April 25, 2025

LRFD Foundation Design within Texas Roadway Projects

Coordination, Investigation, Calculation, and Plan Presentation

Edward Galbavy

TxDOT Bridge Division

Field Ops / Geotechnical Branch

TxDOT Bridge Geotech Branch

- Standards, Specifications, Contracts, Review, Recommendations, Research
- Bridge Foundation Design
- Retaining Wall Management & Design
- Slopes and Embankments
- Culverts and Scour
- Preliminary design, construction, monitoring, maintenance, and repair
- Drilling, Testing and incorp. into Statewide Geotechnical Digital Data Management

Table of Contents

BACKGROUND – Thinking Geotechnically

Engineering is overcoming challenges

Why do highway and interstate construction projects appear to last so long?

Construction widening the I-66 in Virginia. Gerald Martineau/The The Washington Post via Getty Images

Engineering is overcoming challenges

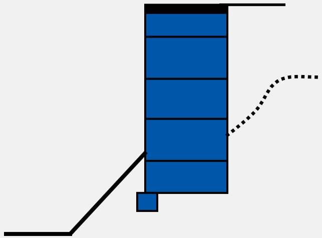
Why do highway and interstate construction projects appear to last soo long?

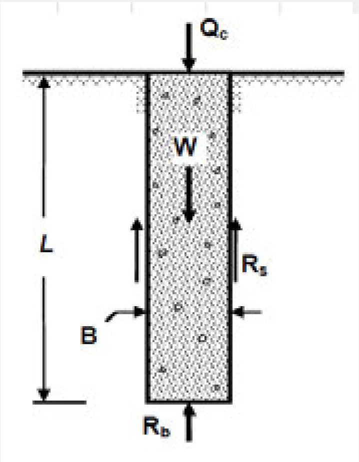
- Availability of labor and materials
- Budget of owners
- Traffic Control and regional coordination
  - Weather and accidents
  - Unforeseen geologic conditions
  - *etc*.
- Unbelievable growth of Texas metro areas

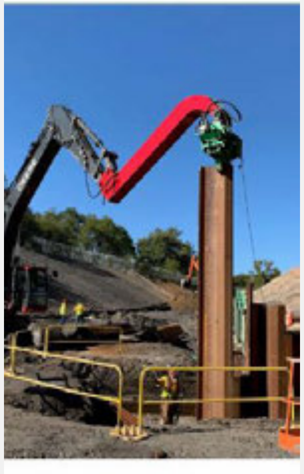
Construction widening the I-66 in Virginia. Gerald Martineau/The The Washington Post via Getty Images

Geotechnical Engineering

How do we design the best suitable TxDOT foundation?



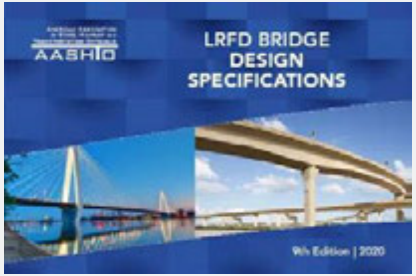


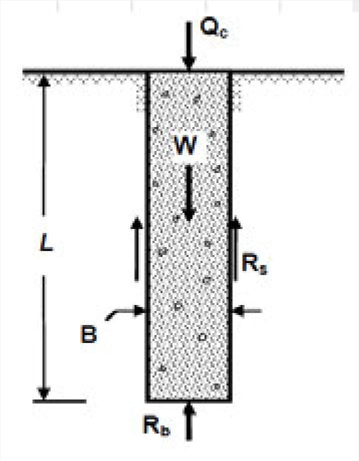


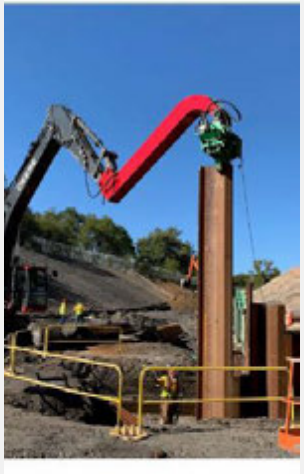
Geotechnical Engineering

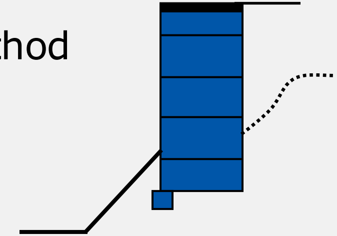
How do we design the best suitable TxDOT foundation?

- Use available resources (Geotechnical Manual, AASHTO 9th Edition LRFD, *etc.*)
- Use best investigation/boring information, survey, H&H, bridge layout and loading
- Use critical thinking and engineering judgment for resistance and reactions to the loading
- Uncertainty (or FOS) through method resistance factors





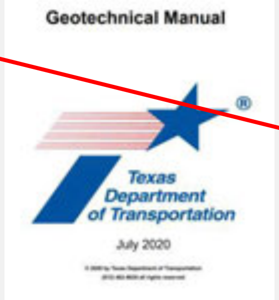


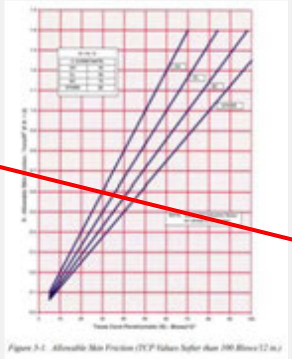


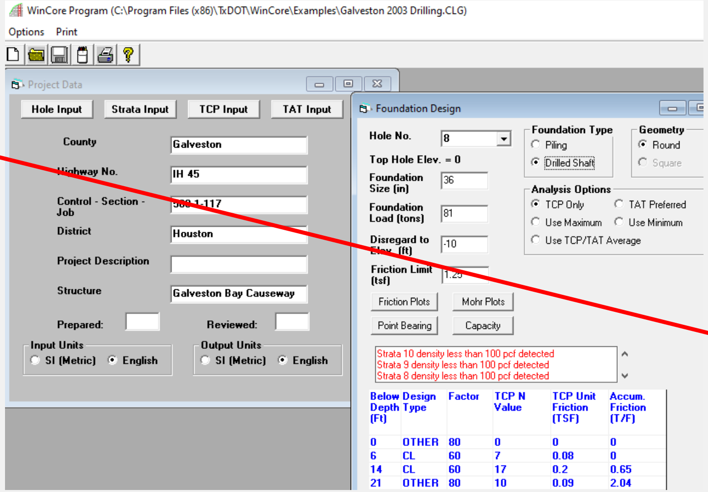
Then and Now

How do we design the best suitable TxDOT foundation?

- TCP Investigations and Wincore Capacity no longer approved
- **Consultant community** have been designing to LRFD foundation specifications long before TxDOT implementation
- Seek out assistance from BRG-Geotech when reviewing projects and designs
- This presentation provides and overview of process, calculations, and deliverables expected







Steps to LRFD Design (Foundations) - Basics

TxDOT INTERNAL ONLY – Design Request Form (2627)

INFORMATION SHEET FOR GEOTECHNICAL DESIGN

Form 2627
(Rev. [illegible])
Page 1 of 4

County:
D/D:
CSJ:
Project:
NBI No.:
Roadway:
Feature Crossed:
Letting Date:
Target Date:
Ready-To-Let (RTL) Date:
Emergency Project Number:
Target Date of Emergency Repair:
Contact Name:
Date:
Phone Number:

Contact/Help

Project Scope (Baseline)

Remove Boring Request if not needed

Boring Request

Project Information

- Geotechnical Design:

LRFD (2024 Geotech Manual) ☐ TCP (Legacy) ☐

Remove Foundation Design/Evaluation if not needed

Foundation Design/Evaluation

Foundation Design/Evaluation Information

Are the bridge layouts available? Yes No

If NO, please provide the date when they will be available:

- Foundation Preferred: Concrete Piling: Drilled Shaft:
  Steel H Piling: Other: Please describe:

- Loading at the Foundations:
  (provide Strength I load case for LRFD design or Service I load for TCP legacy design)

Abutment 1 Axial Lateral
Abutment # Axial Lateral
Bent: # Axial Lateral
Bent: # Axial Lateral

Complex nonstandard bridges require more extensive load analysis to be forwarded.

- Provide any settlement tolerance criteria, acceptable deflection at top of shaft/pile, structural constraints to loading and moment, etc. :

TxDOT INTERNAL ONLY – Design Request Form (2627)

- Foundation Preferred: Concrete Piling: ☐ Drilled Shaft: ☒
  Steel H Piling: ☐ Other: ☐ Please describe: 24" Dia. DS for Abutments and Bents

- Loading at the Foundations:
  (provide Strength I load case for LRFD design or Service I load for TCP legacy design)

Abutment 1		Axial	110 tons/shaft	Lateral	
Abutment #	4	Axial	110 tons/shaft	Lateral	
Bent: #	2	Axial	156 tons/shaft	Lateral	
Bent: #	3	Axial	160 tons/shaft	Lateral	

Complex nonstandard bridges require more extensive load analysis to be forwarded.

