2024 ASCE KCGI Specialty Seminar;
Burns & McDonnell World Headquarters - Session 7

"Practical Design-Build Applications of Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems"

Presented By:
William F. Powers III, P.E.

Friday, September 13, 2024
2:50 – 3:40 PM CST

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Engineered Foundation Construction

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Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

What Are They?

- Series of continuous, drilled, reinforced concrete piles or piers utilized to provide the vertical elements of an excavation support and protection system.
- Typical pile/pier diameters range from 18 to 30 inches, sometimes larger. In the author's opinion, the most efficient cost/use diameter is either 24 or 30 inches due to volumetric cost of concrete/reinforcing steel vs. wall resistance.
- Typical pile/pier lengths are a function of the exposed excavation height and ground conditions. Piles/piers can be buried in place or exposed/shotcreted.
- Typical pile/pier spacings range from the net "span" length to the span length plus two to three inches, depending upon the ground conditions.
- Lateral wall resistance to earth pressures and adjacent surcharge loadings is provided either via cantilever in the pile/pier embedment below the bottom of excavation or via tiebacks or internal bracing.
- "Filler" for piles/piers consists of drilled pier concrete mix, augercast pile grout or flowable fill. Reinforcing steel consists of cages or structural steel sections (commonly wide flange beams, sometimes double channels or pipe).

Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Where Are They Used?

- Mixed face geologic conditions where rock may be present above the bottom of excavation ("flagpole" condition). Very effective for higher (>25 feet) exposed wall heights and efficient for mass excavation process. Ideal for shales, sandstones and very stiff clays (N-values > 25). Not particularly suitable for extremely hard rock above the bottom of excavation.

- Rock immediately below bottom of excavation for pile/pier embedment. Minimizes pile/pier lengths and facilitates true cantilever condition, enabling efficient design for exposed wall heights in the 15 to 20-foot range.

- River bottom areas with cohesionless soils (rock generally deeper than 30 feet) with control of high groundwater conditions above the bottom of excavation. Not suitable for unmitigated high groundwater conditions.

- Softer overburden conditions above bottom of excavation where the exposed excavation face may not be conducive to lagging or shotcrete.

Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

How Are They Installed?

- Open hole drilling with conventional pier drilling rig – earth/rock augers and core barrels.

- Temporarily cased drilling with conventional pier drilling rig (complete hole, place steel and concrete, extract casing) – drill open hole and drop temporary casing; vibratory hammer driven/extracted temporary casing; sectional casing via casing driver or oscillator (both techniques very expensive).

- Augercast drilling with crane attachment or fixed mast setup on conventional drilling rig (drill and grout hole, wet set reinforcing steel).

- Permanently cased – vibrate or twist casing to depth, cleanout inside of casing, place steel and concrete (materials very expensive, reduces cost effectiveness of wall system).

Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

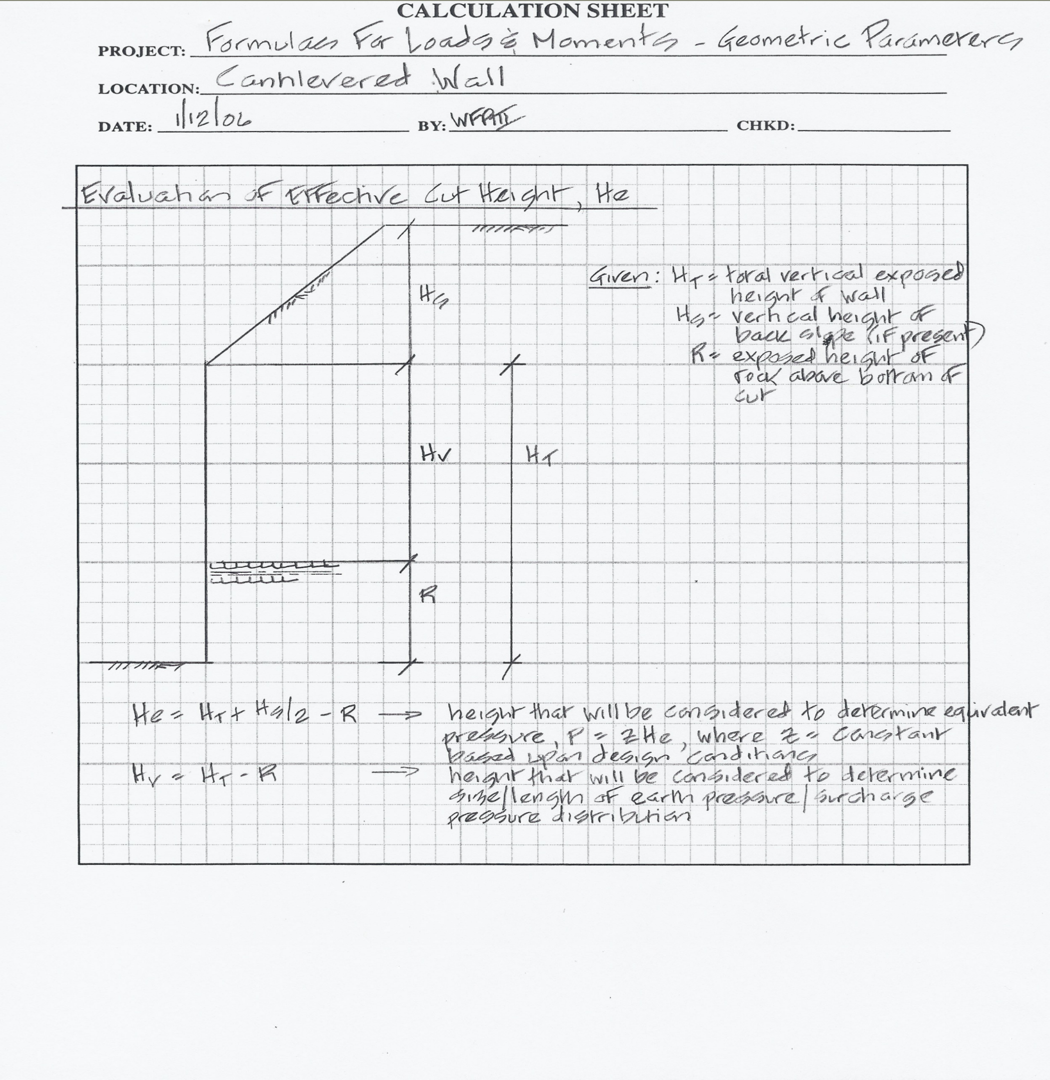
<u>Why Are They Installed (Applications)?</u>

- Limited access conditions – presence of existing utilities in proximity of wall.
  - Precluded use of tiebacks for lateral wall resistance
  - MSE wall geogrid lengths not available, requiring a terminal point for reinforcement

- Limited access conditions – right-of-way restrictions, property boundaries, structure space and easement locations in proximity of wall.
  - Not enough room for traditional double sided formed basement wall system

Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

<u>Design Approach - Geometric Wall Parameters</u>



CALCULATION SHEET

PROJECT: Formulas For Loads & Moments - Geometric Parameters

LOCATION: Cantilevered Wall

DATE: 1/12/06 BY: WFAIII CHKD:

Evaluation of Effective Cut Height, He

Given: H_T = total vertical exposed height of wall
H_S = vertical height of back slope (if present)
R = exposed height of rock above bottom of cut

$He = H_T + H_S/2 - R$ → height that will be considered to determine equivalent pressure, $P = ZHe$, where Z = constant based upon design conditions

$H_V = H_T - R$ → height that will be considered to determine size/length of earth pressure/surcharge pressure distribution

Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Design Approach - Embedment Analysis

SPECIFICATIONS	COMMENTARY

Preliminary design methods include Broms (1964, 1965), Hanson (1961), and Singh et al. (1971). Detailed design methods are provided in studies by GAI Consultants (1982), Poulos and Davis (1980), Borden and Gabr (1987), and Reese (1984). Broms' procedures for embedment length in cohesive and cohesionless soils are summarized herein, regarding the ultimate lateral soil resistance of the soils. Certain structures may warrant additional considerations regarding limitations to the lateral displacement at the top of the shaft. Some structures or soil conditions may require a more detailed final design procedure than Broms' procedures.

Broms studied laterally loaded piles in cohesive and cohesionless soils. Simplifying assumptions concerning the distribution of the soil reactions along the pile and statics were used to estimate the lateral resistance of the pile.

Since the Broms' design method is based on ultimate strength, an appropriate safety factor shall be included in the shear load V_F and the moment M_F.

$$V_F = V(\text{Safety factor}) \qquad \text{Eq. C 13–1}$$

$$M_F = M(\text{Safety factor}) \qquad \text{Eq. C 13–2}$$

The safety factor shall account for the possible under-capacity of the soil strength and overload factor for the loadings. In his paper *Design of Laterally Loaded Piles*, Broms suggested using an under-capacity factor of 0.7 and an overload factor of 2 to 3. The value for the safety factor is the selected overload factor divided by the under-capacity factor. Other safety factor values may be used as approved by the owner. The reliability of the soil information should be considered in determining the safety factor.

