# Issues in Cofferdam Design & Construction

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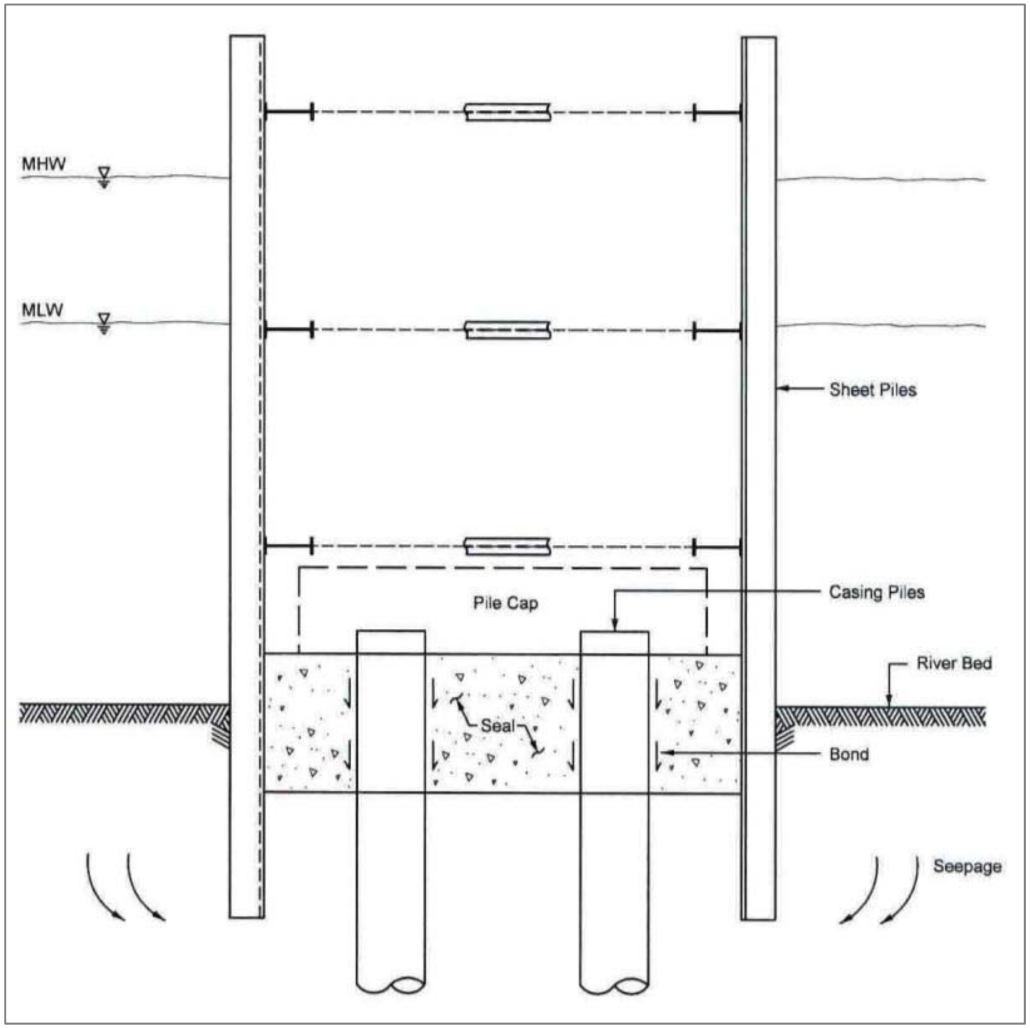
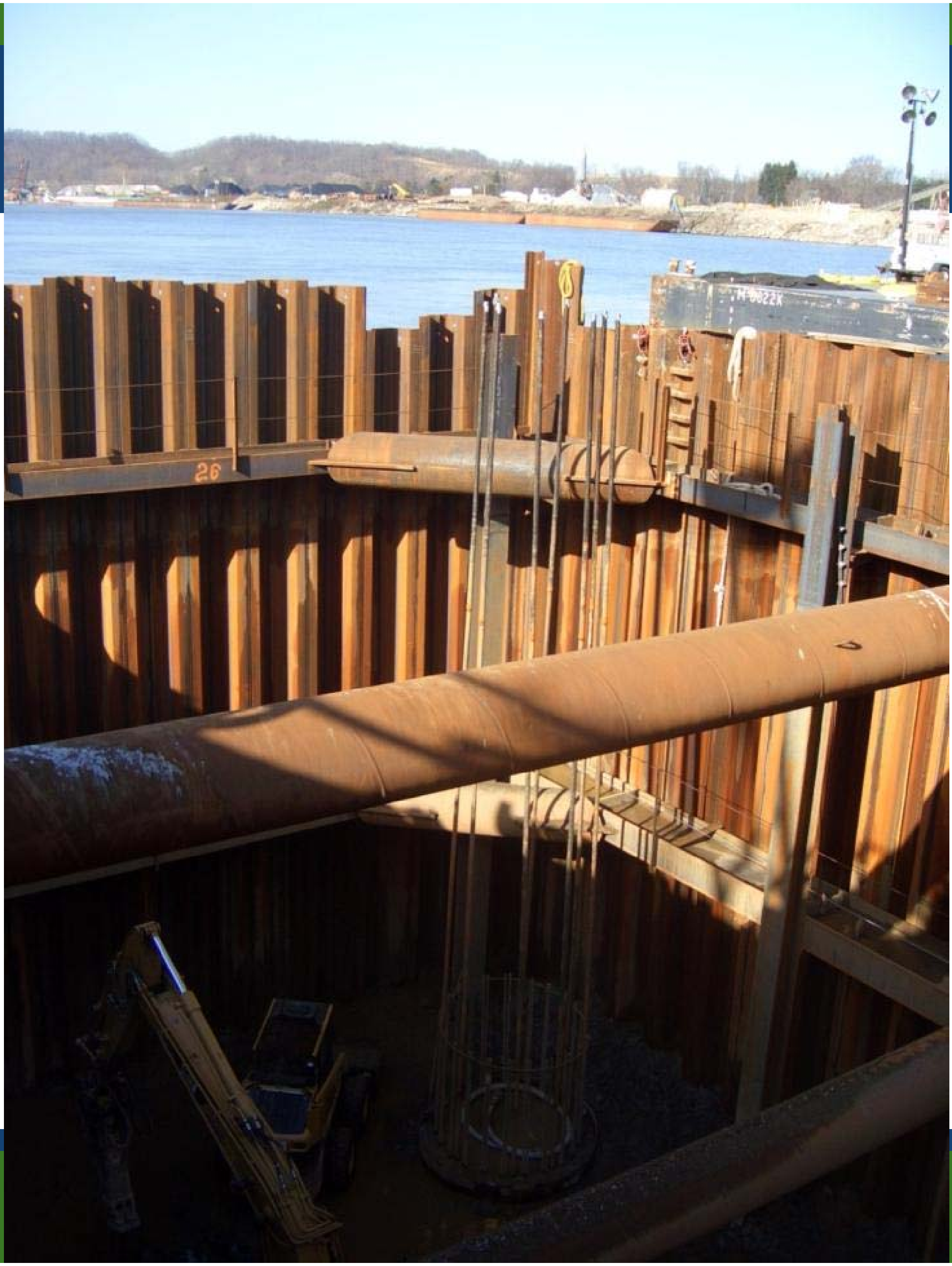
# Marine Cofferdam