- Provide any settlement tolerance criteria, acceptable deflection at top of shaft/pile, structural constraints to loading and moment, etc. :

Top of shaft settlement tolerance 1", Bent column height potential to up to 25 to 30ft, shear and moment will be provided separately for lateral analysis.

- Are there any unique circumstances that need to be addressed (utilities, existing foundations, railroad ROW, etc)

Existing foundation due to bridge replacement.

Has a scour evaluation been completed? ☒ Yes ☐ No ☐ N/A

'HL93' in Loading would indicate to use the Foundation load sheets

Include thoughts on service level criteria, and potential non-standard loading conditions

Geotech Manual Framework

Chapter 5 — Foundation Design *Section 1 — Design Methodology*

Design Process

Typical design steps are as follows:

1. Establish design requirements for layout/geometry, loading, scour depths, tolerance to settlement (see recommendations above) and other service deformation/deflection
2. Determine depth of scour and hydraulic requirements of the structure in coordination with the hydraulic engineer
3. Conduct geotechnical investigation (see Chapters 2, 3, and 4)
4. Select most appropriate foundation type and shaft/pile diameter(s) in coordination with structure designer
5. Evaluate need for permanent casing at individual foundations
6. Calculate nominal (unfactored) resistance of single drilled shafts or static compressive resistance (for piles) as a function of depth
7. Apply resistance factors to nominal axial resistance for strength and extreme limit states. Driven piles require additional resistance factors to be used during dynamic analysis based on field method to be used for pile acceptance (e.g., Hammer Formulas, wave equation, high strain dynamic load testing, etc.)
8. Conduct more extensive, nonstandard design required if deemed from subsurface conditions, bridge geometry, lateral loading, or service level criteria:
   a. Estimate downdrag potential and downdrag loads

<u>Info Needed</u>:

- Prelim Bridge Layout, Loading
- H&H Report w/ Scour (if over water)
- Geotechnical Data Report
  - Boring Logs
  - In situ and lab testing
- Resistance methods based on material properties, disregard based on many 'factors' (scour, construction, anticipated soils, etc.)
- Coordination with structural on lateral, service level, potential nonstandard conditions..

Investigation - Texas Geology

Foundations placed on earth, walls retaining earth

- State is very diverse
- Soils: Clays, Sands, Gravel, Muck, Fill, etc.
- Bedrock: Everything
  - Sedimentary (limestone/shale)
  - Igneous (granite/basalt)
  - Metamorphic (schist/gneiss)
- 254 Counties within 25 TxDOT Districts

Investigations - Geotech Manual, Ch 2, Sec 1, Boring Spacing

- 2 min, 100’ from center bent, 50’ from any monoshafts, 300’ spacing (max)

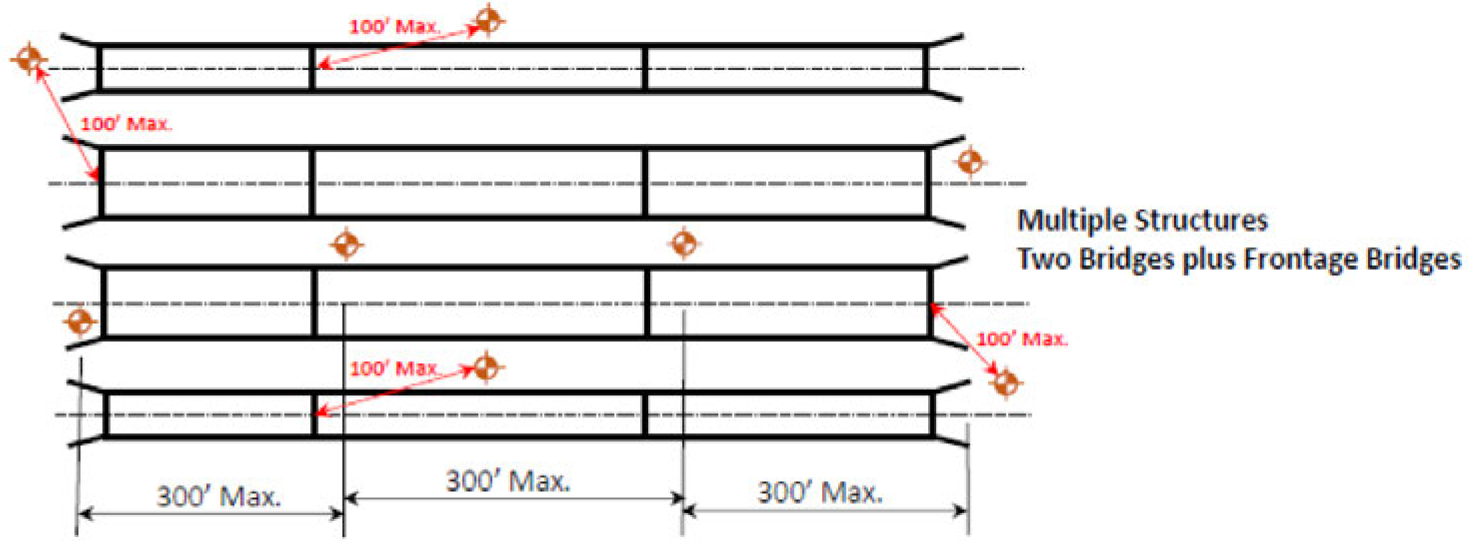
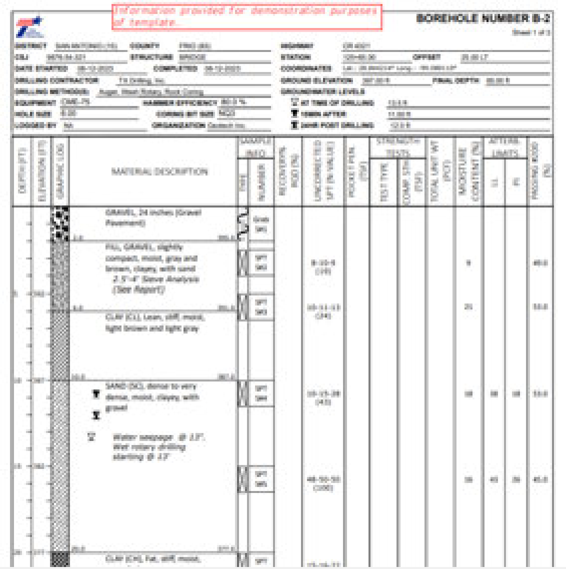


Figure 2-1. Minimum number of test holes for common types of structures

Geotechnical Data Collection (Logs and Labs)

- Data Report and Log/Lab requirements in Manual and/or (past data webinar)
- https://www.txdot.gov/business/resources/highway/bridge/webinar-presentations.html



Information provided for demonstration purposes of template.

BOREHOLE NUMBER B-2

Sheet 1 of 3

DISTRICT SAN ANTONIO (15) COUNTY FRIO (83) HIGHWAY CR 4321

CSJ 9876-54-321 STRUCTURE BRIDGE

MATERIAL DESCRIPTION

GRAVEL, 24 inches (Gravel Pavement)

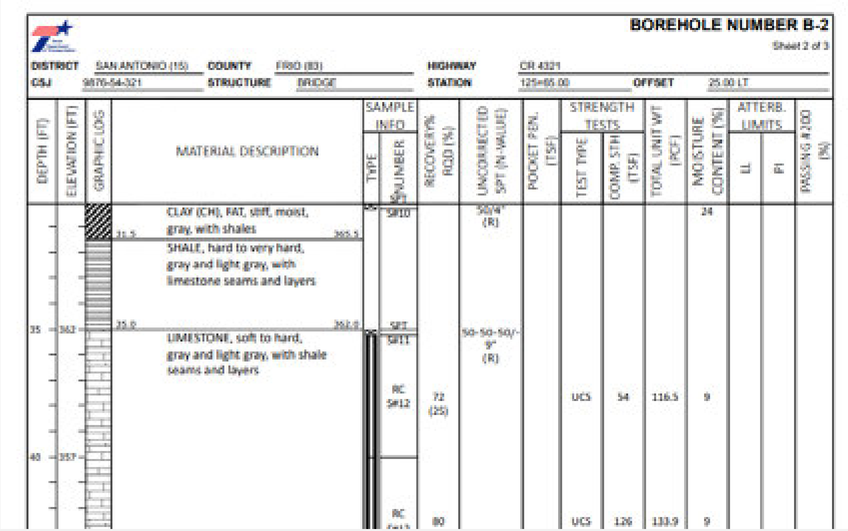
FILL, GRAVEL, slightly compact, moist, gray and brown, clayey, with sand 2.5'-4' Sieve Analysis (See Report)

CLAY (CL), Lean, stiff, moist, light brown and light gray

SAND (SC), dense to very dense, moist, clayey, with gravel

Water seepage @ 13'. Wet rotary drilling starting @ 13'

