# LRFD Sheet Pile

## Design Concepts & Background

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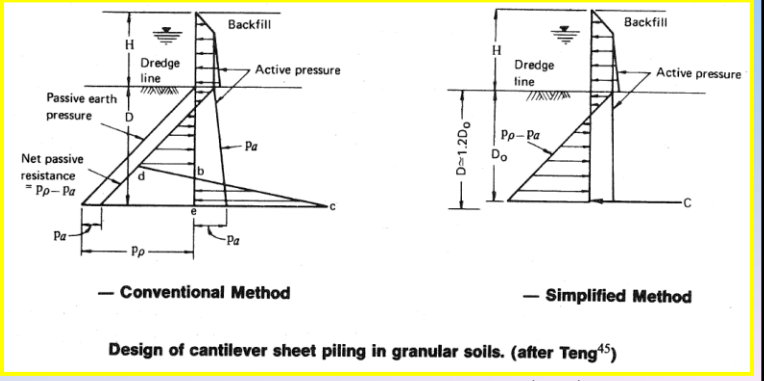
## LRFD Sheet Pile Walls

- Cantilevered Sheet Pile Walls
  - ASD Method
  - AASHTO LRFD Method
  - Compare AASHTO LRFD to FDOT Past Practice
  - LRFD Method Acceptable to FDOT
  - Plans Requirements
- Anchored Sheet Pile Walls
  - Design Method
  - Plans Requirements

# Review ASD Method

- Determine Soil & Water Parameters
- Compute Active & Passive EP Diagrams

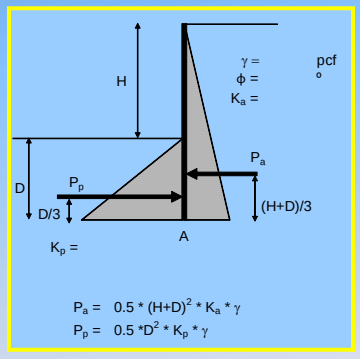



Design of cantilever sheet piling in granular soils. (after Teng[45])

Pile Buck, 1987

# Review ASD Method

- Compute $P_A$ & $P_P$ as a Function of D

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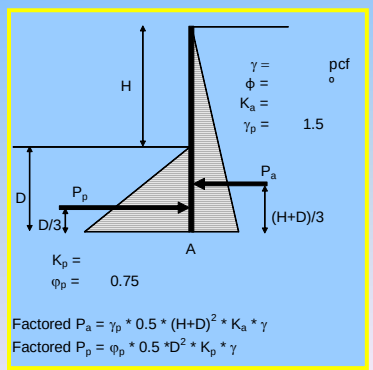
# Review ASD Method

- Compute Moments about Tip due to $P_A$ & $P_P$
- Determine Embedment for Balanced Moments
- Increase Embedment by 20% to 40%
- Determine Required Section Modulus (S) for $\sigma \leq 0.6$ Fy
- Determine Required Section Stiffness to limit deflection

# LRFD Method

- Determine Soil, Water & Surcharge Parameters
- Compute Factored EP Diagrams
- Compute Factored $P_A$ & $P_P$ as Function of D



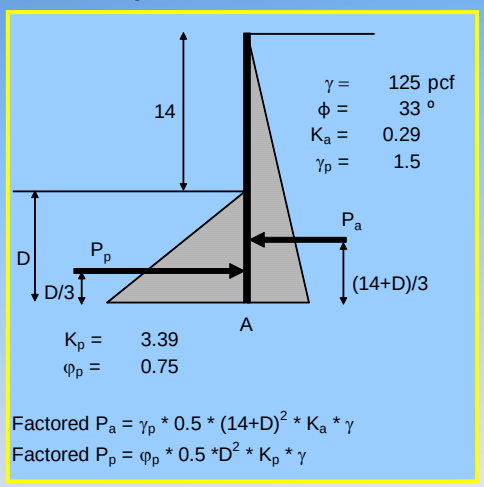
# LRFD Method

- Compute Factored Moments about Tip due to Factored $P_A$ & $P_P$
- Determine Embedment to Balanced Factored Moments
- Increase Embedment by 20%
- Determine Required Section Modulus (Z):

