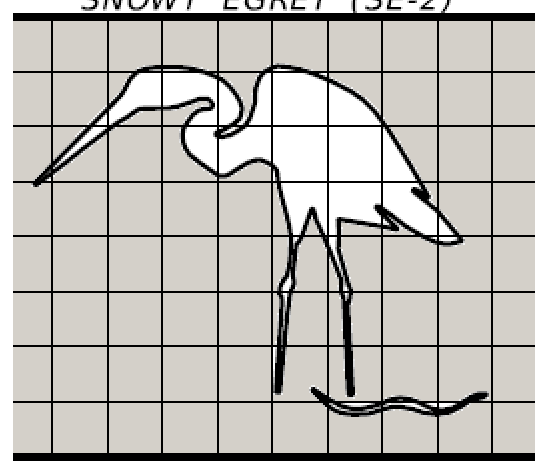
Graphic Designs:







SNOWY EGRET (SE-2)



See IDS for available Cells

July 2013 Release

“SOUND BARRIERS” are now “NOISE WALLS”

Why the Name Change?

- **WHY?**
  - ✓ Justification is based on Noise Studies (Noise is unwanted Sound).
  - ✓ Barriers can be berms, a wall of trees or shrubs, distance, etc.
  - ✓ Walls are man made structures.
  - ✓ We are building Walls that lower highway Noise; therefore, “Noise Walls”.
- **To keep a consistent nomenclature with that used in public meetings, Noise Studies and Noise Walls are the terms used in Public Meetings and the PD&E Process.**

Recent Updates to Index 5200:
Noise Walls (Outside Clear Zone)

- **<u>January 2012:</u>**
  - ✓ Updated to LRFD 2012 (as amended by the SDG)
  - ✓ Added designs <u>for 3 wind zones</u>
  - ✓ Dropped the assumed 5’ berm
  - ✓ Dropped 1” max. deflection at top of pile
    - Designed foundations using Broms Method
      - Checked with Com 624 and FB MultiPier
  - ✓ <u>Added Loose Soil foundation depths</u>
  - ✓ <u>Added back a Low Clearance Option</u>

Recent Changes/Updates to Index 5200 Noise Walls (Continued)

- <u>July 2012 (**2013 Book**)</u>
  - ✓ Removed ***QPL*** requirement
    - Precast – If according to Standard, no Shop Drawings Required
  - ✓ Rearranged drawings by use
  - ✓ Eliminated the H post C-I-P Collars
  - ✓ Added Corner Post details and redesigned the C-I-P collar –constructability

Recent Changes/Updates to Index 5200 Noise Walls (Continued)

Coming Soon to a website near you………….

<u>July 2013 (**2014 Book**):</u>

- ✓ Renamed Index: *"Noise Walls"*
- ✓ Added details for **Side Installed Panels**
- ✓ Changed the reentrant corner reinforcing (fire and drainage holes)
- ✓ Refined wind loading calculations

IDS – Instructions for Design Standards

On the website:

http://www.dot.state.fl.us/rddesign/DesignStandards/Standards.shtm

⇩

880	5	Steel Pipe Guiderail		IDS-880		
		* SOUND BARRIER SYSTEMS *	Structures Contact			
5200	16	Precast Sound Barriers		IDS-5200	CEL-5200 CEL-5200-Graphics	DGN-5200
5210	5	Traffic Railing/Sound Barrier (8'-0")		IDS-5210		DGN-5210
5211	3	Traffic Railing/Sound Barrier (14'-0")		IDS-5211		DGN-5211
5212	2	Traffic Railing/Sound Barrier (8'-0") Junction Slab		IDS-5212		DGN-5212
5213	2	Traffic Railing/Sound Barrier T-Shape Spread Footing		IDS-5213		DGN-5213
5214	4	Traffic Railing/Sound Barrier L-Shaped Spread Footing		IDS-5214		DGN-5214
5215	1	Traffic Railing/Sound Barrier Trench Footing		IDS-5215		DGN-5215
		* WALL SYSTEMS *	Structures Contact			

Information for the Designer:

- Design Criteria
- Design Assumptions and Limitations
- Plan Content Requirements
- Pay Items Numbers

IDS

If you have questions, after reading the IDS, we will be glad to help.

Contact Central Office: Design Standards Group

Design Criteria

AASHTO LRFD Bridge Design Specifications, 6th Edition; ***Structures Design Guidelines (SDG)***

Design Assumptions and Limitations

See ***SDG*** 3.16 for structural design criteria.

This Design Standard has not been designed for vehicle impact loads. If there is insufficient room to accommodate the sound barrier and required set back, use Index 5210 and/or 5211.

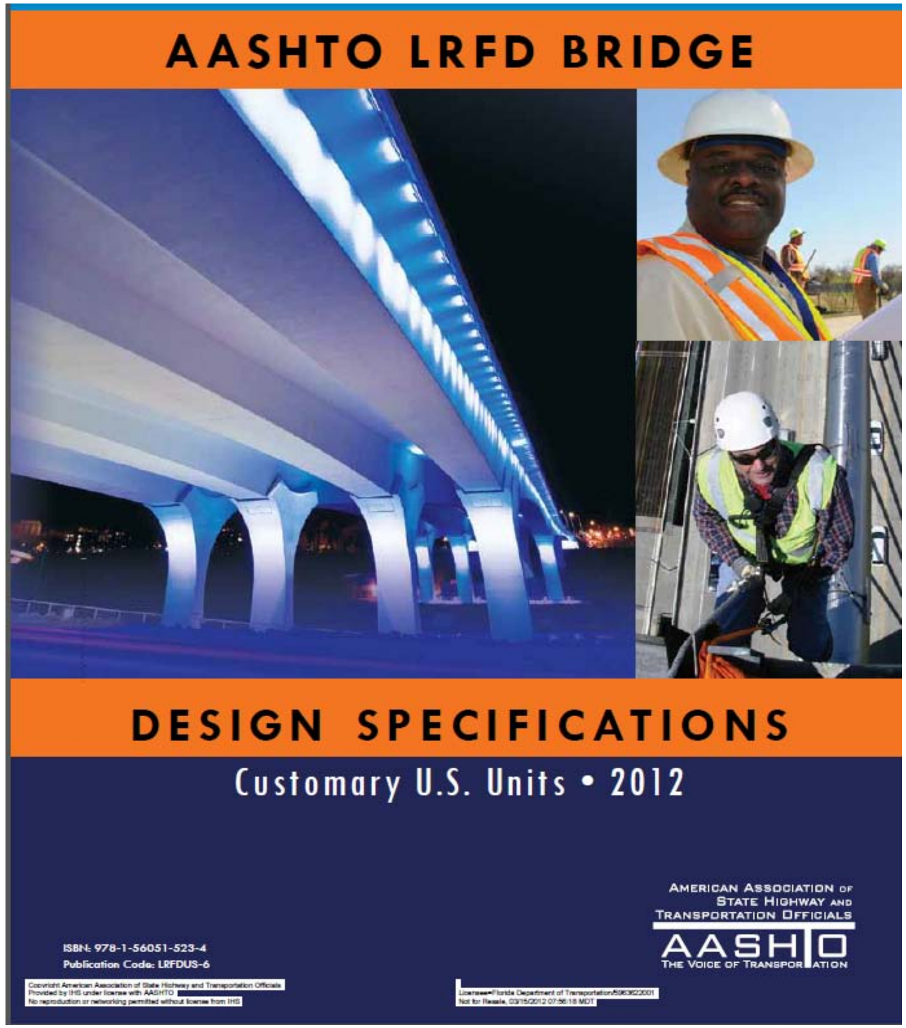
General Assumptions/Limitations:

- Elevation at the base of the wall is the same as the surrounding terrain.
- Foundations depths are calculated using Broms method for overturning.
- Post heights range from 12' to 22' in 1'-0" increments.
- Post Spacing is either 10' or 20'.
- Panels are designed for the 150 MPH wind speed (wind pressure = 52 psf) and a maximum panel height of 12'.
- Posts are designed for 110 MPH, 130 MPH and 150 MPH wind speeds.

Ensure system is constructible with consideration of overhead clearances (i.e. overhead services, tree canopies, existing overhead structures, etc.) and existing underground services along the entire length of barrier. Field stake wall alignment at 20'-0" spacing during the design process to locate potential conflicts or severe base elevation changes.