CLAY (CH), Fat, stiff, moist,



BOREHOLE NUMBER B-2

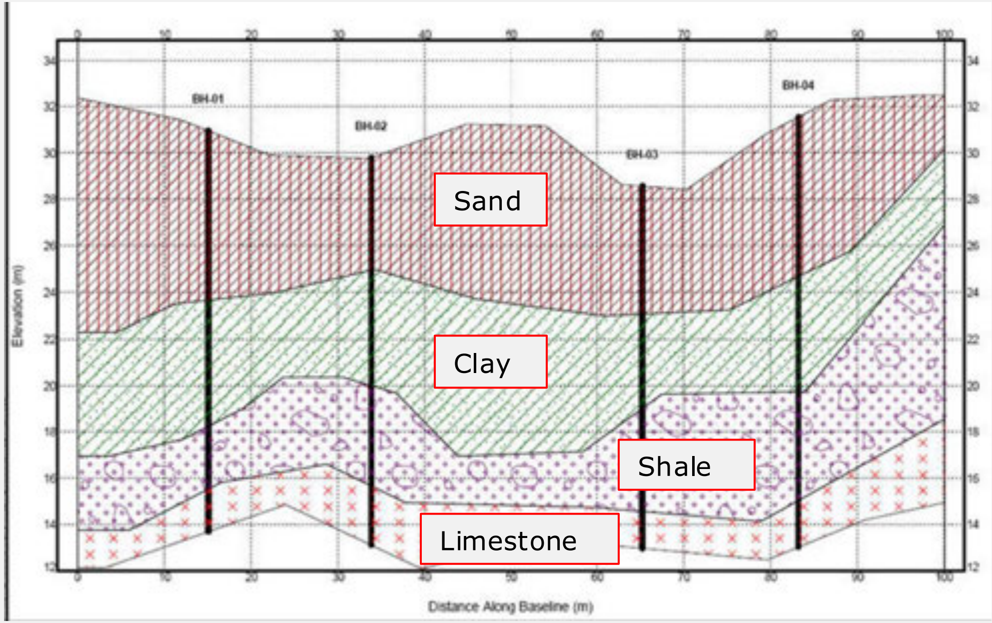
Sheet 2 of 3

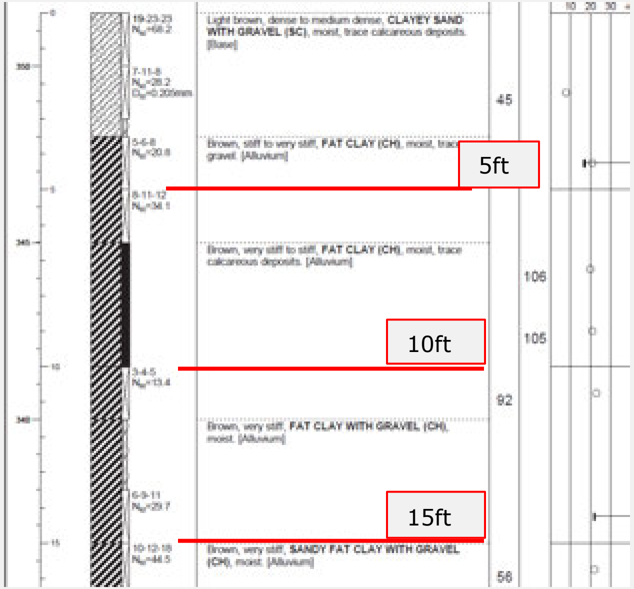
DISTRICT	SAN ANTONIO (15)	COUNTY	FRIO (83)	HIGHWAY	CR 4321		
CSJ	9876-54-321	STRUCTURE	BRIDGE	STATION	125+65.00	OFFSET	25.00 LT

DEPTH (FT)	ELEVATION (FT)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE INFO TYPE	SAMPLE INFO NUMBER	RECOVERY% RQD (%)	UNCORRECTED SPT (N-VALUE)	POCKET PEN. (TSF)	STRENGTH TESTS TEST TYPE	STRENGTH TESTS COMP. STH (TSF)	TOTAL UNIT WT (PCF)	MOISTURE CONTENT (%)	ATTERB. LIMITS LL	ATTERB. LIMITS PI	PASSING #200 (%)
			CLAY (CH), FAT, stiff, moist, gray, with shales		SPT S#10		50/4" (R)					24			
			31.5 — 365.5 SHALE, hard to very hard, gray and light gray, with limestone seams and layers												
35	362		35.0 — 362.0 LIMESTONE, soft to hard, gray and light gray, with shale seams and layers		SPT S#11		50-50-50/-9" (R)								
					RC S#12	72 (25)			UCS	54	116.5	9			
40	357														
					RC	80			UCS	126	133.9	9			

Engineering Subsurface Units or 5ft (or smaller) Intervals

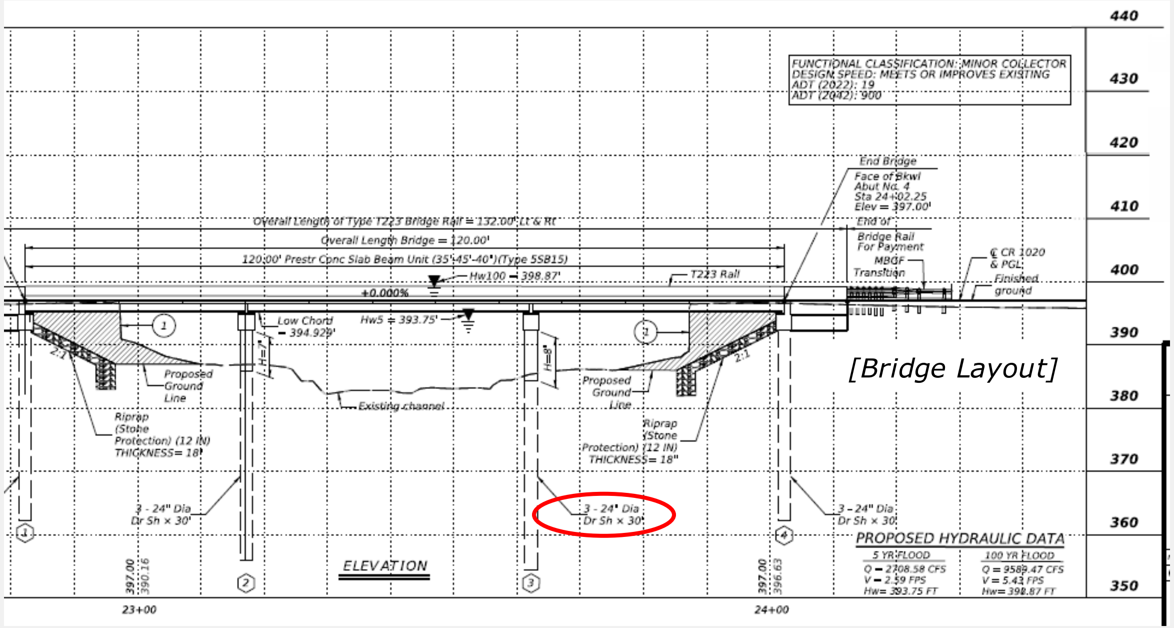
- Understand that either will arrive at accurate design



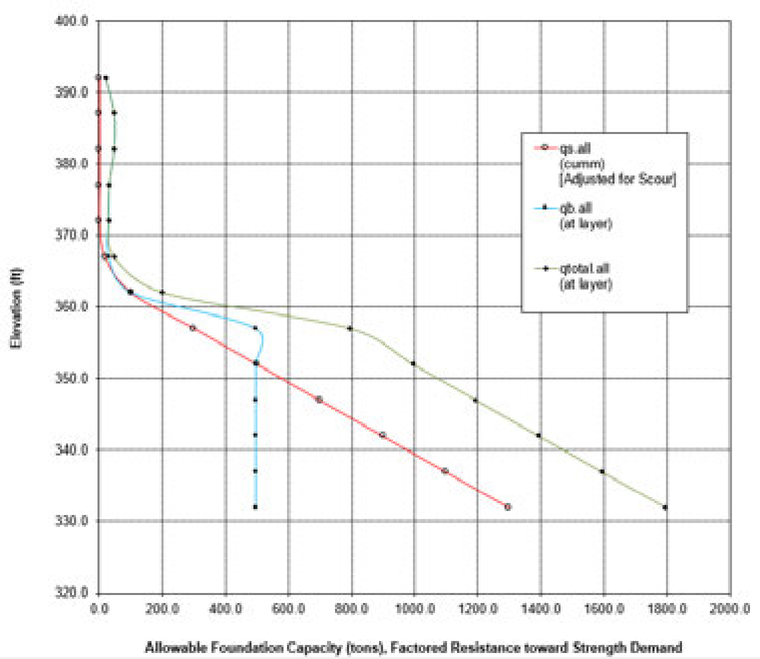


Trial Length (used to check resistance)

- Disregard Depth & **Initial** Tip Elevations = Conservative
- Re-evaluate depths/elevations when optimizing