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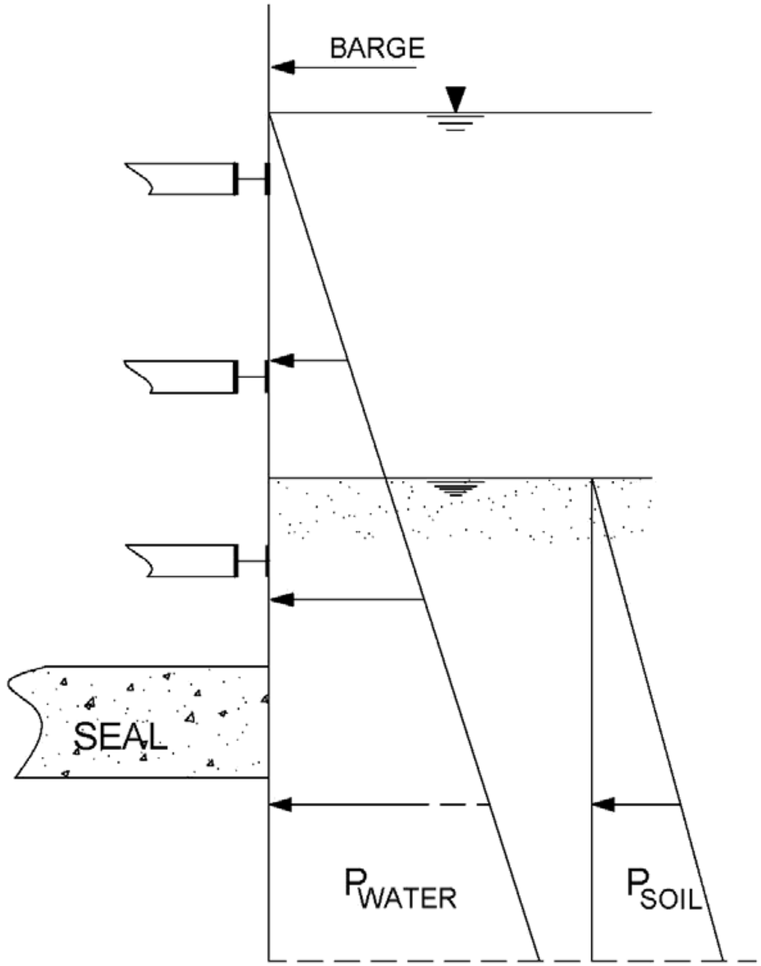
# Marine Cofferdams

- Loads
  - Water
  - Soil
  - Current and waves
  - Vertical
- Barges
- Vessel impact
- Scour

# Construction Sequence

- Set Template
- Drive Sheeting
- (Drill Shafts)
- Excavate
- Lower/Install Bracing (if required)
- (Drive Piles)
- Install Seal
- Dewater (Install Bracing)
- Construct Foundation
- Flood/Remove Bracing
- Pull Sheeting

# Lateral Loads




<u>Types</u>

- Barge
- Waves
- Ice
- Collision
- Unbalanced Soil

# Current Loads

$P_{CURRENT} = C_D v^2$ (psf)

- $C_D$= 1.4 (Square)
- $C_D$= 0.7 (round nose)

v = current velocity (fps)

(Reference: AASHTO 2012)

