MECHANICALLY STABILIZED EARTH WALL INSPECTOR'S HANDBOOK

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MECHANICALLY STABILIZED EARTH (MSE) WALLS

INTRODUCTION

This manual is designed for the inspector of mechanically stabilized earth walls. It will provide general guidelines for the inspector; however, the plans, specifications and special provisions govern and must be read and followed.

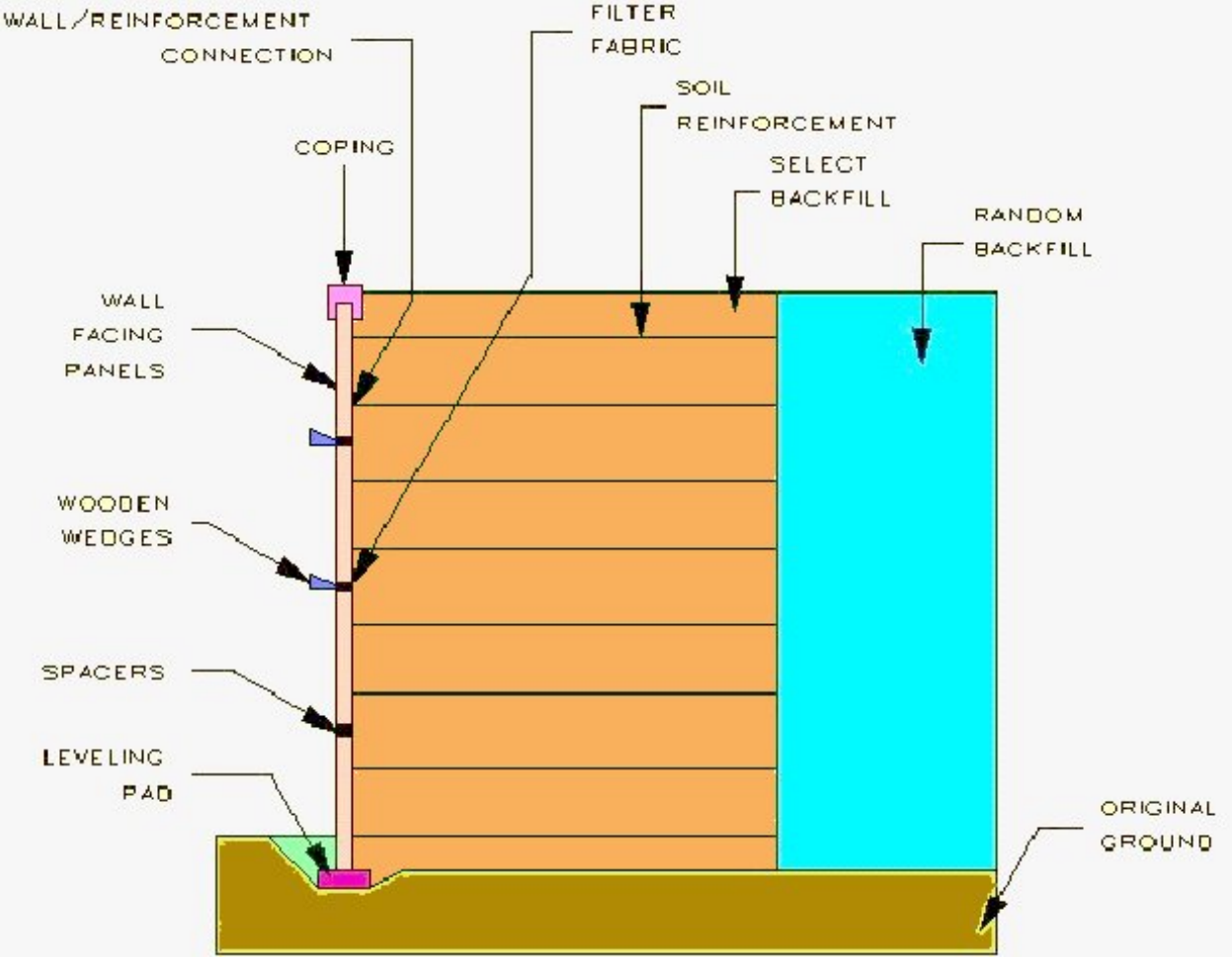

Figure 1, Wall Components

TERMS

The following is a list of terms that will be used in the handbook, see **Figure 1** for reference.

Coping

The coping is used to tie in the top of the wall panels and to provide a pleasing finish to the wall top. It can be cast-in-place or prefabricated segments.

Extensible Reinforcement

Polymeric reinforcement materials (exhibits creep characteristics under stress).

Filter Fabric

A geotextile filter fabric is used to cover the joint between panels. It is placed on the backside of the panels. This keeps the soil from being eroded through the joints and allows any excess water to flow out.

Inextensible Reinforcement

Metallic reinforcement material (both strips and grids) (does not exhibit creep characteristics under stress).

Leveling Pad

The leveling pad is a non-reinforced concrete pad used to provide a level, consistent surface at the proper grade to place the panels.

Original Ground

This is the existing ground surface at the site.

Random Backfill

Random backfill is the backfill that is allowed in normal embankment construction.

Select Backfill

Select backfill is the fill that meets the gradation, corrosion, unit weight, internal friction angle and any other requirements of the specifications.

Soil Reinforcement

Soil reinforcement holds the wall facing panels in position and provides reinforcement for the soil. The soil reinforcement can be strips, grids, or mesh. The reinforcement can be made of steel (inextensible materials) or polymers (extensible materials).

Spacers

Wall panel spacers are typically ribbed elastomeric or polymeric pads. They are inserted between panels to help provide the proper spacing. Proper spacing keeps

the panels from having point contact and spalling the concrete.

Wall Facing Panel

Wall Facing panels or panels are used to hold the soil in position at the face of the wall. The panels are typically concrete but they can be metal, wood, block, mesh or other material.

Wall/Reinforcement Connection

This is where the connection is made between the wall facing panel and the soil reinforcing.

Water

The water described here is that which may be necessary for bringing the select backfill material up to optimum moisture content. It shall meet the electro-chemical properties of the select backfill.

Wooden Wedges

Wooden wedges are used to help hold the panels at the correct batter during the filling operation. The wooden wedges should be made from hard wood (such as oak, maple or ash).

MECHANICALLY STABILIZED EARTH WALL SYSTEM

The wall system consists of the original ground, concrete leveling pad, wall facing panels, coping, soil reinforcement, select backfill and any loads and surcharges. All of these items have an affect on the performance of the MSE wall and are taken into account in the stability analysis. A change in any of these items could have a detrimental effect on the wall.

PREPARATION OF THE SITE

The MSE wall footprint area needs to be prepared, that is, the zone of the wall facing, soil reinforcement and select backfill. The foundation for the structure shall be graded level for a width equal to or exceeding the length of soil reinforcement or as shown on the plans. Any soft or loose material that is encountered should be compacted or removed and replaced. If soils are encountered that do not match the borings performed for the wall they should be brought to the attention of the geotechnical engineers for analysis.