Broms' assumptions for the distribution of a cohesive soil's reactions at ultimate load are shown in Figure 13–1. Broms' solution for cohesive soils may be presented by the following equation from which the required embedment length L can be found:

$$L = 1.5D + q\left[1 + \sqrt{2 + \frac{(4H + 6D)}{q}}\right] \qquad \text{Eq. C 13–3}$$

SPECIFICATIONS	COMMENTARY

where $H = \dfrac{M_F}{V_F}$ Eq. C 13–4

and $q = \dfrac{V_F}{9cD}$ Eq. C 13–5

For the required embedment length L, the maximum moment in the shaft can be calculated as

$$M_{F\,max} = V_F(H + 1.5D + 0.5q) \qquad \text{Eq. C 13–6}$$

and is located at $(1.5D + q)$ below groundline.

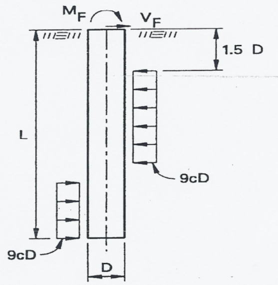


Figure 13–1. Foundation in Cohesive Soil

Broms' assumptions for the distribution of a cohesionless soil's reactions at ultimate load are shown in Figure 13–2. For cohesionless soils, Broms' procedure may be given by the following equations, from which the required embedment length L can be found by using trial and error:

$$L^3 - \frac{2V_F L}{K_p \gamma D} - \frac{2M_F}{K_p \gamma D} = 0 \qquad \text{Eq. C 13–7}$$

where $K_p = \tan^2\left(45 + \dfrac{\phi}{2}\right)$ Eq. C 13–8

Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Design Approach - Embedment Analysis

For the required embedment length ***L***, the maximum moment in the shaft can be calculated as:

$$M_{F\max} = V_F\left(H + 0.54\sqrt{\frac{V_F}{\gamma\, DK_p}}\right) \qquad \text{Eq. C 13–9}$$

and is located at $\left(0.82\sqrt{\frac{V_F}{\gamma\, DK_p}}\right)$ below groundline.

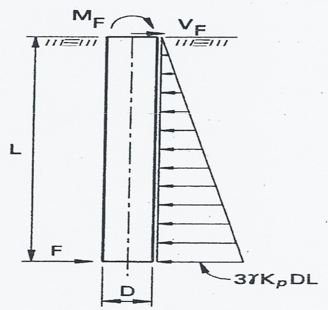


Figure 13–2. Foundation in Cohesionless Soil

13.6.1.2 Capacity

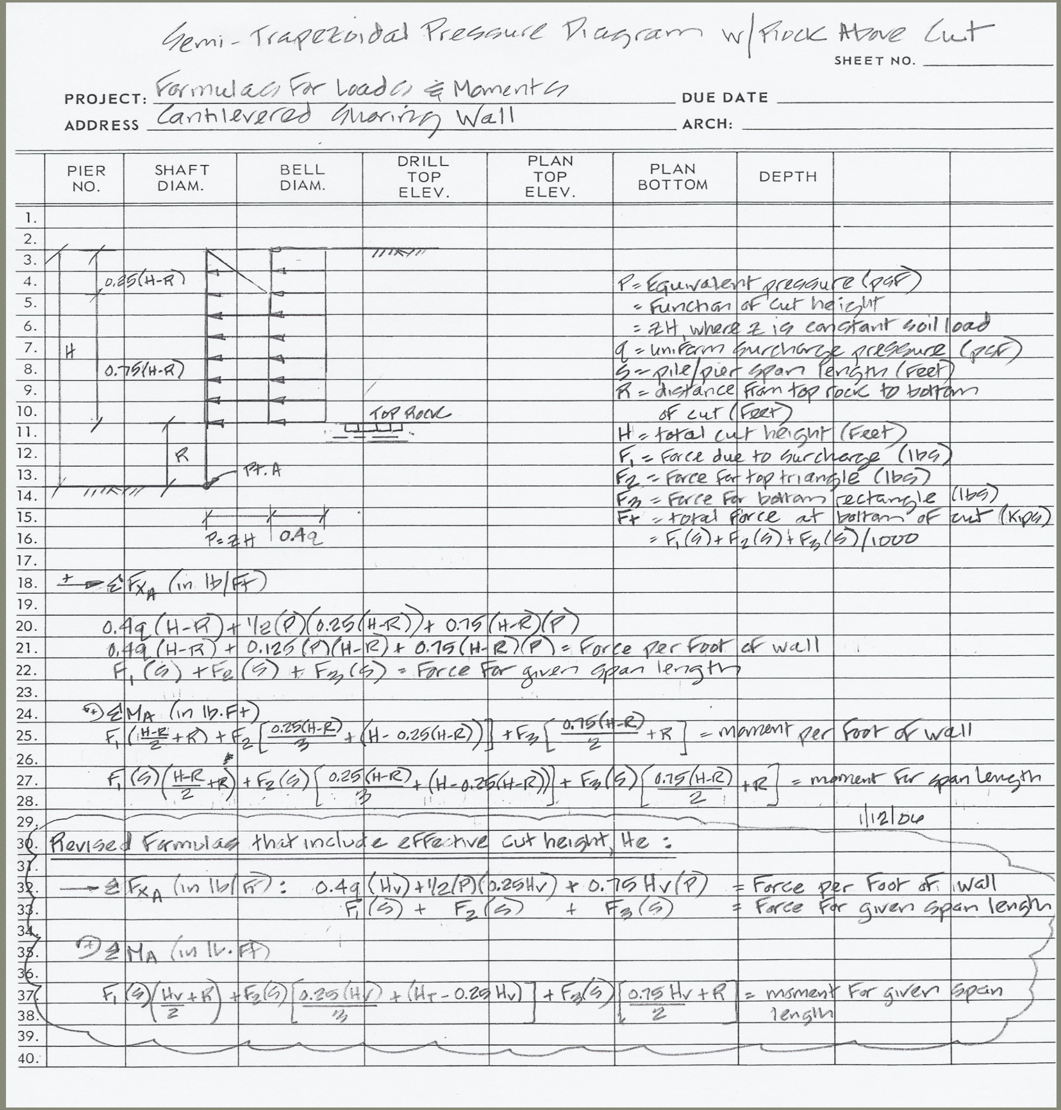
The axial capacity, lateral capacity, and movements of the drilled shaft in various types of soils may be estimated according to methods prescribed in the *Standard Specifications for Highway Bridges*.

13.6.2 Structural Design

The structural design of drilled shafts shall be in accordance with the provisions for the design of reinforced concrete given in the *Standard Specifications for Highway Bridges*.

Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Design Approach – Cantilevered Wall Parameters



Semi-Trapezoidal Pressure Diagram w/ Rock Above Cut

SHEET NO.

PROJECT: Formulas For Loads & Moments — DUE DATE

ADDRESS: Cantilevered Shoring Wall — ARCH:

PIER NO.	SHAFT DIAM.	BELL DIAM.	DRILL TOP ELEV.	PLAN TOP ELEV.	PLAN BOTTOM	DEPTH		

P = Equivalent pressure (psf)
= Function of cut height
= ZH, where Z is constant soil load
q = uniform surcharge pressure (psf)
S = pile/pier span length (feet)
R = distance from top rock to bottom of cut (feet)
H = total cut height (feet)
F_1 = Force due to surcharge (lbs)
F_2 = Force for top triangle (lbs)
F_3 = Force for bottom rectangle (lbs)
F_T = total force at bottom of cut (Kips)
$= F_1(S) + F_2(S) + F_3(S)/1000$

$\xrightarrow{+} \sum F_{X_A}$ (in lb/ft)

$0.4q(H-R) + 1/2(P)(0.25(H-R)) + 0.75(H-R)(P)$

$0.4q(H-R) + 0.125(P)(H-R) + 0.75(H-R)(P)$ = Force per foot of wall

$F_1(S) + F_2(S) + F_3(S)$ = Force for given span length

$\circlearrowleft^{+} \sum M_A$ (in lb.ft)

$F_1\left(\frac{H-R}{2}+R\right) + F_2\left[\frac{0.25(H-R)}{3} + (H-0.25(H-R))\right] + F_3\left[\frac{0.75(H-R)}{2}+R\right]$ = moment per foot of wall

$F_1(S)\left(\frac{H-R}{2}+R\right) + F_2(S)\left[\frac{0.25(H-R)}{3} + (H-0.25(H-R))\right] + F_3(S)\left[\frac{0.75(H-R)}{2}+R\right]$ = moment for span length

1/12/06

Revised Formulas that include effective cut height, He :