Resistance w/ Depth (*example*)



Sand and Clay Methods

Shale/IGM Methods

Solid/intact Bedrock Methods

LRFD Equation

$$\eta(\Sigma\gamma_{DL}DL + \Sigma\gamma_{LL}LL) \leq \phi R_n$$

- η = Load modifier applied to all loads
- γ_{DL} = Load factor applied to dead loads
- γ_{LL} = Load factor applied to live loads
- DL = Dead load
- LL = Live load
- Φ = Resistance factor
- R_n = Nominal resistance of the element under consideration

$$R_R = \varphi R_n = \varphi_{stat} R_p + \varphi_{stat} R_s \qquad (10.7.3.8.6a\text{-}2)$$

Soils – Driven Piles

- α-method (clays)..from Su

$$q_s = \alpha S_u \qquad (10.7.3.8.6b\text{-}1)$$

where:

S_u = undrained shear strength (ksf)
α = adhesion factor applied to S_u (dim)

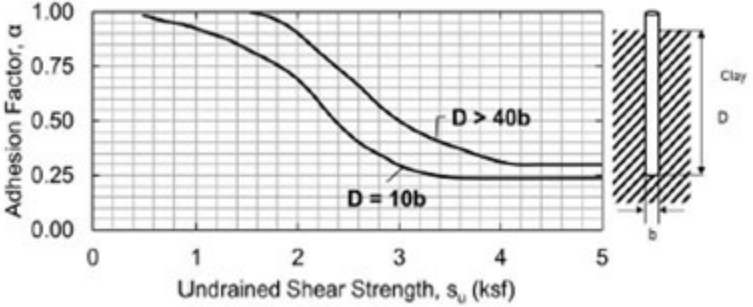


Figure 7-18 Adhesion factors for driven piles in clay (Tomlinson 1980).

Nordlund (sands)..from ϕ

$$q_s = K_\delta C_F \sigma'_v \frac{\sin(\delta + \omega)}{\cos\ \omega} \qquad (10.7.3.8.6f\text{-}1)$$

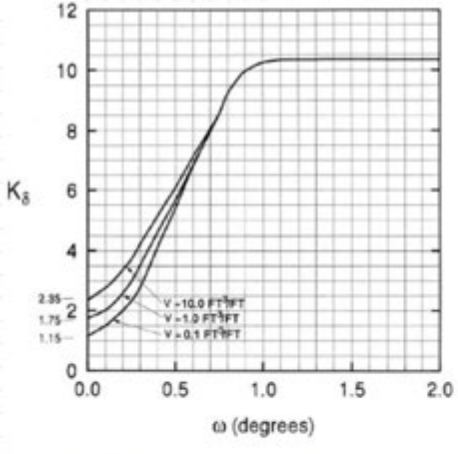


Figure 10.7.3.8.6f-3—Design Curve for Evaluating K_δ for Piles where ϕ_f = 35 degrees (Hannigan et al., 2006 after Nordlund, 1979)

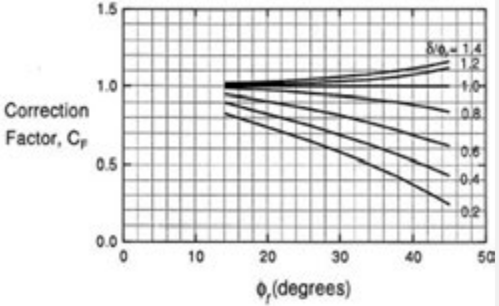


Figure 10.7.3.8.6f-5—Correction Factor for K_δ where $\delta \neq \phi_f$ (Hannigan et al., 2006 after Nordlund, 1979)

Soils – Drilled Shafts

$$R_R = \varphi R_n = \varphi_{qp} R_p + \varphi_{qs} R_s \quad (10.8.3.5\text{-}1)$$

- α-method, total stress (clays)..from Su

$$q_s = \alpha S_u \quad (10.8.3.5.1\text{b-}1)$$

in which:

$$\alpha = 0.55 \text{ for } \frac{S_u}{p_a} \leq 1.5 \quad (10.8.3.5.1\text{b-}2)$$

$$q_p = N_c S_u \leq 80.0 \text{ ksf} \quad (10.8.3.5.1\text{c-}1)$$

in which:

$$N_c = 6\left[1 + 0.2\left(\frac{Z}{D}\right)\right] \leq 9 \quad (10.8.3.5.1\text{c-}2)$$

where:

D = diameter of drilled shaft (ft)
Z = penetration of shaft (ft)
S_u = undrained shear strength (ksf)

β-method (sands)..from ϕ

$$q_s = \beta\, \sigma'_v \quad (10.8.3.5.2\text{b-}1)$$

in which:

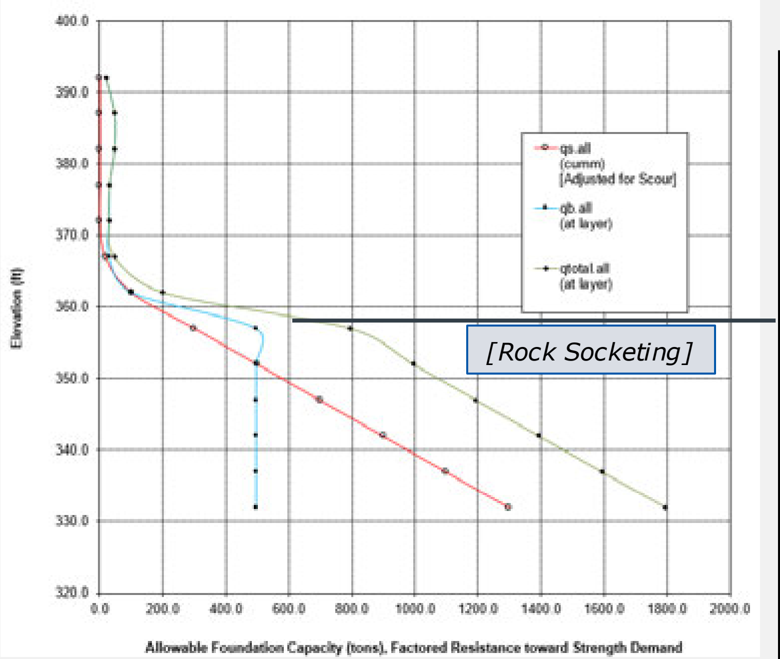
$$\beta = \left(1 - \sin\varphi'_f\right)\left(\frac{\sigma'_p}{\sigma'_v}\right)^{\sin\varphi'_f} \tan\varphi'_f \quad (10.8.3.5.2\text{b-}2)$$

The correlation for effective soil friction angle for use in the above equations shall be taken as:

$$\varphi'_f = 27.5 + 9.2\log\left[(N_1)_{60}\right] \quad (10.8.3.5.2\text{b-}3)$$

$$\phi'_f = 0.9 * (27.5 + 9.2 \log[(N_1)_{60}])$$

Resistance w/ Depth (*Rock Socketing, Shafts*)



Sand and Clay Methods

Shale/IGM Methods.. from SPT and/or qu

Solid/intact Bedrock Methods..from qu

For drilled shafts socketed into rock, unit side resistance, q_s in ksf, shall be taken as (Kulhawy et al., 2005):

$$\frac{q_s}{p_a} = C\sqrt{\frac{q_u}{p_a}} \quad (10.8.3.5.4b\text{-}1)$$

where:

p_a = atmospheric pressure taken as 2.12 ksf
C = regression coefficient taken as 1.0 for normal conditions
q_u = uniaxial compressive strength of rock (ksf)

$$q_p = 2.5q_u$$

Solid and Intact Bedrock (Limestone)

Vuggy and Porous

Moderately Weathered

Slightly Weathered (Indiana Core)

Combination of Rock Structure, surface quality/weathering, and discontinuities (joints, fractures, bedding), would trigger non-solid/intact resistance analysis

Non-Weathered, Fresh, Intact (Edwards Core)

Rock, jointed and fractured – Factor Down Resistance

Figure 10.4.6.4-1—Determination of GSI for Jointed Rock Mass (Hoek and Marinos, 2000)

Jointed and Fractured Bedrock Methods
..from qu, RQD, GSI, 'core' inspection

$$\frac{q_S}{p_a} = 0.65\alpha_E \sqrt{\frac{q_u}{p_a}} \qquad (10.8.3.5.4b\text{-}2)$$

The joint modification factor, α_E is given in Table 10.8.3.5.4b-1 based on RQD and visual inspection of joint surfaces.