LEVELING PAD

Once the area has been properly prepared an unreinforced concrete leveling pad is poured in place. The leveling pad concrete must cure for a minimum of 12 hours before placement of the wall panels can begin. Even though the leveling pad is not

"structurally" important, it is important to the construction of the wall. The leveling pad sets the horizontal and vertical alignment of the wall. It must be in the correct horizontal position, level and at correct grade. No more than 2 shims (each 3/16" thick) should be required to level the panels on the leveling pad. If the wall is not level, the panels will bind against each other causing spalling of the edges and corners. Experience has shown that if the wall is not started correctly, the finished product is seldom satisfactory.

Figure 3, Leveling Pad

Figure 2, Improper Leveling Pad

WALL FACING PANELS

Wall panels come in many shapes and sizes (see **Figure 4** for a few of the most common shapes). They can be custom built into any configuration that will fit together. The front face can have any type of finish, shape, texture or other surface treatments that can be formed.

Figure 4, Some Panel Finishes and Shapes

Before the panels are placed, the wall and shop drawings must be checked to ensure that the proper panels are being used. Depending on the wall height, the number of reinforcement connections on the back

of the panel may vary. The panels with the most connections will be typically the lower panels of the wall. In the upper portions of the wall, the number of connections may be less. It is important that the panels are used in their proper position. The panels need to be inspected to ensure they meet the plans, specifications, and shop drawings. They also need to be inspected for damage (bent connectors, damaged panels, etc.).

Figure 7, Placing Panels

The correct placement of the first row or two of panels is very important (see **Figure 7**). A spacer bar should be used to get the correct placement. They need to be on the proper alignment, grade and be level. The correct spacing is also very important. Without the correct spacing, panel corners will crack and spall with settlement. Spacing blocks must be used. Wooden wedges are also used to help hold the vertical alignment of the panels. The contractor should not keep more than three levels of the wooden wedges in the wall. If more than three levels of wedges are used they may become bound in the wall making them very difficult to remove and can cause the panel to spall.

Figure 6, Slip Joint

Figure 5, Slip Joint

Figure 8, Corner Panel

The vertical and horizontal alignments need to be checked periodically to ensure proper alignment. This will also allow problems to be spotted early and make corrections before the panels get too far out of alignment.

Figure 9, Panel Storage

Slip Joints

Typical a slip joint used to handle large differential vertical movement of the wall (see **Figure 5**).

Corner Panels

Corner panels provide a good connection between the two walls and act like slip joints for the wall allowing differential movement between the two walls (see **Figure 8**).

Figure 10, Improper Panel Storage

PANEL STORAGE

Panels should be stored flat and on dunages (see **Figure 9**). **Figure 10** is an example of improperly stored panels. This is done for a couple of reasons; 1) it protects the connections from being bent and damaging the galvanization (see **Figure 11**) and 2) they should be stored out of the mud to avoid staining the panel face.

Figure 11, Damaged Tabs

SOIL REINFORCEMENT

The soil reinforcement is used to tie the wall to the soil. The metallic reinforcement should not be bent, torn, galvanization chipped off or otherwise damaged. The polymer reinforcement should not be torn, cut, left in the sun or otherwise damaged. The inspector should check the reinforcement for the required length and gauge. No equipment should

be allowed to run directly on the reinforcement. Typically, the reinforcement is placed perpendicular to the wall face. Any slack in the reinforcement should be removed. The polymer reinforcement should have some tension placed in the reinforcement. The reinforcement should not be connected to the wall until the compacted fill is at or slightly higher than the facing panel connector.

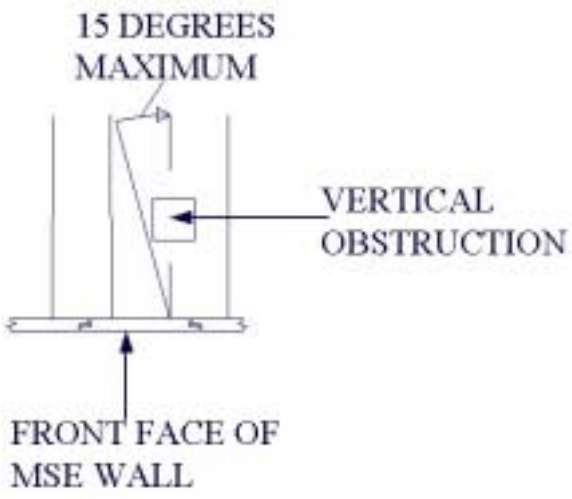

Figure 12, Vertical Obstructions

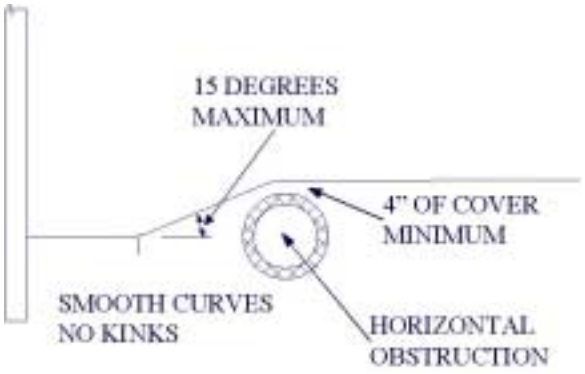

Figure 13, Horizontal Obstructions

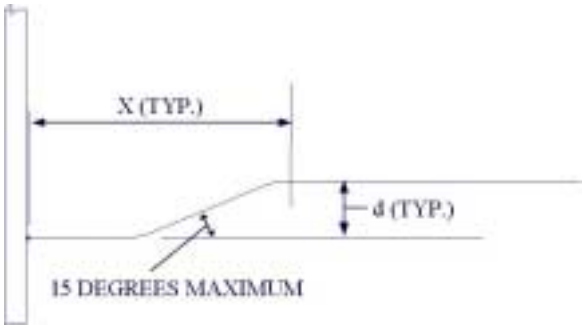

Figure 14, Transition Distances

Table 1. Transition Distances

Offset Distance "**d**"	Recommended Transition Distance "**X**"
0" – 3.99"	2' – 0"
4" – 5.99"	2' – 3"
6" – 7.99"	2' – 7"
8" – 9.99"	3' – 3"
10" – 11.99"	4' – 0"
12" – 14.99"	5' – 0"
15" – 17.00"	6' – 0"

At vertical obstruction the reinforcement should not be angled more than 15 degrees from perpendicular (see **Figure 12**) to the wall. No exceptions to this should be allowed without verifying with the wall supplier and engineer of record.

At horizontal obstructions, if the reinforcement must be more than 15 degrees from horizontal (see **Figure 13**) the supplier and engineer of record should be

contacted. It may require additional reinforcement length to meet design. Also when clearing horizontal obstructions, the reinforcement should be smoothly curved around the obstruction. The reinforcement should not be kinked at any time. There should also be a minimum of 4 inches of cover between the obstruction and the reinforcement. **Table 1** shows the recommended transition distance X (see "X" in **Figure 14**) from the point of connection to provide a smooth curve of the reinforcement with an offset of d (see "d" in **Figure 14**). If these distances cannot be achieved the wall supplier should be contacted to check the design.