- If vertical clearance is limited, consider the low clearance post/foundation option and

Update 2012:
AASHTO Added Sound Barriers



NCHRP Project 20-07/Task 270

- Started with ***Guide Specifications for Structural Design of Sound Barriers*** *(1989)*
- Updated to LRFD
- Integrated into Design Standards by:
  - Updating Section 3
    - Loads and Load Factors
  - Adding Section 15
    - Sound Barriers

Standard Noise Walls
Index 5200

AASHTO LRFD 2012

- **Wind Pressures** Amended by ***SDG 2.4***
  - See ***SDG Table 2.4.1-2*** for Wind Speeds by County

Loading

- **Post & Foundation Designs**
  - Controlled by Wind
- **Panel Design**
  - Controlled by Fabrication
  - Checked for 150 mph wind

Standard Noise Walls
Indexes 5210-5215

Inside Clear Zone

- ***AASHTO LRFD 2012*** as amended by ***SDG***
- 5210 & 5212 Crash Tested: Jan. 2001
- Located on top of F-Shaped Traffic Railings
  - ✓ Foundations based on location
  - ✓ 14’ only on ground mounted.

Controlling Design

- Vehicle Collision (CV) Loads Control
  - ✓ Check Wind Loading for Elevations:
    - Bridge over 75 ft
    - Wall over 30 ft

Let's Get Technical

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Noise Wall Design Criteria

Wind Pressure: *SDG 2.4*

2.4.1 Wind Pressure on Structures: WS

A. General

The design wind pressure shall be computed using the following equation:

$$P_z = 2.56 \times 10^{-6} K_z V^2 G C_p \qquad \text{[Eq. 2-1]}$$

Note: V^2

Where:

P_z = Design wind pressure (ksf)

K_z = Velocity pressure exposure coefficients (2.4.1.D)

V = Basic wind speed (2.4.1.C) (mph)

G = Gust effect factor (2.4.1.E)

C_p = Pressure coefficient (2.4.1.F)

Wind Pressure (Continued)

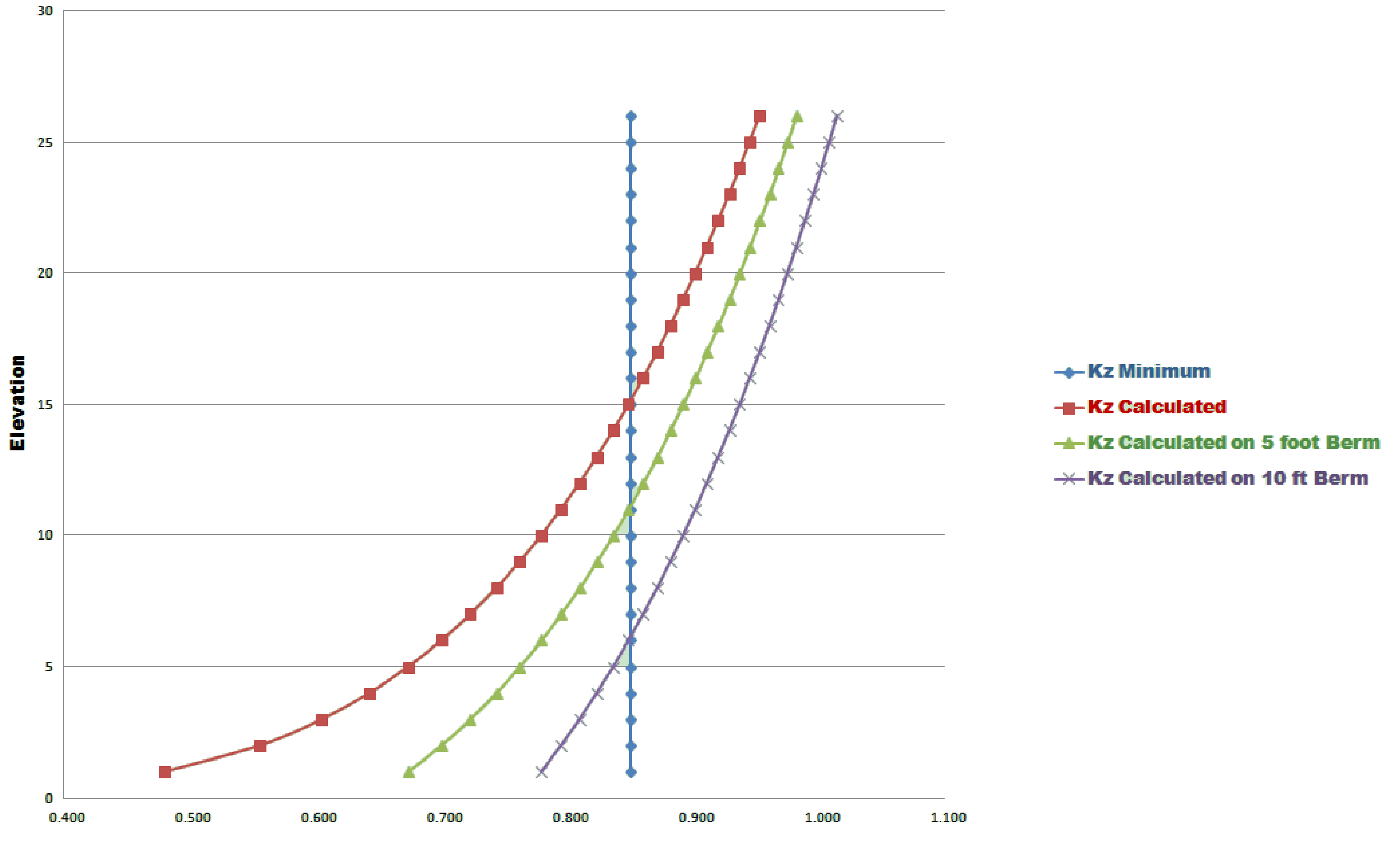
$K_Z = 2.01(\mathbf{z}/900)^{0.2015}$

- **z** = height to the centroid of the exposed area (ft).
  - ✓ Exposure Category C: **$K_Z \geq 0.85$**

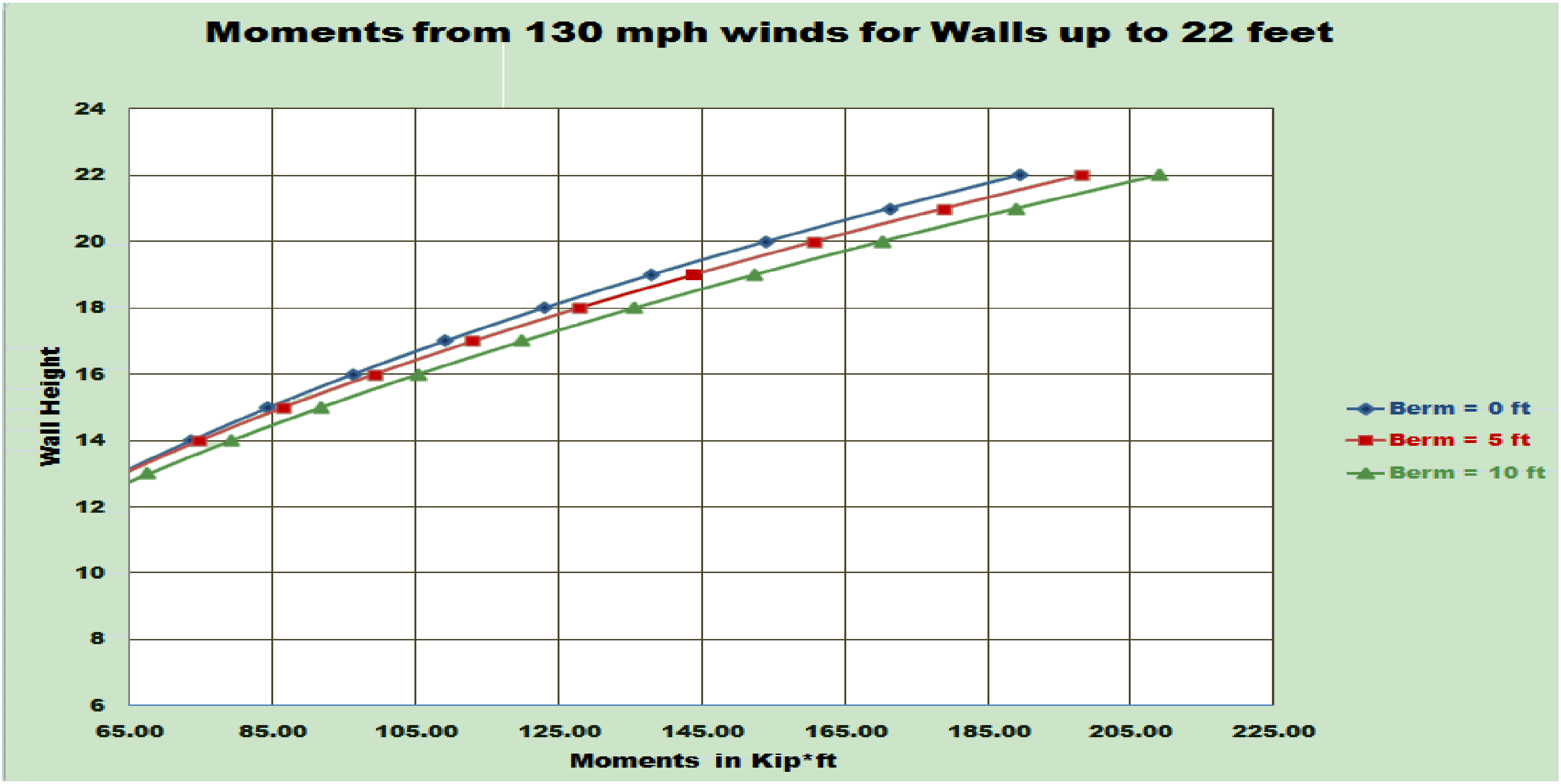
2013 Book Index 5200 designs were based on $\mathbf{K_Z}$ = 0.85 for wall areas less than 15 feet high with **z** = H/2. Wall areas over 15 high; pressure was based on the average K_Z =0.891; with **z** = 15ft+ (H – 15ft)/2.

