Bridge Design Manual Requirements Related to Foundations and MSE Walls

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Geotechnical Requirements for Foundations

Preliminary Engineering

- Structure Type Study
  - General foundation type
  - Boring logs, including moisture content, grain size, plasticity limits, and RQD

Stage 1 Detailed Design

- Bridge Preliminary Design Report
  - Structure foundation report as described in the Specifications for Subsurface Investigations

Stage 2 Detailed Design

- Participate in plan development and review process

Bridge Design Manual

Geotechnical information is primarily in

- Section 200 – Preliminary Design
- Section 300 – Detailed Design

Although Stage 1 Detailed Design is considered to be preliminary design, some geotechnical information required for Stage 1 is found in Section 300.

Foundation Types

- Spread Footings
- Piles
  - H-piles
  - Cast-in-place Concrete Piles
- Drilled Shafts

Spread Footings

Used for:

- Grade separation structures
  (if foundation soils are cohesive, then settlement is a concern)
- Water crossings where the spread footing is on bedrock

Procedures for calculating allowable bearing pressure are in the AASHTO specifications and FHWA manuals

Factor of Safety = 3.0

Spread Footings

- Consider the footing dimensions when determining allowable bearing pressure (estimate dimensions for preliminary design).
- Revise the allowable bearing pressure during Stage 2 detailed design based on actual footing dimensions.
  (note that this is after the foundation report is complete.)

Spread Footings

Stage 1 plans are to include:

- Elevation at bottom of footing
- Preliminary design loads
- Estimated size of the footing
- Allowable bearing pressure

Spread Footings

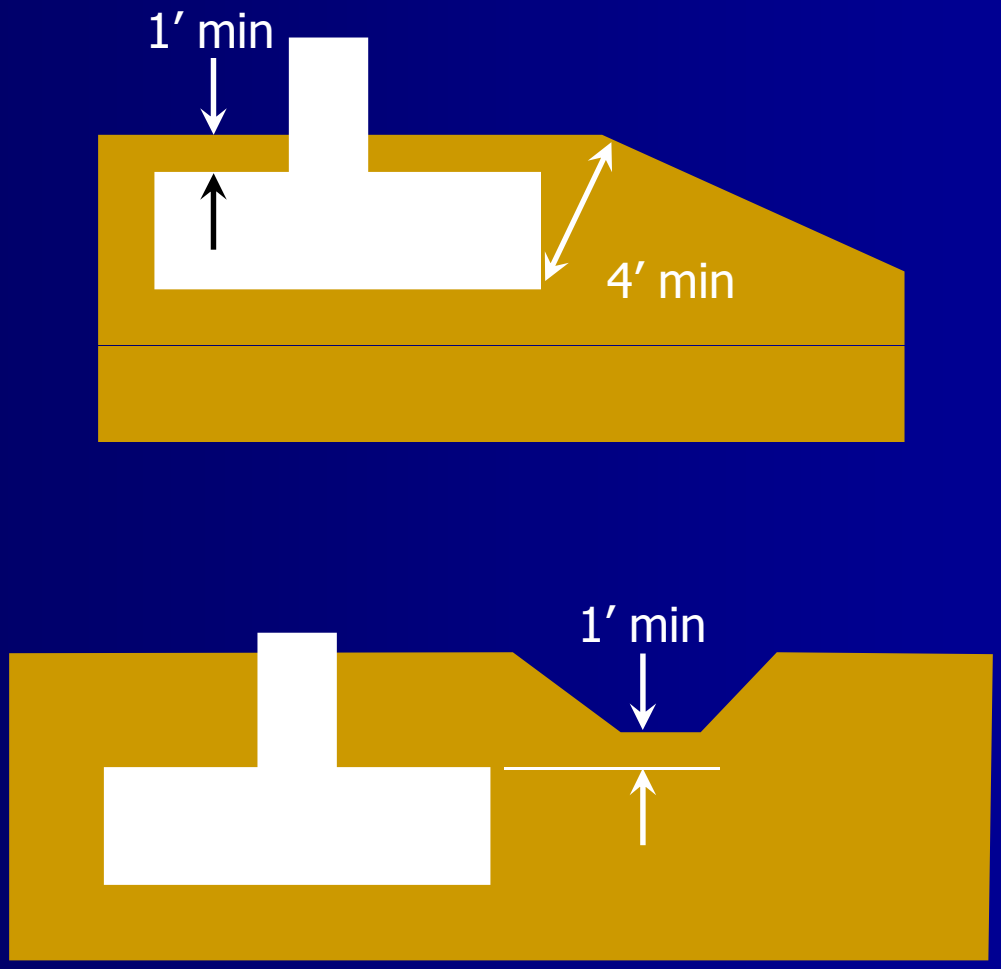
Spread footings not on bedrock require elevation reference monuments constructed in the footings. This is for monitoring settlement of the footing.