Reinforcement Storage

Like the panels the reinforcement should be stored on dunage (see **Figure 15**) and carefully handled to prevent damage. Damage may include bending of the reinforcement and damaging the galvanization.

Figure 15, Reinforcement Storage

Coping/Barrier

Precast or cast-in-place coping/barriers may be used. For precast units a leveling course of concrete is placed prior to setting the units in place (see **Figure 16**). This provides the vertical control needed. Precast barriers are tied together and strengthened against vehicle impact by a slab cast typically in 30-foot sections (see **Figure 17**).

Figure 16, Leveling Course for Coping/Barrier

Figure 17, Barrier with Slab

Abutment Cheek Walls

When abutments are on a deep foundation, a bond breaker is needed between the MSE Wall panel and the cheek wall (see **Figure 18**). If this is not done, when the wall settles and the abutment doesn't, it creates a tension load in the cheek wall and the panel. This eventually leads to one or both to crack (see **Figure 19** and **Figure 20**). When rough panel finishes are used (such as shown **Figure 19**) a heavy/thick bond breaker is required. In case such as this a thin paper bond breaker forms to the panel irregularities and the panel locks into the poured concrete. Where as with smooth panel finishes a paper bond breaker would usually be sufficient.

Figure 19, Cracked Panel and Cheek Wall

Figure 18, Bond Breaker

Figure 20, Tension Break in Cheek Wall

SELECT BACKFILL

The select backfill must meet the specification requirements for gradation, electro-chemical, soil properties and organic content.

Placing Backfill

The select backfill lift should be placed parallel to the wall and starting approximately three (3) feet from the back of the wall panels. The backfill should be placed in 6" compacted lifts (it may be helpful to mark your lifts on the back side of the wall panels). The fill is then leveled by machinery moving parallel to the wall, windrowing the material toward the reinforcement ends. This action works out any slack in the reinforcement then locking the reinforcement and the panels in position. Once this has been accomplished, fill is then placed within 3'

behind the wall by windrowing the material.

Except for the initial layer the fill must be brought up uniformly for the whole layer.

COMPACTION

Compaction equipment used within three (3) feet of the wall should be a vibratory roller or plate weighing less than 1000 pounds. From beyond three (3) feet of the wall facing panels a roller up to 8 tons may be used subject to satisfactory performance (see **Figure 21**). A smooth wheeled or a rubber-tired roller is also acceptable. Compactors, which employ a foot such as a sheepsfoot (see **Figure 22**) or grid rollers, are not acceptable.

Figure 21, Compaction Equipment

Backfill compaction shall be performed in such a way that the compactor shall move in a direction parallel to the wall facing panels and proceed from a distance not less than three feet behind the wall facing panels and work toward the end of the soil reinforcement away from the wall facing (see **Figure 42**).

The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer of material. Backfill material shall have placement moisture content on the dry side of the Optimum Moisture content. If additional water is required for the material, the water must meet the specification requirements.

Figure 22, Sheepsfoot Rollers Not Allowed

DAYS END

At the end of each day's operation, the Contractor shall shape the last level of backfill as to permit runoff of rainwater away from the wall face or shall provide a positive means of controlling runoff away from the wall such as temporary pipes, etc. Failure to do this could result in wall damage due to hydrostatic pressure

or the erosion of material from around the soil reinforcement (see **Figure 23**).

BACKFILL IN FRONT OF WALL

The area in front of the wall and around the leveling pad should be backfilled as soon as practically possible. A strong rainstorm could cause heavy flow along the wall. This could cause soil erosion and undermining of the leveling pad and the wall.

Figure 23, Wash Out From Around Reinforcement

MISCELLANEOUS POINTS

Before the actual start of construction of the wall, the various parts of the plans (shop drawings, drainage, lighting, etc.) need to be compared to the contract wall plans to check for conflicts. A conflict may not have been noticed in the design stage.

Figure 24, Construction Load

If the plans show heavy loads on the wall and the shop drawings do not indicate it, the wall supplier should be questioned. The wall supplier may not have seen a full set of plans. Due to this, he may have missed loadings from various types of structures. If he did not take these loads into consideration, the wall could fail. This also can be temporary loads that the contractor may impose that was not accounted for (see **Figure 24**)

Figure 25, Not Proper Avoidance of Drainage Structure

Design for drainage structures in the wall mass are also sometimes missed by the wall supplier. It is not acceptable to just cut the reinforcement (see **Figure 25**). Sometimes it is necessary to angle the reinforcement, but never angle them more than 15 degrees from the perpendicular to the wall without verifying adequacy with the wall supplier and engineer of record.

Retention ponds located next to MSE walls need to be checked. Check that the wall is protected from scour by the drainage pipes. It has happened on projects where the drainage plans and the wall plans were not coordinated.

Excavations next to existing MSE Walls can cause settlement problems with the wall. As the area is excavated in front of the wall the material under the wall moves into the excavation. The wall than settles, this usually leaves a large gap at the panel joints (see **Figure 26** and **Figure 27**).

Figure 26, Settlement from Excavation

This can also happen if a trench is dug before erecting a wall and not properly compacting the trench back fill. As can be seen in **Figure 28** a drainage pipe was installed prior to erecting the wall. Once the rains came and softened up the soils the material under the wall moved into the pipe trench that was not properly compacted.

Figure 27, Joints Opening from Settlement

Figure 28, Wall Failure from Exterior Excavation

Settlement can also happen if the wall is built over an old drainage pipe. **Figure 29** shows a case where a wall was built over an old drainage pipe. After several years some of the joints started leaking allowing soil from under the wall to migrate into the pipe. This resulted in the wall settling.

Figure 29, Settlement from Pipe Joint Leakage

Temporary Wall Facing

Temporary wall facings are used at times to handle large settlements that the permanent wall facings could not handle. The wall is built using a temporary facing such as fabric wrapping with tabs sticking out for eventual connection of a permanent facing (see **Figure 30**). The permanent facing is not attached until the majority of the settlement has been occurred.

Figure 30, Temporary and Permanent Wall Facings

One problem that has occurred with the extensible (plastic) reinforcement is that fire can damage the material that is at the face of the wall (see **Figure 31**). This can be repaired by connecting new reinforcement from the undamaged reinforcement in the embankment mass out to the wall face.

Figure 31, Fire Damaged Reinforcement

CONSTRUCTION

The construction sequence is typically as follows:

1. First, the site is cut to grade and all unsuitable material is removed.
2. The site is proof rolled to delineate any loose and/or unsuitable materials. Compacting any loose material and remove and replacing any unsuitable material found. The proof rolling is accomplished by at least 5 passes of a vibratory roller weighing a minimum of eight tons.

