Key Lessons Learned – Design & Construction of MSE Wall Structures

36th Annual Seminar
GEO-Omaha 2019

By:
Ryan Berg, P.E., D.GE, F.ASCE
Ryan R. Berg & Associates, Inc

© Ryan R. Berg, 2019

a.k.a. –
Keys to Success for Design & Construction of MSE Walls
Outline

• Design Procedures/Standards
• Contracting Procedures/Relationships, and Assumptions
• Design and Detailing
• Construction
• Summary

Design Procedures/Standards
AASHTO/FHWA

- SIMPLIFIED Method
- COHERENT GRAVITY Method

AASHTO/FHWA - Typical Structure
NCMA

• Tied Back-Wedge Method

NCMA

- Typical Structures
NCMA – Taller, Non-Typical (?) Structures

GRS-IBS – COMPOSITE DESIGN
Composite Bridge Abutment

GRS-IBS
- Typical Structure

STH 40 Bloomer, WI
Emerging Design Procedures/Standards

- **SIMPLIFIED STIFFNESS** Method, see Allen and Bathurst, ASCE JGGE

- *Limit Equilibrium Design for MSE Structures with Geosynthetic Reinforcements*, see FHWA report by Leshchinsky et al.

Design Procedures/Standards

- AASHTO/FHWA
- NCMA
- GRS-IBS
- Simplified Stiffness
- LEM for Geosynthetic Reinforced MSEs

Any Questions??

Which one should I use?
Which one is correct?

- Do Not Mix Design Procedures
- Engineer your Structure
MBW Unit Faced Walls
NCMA Design
Engineer Your Structure

Contracting Procedures/Relationships, and Assumptions

• Highway v. Private
• Well-defined roles v. varying roles
• Common assumptions/notes
Commonly Seen Assumptions

- Wall is designed for drained conditions. Owner’s engineer shall verify.
- Global stability is the responsibility of the Owner. Owner’s engineer shall verify.
- Assumed minimum foundation bearing capacity of 4,000 psf. Owner’s engineer shall verify.
- Construction inspection by the Owner’s engineer.
- Wall is designed with the following assumptions:
  - Soil shear strength and unit assumed weight values.
  - Values shall be verified by the Site Soils Engineer.
  - Wall should be redesigned if values are lower.

Assumptions

- Lead to narrowly defined work scopes by the various engineers providing services on a development project
  - Wall Engineer;
  - Subsurface Investigation Engineer;
  - Civil Engineer;
  - Structural Engineer;
  - Construction Observation Engineer;
  - Landscape Architect; and
  - others
Relationship Example

22-foot high wall, to extend yard behind a house

Relationship Example

Subsurface Invest.
Slope Stability

Wall Design
Failure
Reinforced mass slid downslope 42 feet

Homeowner’s 4-year old daughter was playing here when wall failed
Figure 6. Geotechnical consultant’s stability model with geotechnical consultant’s critical global stability failure surface (FS = 1.24) and authors’ compound stability failure surface (FS = 1.13).

Figure 10. Authors’ stability model with critical global stability failure surface (FS = 1.00) and critical compound failure surface (FS = 0.99).
**Relationship Example**

Subsurface Invest.  
Slope Stability

* Slope stability excluded any failure modes through the reinforced mass;  
Used Prelim Design for analysis

No direct Communication link between structure designers

**Assumptions**

- **Engineer – Design Assumptions**
  - Use appropriate, and verify
  - Do not assume
  - Do not release drawings for construction, until verified
Design and Detailing

5.10.4: Factors of Safety and Design Criteria Summary

Table 5-2: Recommended Minimum Factors of Safety and Design Criteria for Conventional Reinforced SRWs (d, 3.1, and 4)

<table>
<thead>
<tr>
<th>Code</th>
<th>Factor</th>
<th>FS</th>
<th>SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Overstrikes</td>
<td></td>
<td>1.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Pullout</td>
<td></td>
<td>1.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Flame阿尔夫</td>
<td></td>
<td>1.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Internal Comp. Stability</td>
<td></td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Geotechnical Parameter</td>
<td></td>
<td>2.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Overall Stability</td>
<td></td>
<td>1.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

NOTES:
1. Minimum FS based on measured site-specific soil/wall data . . .
2. . . . . . . designer may need to use larger factors of safety . . . or conservative estimates of parameter values. . . . .

1. . . . . . assume that stability calcs are based on measured site-specific soil/wall data . . .
Design and Detailing

- Are you using site-specific soil data defined on actual samples of soils
- Are you observing construction