$$Z \geq M_{max} / \phi F_y \qquad \phi=0.9 \text{ for flexure}$$

- Determine Required Section Stiffness to limit deflection

# Simple Example to Compare Methods



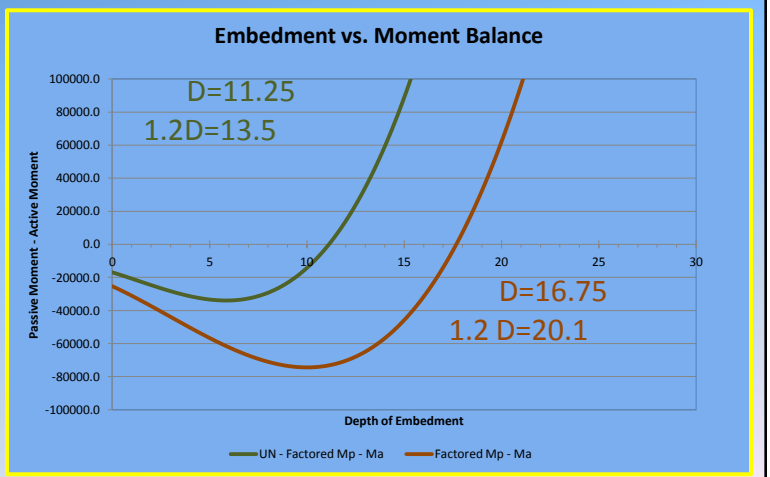

Factored $P_a = \gamma_p * 0.5 * (14+D)^2 * K_a * \gamma$

Factored $P_p = \varphi_p * 0.5 * D^2 * K_p * \gamma$

# Simple Example to Compare Methods

- Wall Supports Permanent Road
- Road will not be repaved
- Limit deflection to 1.5 inches

# Embedment, D



# ASD Section for Flexure

- Max Moment = 33,879 ft-lb/ft
- $S_{min}$ = 33,879 ft-lb / 0.6Fy
- $S_{min}$ = 33,879 ft-lb / 0.6(42,000 psi)
- $S_{min}$ = 16.13 $in^3$/ft

| S/ft | Z/ft | I/ft | Section |
|---|---|---|---|
| 18.1 | 21.79 | 84.38 | PZ 22 |
| 30.2 | 36.49 | 184.20 | PZ 27 |
| 48.5 | 57.17 | 361.22 | PZ 35 |
| 60.7 | 71.92 | 490.85 | PZ 40 |

# AASHTO Section for Flexure

- Max Factored Moment = 74,352 ft-lb/ft
- $Z_{min}$ = 74,352 ft-lb / 0.9Fy
- $Z_{min}$ = 74,352 ft-lb / 0.9(42,000 psi)
- $Z_{min}$ = 23.60 $in^3$/ft/ft

| S/ft | Z/ft | I/ft | Section |
|---|---|---|---|
| 18.1 | 21.79 | 84.38 | PZ 22 |
| 30.2 | 36.49 | 184.20 | PZ 27 |
| 48.5 | 57.17 | 361.22 | PZ 35 |
| 60.7 | 71.92 | 490.85 | PZ 40 |

# Check Deflection

- Deflection is a Service Limit State
- Various Methods & programs
- PZ 22: Δ = 3.3 inches
- PZ 27: Δ = 1.5 inches
- PZ 35: Δ = 0.8 inches
- PZ 40: Δ = 0.6 inches

# Review Results

- ASD:
  - Required Embedment = 13.5’
  - Section for Flexure = PZ 22
  - Section for Deflection = PZ 27
- AASHTO LRFD:
  - Required Embedment = 20.1’ (33% deeper)
  - Section for Flexure = PZ 27
  - Section for Deflection = PZ 27