Figure 32, Preparing Site, Proof Roll & Excavate Footing

3. The leveling pad excavation is dug (see **Figure 32**).
4. The leveling pad is placed (see **Figure 33**). The concrete is allowed to cure a minimum of 12 hours before any panels are placed.

Figure 33, Place Concrete Leveling Pad

5. The first row of panels are placed on the leveling pad and braced (see **Figure 34**). If ½ panels are used they are placed at the correct spacing using a spacing guide; then the second row is set and braced. The panels should be set with a backward batter, typically ±1/8 inch per foot. This may allow the panel to be vertical once fill is placed against it. The batter is adjusted for the site conditions e.g. backfill properties, the finer sand may require a larger batter.

Figure 34, Install & Brace 1st Row of Panels

6. An adhesive is used to hold the filter fabric across all of the panel joints. The adhesive should be applied on the panel next to the joints then the filter fabric is placed over the joint (see **Figure 35**), because applying adhesive on the filter fabric tends

Figure 35. Attach Filter Fabric

to clog the filter fabric.

7. The select backfill is then placed and compacted to the level of the first row of connections. The compacted fill should be at or slightly higher than the panel connections (see **Figure 36**). On the initial row of panels (and only the initial row of panels) the backfill is not placed against the panel until the first row of reinforcement have been connected and the initial 6 inch layer of compacted fill is placed on the reinforcement. This is to keep the bottom of the panels from "kicking out". From that point, the backfill is brought up uniformly from the back of the panels to the end of the reinforcement.

8. The reinforcement is then placed typically perpendicular to the wall panel and the connection (see **Figure 37**). Any slack in the reinforcement should be removed to avoid excessive panel movement. With polymer reinforcement some tension should be applied to the reinforcement by means of a kicker tension device or a rod (see **Figure 38**).

9. Then another row of wall panels is placed with the proper batter.

Figure 36, Fill in 6" Lifts to Reinforcement

Figure 37, Connect and Tighten Reinforcement

Figure 38, Tensioning Polymer Reinforcement

Figure 39, Continuation of Fill Placement

10. The select backfill is then placed (see **Figure 36**) in 6 inch compacted lifts until the fill is at or slightly above the next set of connections. Any additional water needed for compaction must meet the specification requirements. The backfill is placed parallel to the wall starting approximately three (3) feet from the back of the panels. The fill is then windrowed toward the reinforcement ends (see **Figure 40**). Once this is complete, the fill is windrowed from the three (3) foot point back toward the panels (see **Figure 41**).

11. The compaction equipment rolls parallel to the wall facing. Compaction starts at least three (3) feet from the wall and works toward the end of the reinforcement (see **Figure 42**).

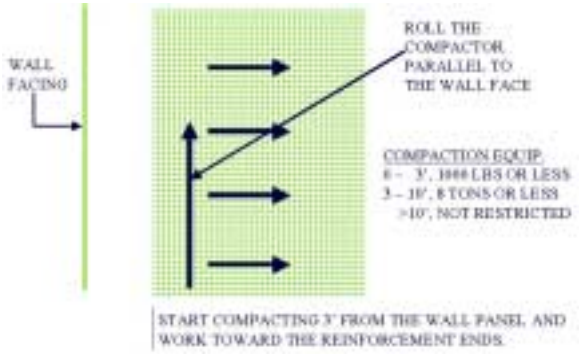

Figure 42, Initial Compaction

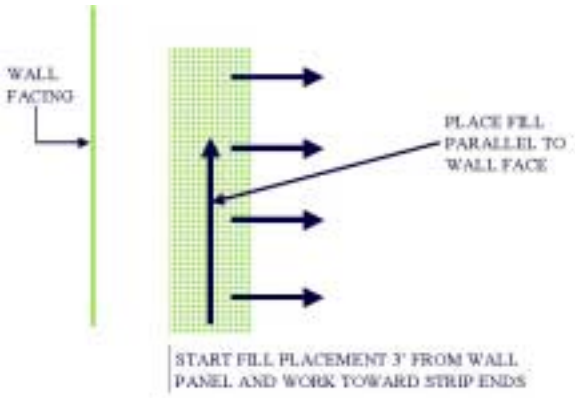

Figure 40, Typical Fill Layer Placement (Plan View)

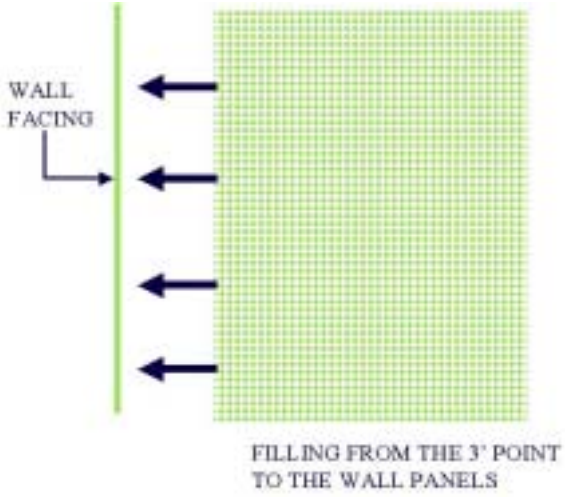

Figure 41, Typical Edge Fill Placement (Plan View)

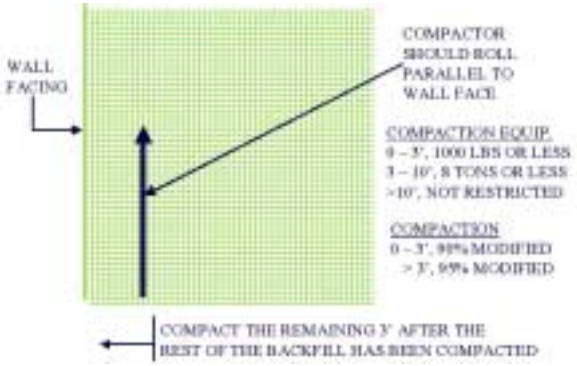

Figure 43, Final Compaction

12. Compacting the remaining three (3) feet next to the wall face then completes the compaction (see **Figure 43).** This

compaction is accomplished with compaction equipment of 1,000 lbs. or less.

13. Remove wooden wedges as soon as the precast component above the wedged precast component is completely erected and backfilled (see **Figure 44**). In no case should there be more than three rows of wooden wedges in place. Failure to remove the wooden wedges can cause the panels to crack or spall.

14. Repeat steps 8, 9, 10, 11 and 12 until the top of the wall is reached. As soon as practical the front of the wall should be backfilled. This should occur prior to reaching the top of the wall (see **Figure 45**).

15. The coping is then placed on the top of the wall. The wall is completed when the coping is properly installed on top of the wall.