$\rightarrow \sum F_{X_A}$ (in lb/ft): $0.4q(H_V) + 1/2(P)(0.25H_V) + 0.75H_V(P)$ = Force per foot of wall

$F_1(S) + F_2(S) + F_3(S)$ = Force for given span length

$\circlearrowleft^{+} \sum M_A$ (in lb.ft)

$F_1(S)\left(\frac{H_V+R}{2}\right) + F_2(S)\left[\frac{0.25(H_V)}{3} + (H_T - 0.25H_V)\right] + F_3(S)\left[\frac{0.75H_V+R}{2}\right]$ = moment for given span length

Design Approach – Cantilevered Wall

William F. Powers III, P.E.
MO Prof. Eng. No. 027226

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Mobile: 913-953-6061
Fax: 913-937-9414
Email: bpowers@powerstaylormills.com

JOB NAME: GEIGER CONCRETE COMPANY - LIBERTY PLANT EXPANSION PROJECT
JOB LOCATION: 526 N. CHURCH ROAD; LIBERTY, MO 64068
JOB NUMBER: JOB NO. SH21-3

CANTILEVERED, DRILLED-IN, TANGENT PILE (TESPS)
MASS EXCAVATION GRADING PLAN

Calculation Location	Tangent Piles - North Wall Elev. Cantilevered TESPS - Tangent Piles 30 thru 51 Section Modulus Calc. - 24" Diam. Hole Borings B-2 & B-8 - clay/limestone over shale TOP SLOPE EL. 976 / TOW EL. 971 / BOE EL. 942 TOP LS EL. 971.0; TOP SHALE EL. 964.0	Tangent Piles - North Wall Elev. Cantilevered TESPS - Tangent Piles 52 thru 79 Section Modulus Calc. - 24" Diam. Hole Borings B-2 & B-8 - clay/limestone over shale TOP SLOPE EL. 976 / TOW EL. 967 / BOE EL. 942 TOP LS EL. 971.0; TOP SHALE EL. 964.0	
Given:			
Total vertical exposed height of wall in feet, "Ht"	29.0	25.0	
Vertical height of slope in feet, "Hs"	6.0	9.0	
Exposed height of rock above bottom of cut in feet, "R"	22.0	22.0	
Pile/pier/beam span length in feet "s"	2.0	2.0	
Lateral component of vertical surcharge pressure in psf "q"	250.0	250.0	
Soldier pile/pier/beam embedment material	limestone over shale	limestone over shale	
Calculate:			
Effective cut height in feet, "He"	10.0	7.5	
Pressure distribution height in feet, "Hv"	7.0	3.0	
Evaluate Semi-Trapezoidal Earth Pressure Dist.:			
Soil load constant "Z"	25.0	25.0	
Equiv. pressure in psf/ft "P"	250.0	187.5	
Force "F1" in lbs	700.0	300.0	
Force "F2" in lbs	218.8	70.3	
Force "F3" in lbs	1312.5	421.9	
Total force "Ft" in kips	4.5	1.6	
Total Toe moment "M" in kip-ft	112.5	37.1	
Eccentricity "e" in ft	25.2	23.4	
Compare to Semi-Trap. to Triangular Dist.:	*45Hv*	*45Hv*	
Total force "Ft" in kips	5.9	3.1	
Toe moment "M" in kip-ft	89.4	23.4	
Eccentricity "e" in ft	15.1	7.5	
Soldier Pile/Pier/Beam Embedment (Broms' Method):			
Under-capacity factor	0.7	0.7	
Overload factor	2.50	2.50	
Safety factor	**3.6**	**3.6**	
Shear load "V" in kips	5.9	3.1	use max. of semi-trap. vs. triang.
Factored shear load "Vf" in kips	21.1	11.2	
Moment "M" in kip-ft	112.5	37.1	use max. of semi-trap. vs. triang.
Factored moment "Mf" in kip-ft	401.8	132.3	
Pile/pier/beam diameter "D" in ft	***2.0***	***2.0***	
Soil / rock cohesion "c" in ksf	10.00	10.00	
"H"	19.1	11.8	
"q"	0.1	0.1	
Required embedment length, "L" in ft	6.34	4.98	
Required Pile/Pier/Beam Size:			
Mmax in kip-ft (above bottom of excavation)	112.5	37.1	use max. of semi-trap. vs. triang.
Mmax in kip-in (above bottom of excavation)	1350.2	444.7	
Allowable steel stress in ksi	***33.0***	***33.0***	***allowable = 0.66Fy***
Required steel section in in^3	40.9	13.5	
Use	W14x30	W14x30	
or			
Design Length	35.3	30.0	
Estimate Lateral Deflection at Top of Beam:			
Empirical Avg. = 0.002He, inches	0.24	0.18	
Calc. Lat. Deflection - Cant. Beam w/ Conc. Load:			
I, in^4	291	291	
E, ksi	29000	29000	
Net Span Length for Deflection, ft	0.0	0.0	
F1 Location, ft	27.0	25.0	
F1 Deflection, inches	0.0000	0.0000	
F2 Location, ft	27.8	24.5	
F2 Deflection, inches	0.0000	0.0000	
F3 Location, ft	24.6	23.1	
F3 Deflection, inches	0.0000	0.0000	
Sum of F1, F2, & F3 Deflections, inches	0.00	0.00	
Avg. Lat. Deflection - Estimated & Calculated:	0.12	0.09	

References - Soldier Pile/Pier/Beam Embedment

1.) Broms' Method - AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals; 4th Edition; 2001; Section 13

2.) Safety Factor - AASHTO Standard Specifications for Highway Bridges; 15th Edition; 1992; Division I - Design; pg. 157; Ammended by 1994 Interim Specifications

Notes:

1.) Deflection calculations are based steel soldier beam sections italicized

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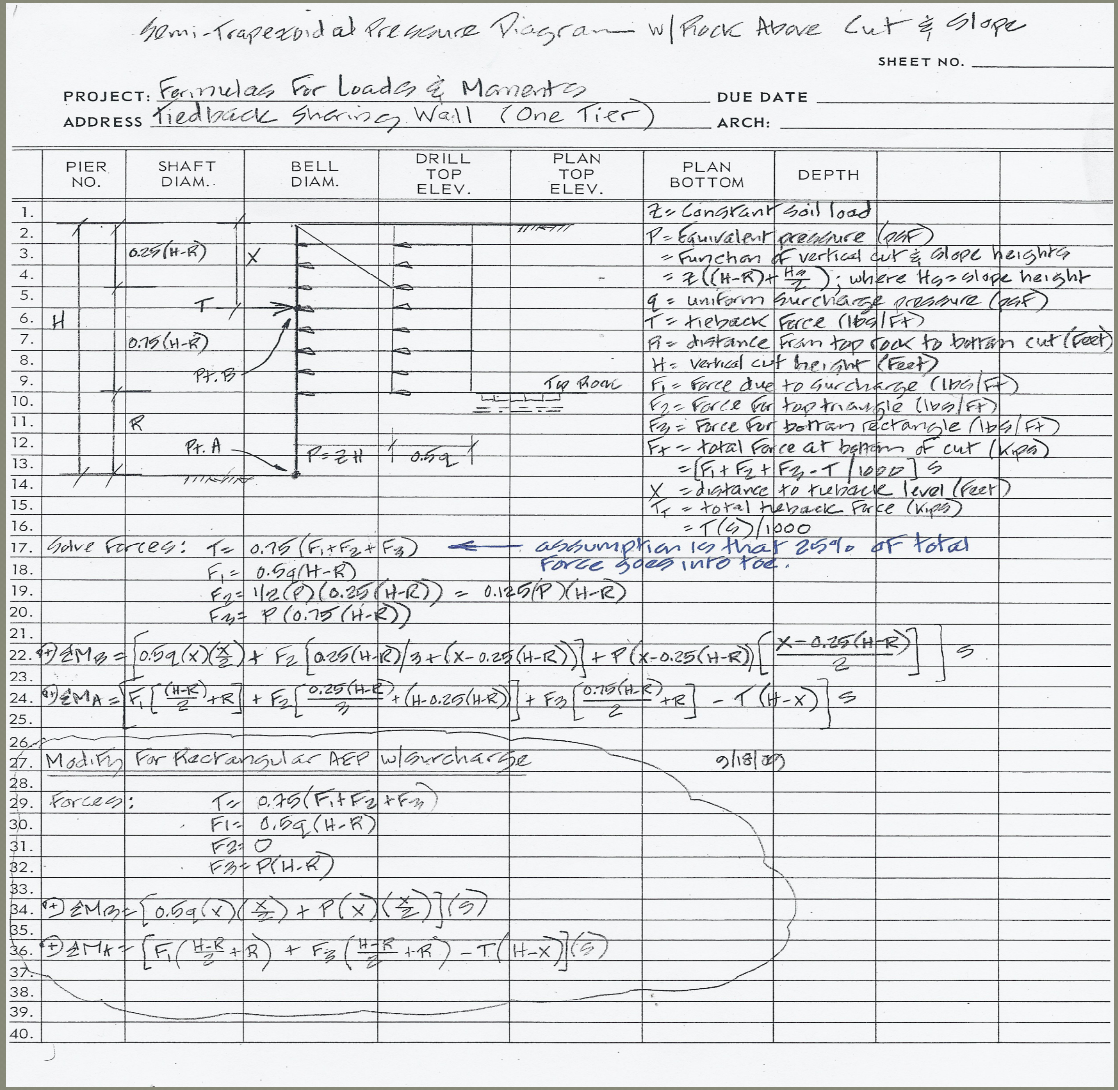
Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Design Approach – One Tier Braced Wall Parameters



Semi-Trapezoidal Pressure Diagram – w/ Rock Above Cut & Slope

SHEET NO.

