69th Annual Ohio Transportation Engineering Conference

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MSE Wall Engineering
A New Look at Contracting, Design, and Construction
Why Do We Need Change?

- Whitman (1984) states that appropriate structural designs should have a failure rate in the range of 1 in 1,000 to 1 in 10,000.

- Soong and Koerner (1999) reported MSE wall failures at a rate of approximately 1 in 1,000 (26 failures reported for approximately 35,000 walls).
Why Do We Need Change?
Why Do We Need Change?
Why Do We Need Change?
Why Do We Need Change?
Why Do We Need Change?
Why Do We Need Change?
Where Do You Want to Put Your Risk?

- **Cost to construct**
  - MSE Wall typical cost - $30 to $65 per sf

- **Cost of failure**
  - MSE Wall stabilization - $60 to $130 per sf
  - MSE Wall replacement - $300 to $650 per sf
What Change is Needed?

- Better communication between designers
- Better identification of conflicts
- Better documentation during construction
- Accountability by all parties
Results in Better MSE Walls
Results in Better MSE Walls
Results in Better MSE Walls
Results in Better MSE Walls
Traditional Design Information

- Civil
- Utility
- Drainage
- Structural
- Geotechnical
  - Recommendations based on 30% plans
  - Simplified MSE Wall parameters (if provided at all)

“Who is looking out for the MSE Wall?”
## Traditional Geotechnical Report Information

### TABLE 3: MSE WALL ALLOWABLE BEARING RESISTANCE

<table>
<thead>
<tr>
<th>MSE Wall</th>
<th>Maximum Wall Height (feet)</th>
<th>Wall Section</th>
<th>Allowable Bearing Resistance (psf)</th>
<th>Maximum Allowable Wall Height</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>70% Anchors</td>
<td>100% Anchors</td>
</tr>
<tr>
<td>A</td>
<td>11</td>
<td>Entire Wall</td>
<td>4,300</td>
<td>11</td>
</tr>
<tr>
<td>B</td>
<td>11</td>
<td>Wall Sections Less Than 18 Feet High</td>
<td>3,000</td>
<td>15</td>
</tr>
<tr>
<td>B</td>
<td>21*</td>
<td>Entire MSE Wall Portion*</td>
<td>4,000*</td>
<td>21*</td>
</tr>
<tr>
<td>C</td>
<td>25</td>
<td>Entire Wall</td>
<td>4,300</td>
<td>23</td>
</tr>
<tr>
<td>D</td>
<td>22</td>
<td>Entire Wall</td>
<td>4,000</td>
<td>22</td>
</tr>
<tr>
<td>E</td>
<td>20</td>
<td>Entire Wall</td>
<td>4,300</td>
<td>20</td>
</tr>
<tr>
<td>F</td>
<td>28</td>
<td>Entire Wall</td>
<td>4,300</td>
<td>23</td>
</tr>
<tr>
<td>I</td>
<td>6</td>
<td>Entire Wall</td>
<td>4,000</td>
<td>6</td>
</tr>
</tbody>
</table>

*Treatment of the wall foundation subgrade as discussed in Section 6.6.2 will be required to develop the allowable bearing resistance.*
### TABLE 5: LATERAL EARTH PRESSURES – MSE AND CIP RETAINING WALLS

<table>
<thead>
<tr>
<th>Wall Backfill</th>
<th>Equivalent Fluid Pressure for Backfill Slopes of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3H:1V</td>
</tr>
<tr>
<td>MSE Wall Reinforced Volume Granular Backfill</td>
<td>44 pcf</td>
</tr>
<tr>
<td>Type C Backfill</td>
<td>53 pcf</td>
</tr>
</tbody>
</table>
Traditional Geotechnical Report Information

6.2 RETAINING WALL DESIGN CRITERIA

The bearing resistance values and maximum allowable wall heights presented in the following report sections are based on the criteria listed below.