Figure 44, Wooden Wedges

Figure 45, Place Backfill in Front of the Wall as Soon as Practical

Figure 46, Excavations Next to MSE Walls

POST CONSTRUCTION

Once the wall construction has begun care must be taken when excavating near it. An MSE wall is a large spread footing, when excavations occur close to the wall, a bearing capacity failure could occur. This is especially true when excavating below the existing water table. Any excavations closer than that shown in **Figure 46** needs to be analyzed and checked by the District Geotechnical Engineer. Also, if dewatering is planned near the wall, it should be analyzed and checked by the District Geotechnical Engineer.

APPENDIX A

Appendix A

CHECK LIST

The following is a general checklist to follow when constructing a Mechanically Stabilized Earth wall (MSE wall). The answer to each of these should be yes unless plans, specifications or specific approval has been given otherwise.

	YES	NO	
1.	□	□	Has the contractor submitted wall shop drawings?
2.	□	□	Has the contractor submitted select backfill certification (showing that it meets the gradation, density and corrosion and other soil requirements)?
3.	□	□	Has the contractor supplied a Certificate of Compliance certifying that the wall materials comply with the applicable sections of the specifications? Has the contractor supplied a copy of all test results performed by the Contractor or his supplier, which are necessary to assure compliance with the specifications?
4.	□	□	Has the contractor furnished a copy of any instructions the wall supplier may have furnished?
5.	□	□	Have the shop drawings been approved?
6.	□	□	Did the contractor receive the correct panels (shape, size and soil reinforcement connection layout) per the approved shop drawings?
7.	□	□	Did the contractor receive the correct reinforcement (proper length and size)?
8.	□	□	Have the panels and the reinforcement been inspected for damage as outlined in the specifications?
9.	□	□	If any panels or soil reinforcement were found damaged have they been rejected or repaired in accordance with the specifications?
10.	□	□	Are the panels and the soil reinforcement properly stored to prevent damage?
11.	□	□	Has the MSE wall area been excavated to the proper elevation?
12.	□	□	Has the area been proof rolled per the specifications (a minimum of five (5) passes by a roller weighing a minimum of 8 tons)?
13.	□	□	Has all soft or unsuitable materials been compacted or removed and replaced?

	YES	NO	
14.	□	□	If the contractor is using any water in the MSE wall area does it meet the requirements shown in the specifications?
15.	□	□	Has the leveling pad area been properly excavated?
16.	□	□	Has the leveling pad been set to the proper vertical and horizontal alignment?
17.	□	□	Has the leveling pad cured for a minimum of 12 hours before any panels are set?
18.	□	□	Is the first row of panels properly placed? Do they have proper spacing, bracing, tilt and where required, do they have the spacers installed?
19.	□	□	Has the proper filter fabric and adhesive been supplied?
20.	□	□	Is the filter fabric being properly placed over the joints?
21.	□	□	Is the adhesive being applied to the panel, than the filter fabric being placed?
22.	□	□	Is the filter fabric being stored properly (stored out of the sunlight and protected from UV radiation)?
23.	□	□	Is the contractor using the correct panels (correct size, shape and with the proper number of connections) for that panel's wall location and elevation?
24.	□	□	Is the fill being placed and compacted in 6 inch lifts?
25.	□	□	Is the equipment being kept off of the soil reinforcement until a minimum of 6 inches of fill is placed?
26.	□	□	Are the lifts being placed by the proper method and sequence
27.	□	□	Is the fill being compacted by the correct equipment and in the correct pattern?
28.	□	□	Is the proper compaction being met? A minimum of 90 percent of maximum density within 3 feet of the wall and a minimum of 95 percent of maximum density 3 feet or greater from the wall as determined by FM 5-521.
29.	□	□	Is the fill being brought up to or slightly above the soil reinforcement elevation before the reinforcement are connected?
30.	□	□	Is the soil reinforcement being properly connected (connections tight and all of the slack in the soil reinforcement removed)?
31.	□	□	Is the soil reinforcement in the proper alignment?

	YES	NO	
32.	□	□	Is the vertical and horizontal alignment being checked periodically and adjusted as needed?
33.	□	□	Is the contractor removing the wooden wedges as per the specifications? (The wooden wedges shall be removed as soon as the panel above the wedged panel is completely erected and backfilled.)
34.	□	□	At the end of each day's operation is the contractor shaping the last level of backfill as to permit runoff of rainwater away from the wall face or providing a positive means of controlling runoff away from the wall such as temporary pipe, etc?
35.	□	□	Has the contractor backfilled the front of the wall?
36.	□	□	Is the correct coping being installed?

APPENDIX B

Appendix B

MSE WALL CONSTRUCTION DO'S AND DON'TS

1. Review approved shop drawings.
2. Review Mechanically Stabilized Earth (MSE) Wall Inspector's Handbook.
3. Confirm foundation has been compacted properly in accordance to the specifications.
4. Verify leveling pad elevations.
5. Confirm receipt of Certificate of Compliance from the wall company.
6. Confirm fill material has been tested and approved before it is brought to the job site.
7. Inspect panels.
8. Inspect soil reinforcement for damage.
9. Reject all panels that are not in compliance with the plans and specifications.
10. Ensure panels, soil reinforcement and filter fabrics are properly stored to prevent damage.
11. Ensure all piles in the reinforced fill are wrapped with two independent layers of 6 mil plastic with lubricating oil between the layers.
12. Install panels in accordance to plans and specifications.
13. Place and properly compact fill in accordance with plans and specifications.
14. DO NOT use thick fill lifts. Fill lifts thicker than 6" compacted lifts require more energy to compact and may move the panels out of alignment.
15. Use corner panels at all corners. If corner panels are not indicated on the plans, the designer should be notified.
16. Soil reinforcement should not be skewed more than 15 degrees from normal. If reinforcement needs to be skewed more than 15 degrees, notify the designer.
17. Check the batter of the panels often. Adjust accordingly. The vertical alignment of the panels below the panels being installed may be affected by the compaction of the soil behind the panels being installed.
18. Check overall batter regularly.
19. Water for soil compaction shall be in compliance with Section 923. NO saltwater or brackish water is to be used.
20. When attaching filter fabric to the back of the panels, the adhesive shall be applied to the panel NOT the filter fabric.

21. Remove wooden wedges as soon as possible.
22. If precast coping is used, ensure top panels have dowels that will extend into the cast-in-place leveling fillet.
23. DO NOT allow excavations in close proximity in front of the wall once the wall construction has started. If excavations are required in front of the wall, the designer's approval will be obtained before the excavation is started. Also, excavations in front of the wall should not be allowed without protection to the wall (i.e. sheet piles, etc.)
24. Soil reinforcement near the top of the wall shall be parallel to the lifts of fill. Soil reinforcement shall not extend into the sub-base that may require mechanical mixing.
25. DO NOT CUT soil reinforcement to avoid obstructions without the designers approval.
26. Place one-half inch minimum preformed expansion material between wall panels and cast-in-place concret

APPENDIX C

Appendix C

GUIDELINES FOR DETERMINING RETAINING WALL APPLICATIONS AND TYPES

By: Don Keenan, P.E., Structures Design Office

Retaining Walls are being used more frequently than ever before. As roads are widened, and new roads are built there are more chances to encounter right of way constraints, poor soil conditions, unusual geometry, environmental problems and construction constraints. Due to the way FDOT has been designing and detailing retaining walls in recent years (use of proprietary designs), many designers have become complacent and do less engineering leaving more responsibility to the proprietary companies. This has allowed many projects to have less than desirable wall types. These projects have either used wall types that were misapplied or not the most desirable wall type.