Table 10.8.3.5.4b-1—Estimation of α_E (O'Neill and Reese, 1999)

RDQ (%)	Joint Modification Factor, α_E Closed Joints	Open or Gouge-Filled Joints
100	1.00	0.85
70	0.85	0.55
50	0.60	0.55
30	0.50	0.50
20	0.45	0.45

$$q_p = A + q_u\left[m_b\left(\frac{A}{q_u}\right) + s\right]^a \qquad (10.8.3.5.4c\text{-}2)$$

In which:

$$A = \sigma'_{vb} + q_u\left[m_b\frac{(\sigma'_{v,b})}{q_u} + s\right]^a \qquad (10.8.3.5.4c\text{-}3)$$

$$\frac{m_b}{m_i} = \exp\left(\frac{GSI - 100}{28}\right) \qquad 10\text{-}25$$

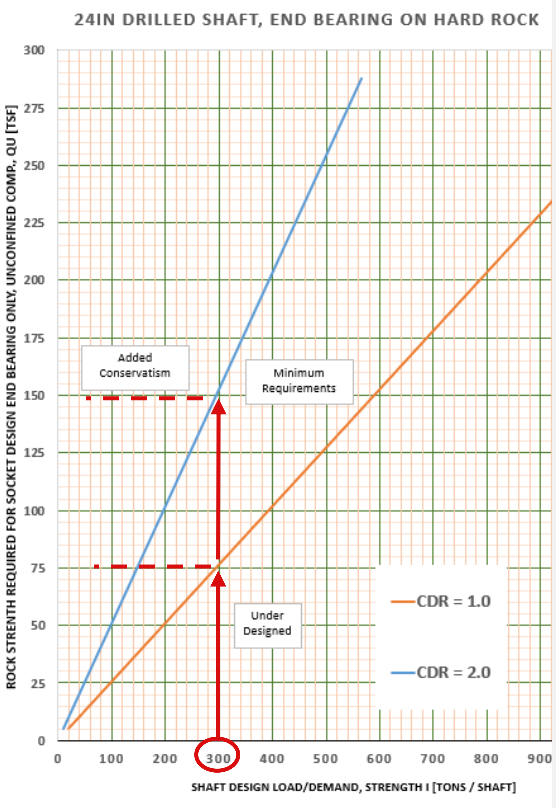
$$s = \exp\left(\frac{GSI - 100}{9}\right) \qquad 10\text{-}26$$

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{\frac{-GSI}{15}} - e^{\frac{-20}{3}}\right) \qquad 10\text{-}27$$

Rock Socketing Allows for Easier Decision Making

- Granted, hard/intact bedrock is logged
- Using *min* 24in shaft
- Min 2 x Dia. Embedded into rock
- Total Shaft Length 10ft or greater
- Reliable Rock Strength Results

End bearing only capacity & 9th Ed. resistance factor (0.5)



LRFD Design (Foundations) – Resistance Factors

Resistance Factors

- Use default AASHTO 9th Ed. LRFD

10-50 AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS, NINTH EDITION, 2020

Table 10.5.5.2.4-1—Resistance Factors for Geotechnical Resistance of Drilled Shafts

Method/Soil/Condition			Resistance Factor
Nominal Axial Compressive Resistance of Single-Drilled Shafts, φ_{stat}	Side resistance in clay	α-method (Brown et al., 2010)	0.45
	Tip resistance in clay	Total Stress (Brown et al., 2010)	0.40
	Side resistance in sand	β-method (Brown et al., 2010)	0.55
	Tip resistance in sand	Brown et al. (2010)	0.50
	Side resistance in cohesive IGMs	Brown et al. (2010)	0.60
	Tip resistance in cohesive IGMs	Brown et al. (2010)	0.55
	Side resistance in rock	Kulhawy et al. (2005) Brown et al. (2010)	0.55
	Side resistance in rock	Carter and Kulhawy (1988)	0.50
	Tip resistance in rock	Canadian Geotechnical Society (1985) Pressuremeter Method (Canadian Geotechnical Society, 1985)	0.50

Table 10.5.5.2.3-1—Resistance Factors for Driven Piles

Condition/Resistance Determination Method		Resistance Factor
Nominal Bearing Resistance of Single Pile—Dynamic Analysis and Static Load Test Methods, φ_{dyn}	Driving criteria established by successful static load test of at least one pile per site condition and dynamic testing* of at least two piles per site condition, but no less than 2% of the production piles	0.80
	Driving criteria established by successful static load test of at least one pile per site condition without dynamic testing	0.75
	Driving criteria established by dynamic testing* conducted on 100% of production piles	0.75
	Driving criteria established by dynamic testing*, quality control by dynamic testing* of at least two piles per site condition, but no less than 2% of the production piles	0.65
	Wave equation analysis, without pile dynamic measurements or load test but with field confirmation of hammer performance	0.50
	FHWA-modified Gates dynamic pile formula (End of Drive condition only)	0.40
	Engineering News (as defined in Article 10.7.3.8.5) dynamic pile formula (End of Drive condition only)	0.10
Nominal Bearing Resistance of Single Pile—Static Analysis Methods, φ_{stat}	Side Resistance and End Bearing: Clay and Mixed Soils α-method (Tomlinson, 1987; Skempton, 1951) β-method (Esrig & Kirby, 1979; Skempton, 1951) λ-method (Vijayvergiya & Focht, 1972; Skempton, 1951)	 0.35 0.25 0.40
	Side Resistance and End Bearing: Sand Nordlund/Thurman Method (Hannigan et al., 2005) *SPT*-method (Meyerhof)	 0.45 0.30

Resistance Factors (Upcoming)

- Future AASHTO code will force a **variable resistance factor** based on COV
- GEC No. 5 proposes limiting COV (<0.3)
- Incorporation of tools with past and current data set based on stratigraphic layers
- Managing geotechnical digital data

$$COV_{d-meas} = \frac{\sigma_{d-meas}}{\bar{y}_d} = \frac{\sqrt{\frac{\sum_{i=1}^{n_d}(y_i-\bar{y}_d)^2}{n_d-1}}}{\bar{y}_d}$$

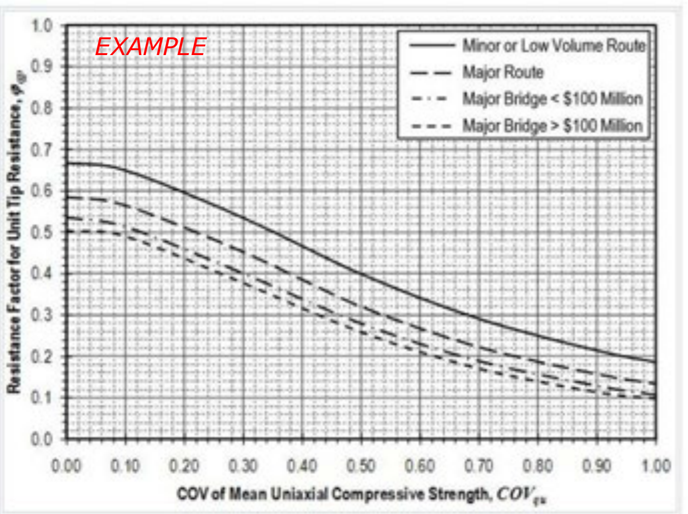
$$COV_{d-model} = \frac{\sigma_{d-model}}{\bar{y}_d} = \frac{\sqrt{\frac{1}{n_d}\cdot\frac{\sum_{i=1}^{n_d}(y_i-\bar{y}_d)^2}{n_d-1}}}{\bar{y}_d}$$

$$COV_{d-total} = \frac{\sigma_{d-total}}{\bar{y}_d} = \frac{\sqrt{\sigma^2_{d-meas}+\sigma^2_{d-model}}}{\bar{y}_d}$$

From FHWA NHI-16-072 (GEC No. 5)

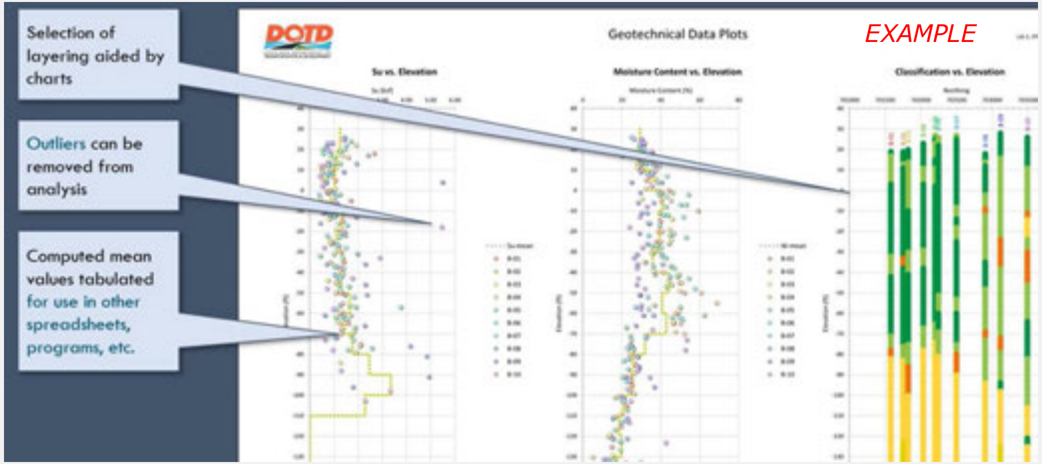
Variable Resistance Factors

- GEC No. 5 proposes limiting COV (<0.3)
- COV ~ Amount of data and variability
- Managing geotechnical digital data



c/o MODOT

c/o LADOT



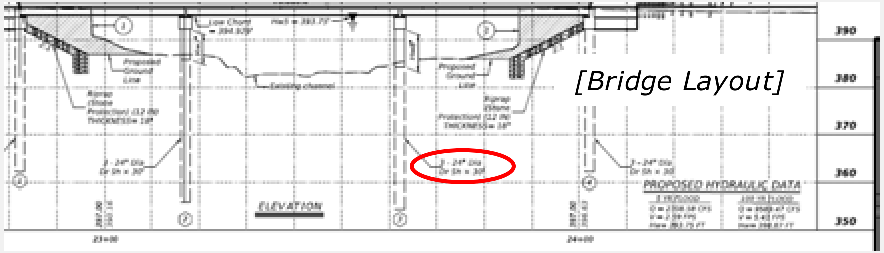
$$q_p = 2.5 q_u$$

- q_u = mean uniaxial compressive strength
- q_p = nominal until tip resistance
- <u>Factored (allowable)</u> = ϕ * q_p