There is a general note in Section 600 that needs to be included in the plans.

Spread Footings

Where a spread footing abutment is bearing on an embankment supported by an MSE wall, the allowable bearing pressure for the spread footing shall be 4,000 lb/ft^2

Footing Elevations



Spread Footings on Bedrock

- Minimum embedment of 3 inches
- Waterway opening cannot be restricted by the footing.

Sliding Resistance for Spread Footings

$$F = P_v \cdot f$$

f is the coefficient of friction or friction factor (tan δ)

Coarse-grained without silt, f=0.55
Coarse-grained with silt, f=0.45
Silt, f=0.35
Clay, f=0.35 but F ≤ ½·cohesion
Shale, f=0.55
Sound rock, f=0.7

- Factor of Safety = 1.5
- Consider jointing and bedding in rock

Sliding Resistance for Spread Footings

If frictional resistance is not sufficient, consider

- Increasing footing width
- Adding a shear key to the footing
- Including passive pressure
- Using sheeting or anchors

Piles

- H-Piles used where piles are driven to refusal on bedrock
- Cast-in-place reinforced concrete piles are used where piles do not bear on bedrock

- Minimum tip elevation required for friction piles where scour is a concern

H-Piles

Size	Design Load (tons)	Ultimate Bearing Value (tons)
HP 10x42	55	110
HP 12x53	70	140
HP 14x73	95	190

- Design load based on 0.25 F_y for 36 ksi steel
- Only the ultimate bearing value should be on the plans, not the design load
- Use the calculated ultimate bearing value on the plans, not necessarily the maximum in the table
- Do not use HP 8x36 size

H-Piles

Steel pile points

- Use when piles are driven to refusal on hard bedrock
- Not required when driving through more than 50 feet of cohesive soil above rock or when driving to refusal on shale

Splices

- Full penetration butt weld or
- Approved commercial splicer

Cast-in-place Concrete Piles

Diameter	Design Load (tons)	Ultimate Bearing Value (tons)
12″	50	100
14″	70	140
16″	90	180

- Only the ultimate bearing value should be on the plans, not the design load
- Use the calculated ultimate bearing value on the plans, not necessarily the maximum in the table
- For capped-pile piers, use 16″ diameter pile
- If exposed length of capped-pile pier is more than 20 feet, 18″ diameter piles can be used.

Cast-in-place Concrete Piles

Pile wall thickness is addressed in CMS Item 507

$$t = R/900{,}000$$

where,

t is the minimum pile wall thickness, inches

R is the ultimate bearing value, pounds

The minimum value of t is 0.25 inches

Pile Spacing

Maximum pile spacing

- Capped-pile piers, 7.5 feet
- Capped-pile abutments, 8 feet
- Front row of stub abutments, 8 feet
- Front row of wall type abutments and retaining walls, 7 feet

Minimum pile spacing is specified in AASHTO

Downdrag Forces on Piles

- A concern when piles are driven through compressible soils
- Include downdrag force in total pile design load
- Try to avoid problem by placing settlement platforms and driving piles after substantial completion of settlement

Prebored Holes

- Prebored holes required for piles driven through 15 feet or more of new embankment
- Neglect skin friction along the length of the prebore for normal design capacity
- Do not neglect skin friction if downdrag is a concern

Pile Load Testing

Dynamic Load Testing

- Required on all projects that include piles
- Establish driving criteria
- One testing item required for each pile size and ultimate bearing value
- Restrikes are in the specification, but are not required unless a pay item is included
- Recommend restrikes for saturated silt, saturated silty sand, and medium stiff clay

Pile Load Testing

Static Load Testing

- Static load test required when pile length for one structure is more than 10,000 feet for piling of the same size and ultimate bearing value
- Each static load test also requires one dynamic testing item and three restrikes

Drilled Shafts

Drilled shafts should be considered when

- They would prevent the need for cofferdams
- They are economical due to high design loads
- They protect against scour
- They provide resistance against lateral and uplift loads
- Bedrock is too shallow for piles but too deep for spread footings
- Vibrations due to pile driving are a concern

Drilled Shafts

- Design procedures are in FHWA Manual "Drilled Shafts: Construction Procedures and Design Methods", FHWA IF-99-025
- Typical diameters are 3.5 feet for piers and 3 feet for abutments
- For piers, the rock socket diameter is generally reduced by 6 inches
- For large lateral loads, specialized testing or a lateral load test may be required

Noise Barriers – Section 800

- Supported by drilled shaft foundations
- Plan insert sheets include design method to determine drilled shaft length
- Design method utilized soil type (cohesionless or cohesive) and corrected blow counts (N')

Retaining Walls

- Conventional cast-in-place reinforced concrete retaining wall
- Mechanically Stabilized Earth (MSE) wall