# FDOT Procedure

- 2008 FDOT Internal Study
- Compared FDOT past ASD & LFD practice to AASHTO LRFD
- Found AASHTO Embedments Much Deeper, with Similar Sections
- Looked for Modification to AASHTO LRFD to more cost effectively implement the LRFD philosophy
- Design Bulletin C09-02 FDOT Procedure for LRFD Design of Sheet Pile Walls, March 2009

# FDOT SDG 3.13.3 Permanent and Critical Temporary Sheet Pile Walls

A. Determine the required depth of sheet pile embedment (D) using the procedure outlined in LRFD [11.8.4] and described in detail in LRFD [C11.8.4.1] with load factors of 1.0 and the appropriate resistance factor from LRFD [11.6.2.3].

B. Determine the required sheet pile section in accordance with LRFD [11.8.5], using the normal load factors for each load case.

## FDOT SDG 3.13.3 Permanent and Critical Temporary Sheet Pile Walls

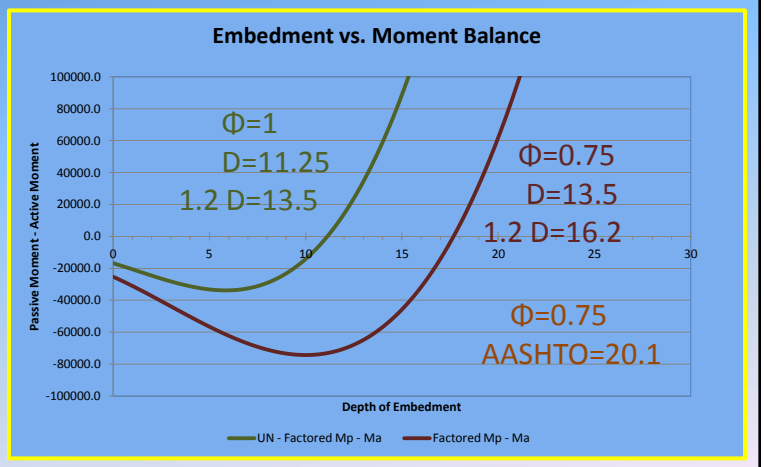
C. When the supported roadway will be paved or resurfaced before the wall deflects, the design horizontal deflection shall not exceed 1-1/2 inches.

D. When the supported roadway will be paved or resurfaced after the wall deflects the design horizontal deflection shall not exceed 3 inches.

## FDOT SDG 3.13.3 Permanent and Critical Temporary Sheet Pile Walls

E. When the wall maintains the structural integrity of a utility, the design horizontal deflection shall be established on a case-by-case basis in cooperation with the utility owner.

# FDOT Procedure




# Corrosion Protection

**AASHTO 11.8.7**

"The level and extent of corrosion protection shall be a function of the ground environment and the potential consequences of a wall failure"

# Corrosion Protection

**SDG 3.13.3 Permanent and Critical Temporary Sheet Pile Walls**

F. For permanent concrete sheet pile walls, comply with the tensile stress limits in *LRFD [5.9.4.2.2] and apply the "severe corrosive conditions" to walls with an Extremely Aggressive environment classification.*

# Corrosion Protection

SDG Table 3.5.3-1 Sacrificial Thickness for Steel Piles (inches)

| Steel Component | Slightly Aggressive | Moderately Aggressive | Extremely Aggressive |
|---|---|---|---|
| Cantilevered Sheet Piles | 0.045 | 0.090 | 0.135 |

- See Commentary for Table in SDG 3.5.3

## Plans Requirements

- Section Modulus $in^3/ft$
- Moment of Inertia $in^4/ft$
- Tip Elevation or Embedment Requirements

## Anchored Walls

- Support Greater Heights
- Support Larger Loads
- Reduce Embedment

# Anchored Walls

- Anchor Types
  - Prestressed Soil Anchor
    - Single or Multiple Levels
  - Dead Man

# Anchored Walls

- Prestressed Soil Anchor
  - Active Support
  - Commonly Drilled & Grouted
  - Drill ≥ 15% Below Horizontal
  - Bonded Zone
  - Unbonded Zone
  - Tendon may be Bar or Strand
  - Corrosion Protection
  - Advantages & Disadvantages