LRFD Design (Foundations) – Plan Presentation & FDN

Data Presented in Plans

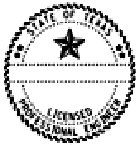
- Bridge Layout (sizes and lengths)
  - Layout notes, casing, etc.
- Boring Sheets
- Foundation Layout (*optional*)
- FD (standard) or Foundation Detail (if non-standard)
- Foundation Notes Sheet (FDN)



[Bridge Layout]

GENERAL NOTES:

See Bridge Layout for drilled shaft lengths and test hole data.
Designed according to AASHTO LRFD Bridge Design Specifications.
See Common Foundation Details (FD) standard sheets for foundation details and notes.
See Foundation Notes sheet for more information on data used for foundation design.



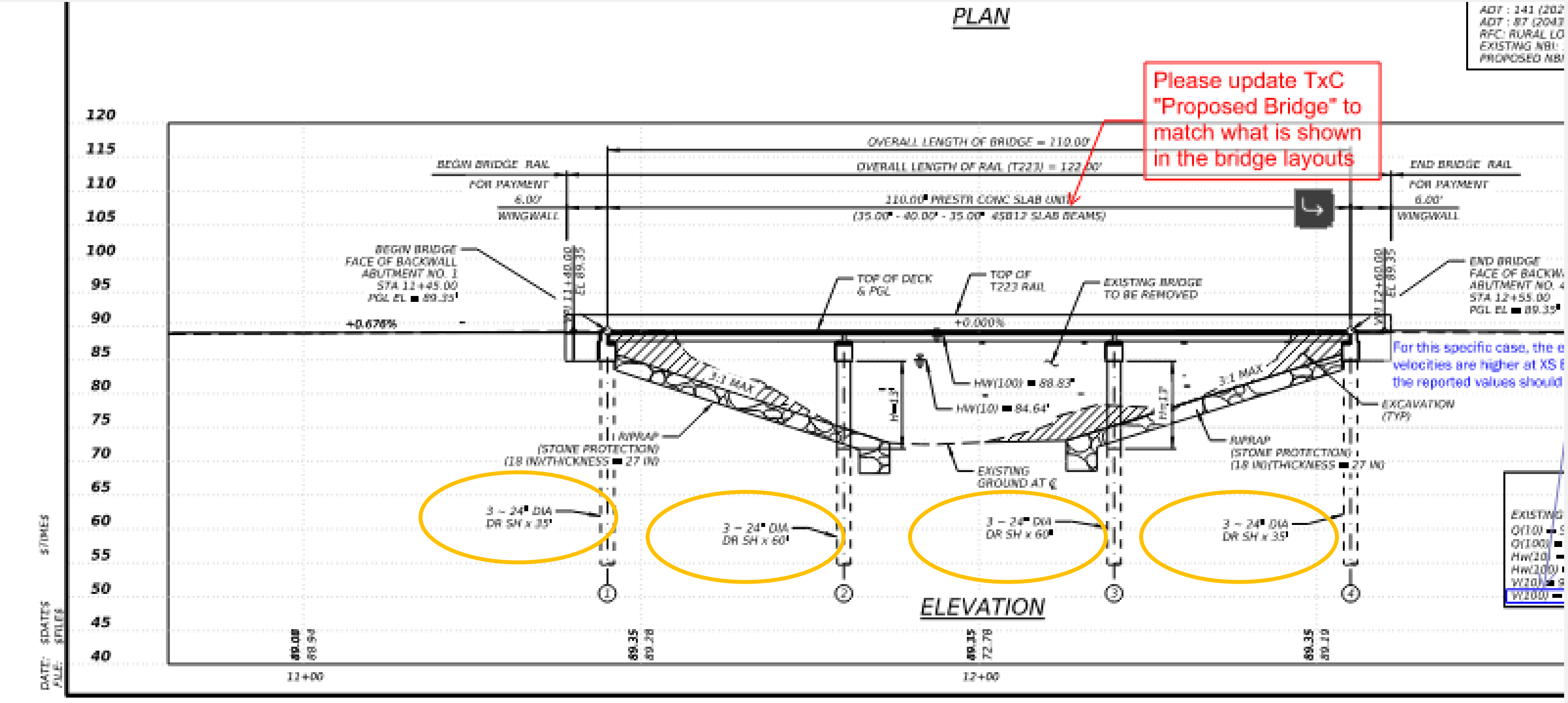
[Foundation Layout or Foundation Note Sheet]

FOUNDATION DESIGN DATA

Abutments				Bents			
Load Case	=	Strength I		Load Case	=	Strength I	
Axial Foundation Loads (tons)	=	81	Abut No. 1	Axial Foundation Loads (tons)	=	134	Bent No. 2
	=	87	Abut No. 4		=	146	Bent No. 3
Nominal Friction Resistance (tons/square foot)	=	1.2	(clay)	Nominal Friction Resistance (tons/square foot)	=	1.2	(clay)
	=	3.8	(shale, IGM)		=	3.8	(shale, IGM)
						11.6	(limestone, intact)
Friction Resistance Factor(s)	=	0.45	(clay)	Friction Resistance Factor(s)	=	0.45	(clay)
	=	0.7	(shale, IGM)		=	0.7	(shale, IGM)
						0.55	(limestone, intact)
Cumulative Factored Friction Resistance (tons/shaft)		99		Cumulative Factored Friction Resistance (tons/shaft)		299	
Nominal Bearing Resistance (tons/square foot)	=	46		Nominal Bearing Resistance (tons/square foot)	=	315	
Bearing Resistance Factor	=	0.7		Bearing Resistance Factor	=	0.5	
Factored Bearing Resistance (tons/shaft)	=	101		Factored Bearing Resistance (tons/shaft)	=	495	
Additional Notes: Design lengths based on skin friction or side resistance alone, and disregarding elevation to 383 feet.				Additional Notes: Design lengths based on skin friction or side resistance alone, and disregarding elevation to 372 feet.			