- Consider using MSE wall if wall area > 5,000 ft^2

MSE Walls

Internal Stability

Responsibility of vendor / manufacturer

- Pullout resistance
- Tensile strength of reinforcement

External Stability

Responsibility of design agency

- Sliding
- Overturning / Eccentricity
- Bearing Capacity
- Global Stability

MSE Walls

Design criteria for external stability analyses

- Sliding, FS > 1.5
- Overturning, FS > 2.0
- Bearing Capacity, FS > 2.5
- Global (overall) stability

  FS > 1.5 for walls supporting spread footing abutments

  FS > 1.3 for all other walls

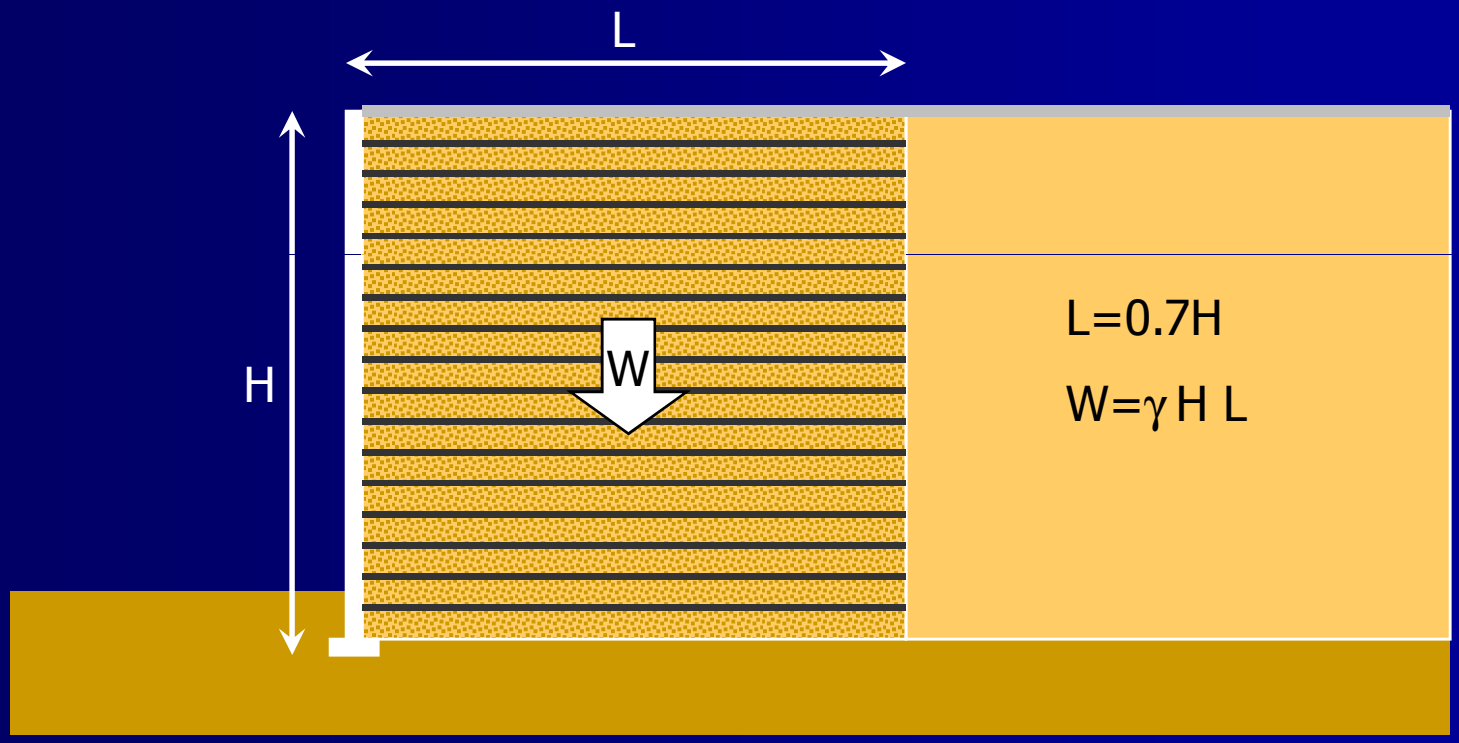
MSE Walls

Soil parameters			
Soil Zone	Unit Weight	Friction Angle	Cohesion
Reinforced zone	120 lb/ft^3	34°	0
Retained soil	120 lb/ft^3	30°	0
Foundation soil	120 lb/ft^3	For sliding see BDM 303.4.1.1, otherwise determine from soil borings	