2014 Book calculates the wind pressure per foot above 15 feet. (H< 15 ft unchanged). $\mathbf{K_Z}$ ranges from 0.860 between 15 &16 ft to 0.9202 between 21& 22 ft.

K_z by Elevation and Exposure Category



Effect of Base Elevation on Moments



Elevation change from 0 to 5 ft for 15 ft wall = 2.3% and 22 ft wall = 4.5%
Elevation change from 0 to 10 ft for 15 ft wall = 8.6% and 22 ft wall = 10.3%

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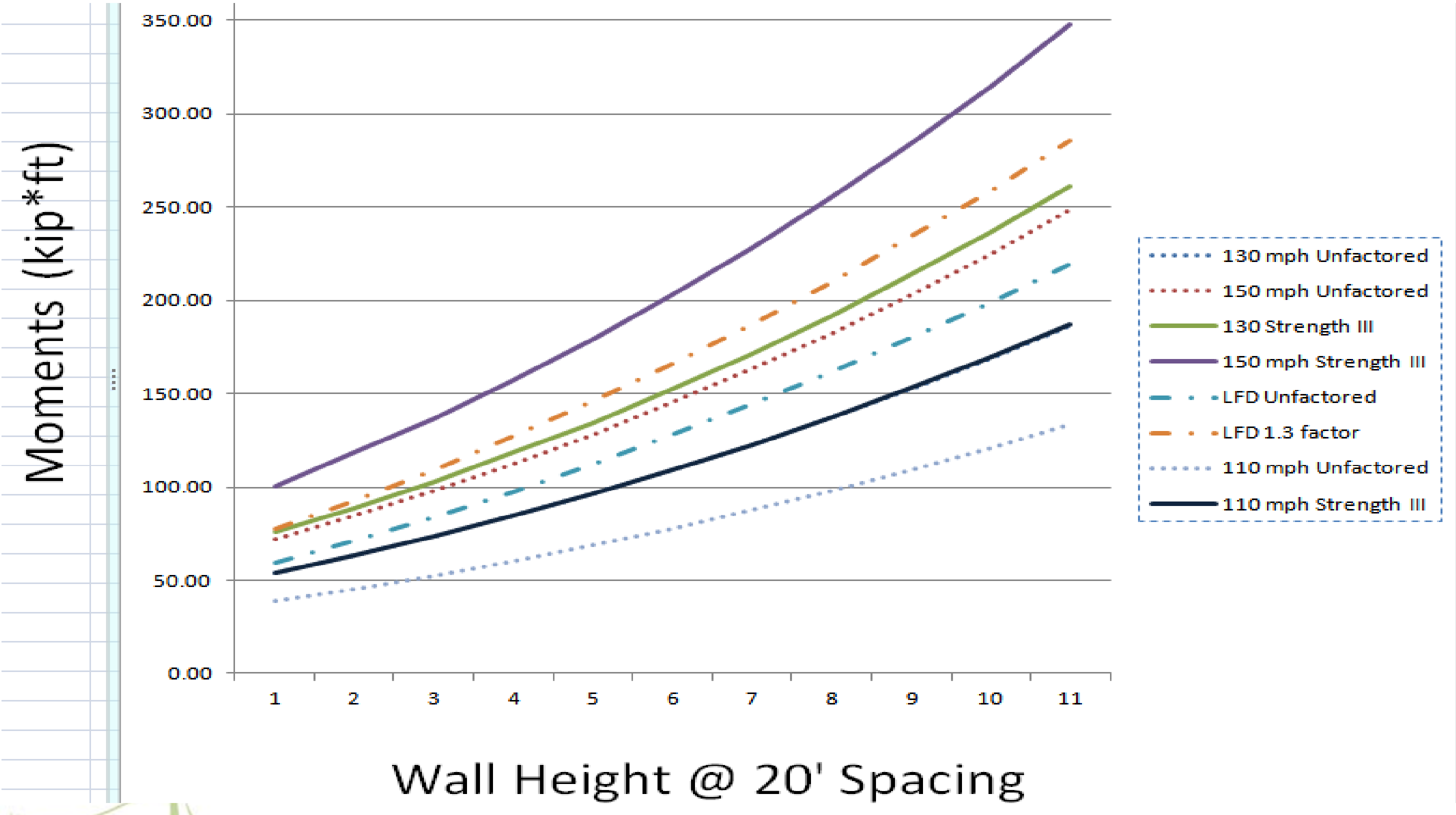
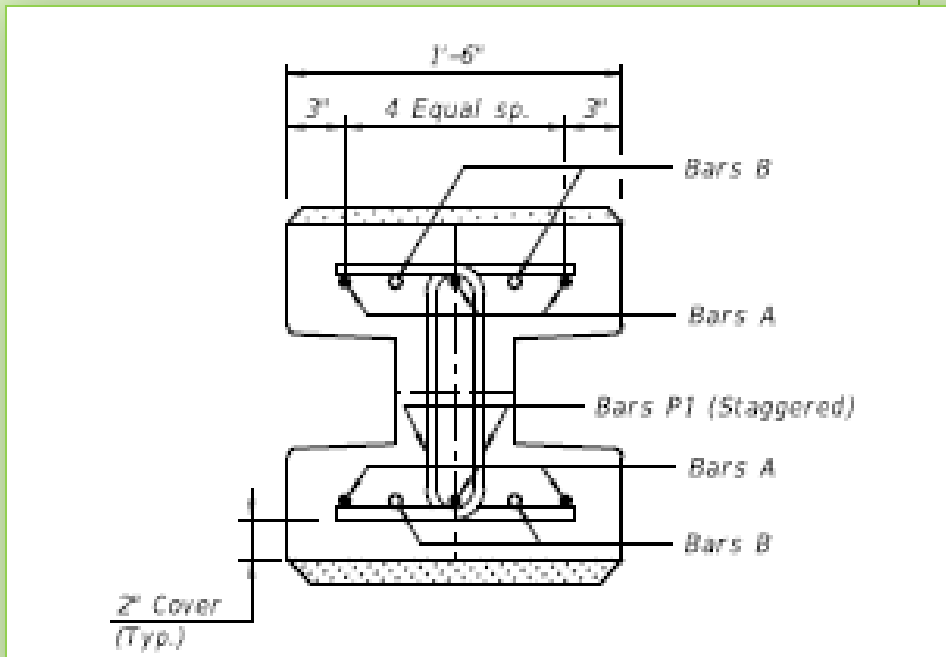
Wind Pressure (Continued)

- Graph of Moments at the base of posts due to Wind Pressure on Panels.
  - ✓ Dashed lines are **LFD**: Based on 110 mph winds with 3 second gust.



Index 5200 Issues



- Why no post designs for 150 mph, 21 & 22 ft. Walls?
  - ✓ From previous graph and equation for wind pressure; M > 300 kip*ft
  - ✓ Without increasing size of forms, 5 ~ #11 bars required.
  - ✓ Bars 1½ " o.c. or clear space of 7/8".