PROJECT: Formulas For Loads & Moments DUE DATE

ADDRESS Tiedback Shoring Wall (One Tier) ARCH:

Z = Constant soil load
P = Equivalent pressure (psf)
= Function of vertical cut & slope heights
= $Z((H-R)+\frac{H_S}{2})$; where H_S = slope height
q = uniform surcharge pressure (psf)
T = tieback force (lbs/ft)
R = distance from top rock to bottom cut (feet)
H = vertical cut height (feet)
F_1 = Force due to surcharge (lbs/ft)
F_2 = Force for top triangle (lbs/ft)
F_3 = Force for bottom rectangle (lbs/ft)
F_T = total force at bottom of cut (kips)
= $[F_1+F_2+F_3-T/1000]$ s
X = distance to tieback level (feet)
T_T = total tieback force (kips)
= T(s)/1000

Solve Forces: $T = 0.75(F_1+F_2+F_3)$ ← assumption is that 25% of total force goes into toe.

$F_1 = 0.5q(H-R)$

$F_2 = 1/2(P)(0.25(H-R)) = 0.125(P)(H-R)$

$F_3 = P(0.75(H-R))$

$(+)\ \Sigma M_B = \left[0.5q(X)\left(\frac{X}{2}\right) + F_2\left[0.25(H-R)/3 + (X-0.25(H-R))\right] + P(X-0.25(H-R))\left[\frac{X-0.25(H-R)}{2}\right]\right] s$

$(+)\ \Sigma M_A = \left[F_1\left[\frac{(H-R)}{2}+R\right] + F_2\left[\frac{0.25(H-R)}{3} + (H-0.25(H-R))\right] + F_3\left[\frac{0.75(H-R)}{2}+R\right] - T(H-X)\right] s$

Modify For Rectangular AEP w/surcharge 9/18/09

Forces: $T = 0.75(F_1+F_2+F_3)$

$F1 = 0.5q(H-R)$

$F2 = 0$

$F3 = P(H-R)$

$(+)\ \Sigma M_B = \left[0.5q(X)\left(\frac{X}{2}\right) + P(X)\left(\frac{X}{2}\right)\right](s)$

$(+)\ \Sigma M_A = \left[F_1\left(\frac{H-R}{2}+R\right) + F_3\left(\frac{H-R}{2}+R\right) - T(H-X)\right](s)$

Design Approach – One Tier Braced Wall

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AR Certificate of Authorization No. 3909
William F. Powers III, P.E.
AR Prof. Eng. No. 20081

JOB NAME: WHO NEO SOUTH LAKE AND GREEN GROOVE / SE 14TH STREET BIKE TUNNEL IMPROVEMENT PROJECT
JOB LOCATION: SE 14TH STREET BETWEEN SE J & SE P STREETS; BENTONVILLE, AR 72712
JOB NUMBER: JOB NO. SH24-6

EXCAVATION SUPPORT AND PROTECTION SYSTEM (ESPS) — ONE-TIER BRACED/TIEBACK WALL
INTERNALLY BRACED, DRILLED-IN, TANGENT PILES; SOLDIER PILES AND UNTREATED TIMBER LAGGING — SEMI-TRAPEZOIDAL PRESSURE DISTRIBUTION
MASS EXCAVATION GRADING PLAN

Calculation Location		Braced TESPS - Tunnel Box - Tangent Piles TB1 thru TB3, TB6 thru TB19, TB22 thru TB24 Section Modulus Calc. - 24" Diam. Hole @ 26" o.c. Borings B-1 thru B-3 - fill/clayey gravel over hard limestone EXIST. EL. 1300.0 +/-; BOTTOM OF SLOPE EL. 1296.0 +/- BOW EL. 1277.5 +/-; TOP OF LIMESTONE EL. 1274.0	Braced TESPS - Tunnel Box - Tangent Piles TB4, TB5, TB20, TB21 Section Modulus Calc. - 24" Diam. Hole @ six feet o.c. Borings B-1 thru B-3 - fill/clayey gravel over hard limestone EXIST. EL. 1300.0 +/-; BOTTOM OF SLOPE EL. 1296.0 +/- BOW EL. 1277.5 +/-; TOP OF LIMESTONE EL. 1274.0	
Given:				
Vertical exposed height in feet "Ht"	31	18.5	18.5	
Slope height "Hs" in feet	32	4.0	4.0	
Distance "R" in feet	33	0.0	0.0	
Distance to brace / tieback "X" in feet	34	4.0	4.0	
Soil load constant "Z"	35	30	30	
Equiv. pressure in psf/ft "P"	36	615	615	
Surcharge in psf "q"	37	250	250	
Pile / Beam / Braced horizontal span length in feet "s"	38	1	6	
Resolve Unit Forces:				
Force "T" in lbs/ft	40	9201	9201	
Force "F1" in lbs/ft	41	2313	2313	
Force "F2" in lbs/ft	42	1422	1422	
Force "F3" in lbs/ft	43	8533	8533	
Total force "Ft" in kips	44	3.1	18.4	
Total brace / tieback force "Tt" in kips	45	9.2	55.2	
Soldier Pile / Beam Moments:				
Toe moment "Ma" in kip-ft	47	-30.9	-185.4	
Brace / Tieback moment "Mb" in kip-ft	48	2.4	14.5	
Soldier Pile/Pier/Beam Embedment:				
Brom's Method				
Under-capacity factor	52	0.70	0.70	
Overload factor	53	2.50	2.50	
Safety factor	54	3.57	3.57	
Shear load "V" in kips	55	3.07	18.40	
Factored shear load "Vf" in kips	56	10.95	65.72	
Moment "M" in kip-ft (max of Ma or Mb)	57	2.42	14.54	
Factored moment "Mf" in kip-ft	58	8.66	51.94	
Pile/pier/beam diameter "D" in ft	59	2.00	1.50	
Soil/rock cohesion "c" in ksf	60	3.50	3.50	
Eccentricity "H" in ft	61	0.79	0.79	
"q"	62	0.17	1.39	
Required embedment length, "L" in ft	63	4.82	8.20	
Mmax in kip-ft	64	42.47	245.51	
Location of Mmax in ft	65	3.17	3.64	
Summary of Calculations (above bottom of excavation)				
Mmax in lb-ft, for span "s"	68	30898	185387	
Mmax in kip-in	69	371	2225	
Allowable steel stress in ksi	70	36.9	36.9	
Required steel section in in^3	71	10.1	60.4	
Use	72	W14x26	W18x46	
Or	73	EQUIV	EQUIV	
Design Length	74	23.3	26.7	0.0
T1 force, for span "s" in kips	75	9.2	55.2	
T1 declination in degrees	76	0	0	
T1 design load in kips	77	9.2	55.2	
T1 design load x 1.33 = max test load at declination angle in kips	78	12.2	73.4	
Mmax in wale from T1 deisgn load in kip-in (13/64Pl)	79	67.3	403.7	
Required Sx in wale from Mmax in in^3	80	1.8	11.0	
Use	81	W12x53	W12x53	

References - Soldier Pile / Pier / Beam Embedment

1.) Brom's Method - AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals; 4th Edition; 2001; Section 13.
2.) Safety Factor - AASHTO Standard Specifications for Highway Bridges; 15th Edition; 1992; Division I - Design; pg. 107; Ammended by 1994 Interim Specifications.

Notes / Design Assumptions:

1.) Utilize factor of safety of 3.57 for soldier pile/beam embedment.
2.) Limit allowable stress in steel members to 0.67Fy.