Problem

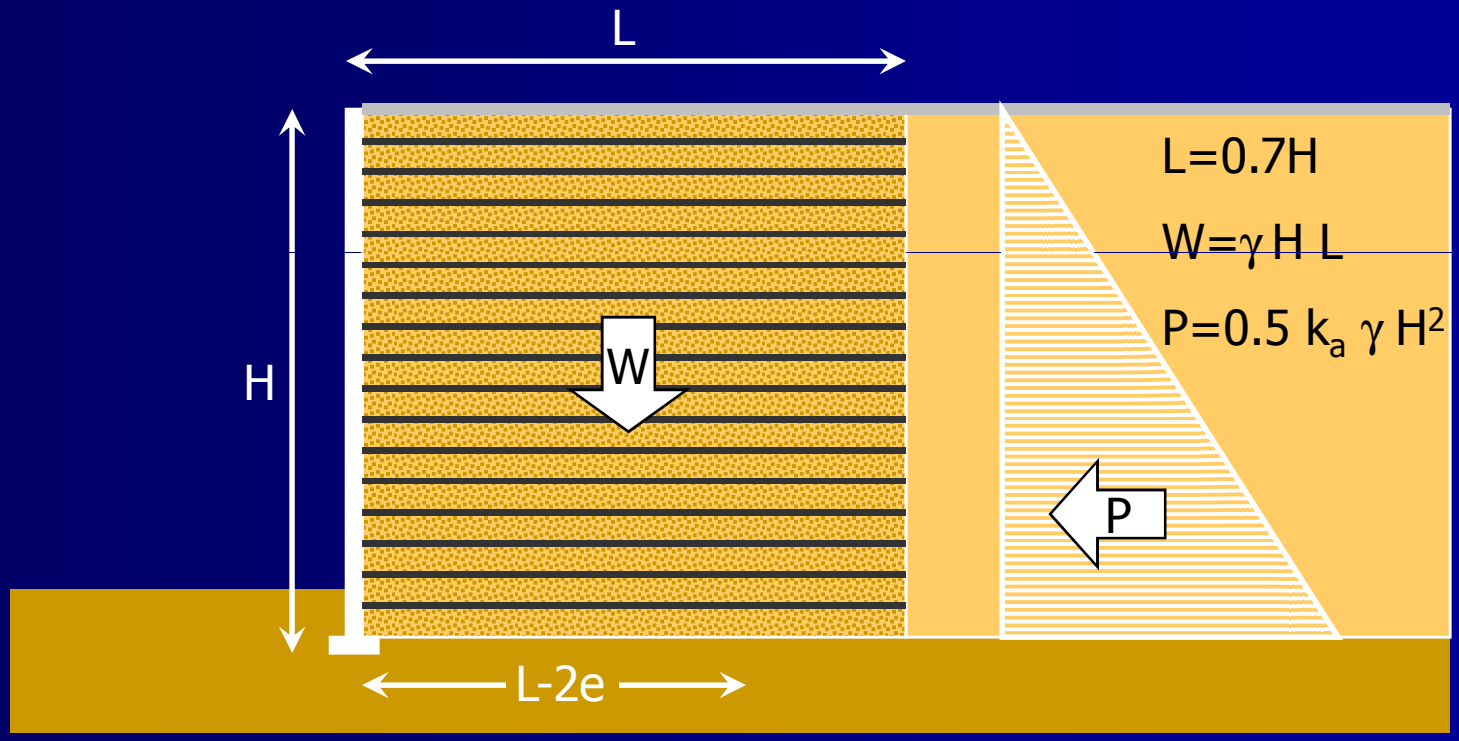
Quite often, the allowable bearing capacity recommended by the design consultant is less than the bearing pressure calculated by the MSE wall vendor.

Bearing Pressure for MSE Wall



Neglects eccentricity of the load!

Correct Bearing Pressure for MSE Wall



$e = 0.33\ H\ P\ /\ W$

Temporary Shoring – Section 208

- Provide design of temporary shoring when it supports a roadway with traffic and the height of the wall exceeds 8 feet.
- Study the feasibility in the Structure Type Study
- If temporary shoring is supporting a railroad, then the design requirements are determined by the railroad company.

Rehabilitation & Repair

- Foundations for widened structures
  - Regardless of the foundation type supporting the existing structure, foundations for widened portion should be supported by piles or drilled shafts to limit differential settlement.
- Scour needs to be considered when reusing existing foundations.

Plan Notes

- General Notes
  - Section 605 – Embankment construction
  - Section 606 – Foundations
- Detail Notes
  - 701.1 – Steel sheet piling
    Minimum section modulus for steel sheet piling left in place

Appendix

- Special Provisions for MSE walls
  - Four manufacturers – 4 sets of special provisions
    - The Reinforced Earth Company
    - Foster Geotechnical
    - SSL, LLC
    - Tensar Earth Technologies
  - Include all four (or three) of the special provisions in the plans (use of the Tensar wall has some restrictions)