1. The walls will be embedded at least 2 feet below final grade next to the wall.
2. The walls will have a two-foot-wide mow strip at the toe of the walls. The ground surface beyond the mow strip will slope down at a maximum slope of 4 horizontal to 1 vertical (4H:1V) for a horizontal distance of 20 feet or less and will then be flat and level.
3. The MSE and CIP walls will be well drained.
4. The MSE walls will have a minimum anchor length of 8 feet and all the wall anchors will have the same length within a vertical section of wall. In addition, the minimum MSE wall anchor length will not be less than 70 percent of the wall height.
5. The walls will have a safety factor of at least 2.0 for bearing resistance.
6. The wall foundation subgrades will be prepared in accordance with the recommendations presented in this report.
7. Design soil strengths for computing the bearing resistance values were selected based on triaxial test results and TCP test results.
8. The maximum allowable wall heights that would not apply a bearing pressure that would exceed the allowable soil bearing resistance were computed based on a lateral earth pressure of 40 pcf, backfill soil unit weight of 125 pcf, and a distributed surcharge load of 240 psf.
9. The wall height is the vertical distance from the base of the wall at the top of the leveling pad to the top of the retained fill.
6.5 SLIDING RESISTANCE

An ultimate coefficient of sliding resistance of 0.40 is recommended for design of the MSE and CIP walls. The retaining walls should have a safety factor of at least 1.5 with respect to sliding.
Traditional Design

- **Project Plans**
  - Civil
  - Utilities
  - Drainage
  - Structural
  - Standard Design Sheets
  - Geotechnical Report “For Information Only”

“Who is looking out for the MSE Wall?”
Traditional Drainage Plan Sheet
Disclaimer: The use of this standard is governed by the “State Engineering Practice Act”. No Warranty of any kind is made by the DOT for any purpose whatsoever. The DOT assumes no responsibility for the conversion of this standard to other formats or for incorrect results or damages resulting from its use.
Traditional MSE Wall Design

- **Construction Contract Design and Coordination**
  - G/C designs MSE Wall (Shop Drawings)
  - CM reviews shop drawings
  - CM coordinates with Contractor to resolve field issues

“Who is looking out for the MSE Wall?”
Geotechnical Investigation and Report

Design Begins

30% to 60% Plans

100% Plans

Owner Review

Project Bid

Contractor Selects Wall Designer

Contract Awarded

Wall "Shop Drawings" Submitted

Owner Review

Construction Begins

Field Issues Addressed by CM

What's Missing???
Design Review

- Civil
- Utility
- Drainage
- Structural
- Geotechnical

“Who is looking out for the MSE Wall?”
Traditional Results
Traditional Results
Traditional Results
Traditional Results
Traditional Results
Traditional Results
Traditional Results
Traditional Results
Retaining Wall Engineer

- Single point of contact
- In charge of coordinating all facets of MSE wall design between disciplines (Design and Construction)
- Works out conflicts between disciplines
- Verify construction documentation
100% Plans

RWE Conflict Review

Geotech Review

Conflict Resolution

Project Bid

Contractor Selects Wall Designer

Contract Awarded

Wall “Shop Drawings” Submitted

Owner Review

RWE IDC

Owner Review

Construction Begins

Wall Issue Resolution Coordinated By RWE

Final Acceptance Report By RWE
RWE Design Duties

- Geotechnical Investigation
  - MSE wall specific strength parameters

<table>
<thead>
<tr>
<th>Wall ID</th>
<th>WALL STATION RANGE</th>
<th>SELECT FILL SOIL</th>
<th>RETAINED SOIL</th>
<th>FOUNDATION SOIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>0+00 to 8+62</td>
<td>130 34</td>
<td>non-select</td>
<td>125 25</td>
</tr>
<tr>
<td>E2</td>
<td>0+00 to 17+79</td>
<td>130 34</td>
<td>combination of non-select and Type A emb.</td>
<td>125 30</td>
</tr>
<tr>
<td>E3</td>
<td>0+00 to 7+35</td>
<td>130 34</td>
<td>non-select</td>
<td>125 25</td>
</tr>
<tr>
<td>E4</td>
<td>0+00 to 9+76</td>
<td>130 34</td>
<td>non-select</td>
<td>125 25</td>
</tr>
<tr>
<td>E5</td>
<td>0+00 to 7+30</td>
<td>130 34</td>
<td>non-select</td>
<td>125 25</td>
</tr>
<tr>
<td>E7</td>
<td>0+00 to 4+80</td>
<td>130 34</td>
<td>combination of non-select and Type A emb.</td>
<td>125 30</td>
</tr>
<tr>
<td>4+80 to 6+10</td>
<td>130 34</td>
<td>combination of undisturbed clay and 5 of Type A emb.</td>
<td>83 30</td>
<td>0</td>
</tr>
<tr>
<td>6+10 to 10+40</td>
<td>130 34</td>
<td>combination of undisturbed clay and 5+16 of Type A emb.</td>
<td>83 30</td>
<td>0</td>
</tr>
<tr>
<td>10+40 to 12+60</td>
<td>130 34</td>
<td>combination of undisturbed clay and 0+17 of Type A emb.</td>
<td>83 30</td>
<td>0</td>
</tr>
<tr>
<td>12+60 to 16+80</td>
<td>130 34</td>
<td>combination of undisturbed clay and 0+17 of Type A emb.</td>
<td>83 30</td>
<td>0</td>
</tr>
<tr>
<td>16+80 to 25+65</td>
<td>130 34</td>
<td>combination of undisturbed clay and 0+17 of Type A emb.</td>
<td>83 30</td>
<td>0</td>
</tr>
</tbody>
</table>
RWE Design Duties