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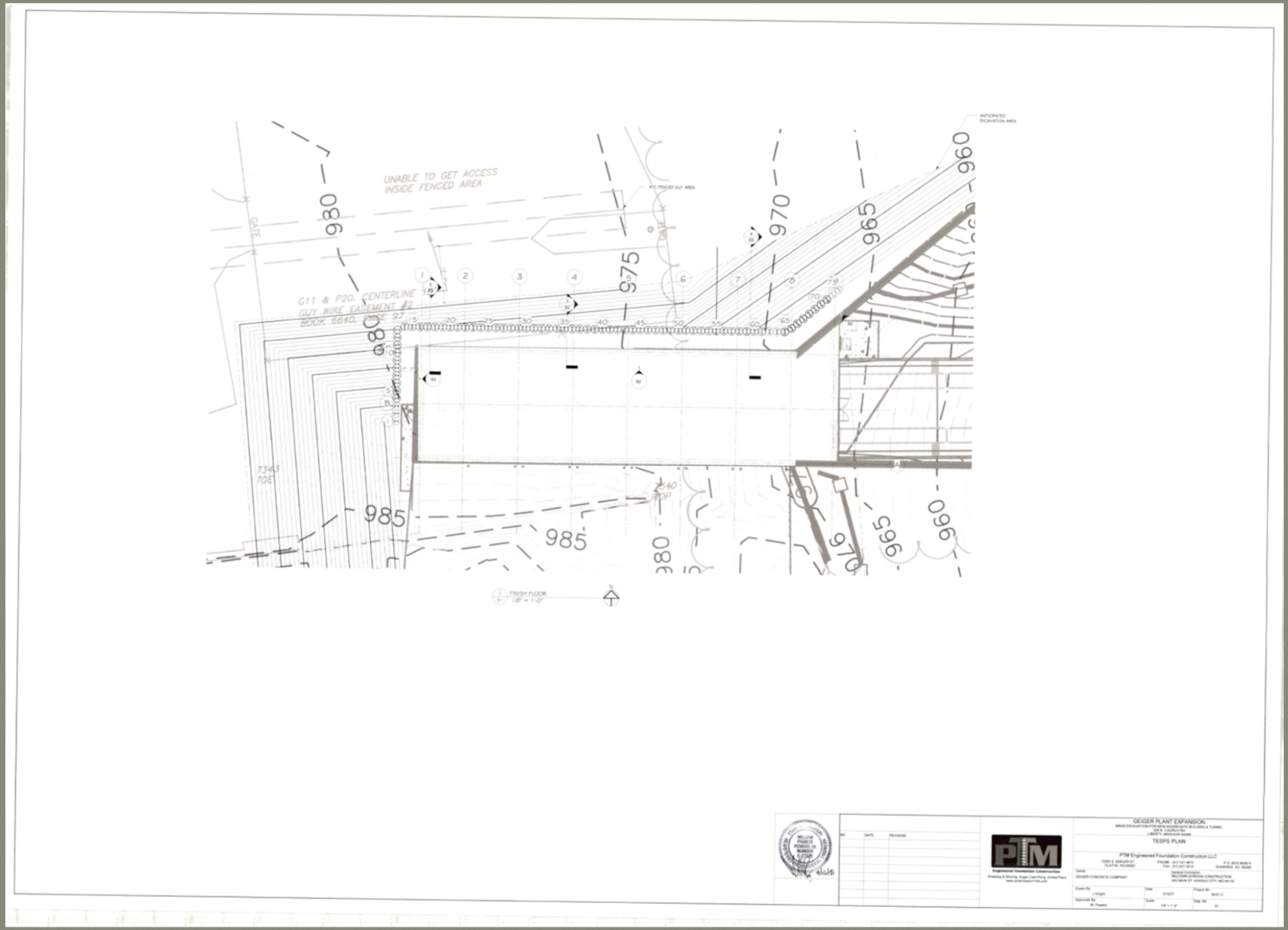
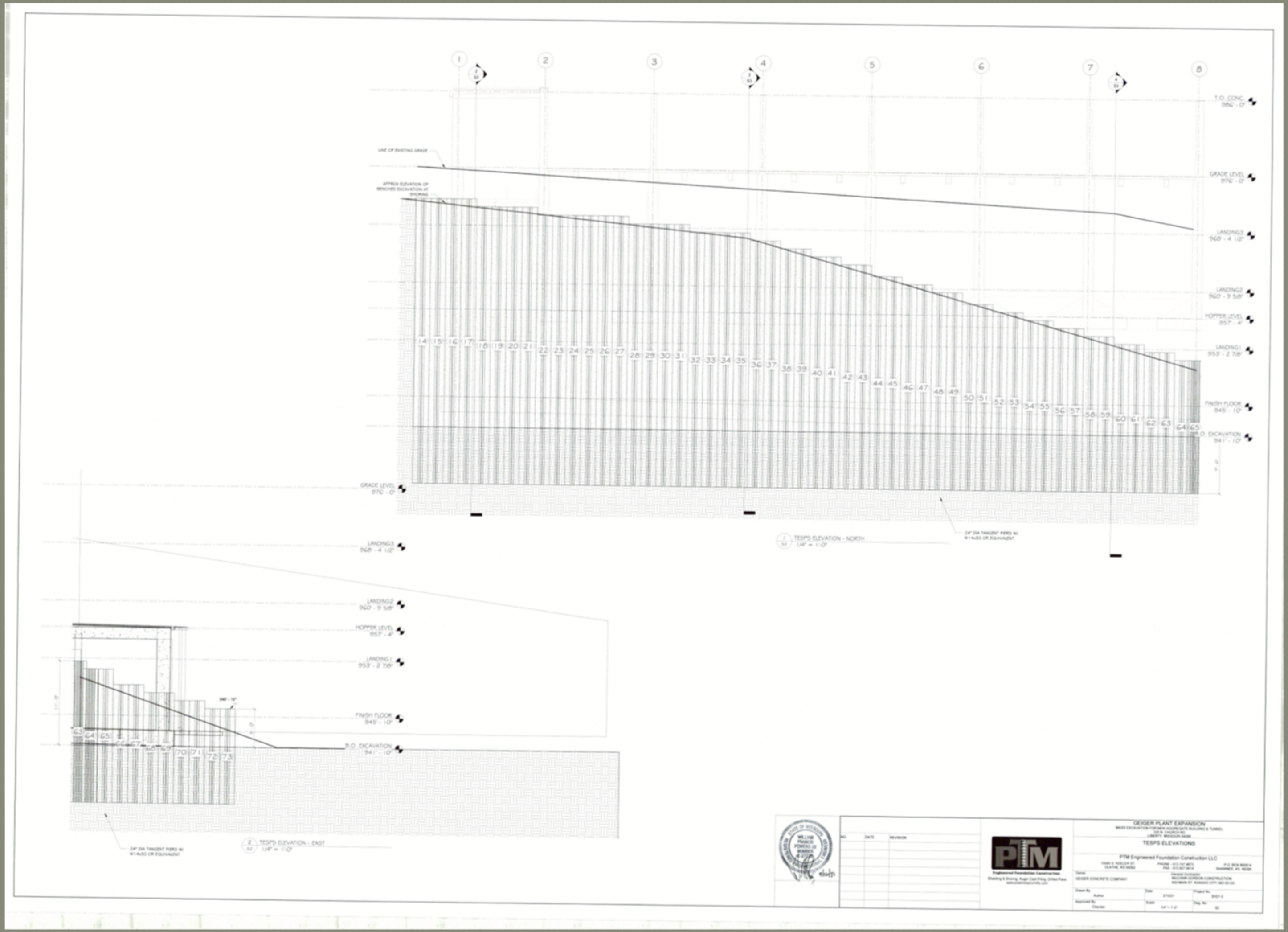
Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Case History – Geiger Ready Mix – Liberty, Missouri



Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Case History – Geiger Ready Mix – Liberty, Missouri