Index 5200 Issues (Continued)

- What if 21-22 ft walls are required in 150 mph wind zone?
  - ✓ Design with 75 ksi steel (Break-even cost of materials about 3/4 mile of wall)
- Why not add 75 ksi option to the Standards?
  - ✓ 33% to 67% increase in cost / lb
  - ✓ Availability
  - ✓ Must be purchased by lot
    - Precasting yard must store 60 and 75 ksi steel separately (doubles storage for each size of reinforcing)
    - Adds inspection and testing criteria

Vehicular Collision: Loading and Design

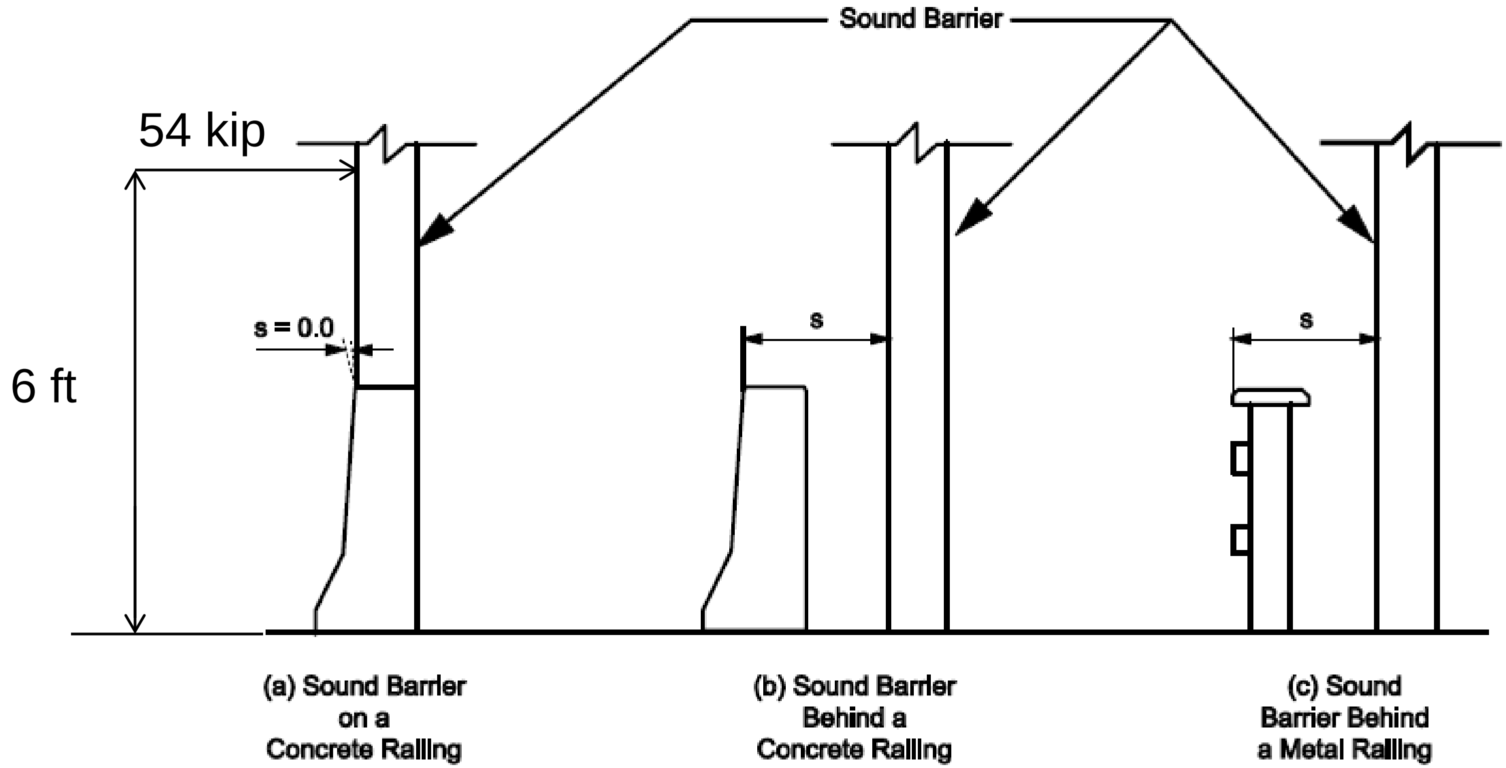


Figure 15.8.4-1—Sound Barrier Setback Distance

Case 1
S = 0 ft =>54 kip @ 6 ft

Case 4
S > 4 ft – No Collision Force

Vehicular Collision: Loading and Design (Continued)

LRFD **15.8.4-1** and **C15.8.4** describe **4 Cases:**

Case	Spacing / Index	Load
Case 1	**S=0 ft** **Indexes 5210-5215**	**54 kip @ 6 ft**
Case 2	**S=4 ft**	**4 kip @ 14 ft**
Case 3	**0<S<4 ft**	**Varies Linearly between Cases 1 & 2**
Case 4	**S>4 ft** **Index 5200**	**0 kip**

Vehicular Collision: Loading and Design (Continued)

- **LRFD Appendix A13** (Yield Line): For analysis of alternate designs based on crash tested wall/traffic railings.
  - ✓ 14 foot walls,
  - ✓ Tapered sections
  - ✓ Stem of Ground Mounted Foundations (T, L, and Trench Footings).

Vehicular Impact Loading and Design (Continued)

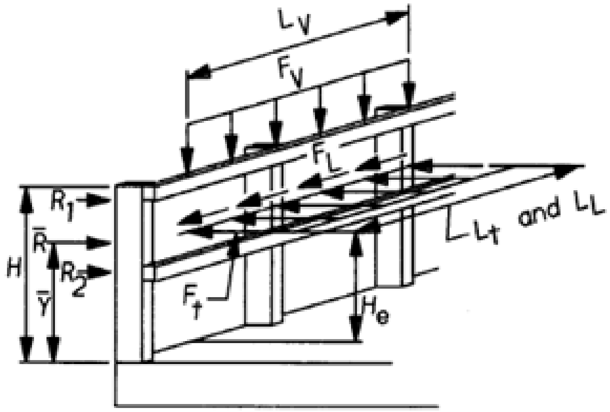


Figure A13.2-1—Metal Bridge Railing Design Forces, Vertical Location, and Horizontal Distribution Length

Figure A13.2-1 shows the design forces from Table A13.2-1 applied to a beam and post railing. This is for illustrative purposes only. The forces and distribution lengths shown apply to any type of railing.

- Where the forces and application lengths and distances are listed in Table A.13.2-1

Table A13.2-1—Design Forces for Traffic Railings

Design Forces and Designations	Railing Test Levels					
	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6
F_t Transverse (kips)	13.5	27.0	54.0	54.0	124.0	175.0
F_L Longitudinal (kips)	4.5	9.0	18.0	18.0	41.0	58.0
F_v Vertical (kips) Down	4.5	4.5	4.5	18.0	80.0	80.0
L_t and L_L (ft)	4.0	4.0	4.0	3.5	8.0	8.0
L_v (ft)	18.0	18.0	18.0	18.0	40.0	40.0
H_e (min) (in.)	18.0	20.0	24.0	32.0	42.0	56.0
Minimum H Height of Rail (in.)	27.0	27.0	27.0	32.0	42.0	90.0

Vehicular Impact Loading and Design (Continued)

- A13.2: Traffic Railing Design Forces:
  - “The transverse and longitudinal loads in Table A13.2-1 need not be applied in conjunction with vertical loads.”
    - Reason: The errant vehicle first contacts the traffic railing or wall applying a horizontal load; then the vehicle rolls over on top of the structure applying the vertical load.

Traffic Railing Analysis LRFD Appendix A13: Yield Line Theory

For TL-4:

- L_t = 3.5 ft
- F_t = 54 kip
- H_e = 6 feet (collision height)
- H = Wall height

L_c = Critical length of yield line failure

M_w = Flexural resistance of the wall about the vertical axis ≥ Flexural resistance of horizontal reinforcing

M_c = Flexural resistance of the wall about the horizontal axis ≥ Flexural resistance of vertical reinforcing

M_b = 0 kip-ft. unless a top rail is attached.

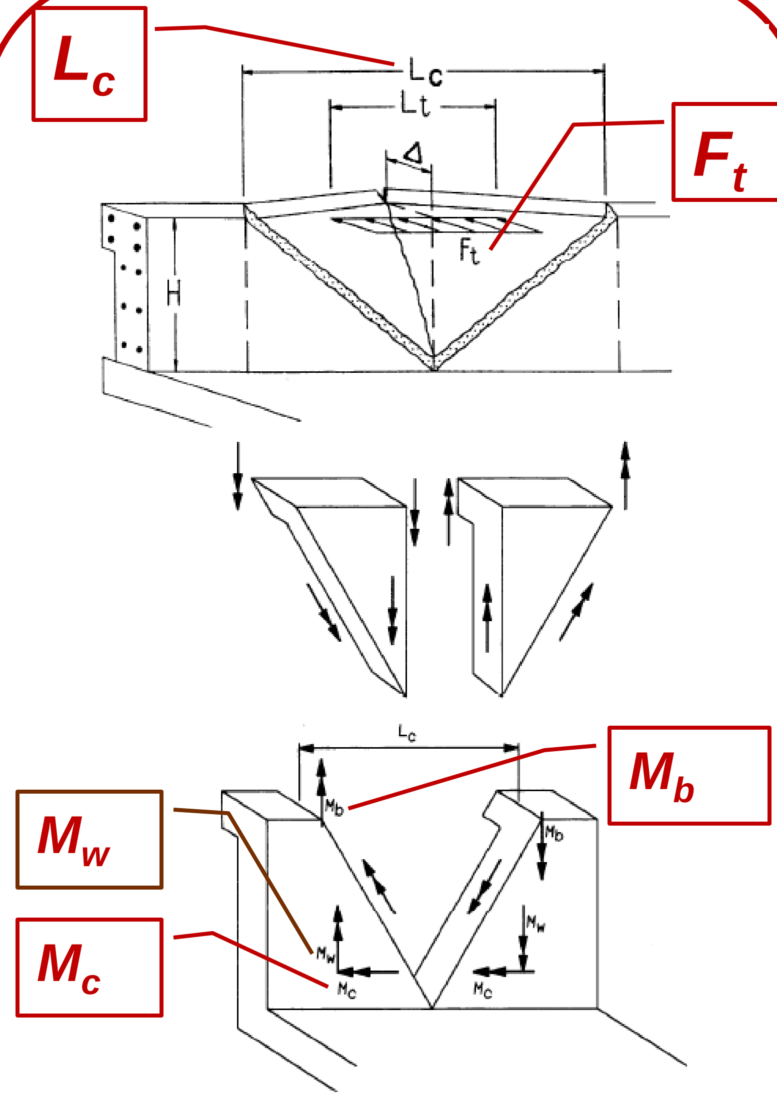


Figure CA13.3.1-1—Yield Line Analysis of Concrete Parapet Walls for Impact within Wall Segment