- **Project Plans**
  - Clearly identify anticipated materials
  - Standard Sheets modified to include site specific parameters
RWE Design Duties

- Review Plans and Specifications
  - Verify the geotechnical parameters
  - Verify that the geotechnical engineer has performed slope stability analyses for the final design
  - Identify conflicts that impact wall design and performance

Verify conflicts have been resolved.
# RWE Verifies Design Checklist

1. **General Information**
   - Is the wall vendor pre-approved? (visit [website] for list of pre-approved wall systems)
   - APL: [ ] Yes [ ] No [ ] NA [ ] Comments/Action Required
   - Is the wall within the limitations of the pre-approved product? (e.g., wall height, external loading, environmental constraints, seismic loading and other project specific constraints, visit for limitations)
   - APL: [ ] Yes [ ] No [ ] NA [ ] Comments/Action Required
   - Has the Contractor used the correct design survey data (e.g., existing ground elevations and horizontal affects) for wall design?
   - Project/Vendor Drawings: [ ] Yes [ ] No [ ] NA [ ] Comments/Action Required
   - Has the Contractor correctly reflected the location of utilities in the area of the wall(s)?
   - Project/Vendor Drawings: [ ] Yes [ ] No [ ] NA [ ] Comments/Action Required
   - Is the wall profile (top and bottom elevations) including start and end stations correct?
   - Project/Vendor Drawings: [ ] Yes [ ] No [ ] NA [ ] Comments/Action Required
   - Is the wall design life specified?
   - Spec/Section 2.8: [ ] Yes [ ] No [ ] NA [ ] Comments/Action Required
   - Have the following items been specified by the vendor and are they in conformance with the project requirements?
     - Material requirements
       - Soil Properties (strength, gradation, PI, workability, electrochemical)
       - Soil Reinforcement (alkaline and yield tensile strengths, reduction factors for geotechnical)
       - Concrete (strength and other properties)
       - Concrete reinforcement (type, number and strength)
       - Leveling Pad (strength)
       - Steel facing elements for wire mesh systems (alkaline and yield tensile strengths)
     - Construction sequences including sequence
     - Soils excavation procedures and restrictions for reinforced fill, retained fill and foundation preparation
       - APL/spec/PGK: [ ] Yes [ ] No [ ] NA [ ] Comments/Action Required
     - Facing alignment tolerances
       - Spec: [ ] Yes [ ] No [ ] NA [ ] Comments/Action Required

- Wall Elevations
- Leveling Pad
- Facing Units
- Utilities
- Drainage
- Wall Details
- Soil Reinforcement
- External Stability
- Internal Stability
RWE Preconstruction Duties

- Independent Design Check of Shop Drawings
  - Review calculations
  - Review plans and specifications
  - Review material submittals
## Drawing Review Checklist

### 1.0 DOCUMENTS

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Have you thoroughly reviewed the design drawings?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>Is there a set of all project drawings in the field trailer?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>Has the contractor submitted shop drawings?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>Have the shop drawings been approved by the designer and/or construction division manager?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.0 LAYOUT

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Have you located the horizontal and vertical control points?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>Do you know where the MSE/W/RSS begins and ends?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>Have you identified any locations of existing utilities, signs, pipes, lights that affect the proposed construction?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>Have you identified the elevations at top and bottom of MSE/W/RSSs?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>Have you identified the existing and finished grades?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>Do you know where the construction limits are?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>Have you identified how the site will be accessed and any provisions for material storage?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td>Is phased construction involved?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.0 FOUNDATION PREPARATION

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Are any special foundation treatments required?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>Is the foundation stepped?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.3</td>
<td>Is concrete leveling pad and the required elevation(s) shown on the drawings?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.4</td>
<td>Is shoring required?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 4.0 DRAINAGE

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Have you located the details for drainage?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>When must the drainage provisions be installed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>Where does the drainage system outlet and does it allow for positive drainage?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>Are geotextile filters required?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>Is a drainage barrier (geomembrane) required for this project?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 5.0 FACING