Engineer –
- Select appropriate levels of safety
- Do not default to $F_{MIN}$

Reinforced Fill

<table>
<thead>
<tr>
<th>Sieve</th>
<th>AASHTO FHWA</th>
<th>NCMA Suggested</th>
<th>GRS-IBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch</td>
<td>Na</td>
<td>100</td>
<td>Na</td>
</tr>
<tr>
<td>¾ inch</td>
<td>100</td>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>½ inch</td>
<td>Na</td>
<td>Na</td>
<td>100</td>
</tr>
<tr>
<td>3/8 inch</td>
<td>Na</td>
<td>Na</td>
<td>90 – 100</td>
</tr>
<tr>
<td>No. 4</td>
<td>Na</td>
<td>100 – 20</td>
<td>20 – 55</td>
</tr>
<tr>
<td>No. 8</td>
<td>Na</td>
<td>Na</td>
<td>5 – 30</td>
</tr>
<tr>
<td>No. 16</td>
<td>Na</td>
<td>Na</td>
<td>0 – 10</td>
</tr>
<tr>
<td>No. 40</td>
<td>0 – 60</td>
<td>0 - 60</td>
<td>Na</td>
</tr>
<tr>
<td>No. 50</td>
<td>Na</td>
<td>Na</td>
<td>0 – 5</td>
</tr>
<tr>
<td>No. 200</td>
<td>0 – 15</td>
<td>0 - 35</td>
<td>Na</td>
</tr>
</tbody>
</table>
MBW Unit Faced Walls

- Engineer – Reinforced Soil
  - Specify an appropriate soil, % fines
  - Design & detail for this soil

Design Assumption

- Soils are, and stay, dry/moist – i.e., no water loads
- State required bearing capacity and others must provide/confirm

- Engineer – Design Assumptions
  - Use appropriate, and verify
  - Do not assume
  - Do not release drawings for construction, until verified
- Soils stay dry – see details
- Bearing capacity/resistance – Model/Calculate correctly
- Engineer – Design Assumptions
  - Use appropriate, and verify
  - Do not assume
Engineering Details

Importance of project specific details
Drainage

- Engineer/Details – Internal Drainage
  – Include, unless you engineer out
Typical Application

Site Slopes to Wall

Cut/Fill

Detention Basin
• Engineer/Details – Surface Drainage
  – Address
  – Coordinate w/ other designers & contractors

• Engineer/Details – Surface Drainage
  – Address, both during & after construction
  – Coordinate w/ other designers & contractors
Surface Drainage Failure During Construction

2nd Failure after Erosion Control Measures Installed
The Engineered Solution!

Tall Walls

- No bearing pads
- FHWA – recommended maximum height of about 32 feet, without setbacks
Tall Walls

• Engineer – Wall Height
  – Increased engineering & detailing for very tall walls (>> typical)

Construction

Largest component, by volume is?
• Poor fill placement/compaction at the face
• Downdrag of geogrid on back of MBW unit
• Add some water
• Failure

Facing Connection Failure Example
Soil Compaction

- Reinforced soil mass critical to wall performance
- Fill placement and compaction at MBW face is critical; but easy to be sloppy

- Construction
  - Observation
  - Compaction of reinforced soil mass
  - Compaction at the face/connection
Typical Wall

- Site development
- Used to build-up low end of the site
- Surface runoff drains to low end of site, i.e., wall structure
- Wall Designer & Wall Contractor – Subs to Prime Contractors
- Designers isolated from each other

Wall Geometry

- Dimensions:
  - Height: 10 ft
  - Width: 1 ft
  - Depth: 3 ft
  - Angle 7°
  - Angle 16°
  - Length: L=13.4 ft

Scale:

0 2 4 6 [ft]
Wall Details

- Curb & Gutter
- Concrete Pavement
- 3 ft
- 1 ft Gravel Column
- 10 ft
- 1 ft Gravel Leveling Pad

Wall Design

- Sliding
- Overturning
- Bearing
- Tensile Overstress
- Pullout
- Face Shear
- Connection
- Global Stability
- Compound Stability

Typical Assumption:
- Drained conditions
- H = 10 ft and All FSs Met

What possibly could go wrong?
Pavement & Structure Above Wall

Top of Wall
Out-Of-Service Wall

Out-Of-Service Wall
Out-Of-Service Wall

Are pavements impervious? NO
Do curb & gutter collect all runoff? NO
Is landscaping irrigated? YES

TYPICAL Wall

In-Service Wall
Drainage

• Engineer/Details – Internal Drainage
  – Include, unless you engineer out

Global/Compound Stability

FS = 1.30
$H_{\text{DESIGN}} = 10 \text{ ft}$

$FS_{G/C} = 1.30$

$H_{\text{NOW}} \approx 12 \text{ ft}$

$FS_{\text{NOW}} \approx \frac{(10)^2}{(12)^2} \times 1.30 = 0.90$

**Summary**

- Do Not Mix Design Procedures
- Engineer your Structure
- Engineer – Design Assumptions
  - Use appropriate, and verify
  - Do not assume
  - Do not release drawings for construction, until verified
Summary (con.)

• Engineer –
  – Select appropriate levels of safety
  – Do not default to $F_{MIN}$

• Engineer – Reinforced Soil
  – Specify an appropriate soil, % fines
  – Design & detail for this soil

• Engineer/Details – Internal Drainage
  – Include, unless you engineer out

Summary (con.)

• Engineer/Details – Surface Drainage
  – Address, both during & after construction
  – Coordinate w/ other designers & contractors

• Engineer – Wall Height
  – Increased engineering & detailing for very tall walls (>> typical)

• Construction
  – Observation
  – Compaction of reinforced soil
  – Compaction at the face connection
THANK YOU

RyanBerg@att.net

Inca Walls, Urubamba River Valley, 14th Century Design & Construction