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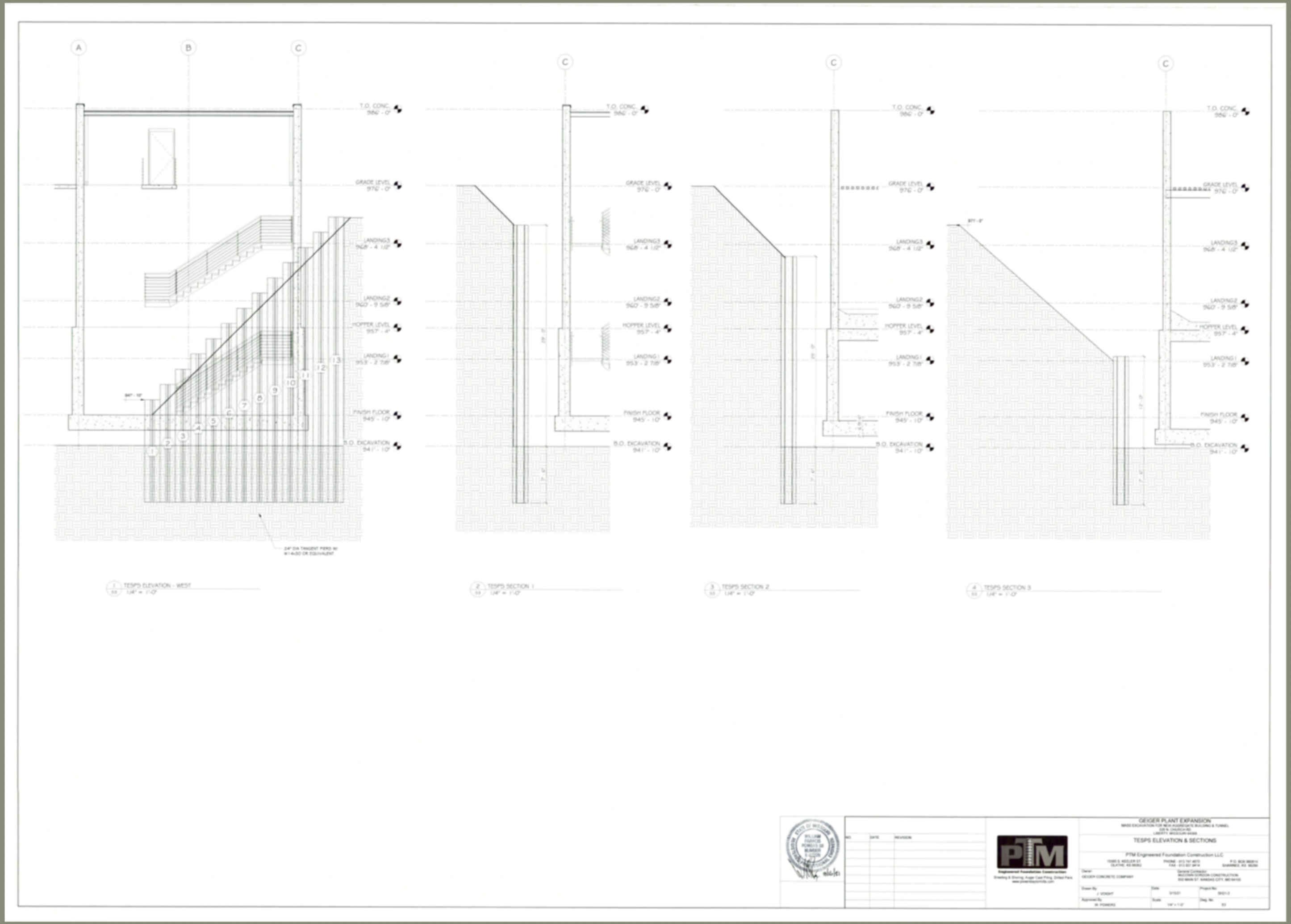
Case History – Geiger Ready Mix – Liberty, Missouri

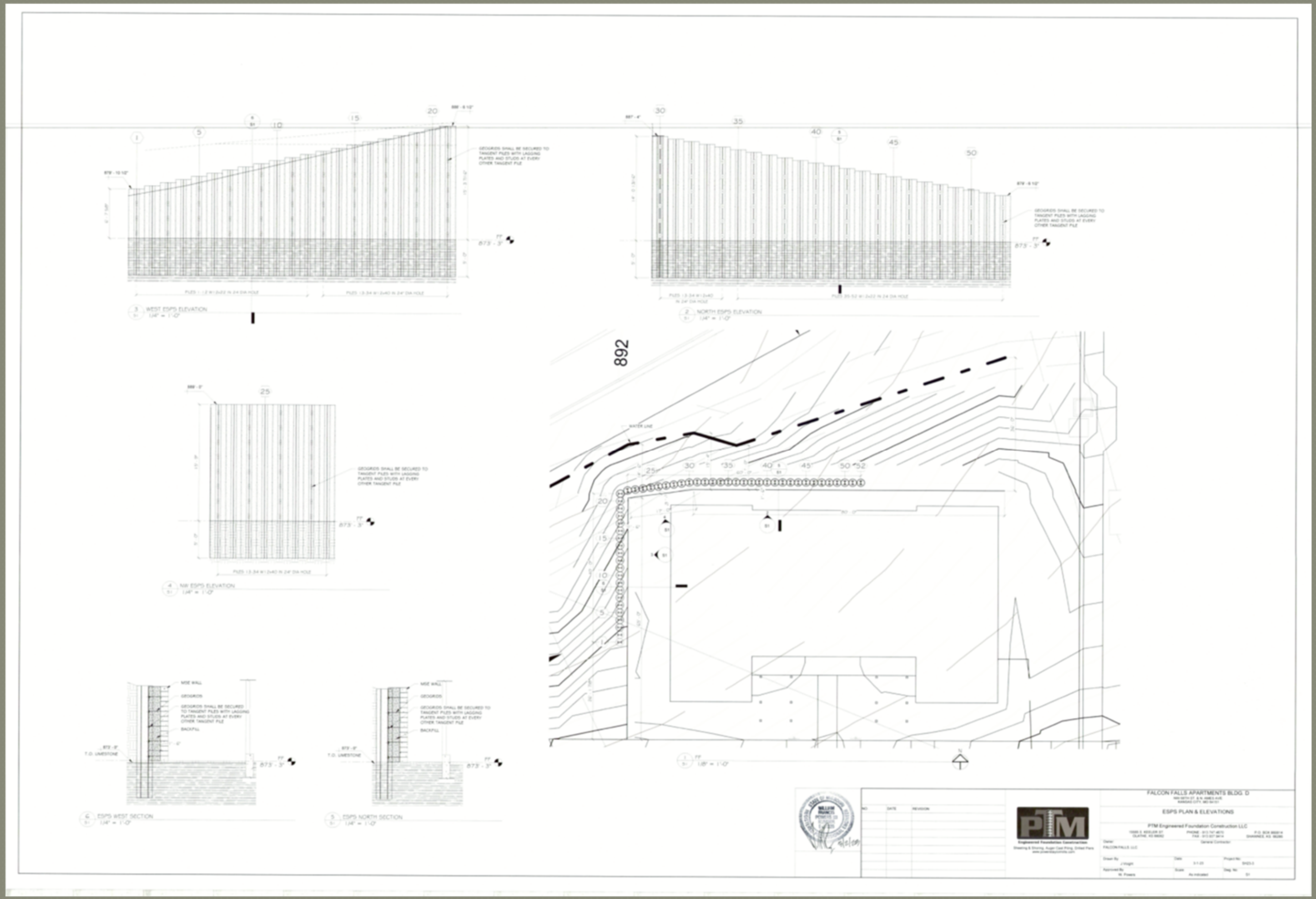


Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Case History – Geiger Ready Mix – Liberty, Missouri


Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Case History – Falcon Falls Apartments, Building D – Gladstone, Missouri



Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

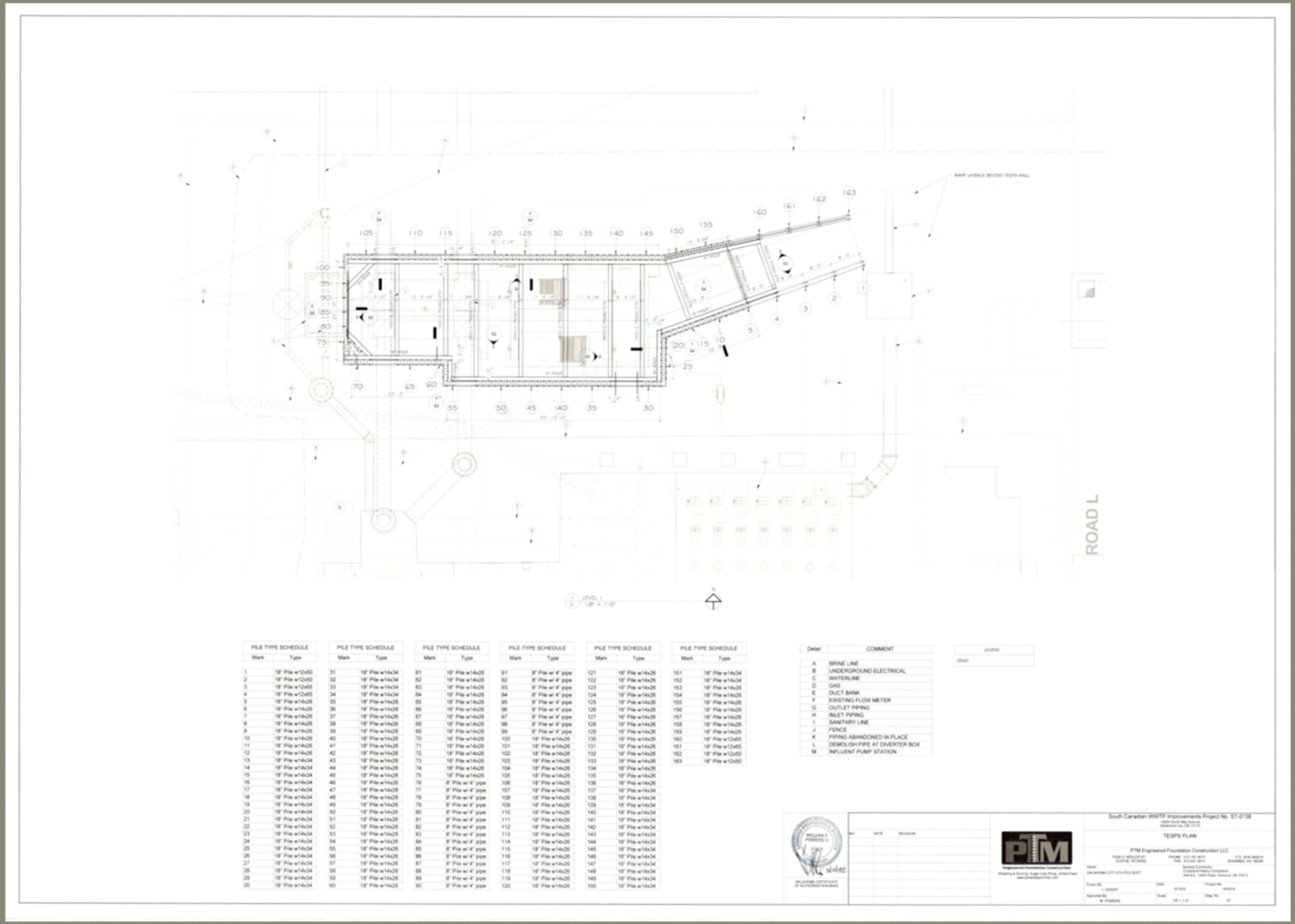
Case History – Falcon Falls Apartments, Building D – Gladstone, Missouri