The different types of walls normally considered and constructed in Florida are as follows;

Cantilevered

- Conventionally reinforced concrete with spread footings
- Conventionally reinforced concrete pile supported
- Steel Sheet Piles
- Concrete Sheet Piles

Mechanically Stabilizes Earth (MSE) Walls

- Metallic soil reinforcement
- Geosynthetic soil reinforcement

Tied-back walls

- Prestressed soil anchors
- Deadman anchors

Gravity walls

I have received many telephone calls from designers concerning retaining wall applications. Many times during our discussions, it becomes apparent that the designer has not done his homework. The designer must gather basic information and ask himself/herself basic questions.

These guidelines/questions are not to cookbook retaining wall selection and design

but to prompt a thought process to properly select a wall type that will best satisfy the particular site and construction constraints. The answers to these questions will be different for every project.

The first thing the designer must obtain is the roadway plans to determine wall location, alignment and right of way constraints.

1. Are walls necessary?
2. Is the wall in water?
3. If, in water do we have a hydraulic report?
4. Is the water corrosive?
5. Is there a fast current?
6. How deep is the water?
7. Is it a cut or fill location?
8. If a cut section, how close to the right of way is the wall located?
9. Are nearby buildings going to impact wall selection (aesthetics, pile supported)?
10. Is more right of way required?
11. Is a MSE wall appropriate for this cut section or would a gravity wall work?
12. If in a fill section, is there room for MSE soil reinforcing?
13. Are steep slopes more appropriate than walls?
14. After it has been determined that a wall is required, the designer should obtain the geotechnical report.
15. How much short term and long term settlement is anticipated?
16. What is the bearing capacity of the soil?
17. What is the internal friction angle of the soil?
18. Will slip joints be required?
19. Are there any unusual geotechnical problems?

Another issue that must be addressed is the environment.

1. Is there corrosive water present? Consider tides and 100-year floods.
2. Are there environmental constraints that will affect construction and wall choice (i.e. noise abatement, pile driving constraints)?
3. What is the electro-chemical analysis of the soil and water?

Any wall type chosen should be constructible within the project site.

1. Is the project phase construction?
2. Does the wall have acute angles or sharp curves?
3. Is this a widening project?
4. Is there room to install the soil reinforcing strips?
5. Are there overhead utilities?
6. Are there buried utilities?
7. How will maintenance of traffic affect construction of wall?
8. Is temporary shoring required?
9. Do soil conditions require special construction requirements (i.e. wick drains, time dependant fill placement, special equipment)?
10. Aesthetics is certainly a consideration in wall type selection. The FDOT is putting a lot of emphasis on aesthetics in bridge and retaining wall selection. The wall finish, color and type should be compatible with the project location.
11. Is the wall site a rural or urban site?
12. Has the project manager been contacted about aesthetic requirements?
13. Is the wall type compatible with the site (i.e. steel sheet piles are not compatible with an urban residential site)?
14. Are surface finishes used more expensive that more attractive finishes (i.e. raised surface finish is sometimes very expensive due to shipping costs)?
15. Does it match other walls in the area?

Any unusual details must be considered in the wall type selection process. If walls are used at bridge ends, this must be considered.

Before the wall selection process can be complete the cost of each wall type must be compared to ascertain the most economical type. Also, the cost of lengthening the bridge must be compared to the cost of the wall. The optimum wall height must be determined by comparing the cost of wall vs. the cost of bridge.

Due to construction, right of way and phasing temporary walls are sometimes required. Their selection should be based on the same criteria as previously mentioned.

APPENDIX D

Appendix D

OUT-of-TOLERANCE CONDITIONS and POSSIBLE CAUSES CRITERIA

The following is taken out of FHWA's Publication "MECHANICALLY STABILIZED EARTH WALLS AND REINFORCED SOIL SLOPES DESIGN & CONSTRUCTION GUIDELINES" Publication No. FHWA-DP.82-1.

Table 12. Out-of-Tolerance Conditions and Possible Causes

MSE structures are to be erected in strict compliance with the structural and aesthetic requirements of the plans, specifications, and contract documents. The desired results can generally be achieved through the use of quality materials, correct construction/erection procedures, and proper inspection. However, there may be occasions when dimensional tolerances and/or aesthetic limits are exceeded. Corrective measures should quickly be taken to bring the work within acceptable limits.

Presented below are several out-of-tolerance conditions and their possible causes.

1. Distress in wall:	
A. Differential settlement or low spot in wall.	1.a. Foundation (subgrade) material too soft or wet for proper bearing. Fill material of poor quality or not properly compacted.
B. Overall wall leaning beyond vertical alignment tolerance.	
C. Panel contact, resulting in spalling/chipping.	
2. First panel course difficult (impossible) to set and/or maintain level. Panel-to-panel contact resulting in spalling and/or chipping.	2.a. Leveling pad not within tolerance.
3. Wall out of vertical alignment tolerance (plumbness), or leaning out.	3.a. Panel not battered sufficiently.
	b. Large backfill placing and/or compaction equipment working within 3-foot zone of back of wall facing panels.

	c. Backfill material placed wet of optimum moisture content. Backfill contains excessive fine materials (beyond the specifications for percent of materials passing a No. 200 sieve).
	d. Backfill material pushed against back of facing panel before being compacted above reinforcing elements.
	e. Excessive or vibratory compaction of uniform, medium-fine sand (more than 60 percent passing a No. 40 sieve).
	f. Backfill material dumped to close to free end of reinforcing elements, then spread toward back of wall, causing displacement of reinforcements and pushing panel out.
	g. Shoulder wedges not seated properly.
	h. Shoulder clamps not tight.
	i. Slack in reinforcement to facing connections.
4. Wall out of vertical alignment tolerance (plumbness) or leaning in.	4.a. Excessive batter set in panels for select granular backfill material being used.
5. Wall out of horizontal alignment tolerance, or bulging.	5.a. See Causes 3c, 3d, 3e. Backfill saturated by heavy rain or improper grading of backfill after each day's operations.
6. Panels do not fit properly in their intended locations.	6.a. Panels are not level. Differential settlement (see Cause 1).

	b. Panel cast beyond tolerances.
	c. Failure to use spacer bar.
7. Large variations in movement of adjacent panels.	7.a. Backfill material not uniform.
	b. Backfill compaction not uniform.
	c. Inconsistent setting of facing panels.