Traffic Railing Analysis (Continued)

- Calculate the nominal railing resistance to transverse loads (R_w)
- Calculate the critical railing length of the yield line failure (L_c)
- Within the wall segment
- End of the wall segment (at expansion joints)

R_w

A13.3.1—Concrete Railings

Yield line analysis and strength design for reinforced concrete and prestressed concrete barriers or parapets may be used.

The nominal railing resistance to transverse load, R_w, may be determined using a yield line approach as:

- For impacts within a wall segment:

$$R_w = \left(\frac{2}{2L_c - L_t}\right)\left(8M_b + 8M_w + \frac{M_c L_c^2}{H}\right) \quad \text{(A13.3.1-1)}$$

The critical wall length over which the yield line mechanism occurs, L_c, shall be taken as:

$$L_c = \frac{L_t}{2} + \sqrt{\left(\frac{L_t}{2}\right)^2 + \frac{8H(M_b + M_w)}{M_c}} \quad \text{(A13.3.1-2)}$$

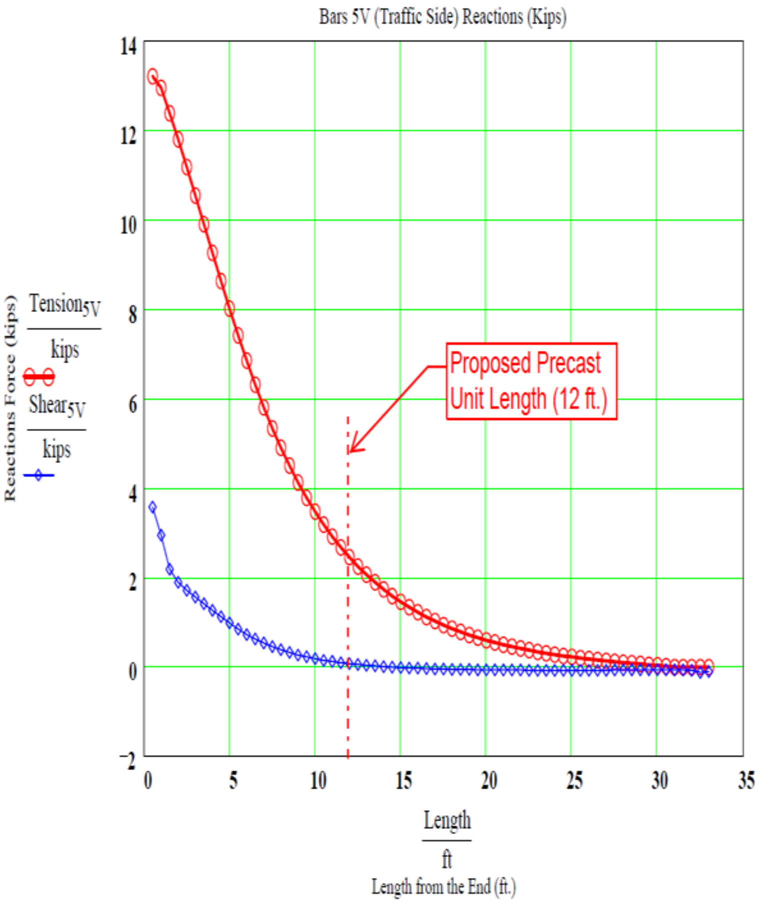
- For impacts at end of wall or at joint:

$$R_w = \left(\frac{2}{2L_c - L_t}\right)\left(M_b + M_w + \frac{M_c L_c^2}{H}\right) \quad \text{(A13.3.1-3)}$$

$$L_c = \frac{L_t}{2} + \sqrt{\left(\frac{L_t}{2}\right)^2 + H\left(\frac{M_b + M_w}{M_c}\right)} \quad \text{(A13.3.1-4)}$$

For 2015 Book

Precast Option for Noise Walls mounted on Traffic Railings.



- ✓ Completed Modeling
- ✓ Working on Details:
  - Pin at wall joints
  - Connections at base/footer
  - Length of precast segments
  - Plan Criteria

Foundation Design

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Design Requirements

Foundation Design: Index 5200 – Auger Cast Piles

- ***AASHTO LRFD*** 15.9 as modified by ***SDG*** 3.16 and the ***Soils and Foundation Handbook***
  - ✓ Resistance Factor for ACP derived from *COM 624* and *FB-MultiPier* lateral stability analysis; compared to Broms' method for overturning.
    - Resistance Factor: $\phi = 0.6$
    - Equivalent SF = 1.4/0.6 = 2.33

Foundations Design - Vehicular Collision Loads

- Equivalent Static Load: **L_s =10 kips**
- Height of application: H_A
  - ✓ Vertical distance from the effective point of impact (6' above base of traffic railing for TL-4) to the point of Interest or rotation.

Project Specific Foundation Evaluation

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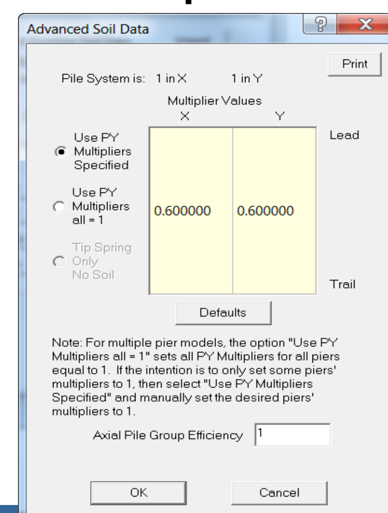
TABLE 1 - WIND SPEED = 110 MPH

POST AND PILE DIMENSIONS											TABLE OF REINFORCING STEEL											
WALL TYPE	POST LENGTH WITHOUT CAP	POST LENGTH WITH CAP	PILE LENGTH								POST REINFORCING											
			N = 10 to 40 Med. Dense Granular Soil				N = 4 to 9 Loose Granular Soil				10'-0" POST SPACING						20'-0" POST SPACING					
			10'-0" POST SPACING		20'-0" POST SPACING		10'-0" POST SPACING		20'-0" POST SPACING		BARS A	BARS B		BARS D	BARS E		BARS A	BARS B		BARS D	BARS E	
			30" Ø	36" Ø	30" Ø	36" Ø	30" Ø	36" Ø	30" Ø	36" Ø	SIZE	SIZE	DIM 'A'	SIZE	SIZE	DIM 'A'	SIZE	SIZE	DIM 'A'	SIZE	SIZE	DIM 'A'
A1	12'-0½"																				#5	9'-2"
B1	13'-0½"																				#5	9'-2"
C1	14'-0½"																				#6	10'-9"
D1	15'-0½"																				#6	10'-9"
E1	16'-0½"																				#7	12'-4"
F1	17'-0½"																				#7	12'-4"
G1	18'-0½"																				#8	13'-10"
H1	19'-0½"																				#8	13'-10"
I1	20'-0½"																				#8	13'-10"
J1	21'-0½"																				#9	15'-4"
K1	22'-0½"																				#9	15'-4"

Are the standard design tables on Index 5200 (Sheets 15 & 16) applicable to your project ?