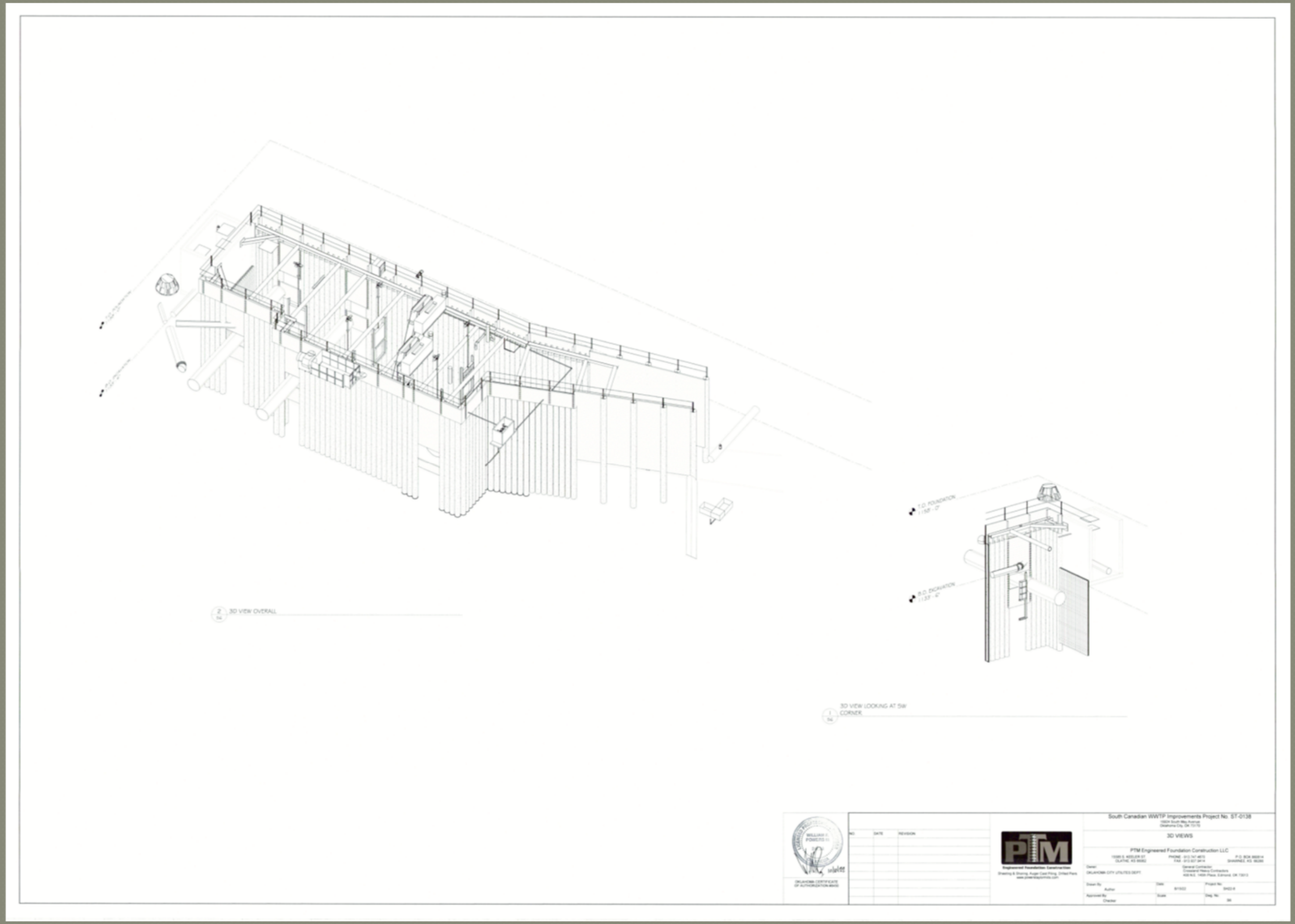

Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Case History – South Canadian WWTP – OKC, Oklahoma



Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Case History – South Canadian WWTP – OKC, Oklahoma



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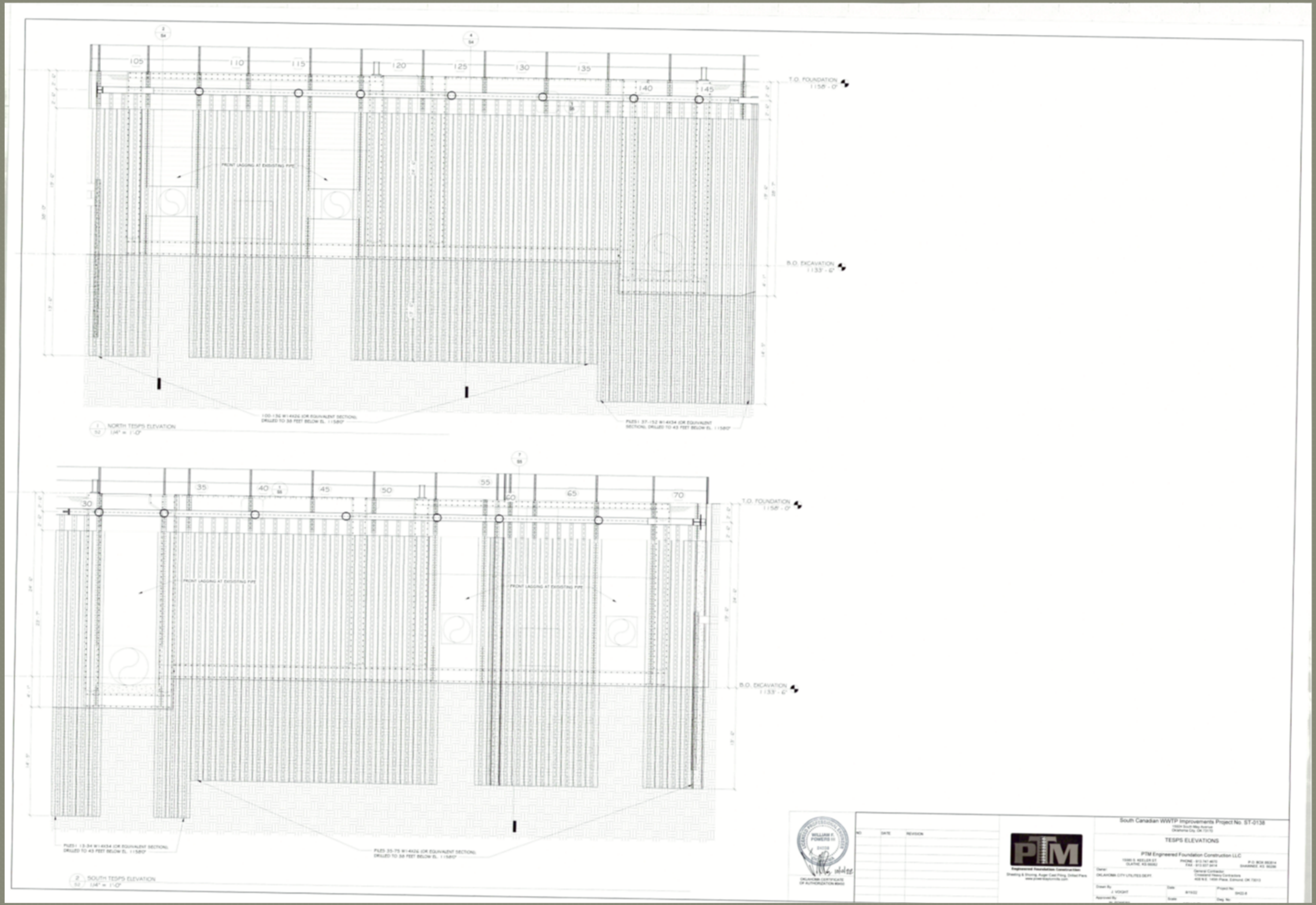
Case History – South Canadian WWTP – OKC, Oklahoma