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Have you identified the facing type, shape, size, and architectural finishing?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>Are there different types, colors, or sized facing units on the job?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.3</td>
<td>How do the facing units fit together?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Specification Compliance Checklist

**Table 11-3. Checklist for Specification Compliance. (after FHWA NHI-08-094/095)**

<table>
<thead>
<tr>
<th>#</th>
<th>YES</th>
<th>NO</th>
<th>NA</th>
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</thead>
<tbody>
<tr>
<td>1.0 DOCUMENTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td></td>
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<tr>
<td>1.2</td>
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<td>1.3</td>
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</tr>
<tr>
<td>2.0 PRE-CONSTRUCTION QUALIFYING OF MATERIAL SOURCES / SUPPLIERS</td>
<td></td>
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</tr>
<tr>
<td>2.1</td>
<td></td>
<td></td>
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<tr>
<td>2.1.1</td>
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<td>2.3</td>
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<td></td>
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<tr>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RWE Preconstruction Duties

- Communicate critical wall system elements
- Provide project specific training to personnel involved with wall construction
- Communicate expectations
Field Inspection Checklist

Table 11-1: Outline of MSE/RSS Field Inspection Checklist Requirements.

1. Review the specifications and become familiar with:
   - material requirements
   - construction procedures
   - soil compaction procedures
   - alignment tolerances
   - acceptance/rejection criteria

2. Review the construction plans and become familiar with:
   - construction sequence
   - corrosion protection requirements
   - special placement to reduce damage
   - soil compaction restrictions
   - details for drainage requirements
   - details for utility consideration
   - construction of slope face
   - contract documents

3. Review material requirements and approval submittals.

4. Check site conditions and foundation requirements. Observe:
   - preparation of foundations
   - leveling pad (construction check level and alignment)
   - site accessibility
   - limits of excavation
   - construction documenting
   - drainage features, slopes, adjacent streams, lakes, etc.

5. On site, check reinforcement and prefabricated units. Perform inspection of prefabricated elements (e.g., concrete wall as required). Inspect around facing elements to:
   - compressive strength of specification requirements
   - rusting/difficult (e.g., bent metal)
   - honey-combing
   - severe cracking, chipping or spalling
   - color of finish variation
   - competence contact
   - mated joints and corners

6. Check reinforcement labels to verify whether they match certification documents.

7. Observe materials in batch of reinforcements to make sure they are the same. Observe reinforcement for flaws and nonuniformity.

8. Obtain test samples according to specification requirements from randomly selected reinforcements.

9. Observe construction to see that the contractor complies with specification requirements for installation.

10. If possible, check reinforcements after aggregate or riprap placement for possible damage. This can be done either by constructing a trial installation, or by removing a small section of aggregate or riprap and observing the reinforcement after placement and compaction of the aggregate, at the beginning of the project. If damage has occurred, contact the design engineer.

11. Check all reinforcement and prefabricated facing units against the initial approved shipment and collect additional test samples.

12. Monitor facing alignment:
   - adjacent facing panel joints
   - precut face panels
   - modular block units
   - snapped face units
   - line and grade
RWE Construction Duties

- Verifies that the specified materials are being provided
- Verifies that the field testing is being performed in accordance with and meets the project specifications
- Verifies that the various disciplines have reviewed the as-built drawings and daily reports as necessary
RWE Construction Duties

- Provides support regarding field changes
- Assures appropriate parties are involved in field change process
- Provide project specific training of field QA/QC personnel with respect to walls
RWE Construction Duties

- **Project Documentation**
  - Review QA/QC documentation for compliance
  - Maintain weekly wall progress reports
  - Prepare final wall acceptance reports
Challenges

- Coordination with multiple entities
Challenges (continued)

- Design interpretations
Challenges (continued)

- Controlling surface water runoff
Challenges (continued)

- Backfilling against the wall facing
Challenges (continued)

- Strapping installation
Final Acceptance Report

- Compile all project specific data for each wall
  - As-built drawings
  - Field inspection reports
  - QA/QC field and laboratory data
  - Manufacturers submittals
  - A statement that the wall was built in conformance with plans and specifications
RWE Results
RWE Results
RWE Results
Where Do You Want to Put Your Risk?

- MSE Wall Typical Cost - $30 to $65 per SF
- Cost of failure
  - MSE Wall Stabilization - $60 to $130 per sf
  - MSE Wall Replacement - $300 to $650 per sf
- Cost of Retaining Wall Engineer
  - MSE Wall Construction Cost with RWE - $5.00 to $10.00 sf
Questions