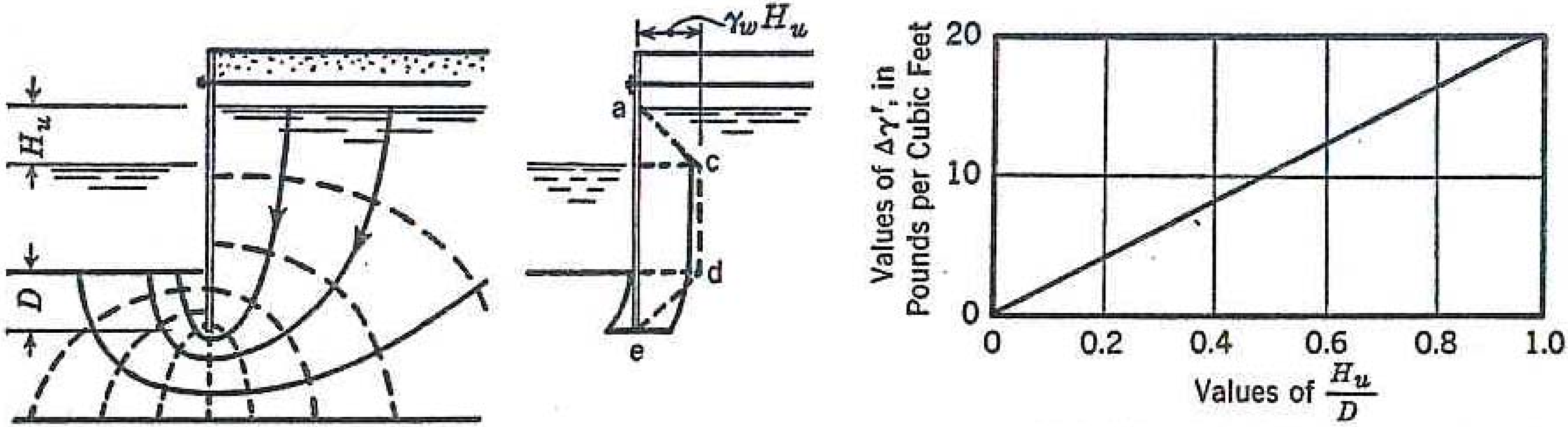
# Water Control

- Water elevation vs. risk
- Seal
- Sheet pile interlocks

# Minimum Toe

- Lateral load capacity
- Flownet
- Basal heave
- Vertical capacity

# Unbalanced Water Pressure



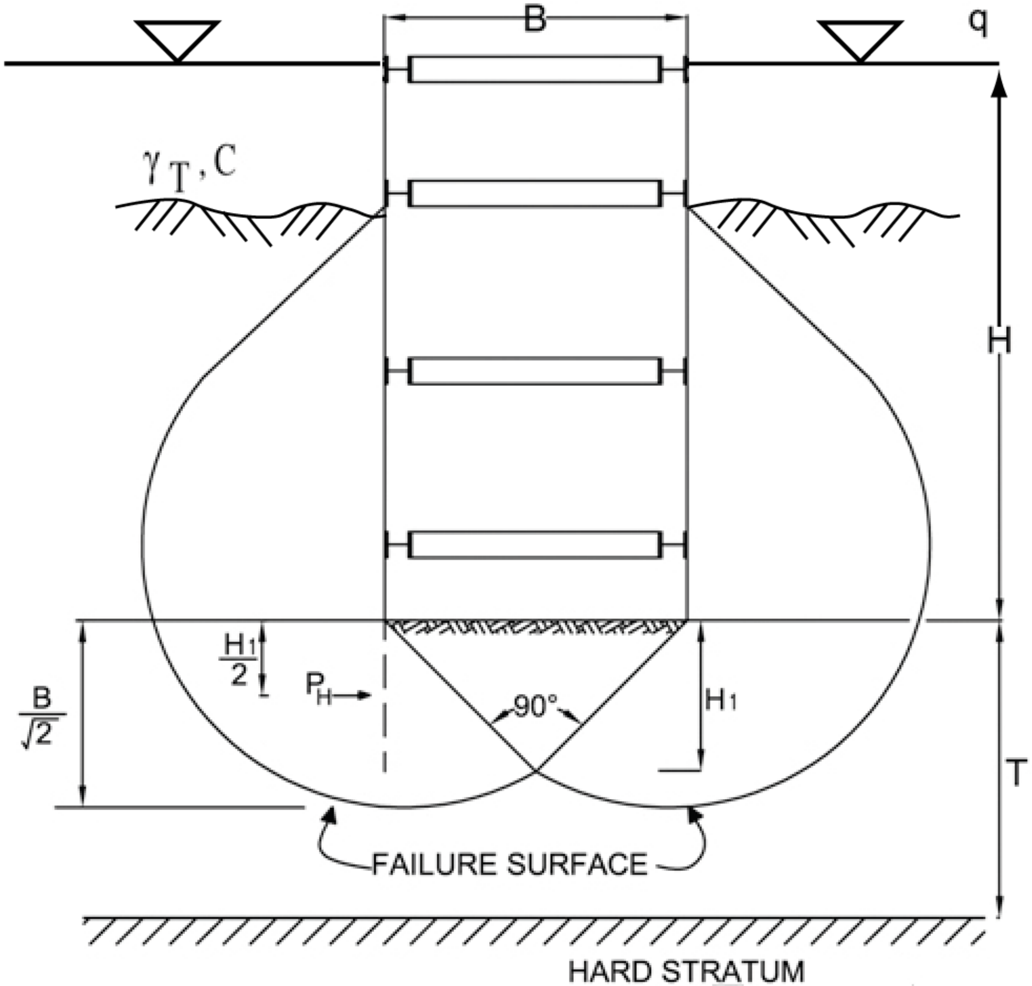

(*a*) FLOW NET

(*b*) DISTRIBUTION OF UNBALANCED WATER PRESSURE

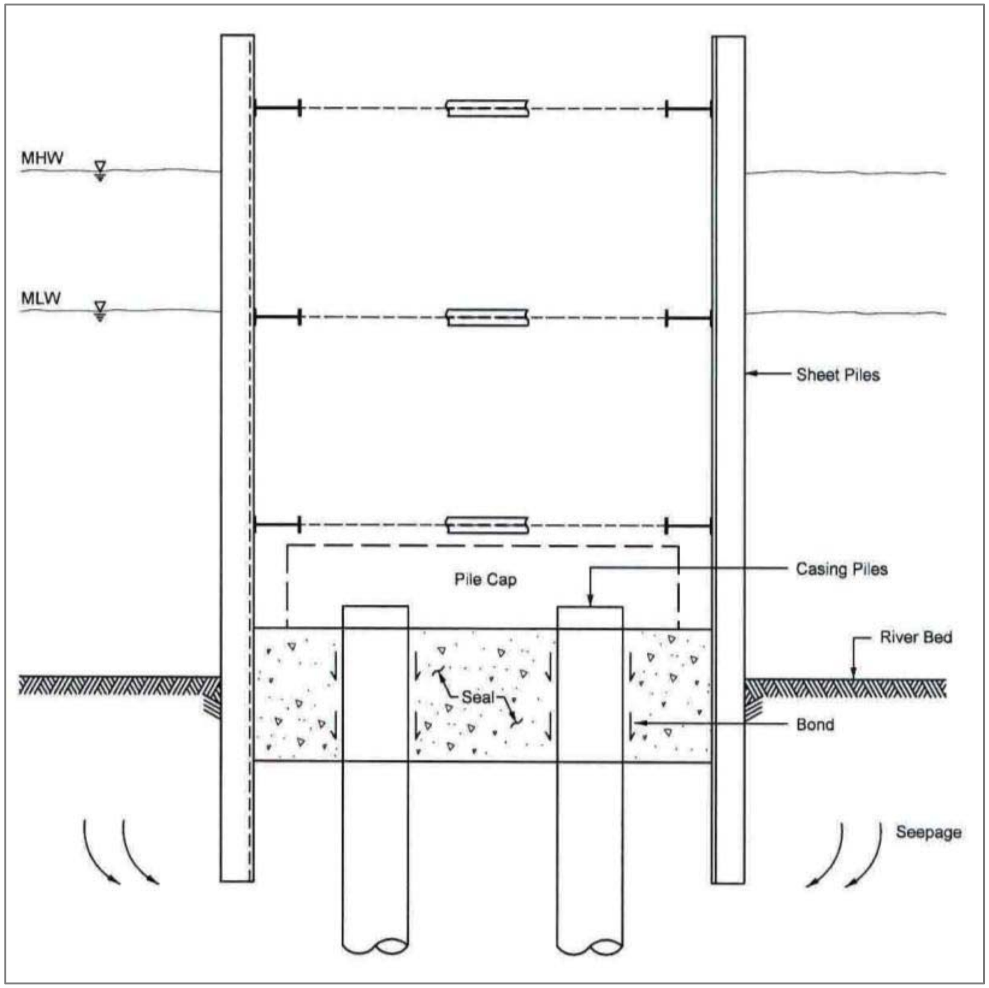
(*c*) AVERAGE REDUCTION OF EFFECTIVE UNIT WEIGHT OF PASSIVE WEDGE DUE TO SEEPAGE PRESSURE EXERTED BY THE UPWARD FLOW OF WATER