Appendix E

Appendix E

MSE Wall Specification

SECTION 548

RETAINING WALL SYSTEMS

548-1 Description

Construct permanent and temporary retaining wall systems in accordance with this Section and in conformance with the lines, grades, design, and dimensions shown in the Contract Documents or established by the Engineer. The wall system chosen must be included in the Roadway and Traffic Design Standards and listed as an alternate in the Contract Documents. Sheet pile walls and Cast-In-Place walls are not included in this specification. Wall systems used to cut back existing slopes are covered by Technical Special Provisions for those systems; however they are paid for under the same pay item numbers shown in the Basis of Payment Article of this Specification. Construct all walls of a specific type (MSE (Mechanically Stabilized Earth), counterfort, etc) using the same wall system and supplier. If different types of wall systems must be used in a manner that causes one wall to interact with or influence another wall, coordinate the detailing of these areas of interaction/influence with the assistance of the Specialty Engineer.

548-2 Materials

Purchase the precast components, soil reinforcement, attachment devices, joint filler, filter fabric, and all necessary incidentals from the wall supplier chosen.

548-2.1 Concrete

Ensure that concrete utilized for wall components is as specified in the Contract Documents and is consistent with the concrete class, environmental classification and admixture requirements for durability as stated in the Contract Documents. Produce and supply concrete for all wall components meeting the requirements of Section 346. Produce and supply concrete for the leveling pad meeting the requirements of Section 347. Assume responsibility for performance of all testing required by Section 346. Use Department approved mix designs.

548-2.2 Reinforcing Steel:

Meet the requirements of Section 931 utilizing Grade 420 (Black) steel.

548-2.3 Soil Reinforcement:

For walls utilizing soil reinforcement, use reinforcement consisting of steel wire mesh, metal strips or structural geosynthetics as required for the wall system chosen.

Use steel wire mesh and embedded loops shop fabricated from cold drawn steel wire meeting the minimum requirements of ASTM A 82, and weld into the finished mesh fabric in accordance with ASTM A 185. Use steel strips hot rolled from bars to the required shape and dimensions with physical and mechanical properties meeting ASTM A 572 [ASTM A 572M] Grade 65 [450] or as shown in the Contract Documents. Use shop-fabricated hot rolled steel tie straps meeting the minimum requirements of ASTM A 570 [ASTM A 570M], Grade 50 [345], or as shown in the Contract Documents.

Ensure that steel reinforcing strips, tie strips, reinforcing mesh and connectors used in permanent walls are galvanized in accordance with ASTM A 123 [ASTM A 123M] or ASTM A 153 [ASTM A 153M], as applicable.

Use structural geosynthetics made of polypropylene, select high density polyethylene or high-tenacity polyester fibers having cross-sections sufficient to permit significant mechanical interlock with the soil/backfill. Use geosynthetics having a high tensile modulus in relation to the soil/backfill. Use geosynthetics having high resistance to deformation under sustained long term design load while in service and resistant to ultraviolet degradation, to damage under normal construction practices and to all forms of biological or chemical degradation normally encountered in the material being reinforced.

Store the geosynthetics in conditions above 20ºF [-7ºC] and not greater than 140ºF [60ºC]. Prevent mud, wet cement, epoxy, and like materials from coming into contact with and affixing to the geosynthetic material. Rolled geosynthetic may be laid flat or stood on end for storage. Cover the geosynthetic and protect from sunlight prior to placement in the wall system.

Carefully inspect all reinforcement, steel and geosynthetics to ensure they are the proper size and free from defects that may impair their strength and durability.

548-2.4 Attachment Devices

Use soil reinforcement attachment devices as required by the wall system chosen.

548-2.5 Joint Materials and Filter Fabrics:

548-2.5.1 Horizontal Joint Filler

Use elastomeric or polymeric pads/fillers in all horizontal joints between precast components as recommended by the wall manufacturer. Ensure that the pads are of sufficient size and hardness to limit vertical stresses on the pad and concrete surface and to prevent concrete-to-concrete contact at the joints.

548-2.5.2 Joint Covers

Cover joints and other wall openings with geotextile fabric meeting the requirements of Section 985 and Type D-5 of the Roadway and Traffic Design Standards, Index No. 199. Apply an adhesive approved by the Engineer to the back of the precast component for attachment of the fabric material.

548-2.5.3 Alignment Pins

Ensure that pins used to align the precast components during construction are of the size, shape and material required for the wall system chosen.

548-2.6 Backfill Material

Ensure that all backfill material used in the retaining wall volume is free draining and meets the requirements of this Section. Have the backfill material tested by a Department approved independent testing laboratory prior to placement. The retaining wall volume is defined to extend from the top of the leveling pad or footing, or bottom of walls which do not have footing or leveling pads, to the finish grade line and from the face of the wall to a vertical plane passing through the end of the extreme wall component (straps, counterforts, etc.) plus 1 foot [300 mm].

For constructing the retaining wall volume, do not use backfill material containing more than 2.0% by weight of organic material, as determined by FM 1-T 267 and by averaging the test results for three randomly selected samples from each stratum or stockpile of a particular material. If an individual test value of the three samples exceeds 3%, the stratum or stockpile will not be suitable for constructing the retaining wall volume.

Ensure that the plasticity index as determined by FM 1-T 090 does not exceed six and the liquid limit as determined by FM 1-T 089 is less than 15. The pH, as determined by FM 5-550, shall not be lower than five and not higher than ten, unless approved otherwise by the Engineer, as follows: For walls utilizing non-metallic soil reinforcement, the Engineer may approve using a backfill with a pH value between three and ten, if no metallic structures, such as metallic pipes, are placed within the backfill. Do not use backfill with a pH lower than three or higher than ten.

Use backfill for walls using soil reinforcements that meets the following gradation limits determined in accordance with FM 1-T 027 and FM 1-T 011:

Sieve Size		Percent Passing
3½ inches	[90 mm]	100
¾ inch	[19.0 mm]	70-100
No. 4	[4.75 mm]	30-100
No. 40	[425 µm]	15-100
No. 100	[150 µm]	5-65
No. 200	[75 µm]	0-15

In addition, for permanent walls utilizing metallic soil reinforcement, use backfill that meets the following electro-chemical test criteria for determining corrosiveness:

Criteria	Test Method
Resistivity: > 30 Ω·m	FM 5-551
Sulfate content: < 200 PPM	FM 5-553
Soluble chloride content < 100 PPM	FM 5-556 or FM 5-552

For walls not using soil reinforcement, use backfill that meets the following gradation limits determined in accordance with FM 1-T 027 and FM 1-T 011:

Sieve Size		Percent Passing
3½ inches	[90 mm]	100
No. 200	[75µm]	0-15

548-3 Concrete Component Construction.

Construct concrete components in accordance with Section 400. Precast wall components are produced using certification acceptance; therefore, assume responsibility for performance of all testing and inspection required by Section 400 for the precast component construction. Perform all Quality Control and Assurance Testing using ACI qualified testing personnel. Perform compressive strength testing in a laboratory inspected by CCRL or CMEC, with all deficiencies corrected. The minimum time for form removal is 12 hours. Unless otherwise indicated in the Contract Documents, apply a Class 3 finish to the concrete surface for the front face, and roughly screed the rear face to eliminate open pockets of aggregate and surface distortions in excess of ¼ inch [6 mm].