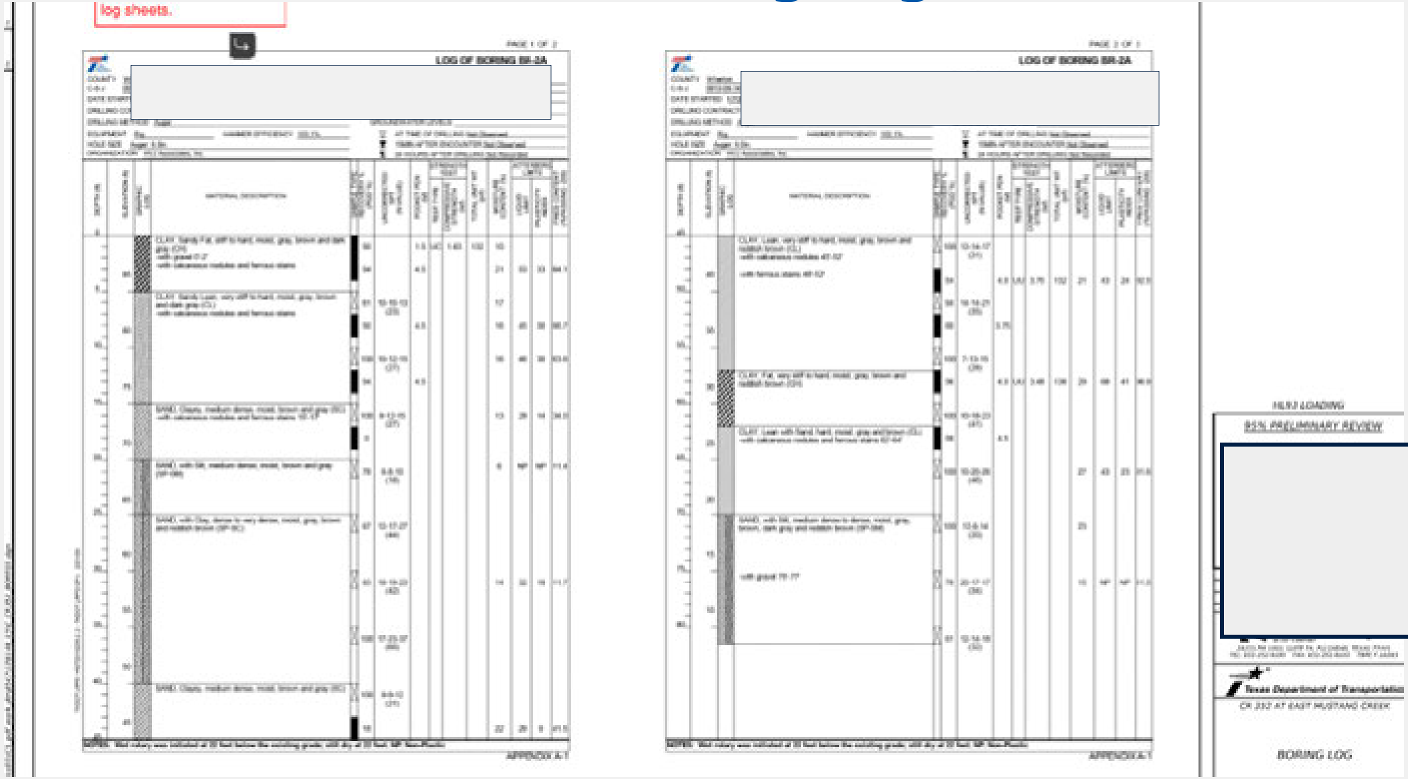
QA/QC

2025 PBLR – Submittal for Review- Bridge Layout



2025 PBLR Submittal – Boring Logs

QA/QC



QA/QC

2025 PBLR Submittal – FDN Sheet

(request this if not included)

Should be produced while designing foundations

Foundation Notes Sheet

- QA/QC of LRFD Foundation Design
- Insight into design assumptions
- Stays with plans for future capacity evaluations

https://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/bridge-e.htm

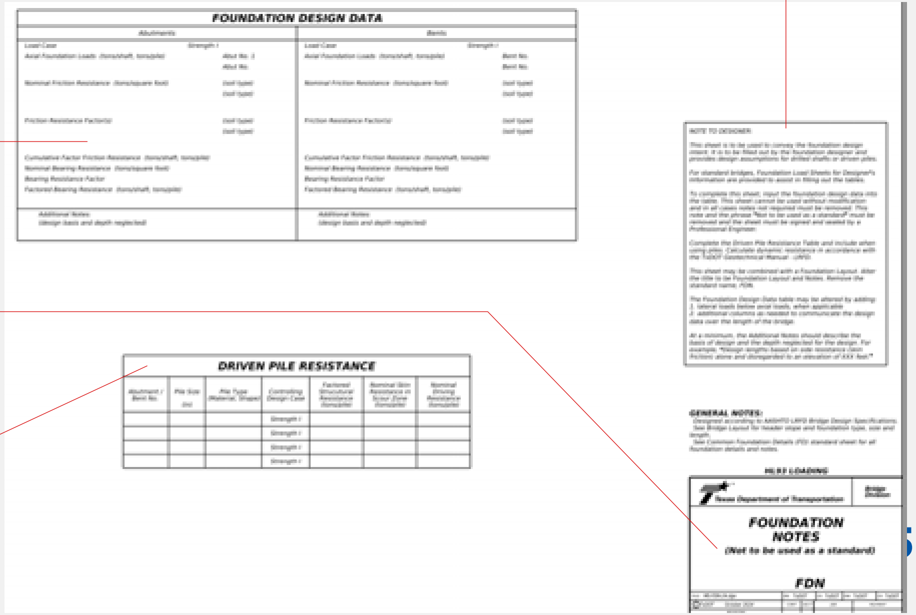
10-24	CSAB	Cement Stabilized Abutment Backfill	MS-CSAB-24.dgn
10-24	FD	Common Foundation Details	MS-FD-24.dgn
10-24	FDN	Foundation Notes	MS-FDN-24.dgn
10-24	MEBR(S)	Min Erection & Bracing Req (Steel Girders & Bms)	MS-MEBR(S)-24.dgn

Note to Designer

Expand and Edit based on individual bridge design

Single FDN Sheet for each bridge

Only include if using Driven Pile Foundations [this additional info is for Inspector during dynamic installation] : Nominal Driving Resistance (R_{ndr}), after static designed factored resistance (above) accounts for the scour zone, that would be in place during installation.



Foundation Notes Sheet – Design Data - Shafts

Loading from Structural or Foundation Load Sheets (axial)

Unit side resistance (skin friction) layer by layer (nominal) & Resistance Factors

Factored (allowable) total side (skin) friction after accounting for scour and shaft size

End (base) resistance layer (nominal), Resistance Factor, and total (allowable)

Notes: To clarify disregard, scour assumptions, bedrock socketing layer, and other important design assumptions.

FOUNDATION DESIGN DATA

Abutments			Bents		
Load Case	Strength I		Load Case	Strength I	
Axial Foundation Loads (tons)	81	Abut No. 1	Axial Foundation Loads (tons)	134	Bent No. 2
	87	Abut No. 4		146	Bent No. 3
Nominal Friction Resistance (tons/square foot)	1.2	(clay)	Nominal Friction Resistance (tons/square foot)	1.2	(clay)
	3.8	(shale, IGM)		3.8	(shale, IGM)
				11.6	(limestone, intact)
Friction Resistance Factor(s)	0.45	(clay)	Friction Resistance Factor(s)	0.45	(clay)
	0.7	(shale, IGM)		0.7	(shale, IGM)
				0.55	(limestone, intact)
Cumulative Factored Friction Resistance (tons/shaft)	99		Cumulative Factored Friction Resistance (tons/shaft)	299	
Nominal Bearing Resistance (tons/square foot)	46		Nominal Bearing Resistance (tons/square foot)	315	
Bearing Resistance Factor	0.7		Bearing Resistance Factor	0.5	
Factored Bearing Resistance (tons/shaft)	101		Factored Bearing Resistance (tons/shaft)	495	
Additional Notes: Design lengths based on side resistance (skin friction) alone, and disregarding to an elevation of 383 feet.			Additional Notes: Design lengths based on side resistance (skin friction) alone, and disregarding to an elevation of 372 feet.		

Load

Skin

End

Foundation Notes Sheet

- There will be different design assumptions

FOUNDATION DESIGN DATA

Abutments			Bents		
Load Case	*Strength I*		*Load Case*	*Strength I*	
Axial Foundation Loads (tons)	81	*Abut No. 1*	*Axial Foundation Loads (tons)*	134	*Bent No. 2*
	87	*Abut No. 4*		146	*Bent No. 3*
Nominal Friction Resistance (tons/square foot)	1.2	*(clay)*	*Nominal Friction Resistance (tons/square foot)*	1.2	*(clay)*
	3.8	*(shale, IGM)*		3.8	*(shale, IGM)*
				11.6	*(limestone, intact)*
Friction Resistance Factor(s)	0.45	*(clay)*	*Friction Resistance Factor(s)*	0.45	*(clay)*
	0.7	*(shale, IGM)*		0.7	*(shale, IGM)*
				0.55	*(limestone, intact)*
Cumulative Factored Friction Resistance (tons/shaft)	99		*Cumulative Factored Friction Resistance (tons/shaft)*	299	
Nominal Bearing Resistance (tons/square foot)	46		*Nominal Bearing Resistance (tons/square foot)*	315	
Bearing Resistance Factor	0.7		*Bearing Resistance Factor*	0.5	
Factored Bearing Resistance (tons/shaft)	101		*Factored Bearing Resistance (tons/shaft)*	495	
Additional Notes: Design lengths based on side resistance (skin friction) alone, and disregarding to an elevation of 383 feet.			*Additional Notes: Design lengths based on side resistance (skin friction) alone, and disregarding to an elevation of 372 feet.*		

Skin Friction Alone
*[Bearing information can be omitted, as N/A,
Or kept for information purposes]*

FOUNDATION DESIGN DATA

Abutments			Bents (N/A)
Load Case	Strength I		
Axial Foundation Loads (tons/shaft)	110	Abut No. 1	
	120	Abut No. 2	
Nominal Friction Resistance (tons/square foot)	N/A	(clay, sand)	
	6.3	(limestone, weak/jointed)	
Friction Resistance Factor(s)	0.55	(limestone, weak/jointed)	
Cumulative Factor Friction Resistance (tons/shaft)	110		
Nominal Bearing Resistance (tons/square foot)	149		
Bearing Resistance Factor	0.5		
Factored Bearing Resistance (tons/shaft)	235		
Additional Notes: Design lengths based on end bearing alone, and disregarding to top of bedrock elevation 337 ft. Shaft will be drilled at least 2 diameters into fractured limestone.			