(Reference: Anchored Bulkheads, Terzaghi, 1953)

# Basal Heave



# Seals




- Driving force = $\gamma_{\omega}\ \mathrm{H}_{\omega}$
- Resisting forces
  - Seal weight
  - Cofferdam weight
  - Sheeting pullout
  - Pile/shaft pullout

# Seals

- Self weight
- Bond
  - Piles/shafts
  - Sheets
  - Cleaning
  - Shear lugs
- Bond stresses
- Concrete placement
- SF $\geq$ 1.2

# Seal Bond

| | | |
|---|---|---|
| TRADITIONAL | 10-15 psi<br>7-10 psi | Piles<br>Sheets |
| FDOT | 36 psi<br>75 psi | Steel Piles<br>Concrete Piles |

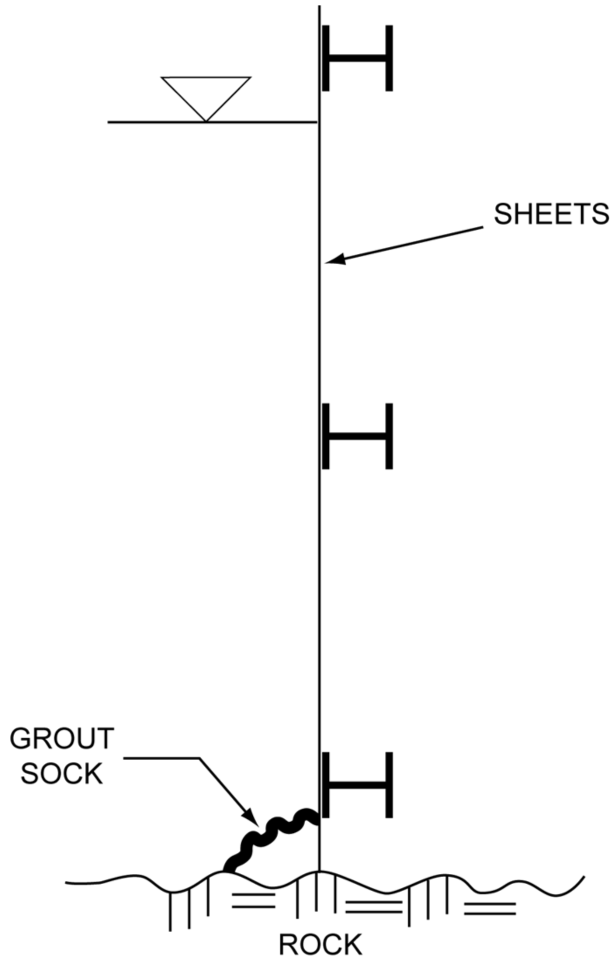
Seal Bending: $f_b = 0.55\left(5\sqrt{f'_c}\right)$ (ACI)

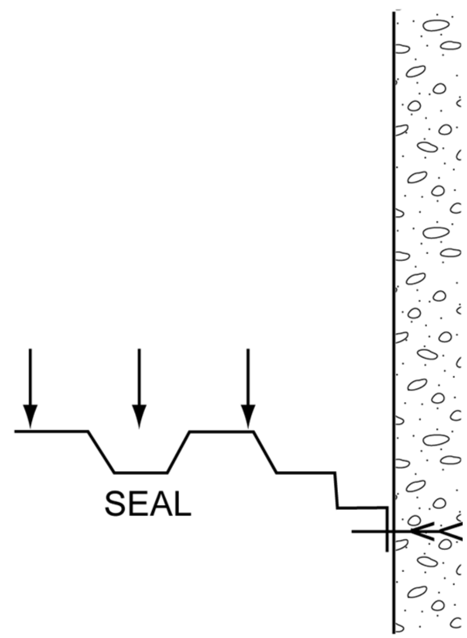
# Tremie Mix

- Slump 8 to 10 inches
- 600 pcy cement
- Fine aggregate, 45 to 55 percent
- W/C ratio .45 max
- Pozzolans and admixtures
- Mass concrete → thermal control
  - DEF
  - Cracking

# Sealing

- On Rock
  - Double Walls
  - Grout Seal
- Adjacent Structures



# Titanic Dock

# Steel Sheet Piling Permeability

- Rule-of-thumb

  0.1 GPM per foot of wall per 10' head
  (NAVFAC DM-7)

- Bare hot-rolled interlocks (Starr)

  Bulk hyd. conductivity = .01 gpd/ft$^2$

  ($5 \times 10^{-9}$ m/sec)

- Proprietary cold-formed sheets with sealer (Smyth, Jowett and Gamble)

  Bulk hyd. conductivity = $10^{-4} - 10^{-5}$ gpd/ft$^2$

  ($10^{-10}$ m/sec)