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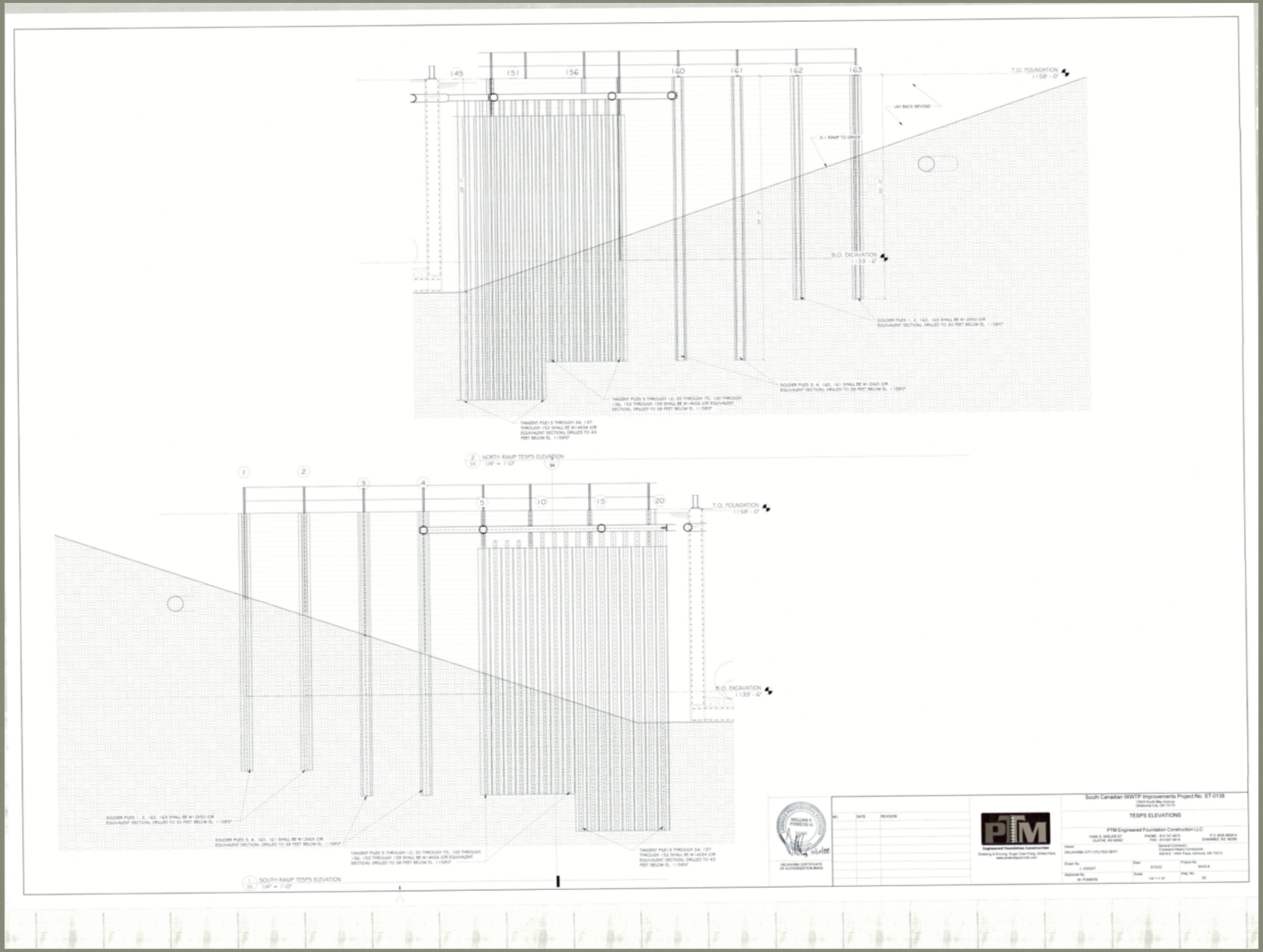
Case History – South Canadian WWTP – OKC, Oklahoma



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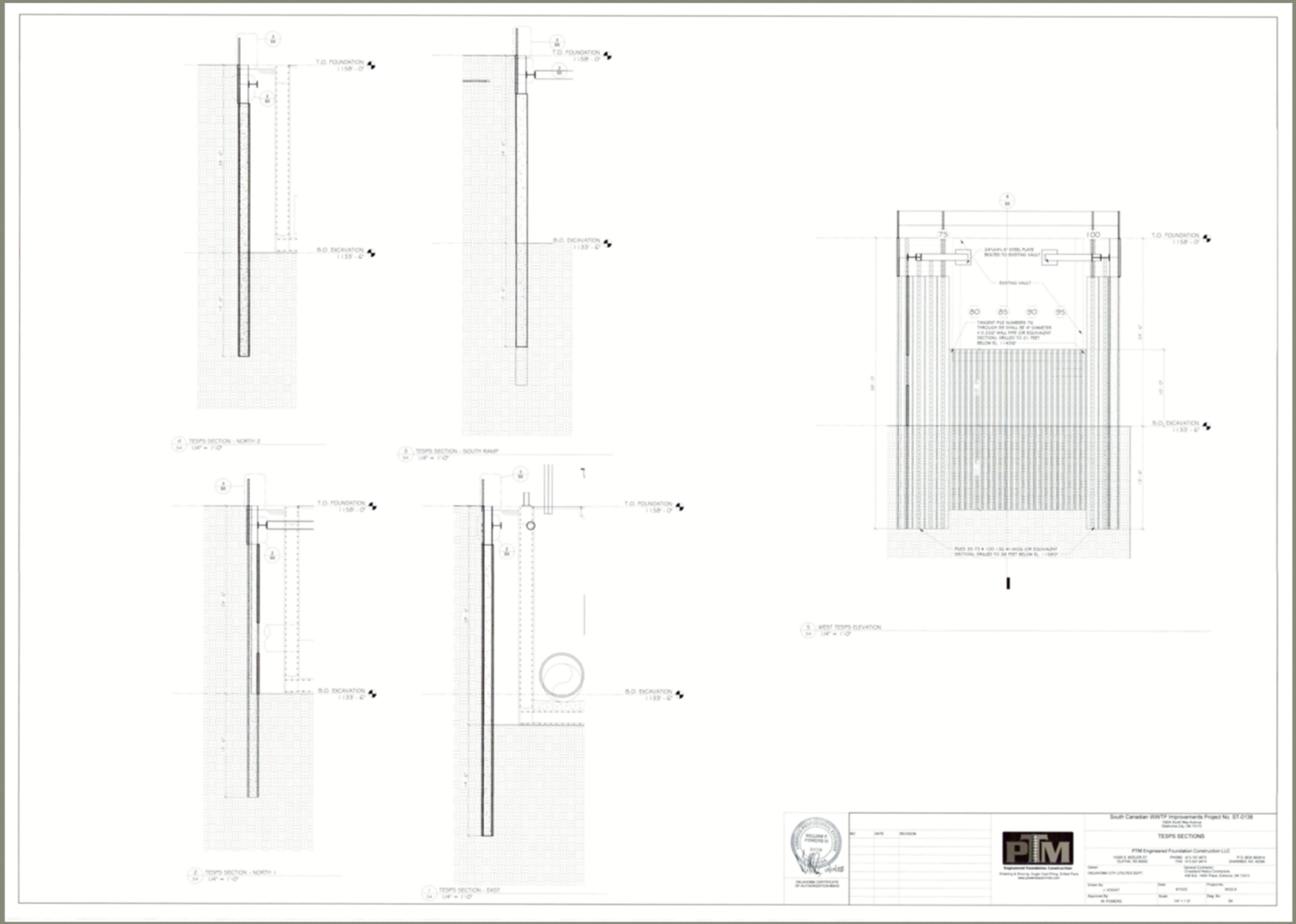
Case History – South Canadian WWTP – OKC, Oklahoma



Drilled, Reinforced Concrete, Tangent Piles for Excavation Support and Protection Systems

Case History – South Canadian WWTP – OKC, Oklahoma

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Thank you for listening!
Questions???

Engineered Foundation Construction