End Bearing Alone – Single Span Bridge
*[Size of shaft on bridge layout, abutments, or bents, designing
To different bearing layers shall expand down the data table]*

Concerns & Next Steps

Other Limit State Checks

[When coordinating with structural, bridge design]

- Top of Shaft Service Settlement – Load Displacement Curves
- Extreme Event: Seismic, Scour at Check Flood, vessel and vehicle collision
- Strength/Structural Resistance (of concrete)..axial
- Strength/Shear-Moment Load for deformation (of concrete)..**lateral**
- Strength-Service Pushover and fixity depth (or entire pile/shaft)..**lateral**
- Service/Shear-Moment Load for deflection at top..**lateral**

Other Concerns / Checks

- Group effects, multi-pile footing analysis
- Uplift pressure (swelling soils), and uplift resistance in multi-pile footing
- Dragload, downdrag (negative skin friction) when embankment surcharge
- Constructability & Cost
- Corrosion & Integrity

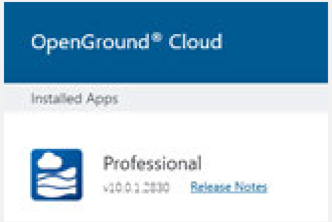
Confidence during construction

Confidence of design results

- [**Not Recommended for verification**] Comparison to capacity design with correlated SPT-to-TCP results
- [**BETTER**] Comparison to design with foundation programs (Ensoft SHAFT for shafts, Ensoft APILE for piles, **or similar program(s))**
- [**BETTER**] Comparison to design with alternate material methods for resistance
- [**BEST**] Seek out BRG Geotechnical Assistance or Geotechnical Consultant

Ongoing and Upcoming Research and Development

- RTI – Trust and Optimization of Hard Clay and Shale in LRFD Design Criteria
- Digital Data Collection and Databasing – following lead of other DOTs
  - Future AASHTO LRFD versions and variable resistance factors
- CPT and MWD for subsurface investigations
- Ancillary Structures Foundation Sheets in better compliance with LRFD and current investigation requirements
- Better and easier web and design tools for efficiency
- Lessons learned from design issues coming in now
- Geotech Manual and Standard Revisions



Websites

- (BRIDGE Standards)
  - https://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/bridge-e.htm
- (DATA Drilling and Reporting)
  - https://www.txdot.gov/business/resources/highway/bridge/webinar-presentations.html
- (BRG Field Operations – Geotechnical)
  - https://crossroads/divisions/brg/sections/field-operations-section.html
- (2024 Geotechnical Manual – LRFD)
  - https://onlinemanuals.txdot.gov/txdotonlinemanuals/txdotmanuals/geo/geo_lrfd.pdf

QUESTIONS?

FOR ASSISSTANCE *Please* CONTACT:

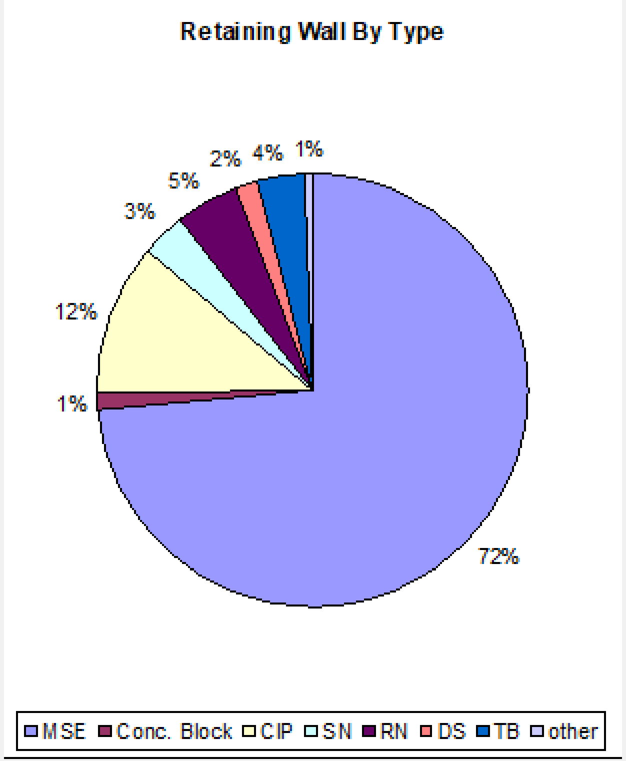
Edward Galbavy, P.E.

Or any of the engineers w/in:

TxDOT Bridge Division - Geotechnical Branch

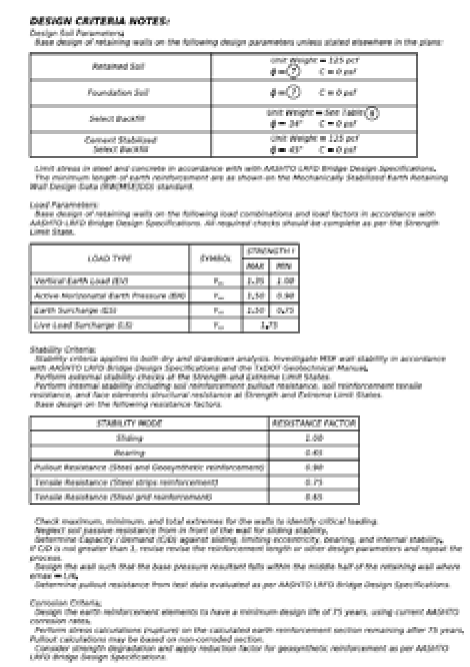
Texas DOT Retaining Walls

- By ft² of Exposed Wall..
- MSE (panel type) most dominant
- Pending formal inventory
- Temp. Special Shoring (mostly)
  - TEW
  - Soil Nail
  - Sheet Pile
  - Solider Pile w/ Lagging



Retaining Wall Standard Revisions for LRFD

- Approved system vendors to submit new calculations to show compliance



DESIGN CRITERIA NOTES:

Design Soil Parameters:
Base design of retaining walls on the following design parameters unless stated elsewhere in the plans:

Retained Soil	Unit Weight = 125 pcf ϕ = ? C = 0 psf
Foundation Soil	ϕ = ? C = 0 psf
Select Backfill	Unit Weight = See Table ϕ = 34° C = 0 psf
Cement Stabilized Select Backfill	Unit Weight = 125 pcf ϕ = 45° C = 0 psf

Limit stress in steel and concrete in accordance with with AASHTO LRFD Bridge Design Specifications.
The minimum length of earth reinforcement are as shown on the Mechanically Stabilized Earth Retaining Wall Design Data (RW(MSE)DD) standard.

Load Parameters:
Base design of retaining walls on the following load combinations and load factors in accordance with AASHTO LRFD Bridge Design Specifications. All required checks should be complete as per the Strength I Limit State.

LOAD TYPE	SYMBOL	STRENGTH I MAX	STRENGTH I MIN
Vertical Earth Load (EV)	γ_{EV}	1.35	1.00
Active Horizontal Earth Pressure (EH)	γ_{EH}	1.50	0.90
Earth Surcharge (ES)	γ_{ES}	1.50	0.75
Live Load Surcharge (LS)	γ_{LS}	1.75	

Stability Criteria:
Stability criteria applies to both dry and drawdown analysis. Investigate MSE wall stability in accordance with AASHTO LRFD Bridge Design Specifications and the TxDOT Geotechnical Manual.
Perform external stability checks at the Strength and Extreme Limit States.
Perform internal stability including soil reinforcement pullout resistance, soil reinforcement tensile resistance, and face elements structural resistance at Strength and Extreme Limit States.
Base design on the following resistance factors.

STABILITY MODE	RESISTANCE FACTOR
Sliding	1.00
Bearing	0.65
Pullout Resistance (Steel and Geosynthetic reinforcement)	0.90
Tensile Resistance (Steel strips reinforcement)	0.75
Tensile Resistance (Steel grid reinforcement)	0.65

Check maximum, minimum, and total extremes for the walls to identify critical loading.
Neglect soil passive resistance from in front of the wall for sliding stability.
Determine Capacity / Demand (C/D) against sliding, limiting eccentricity, bearing, and internal stability. If C/D is not greater than 1, revise revise the reinforcement length or other design parameters and repeat the process.
Design the wall such that the base pressure resultant falls within the middle half of the retaining wall where [illegible] = 1/6.
Determine pullout resistance from test data evaluated as per AASHTO LRFD Bridge Design Specifications.

Corrosion Criteria:
Design the earth reinforcement elements to have a minimum design life of 75 years, using current AASHTO corrosion rates.
Perform stress calculations (rupture) on the calculated earth reinforcement section remaining after 75 years. Pullout calculations may be based on non-corroded section.
Consider strength degradation and apply reduction factor for geosynthetic reinforcement as per AASHTO LRFD Bridge Design Specifications.