# Scour

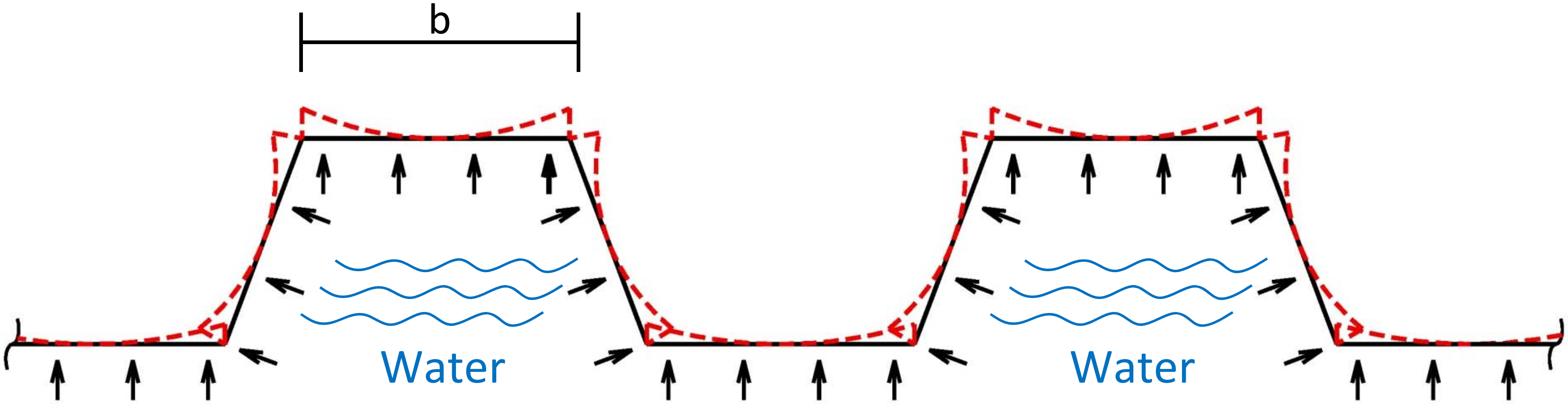
# Sheet Piling Design

- Bending
- Transverse Bending
- Vertical Loads
- Combined Loading

# Bending

- $F_b \leq 0.65\ F_y$ (ASD)
- Continuous over wales
- No "arching" in water

# Transverse Bending



# Transverse Bending

Transverse bending is accounted for by utilizing a reduced yield strength:

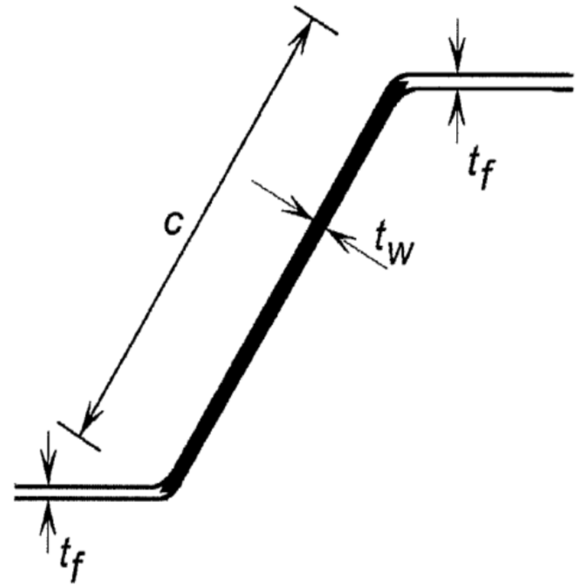
$$F_{y\ red} = (\rho_P)(F_y)$$

where:

$\rho_P$ = strength reduction factor based on the cross-sectional properties of the sheet pile

# Reduction Factor, $\rho_P$

| $D_P$ | $(b/t_{min})*f = 20.0$ | $(b/t_{min})*f = 30.0$ | $(b/t_{min})*f = 40.0$ | $(b/t_{min})*f = 50.0$ |
|---|---|---|---|---|
| 1000 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2000 | 0.99 | 0.97 | 0.95 | 0.87 |
| 3000 | 0.98 | 0.96 | 0.92 | 0.76 |
| 4000 | 0.98 | 0.94 | 0.88 | 0.60 |




Where:

b = flange width (should not be not less than $c/\sqrt{2}$)

e = $\sqrt{\dfrac{34\ ksi}{F_y\ ksi}}$

$F_y$ = yield strength (ksi)

c = slant height of web

$t_{min}$ = minimum of $t_f$ and $t_w$

$t_f$ = flange thickness

$t_w$ = web thickness

$D_P$ = differential water pressure in drained soils or the net active pressure in undrained soft clays (psf)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# Vertical Load Capacity

- Embedment Depth =

  Vertical Load Required + Lateral Load Required

- Load transfer may include contributions from skin friction and end bearing.

- Similar Theory to Driven Bearing Pile Design

- Perform Load Test (ASTM D1143)