Foundation Soil Assumptions: ***SDG*** *3.16*

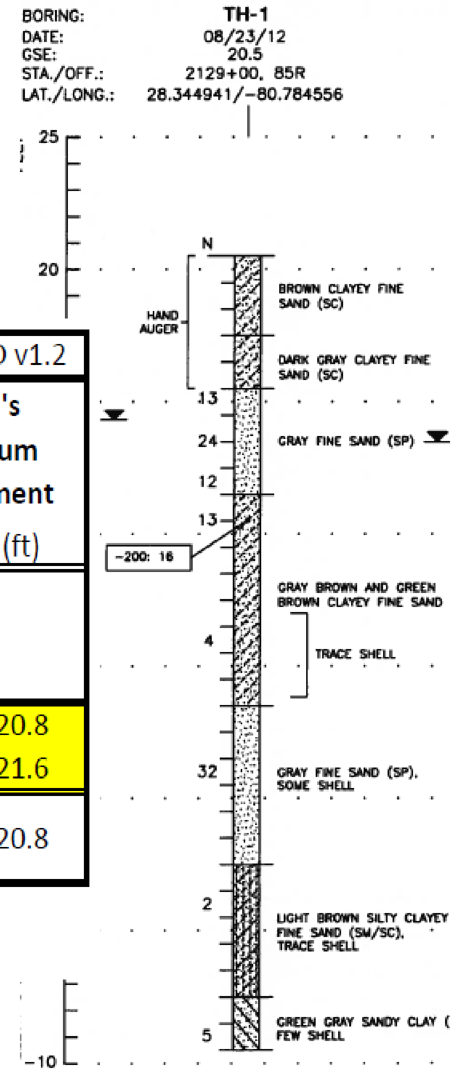
- Medium Dense Granular Soils – Majority of projects statewide (SPT blow counts N = 10 to 40);
- Loose Granular Soils (SPT blow counts N = 4 to 9)
- Recommended to use the weighted average of N values within the depth of the pile embedment.
- Can verify with FB-MultiPier for usual soil profiles:
  - Plot deflections for Strength III (LF = 1.4 on wind loads);
  - Apply 0.6 reduction factor for design soil resistance (Use PY Multiplier within the "Advanced Soil Data" dialogue window).



Project Example

- Variable Soil Profile – SPT blow counts range N = 2 to 36;

Boring TH-1			Estimated Pile Length (ft) = 21						MathCAD v1.2
Depth to Top of Layer (ft)	Depth to Bottom of Layer (ft)	Effective Soil Layer Thickness (ft)	Sand Layers (ft)	Material Type	Saturated Unit Weight (pcf)	SPT "N"	Angle of Internal Friction (degrees)	Cohesion (psf)	Brom's Minimum Embedment (ft)
0	11	11	11	Sand	111	12	31	0	
11	17	6	6	Sand	113	5	29	0	
17	23	4	4	Sand	118	36	36	0	
23	28	0	0	Sand	111	2	29	0	Sand 20.8
28	30	0	0	Clay	110	6	0	775	Clay 21.6
	Total (ft) =	21	21	Weight Average =	112.9	14.6	31.4	0.0	Wt. Avg = 20.8
				Submerged density =	50.5 pcf				



Meets "Medium Dense Granular Soil" range on Index 5200

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Project Example (Continued)

- Broms' Method Analysis – use FDOT Drilled Shaft Mathcad program.
  - Use equivalent Safety Factor for wind loads 1.4/0.6 = 2.33
  - Use weighted average soil properties for:
    - unit weight (γ_{soil});
    - soil friction angle (ϕ_{soil});
    - and shear strength (cohesion).

Drilled Shaft Foundation for Sign & Signal Structures

© Florida Department of Transportation

SUBJECT INDEX 5200 DEVELOPMENT
FIN # 999999-1-A1-01-123 LOCATION Sta 100+00
DESIGNED BY SJN DATE 11-7-12
CHECKED BY XYZ DATE X-X-XX

Input

SoilType:= Sand / Clay

WaterElevation:= Below Bottom of Shaft / Above Top of Shaft

$\gamma_{soil.dry} := 112.9 \cdot pcf$ *dry soil density* $\gamma_{water} := 62.4 \cdot pcf$ *water density*

$\gamma_{soil} := \gamma_{soil.dry} - \text{if}(\text{WaterElevation} = \text{"Above Top of Shaft"}, \gamma_{water}, 0 \cdot pcf) = 50.5 \cdot pcf$

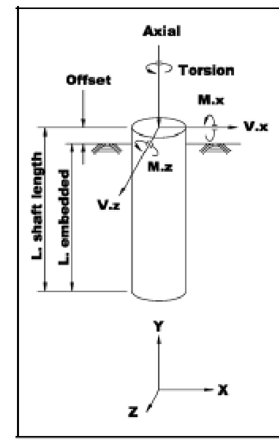
$b := 2.5 \cdot ft$ *shaft diameter* $\text{Offset} := 0 \cdot ft$ *groundline to top of foundation*

$\phi_{soil} := 31.4 \cdot deg$ *soil friction angle (sand)* $c_{soil} := 0.775 \cdot \frac{kip}{ft^2}$ *soil shear strength (clay)*

Applied Loads

$M_x := 266.39 \cdot kip \cdot ft$ $V_x := 0.0 \cdot kip$ $\text{Torsion} := 0.0 \cdot kip \cdot ft$

$M_z := 0.0 \cdot kip \cdot ft$ $V_z := 23.85 \cdot kip$ $\text{Axial} := 33.0 \cdot kip$



Shaft Depth Required to Resist Overturning

$SF_{ot} := 2.33$ *Safety Factor against Overturning* SM Vol-9 13.6

$M_{total} := (SF_{ot}) \cdot \sqrt{M_x^2 + M_z^2} = 620.7 \cdot kip \cdot ft$

$P_{total} := (SF_{ot}) \cdot \sqrt{V_x^2 + V_z^2} = 55.6 \cdot kip$

short free-head pile in cohesionless soil using Broms method

$K_p := \tan\left(45 \cdot deg + \frac{\phi_{soil}}{2}\right)^2 = 3.2$ $e_{sand} := \text{Offset} = 0$

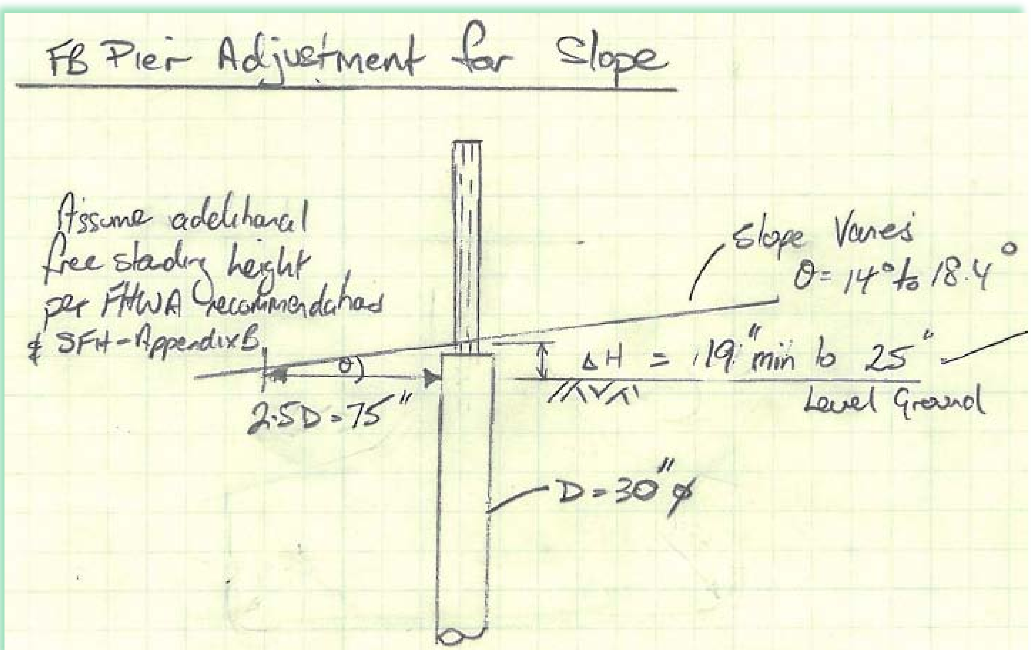
Guess value $L_{otSand} := 21 \cdot ft$

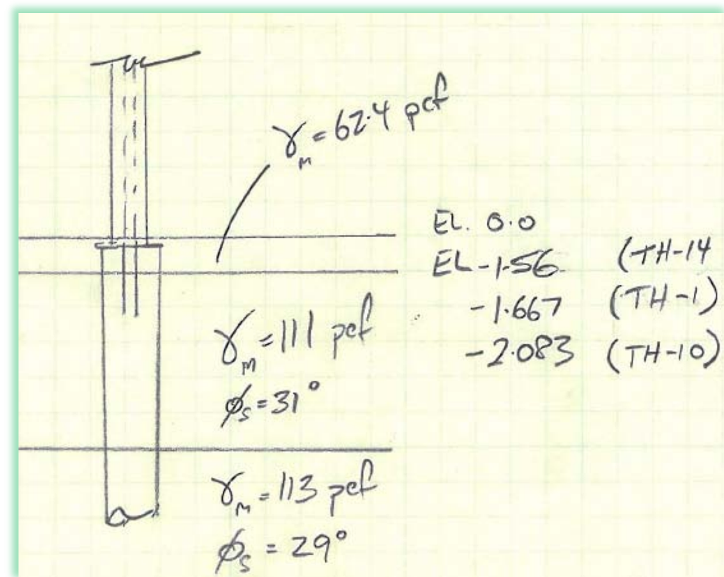
Given $\frac{\gamma_{soil} \cdot b \cdot L_{otSand}^3 \cdot K_p}{2} - P_{total} \cdot (e_{sand} + L_{otSand}) - M_{total} = 0 \cdot kip \cdot ft$