# Anchored Walls

- Dead Man
  - Normally Passive Support
  - Any Tendon Angle
  - Dead Man Position Critical
  - Corrosion Protection
  - Advantages & Disadvantages

# Anchored Walls

- AEP Diagram for Earth Load

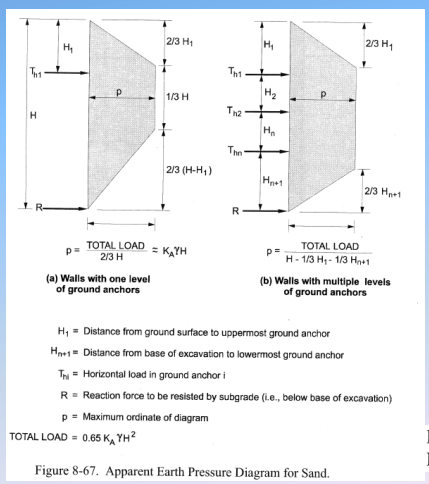



Figure 8-67. Apparent Earth Pressure Diagram for Sand.

FHWA NHI-07-071
Earth Retaining Structures

# Anchored Walls

- Superimpose Normal Diagrams for Other Factored Loads: (water, surcharges, etc.)
- Compute Horizontal Anchor Loads
- $\sum F_H$ for Base Reaction
- Embedment or Anchor for Base Reaction
- Use appropriate resistance factor for passive earth pressure to compute Embedment

# Anchored Walls

- Compute Horizontal Anchor Loads

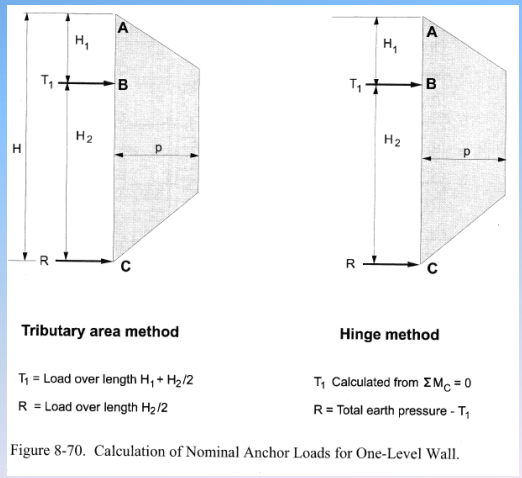



Figure 8-70. Calculation of Nominal Anchor Loads for One-Level Wall.

# Anchored Walls

- Anchor Loads
  - Determine anchor inclination
    - ROW
    - Location of Anchoring Stratum
    - Location of Utilities
  - Resolve Longitudinal & Vertical Loads
    - Resistance Factors vary w- Tendon Type

# Anchored Walls

- Evaluate Tendon Type
  - Distance to Anchor Stratum
  - Design Life
  - Corrosion Hazard
  - Corrosion Protection
  - Construction Methods
  - Consequence of Failure
- Size Bonded Zone or Dead Man

# Anchored Walls

- Determine Unbonded Zone or Locate Dead Man
- Bonded Zone must not Load the Active Failure Wedge
- Locate Entire Passive Resistance Wedge Behind Active Failure Wedge

# Anchored Walls

- Evaluate Section for Bending Moments
  - Revise Section or Anchor Position(s)
- Evaluate Bearing Resistance Below Excavation for Vertical Loads & Vertical Component of Anchor Loads

# Anchored Walls

- Evaluate Global Stability at Service Limit State
- Evaluate Deflection & Ground Settlement at Service Limit State
- Design Walers, etc for Maximum Anchor Spacing

# Anchored Walls

- Plans Requirements
  - Wall Section, Walers, Connections
  - Tip Elevation
  - Factored Anchor Load (kpf)*
  - Service Anchor Load (kpf)*
  - Maximum Anchor Spacing
  - Dead Man & Anchor Rod Details

# Questions?

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