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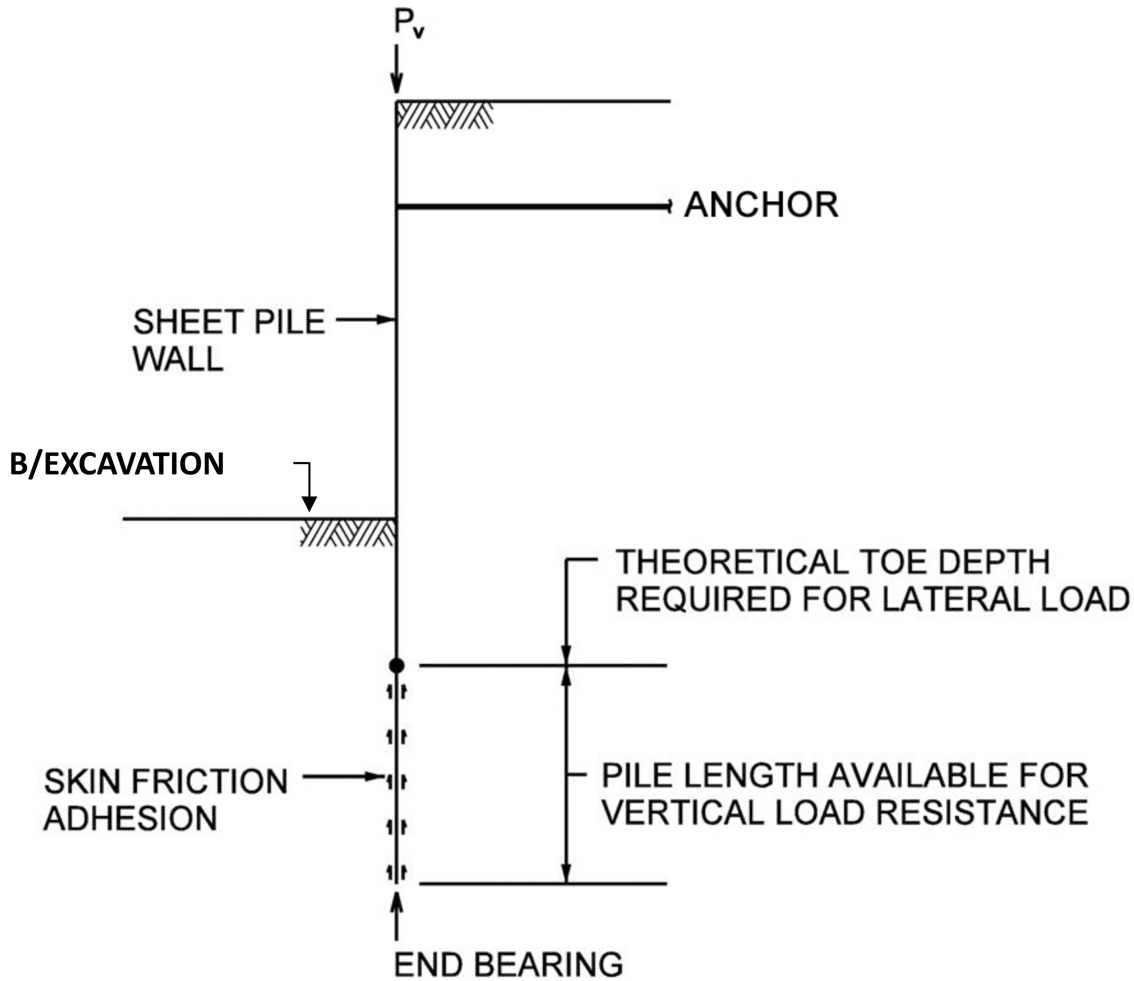
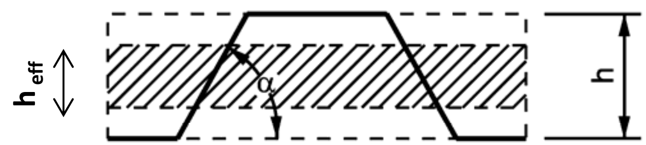
# Vertical Load Capacity



# Vertical Load Capacity

- The contact area for skin friction–vertical surface extending along the outside face of the steel sheet pile.
- The end bearing area may be calculated based on a contact area equal to $E_f$ times the section depth
  - $h_{eff}=(E_f)h$
- A value of 0.55h may be used as a typical value.




| α | 90° | 80° | 70° | 60° | 50° | 40° | 30° |
|---|---|---|---|---|---|---|---|
| $E_f$ | 1.00 | 0.85 | 0.70 | 0.55 | 0.40 | 0.25 | 0.10 |