$L_{otSand} := \text{Find}(L_{otSand}) = 20.7 \, ft$

Project Example (Continued)

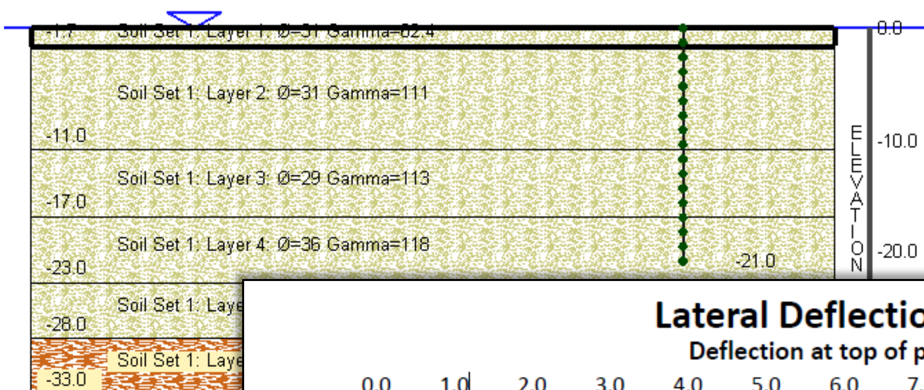
- Variable Cross Slope requires adjustment in soil profile:
  - For Drilled Shaft Mathcad - input as equivalent “Offset”;
  - For FB-MultiPier - add equivalent soil layer with no effective unit weight.
  - ***SFH*** Appendix B recommends neglecting soil above point with less than 2.5D horizontal soil cover (face-of-pile to face-of-slope).
    - For a refined slope effect analysis, see ***Caltrans*** Report No. CA-11-0932 by Oregon State University, March 2012.

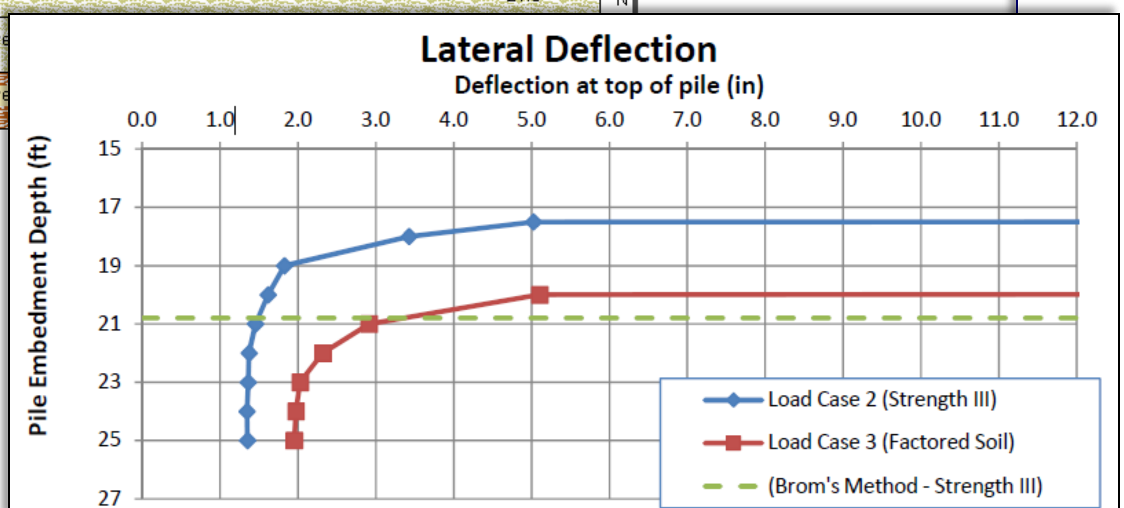


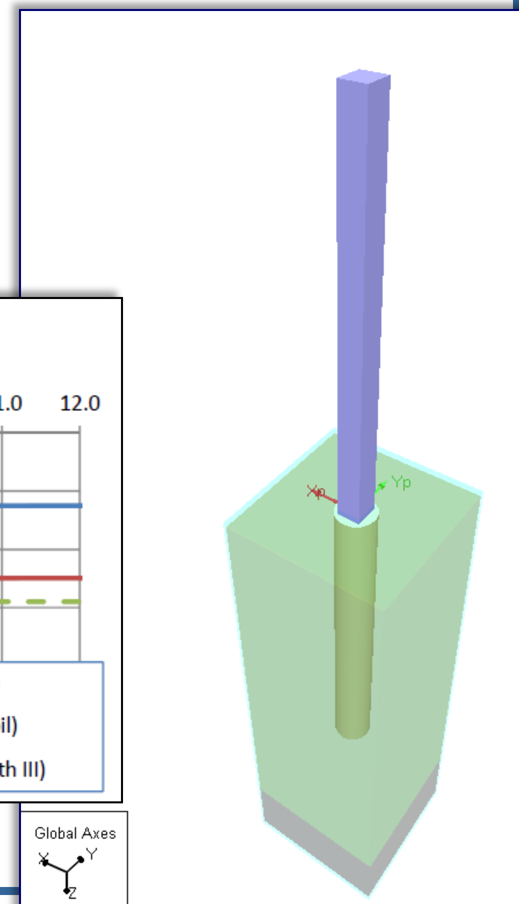


Project Example (Continued)

- Refined Analysis with FB-MultiPier:
  - Add typical profile from Geotechnical Report recommendations or individual soil boring information.
  - Plot lateral deflection with decreasing embedment