EFFECTIVE CONTACT AREA AND SKIN AREA OF DRIVEN SHEET PILE WALLS

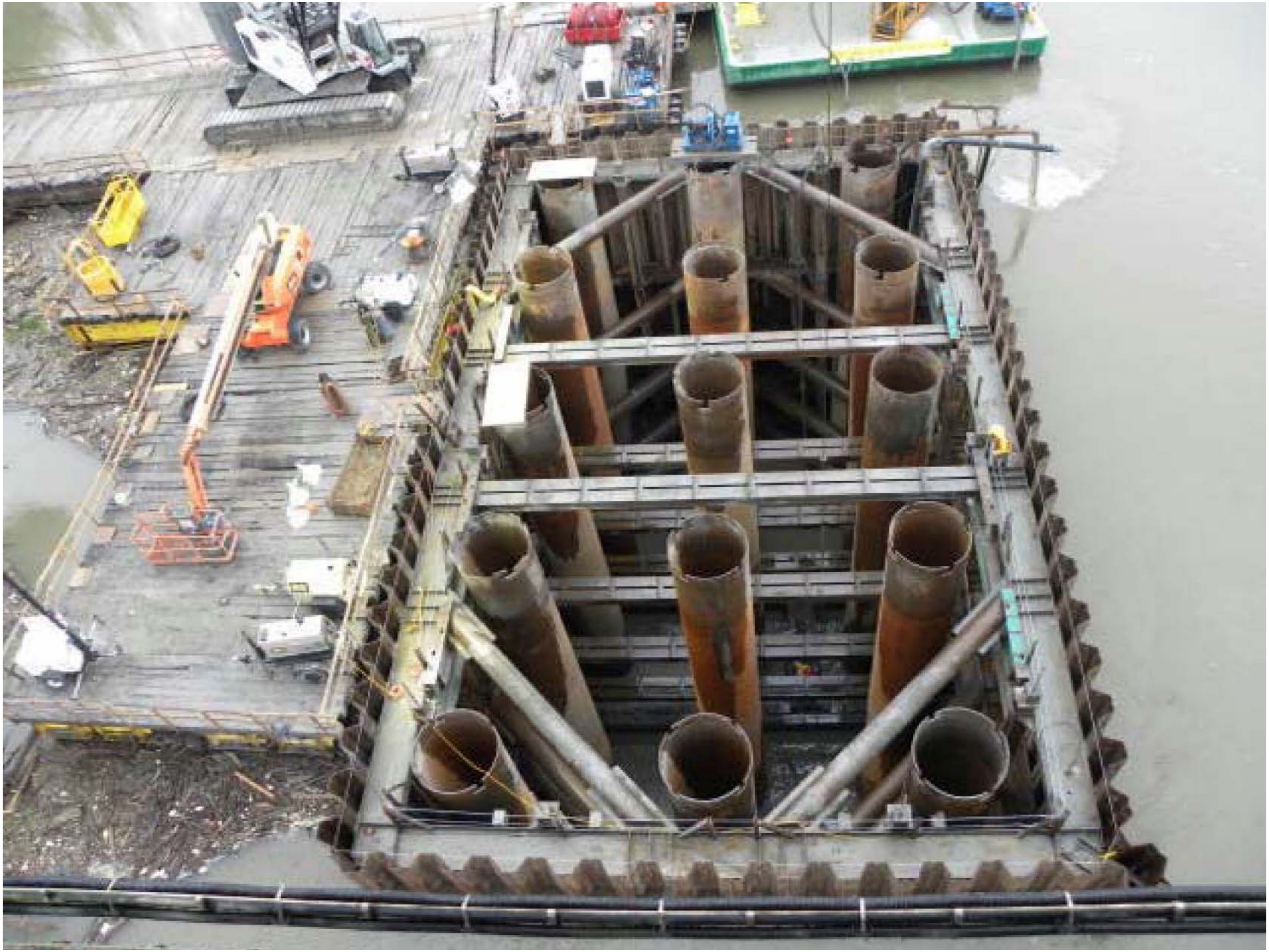
# Combined Loading

- Steel sheet pile subject to axial compression and bending shall satisfy the applicable AISC interaction equations.

$$\frac{P_r}{P_a} + \frac{M_r}{M_a} \leq 1.0$$

$$P_r, M_r = applied$$

$$P_a M_a = available$$



# Bracing Design

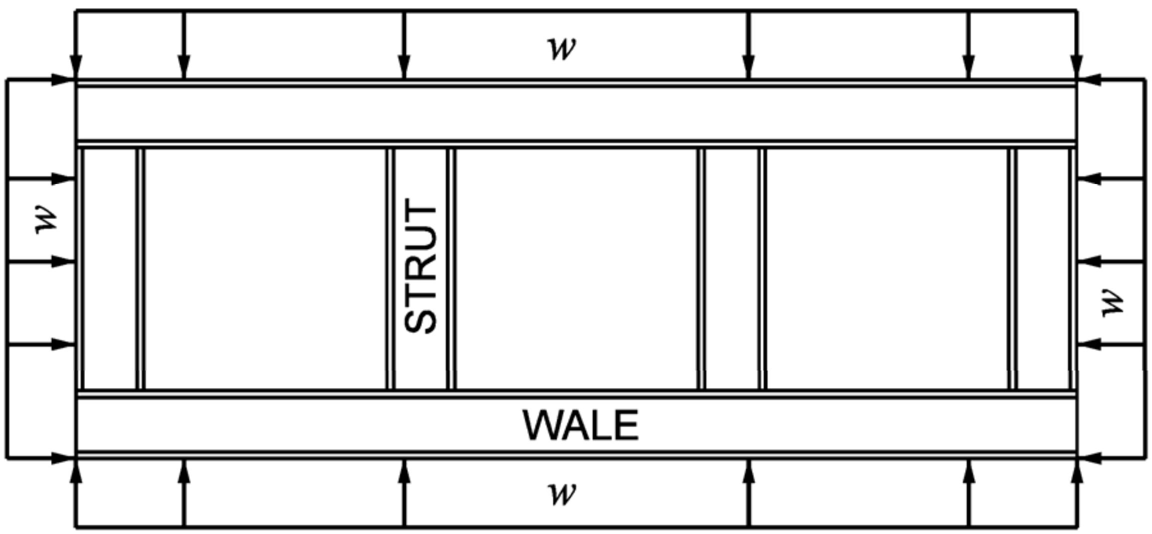
- Materials
  - New
  - Used

- Connections
  - Bolted
  - Welded

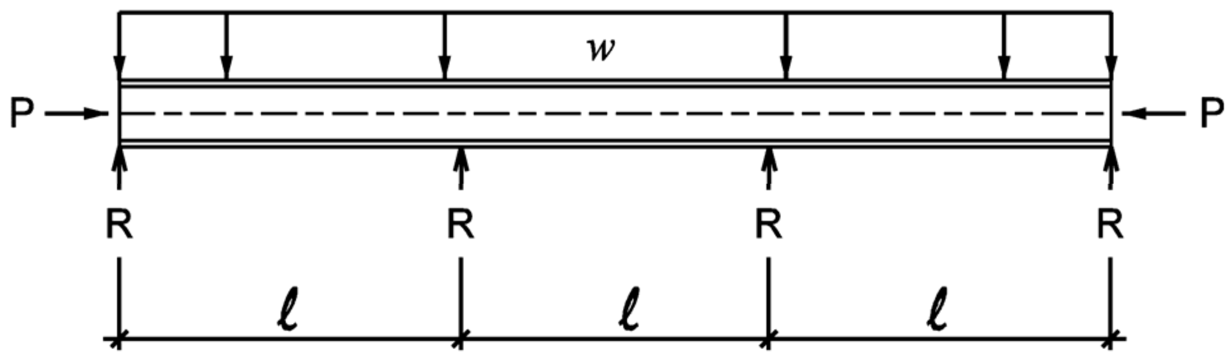
- Local effects

- Installation methods

## Bracing Plan




## Load on Wale Section




*w* = soil loading

P = axial load

R = load at strut

*ℓ* = spacing between supports

# Bracing Design

- Wales
  - Bending
  - Axial loads
- Struts
  - Axial loads
  - Self weight
- Installation stresses
- Accidental loads