Alternate Foundation to Auger Cast Piles

Precast Cylinder Piles

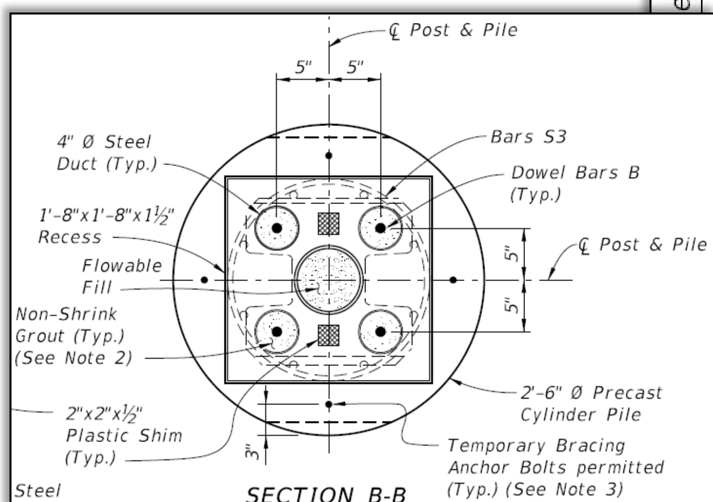
2013 Design Training Expo

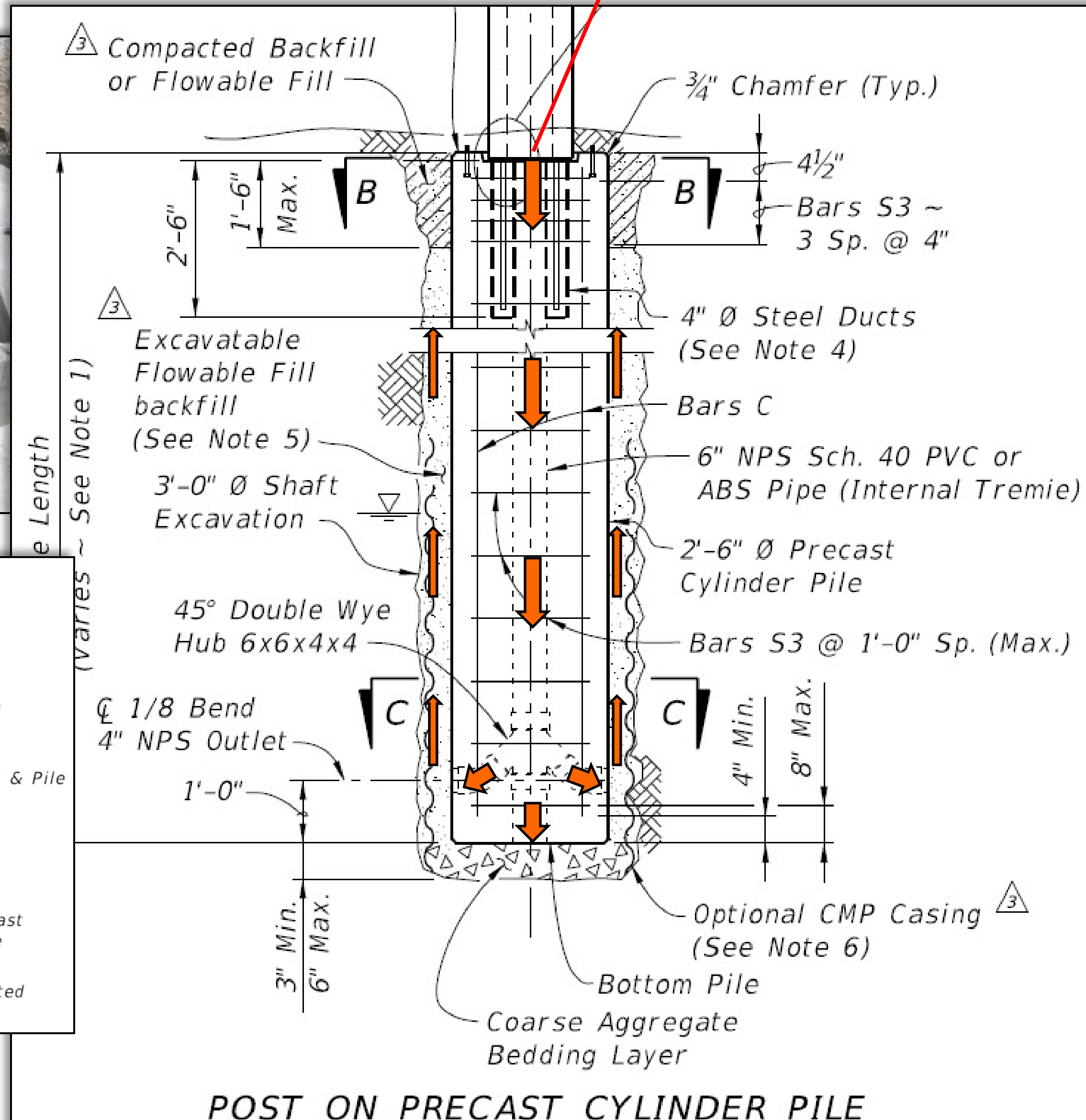
Demonstration Project

- District 2 Perimeter Wall and Landscaping Project: FPID 208207-4-52-01, US17 in Orange Park
- Design Build Team was given option to use SDO's Precast Cylinder Pile (Option "C") under ***Developmental Design Standard*** - Index D5250
- Advantages:
  - ✓ Minimizes size of installation equipment;
  - ✓ Low overhead clearance design;
  - ✓ Eliminates need for temporary support frames;
  - ✓ Allows staged installation;
  - ✓ Improved control over construction tolerances;
  - ✓ Simple non-proprietary connection details;

Demonstration Project

Grout or Flowable Fill injection



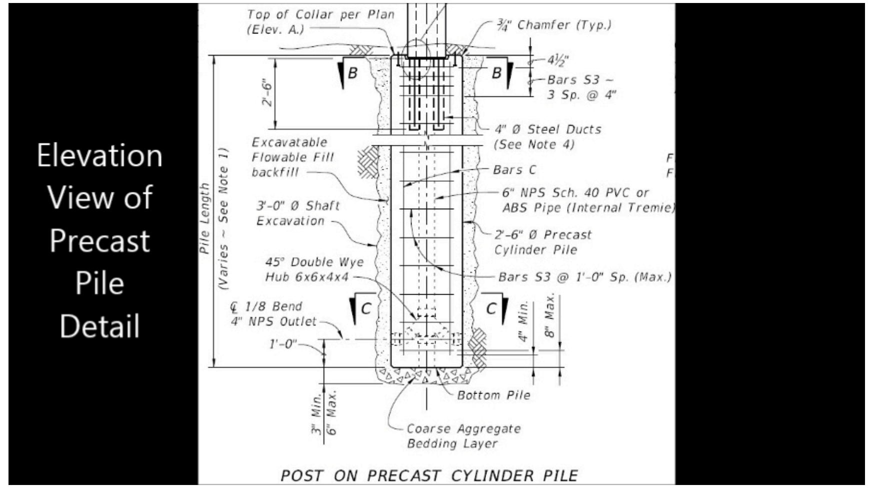


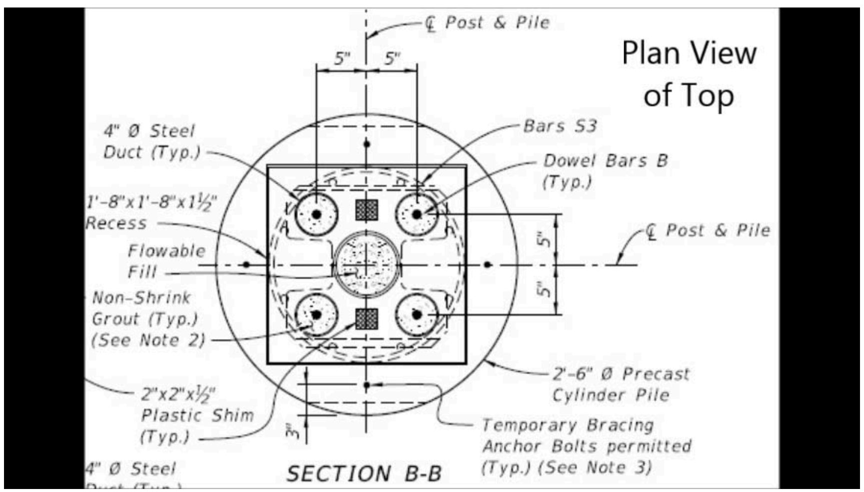
2013 Design Training Expo

Demonstration Project (Video Clips)

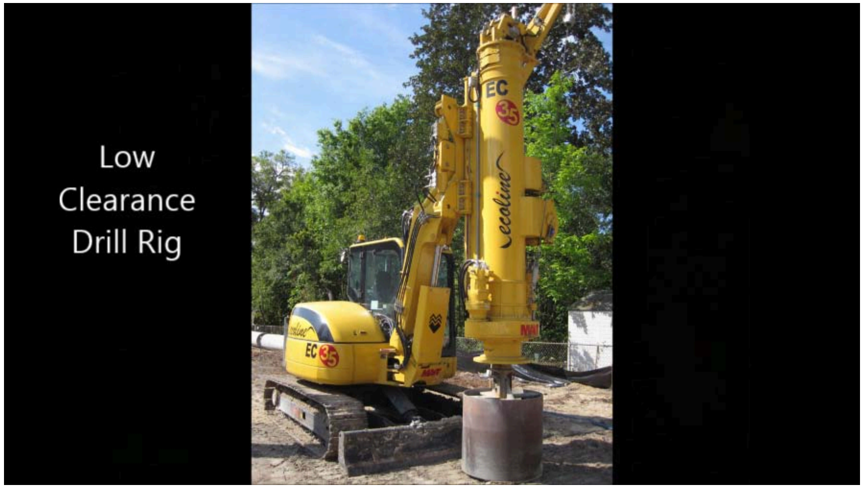
Perimeter/Noise Wall Precast Cylinder Pile Demonstration Project (Spring 2013)

FPID 208207-4-52-01





Demonstration Project (Video Clips)

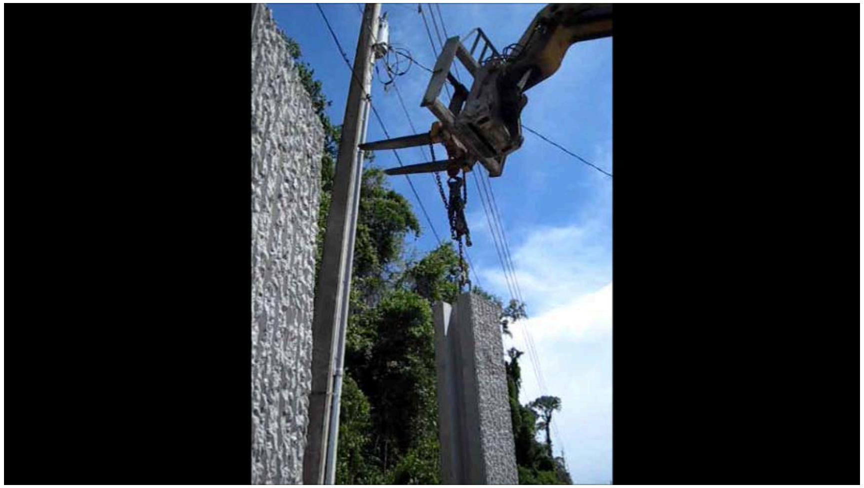


Demonstration Project (Video Clips)

Demonstration Project (Video Clips)

2013 Design Training Expo

Demonstration Project (Video Clips)



Demonstration Project (Video Clips)

Demonstration Project (Video Clips)

FDOT District 2

and

Oldcastle Precast , Inc.

and

P&K Engineering, LLC.

Questions and Comments?

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