# Bracing Design

- Wale restraint varies with construction stage
- Cannot "redistribute"
- Spud pile interaction
- Wale support brackets – only after dewater
  - Carry wale vertical loads
  - Control weak axis buckling (if axial loads)
  - Design load = dead + buckling load
  - Buckling load = 0.04 (axial load)
- Wale local buckling
- Drainage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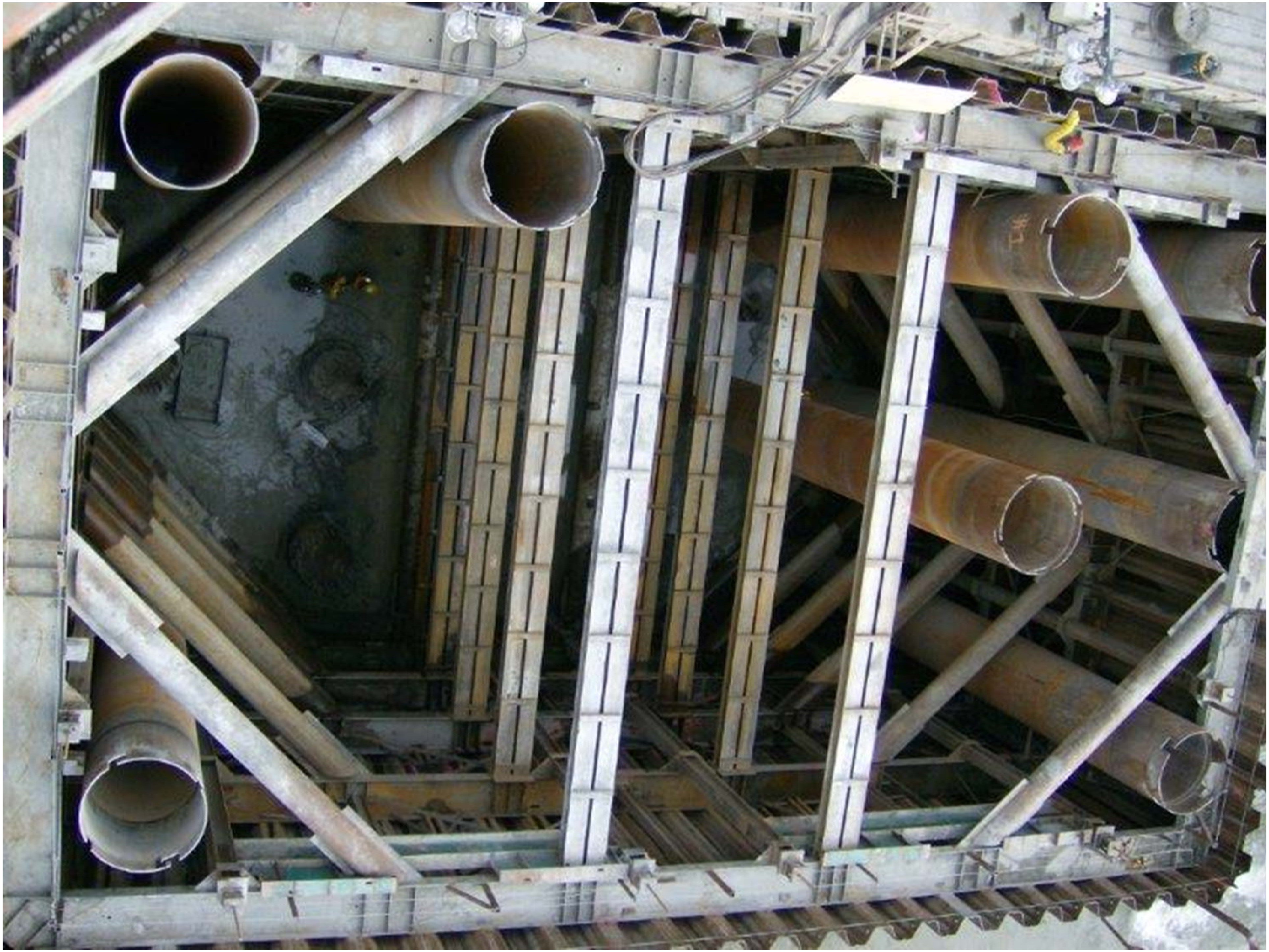


# Circular Wale—Axial Stress

$F_s = T/A + M/S$

where:

$F_s$ = Wale stress

T = Wale axial load

M = Wale bending moment

= 0.86Tb

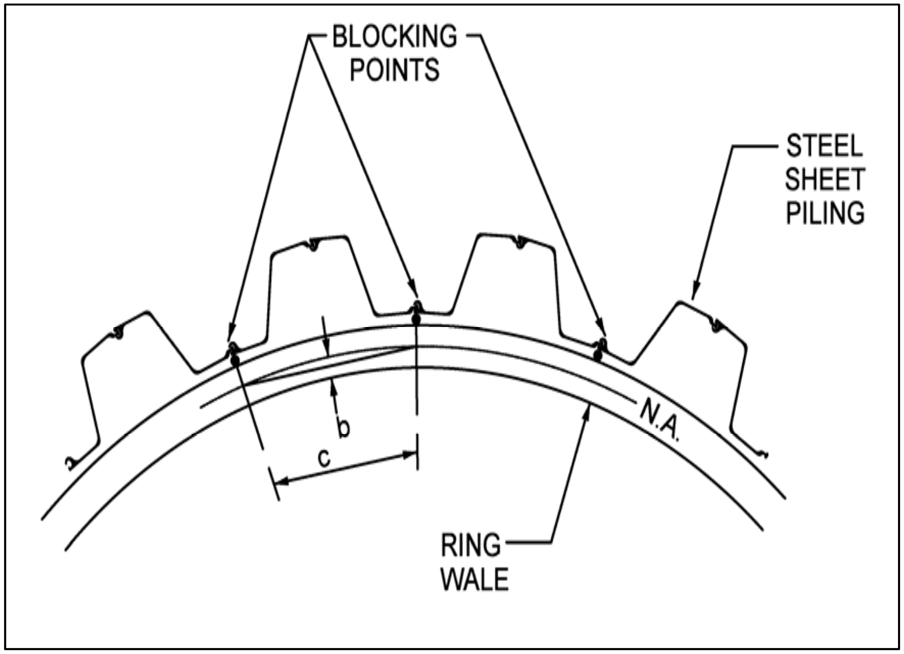
b = arc rise = $R - [R^2 - (c/2)^2]^{1/2}$

R = Radius to wale neutral axis

c = Chord length over arc

A = Wale cross section area

S = Wale section modules



# Circular Wale—Buckling

$P_{cr} = 3EI/R^2$

where

$P_{cr}$ = Critical buckling load in wale

$E$ = Modulus of elasticity of wale

$I$ = Moment of inertia of wale about the vertical axis

For steel, $E = 29{,}000$ ksi

For concrete, $E = 57{,}000\sqrt{f'_c}$

- The factor of safety for buckling ≥1.5
- No allowance for temporary conditions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QUESTIONS