548-3.1 Curing

Cure concrete components in accordance with Section 400.

548-3.2 Tolerances

Meet the following manufactured tolerances:

1. Precast Component Dimensions: Lateral position of soil reinforcement attachment devices - within 1 inch [25 mm]. All other dimensions - within 3/16 inch [5 mm].
2. Precast Component Squareness: Angular distortion of the component shall not exceed 0.2 inches in 5 feet [5 mm in 1.5 m].
3. Precast Component Surface Finish: Surface defects on smooth formed surfaces measured on a length of 5 feet [1.5 m] shall not exceed more than 0.1 inch [3 mm]. Surface defects on textured finished surfaces measured on a length of 5 feet. [1.5 m] shall not exceed 5/16 inch [8 mm].

548-3.3 Marking of Precast Components

Clearly mark each precast components with the date of manufacture, the 346

concrete production LOT number and the piece-mark.

548-4 Rejection of Precast Components.

Precast wall components not meeting the quality standard of this Section and referenced Specifications will be rejected by the Department. In addition, any of the following defects will be sufficient cause for rejection by the Department.

1. Defects that indicate unsatisfactory molding.
2. Defects indicating honeycombed or open texture concrete.
3. Defects in the physical characteristics such as:

    Signs of aggregate segregation;

    Broken or cracked corners;

    Soil reinforcement attachment devices improperly installed/damaged;

    Lifting inserts not useable;

    Exposed reinforcing steel;

    Insufficient cover over reinforcing steel;

    Cracks at the alignment pipe or pin;

    Insufficient concrete compressive strength;

    Precast Component thickness in excess of ±3/16 inch [±5 mm] from that shown in the Contract Documents; or

    Stained front face, due to excess form oil or other reasons.

If the face of the precast component is stained or discolored to the point of rejection, the stain or discoloration may be removed or a Department approved stain or a Class 5 finish may be applied to attain a uniform appearance for the entire structure, to the satisfaction of the Engineer.

548-5 Handling Storage and Shipping.

Handle, store and ship all components in a manner that prevents chipping, cracks, fractures, excessive bending stresses, mud, dirt and debris. Support precast components in storage on firm blocking located immediately adjacent to the attachment device.

548-6 Construction Requirements.

548-6.1 General

Due to the unique nature of the structure and concept, procure from the Wall Supplier fully detailed shop drawings, technical instructions, guidance in preconstruction activities and on-site technical assistance during construction. Closely follow any instructions from the Wall Supplier, unless otherwise directed by the Engineer. Submit a copy of any instructions from the Wall Supplier to the

Engineer. Verify all pertinent retaining wall information (soil parameters, wall alignment, utility locations, conflicting structures) prior to the Wall Supplier finalizing shop drawings. Bring any conflicts not shown in the Contract Documents to the Engineer's attention.

548-6.2 Wall Excavation

Excavate to the limits shown in the Contract Documents and in conformance with Section 125.

548-6.3 Foundation Preparation

Grade the foundation for the structure level for a width equal to or exceeding the limits of the retaining wall volume or as shown in the Contract Documents. Prepare the foundation in conformance with Section 125.

In addition to the compaction requirements of Section 125, compact the graded area with an appropriate vibratory roller weighing a minimum of 8 tons [7 metric tons] for at least five passes or as directed by the Department's District Geotechnical Engineer. Remove and replace any soft or loose foundation subsoils, which, in the Engineer's opinion, are incapable of sustaining the required compaction.

For permanent MSE wall systems, provide an unreinforced concrete leveling pad as shown in the Contract Documents. Cure the leveling pad a minimum of 12 hours before placement of precast wall components.

548-6.4 Wall Erection

Assemble, connect and support wall components as recommended by the Wall Supplier. As backfill material is placed behind the wall face, maintain the wall in the vertical position or slightly battered into the backfill to provide a final vertical alignment (by means of bracing, temporary wooden wedges placed in the joint at the junction of the two adjacent precast components on the external side of the wall or other alignment aids). Remove wooden wedges as soon as the precast component above the wedged precast component is completely erected and backfilled. External bracing is required for the initial lift of MSE systems.

Place soil reinforcement normal to the face of the wall, unless otherwise shown in the Contract Documents or directed by the Engineer. Prior to placement of the reinforcement, compact the backfill in accordance with 548-7.5.

548-6.4.1 Tolerances for Permanent Walls

Ensure that vertical tolerances (plumbness) and horizontal alignment tolerances do not exceed ¾ inch [20 mm] when measured with a 10-foot [3.048 m] straight edge. The maximum allowable offset in the joint between precast components is ¾ inch [20 mm]. The final overall vertical tolerance of the completed wall (plumbness from top to bottom) shall not exceed ½ inch per 10 feet [5 mm per meter] of wall height. Horizontal and vertical joints between precast components shall not be less than ½ inch [13 mm] or more than 1¼ inch [30 mm]. Walls, which do not meet these tolerances, will not be accepted by the

Department and must be removed and reconstructed at no cost to the Department.

548-6.4.2 Tolerances for Temporary Walls

Ensure that vertical tolerances (plumbness) and horizontal alignment tolerances do not exceed 3 inches [75 mm] when measured with a 10-foot [3.048 m] straight edge. The final overall vertical tolerance of the completed wall (plumbness from top to bottom) shall not exceed 1 inch per 3 feet [13 mm per meter] of wall height, not to exceed a total of 6 inches [150 mm]. Walls, which do not meet these tolerances, will not be accepted by the Department and must be removed and reconstructed at no cost to the Department.

548-6.5 Backfill Placement

Place the backfill closely following the erection of each course of precast components or soil reinforcement layers and spread by moving the machinery parallel to the wall face. Do not allow equipment heavier than 8 tons [7.5 metric tons] closer than 3 feet [1 m] behind the wall face. Place backfill in a manner to avoid any damage or disturbance to the wall materials or misalignment of the facing materials. Remove and replace any wall materials which become damaged or disturbed during backfill placement at no cost to the Department, or correct as directed by the Engineer. Remove and reconstruct any misalignment or distortion of the wall facing due to placement of backfill outside the limits of this specification at no cost to the Department.

Compact retaining wall backfill and embankment fill from the beginning stationing of the retaining wall volume to the ending stationing of the retaining wall volume to at least 95% of the maximum dry density as determined by FM 5-521. As an exception, compact backfill placed within 3 feet [1 m] behind the wall face to at least 90% of the maximum dry density. Sheepsfoot, grid rollers or other types of equipment employing a foot are not allowed. Achieve compaction within 3 feet [1 m] of the back of the wall face using a power operated roller or plate weighing less than 1,000 lbs [450 kg]. At a distance greater than 3 feet [1 m] from the back of the wall, a vibratory roller may be used, provided that the frequency and amplitude combined with bulk weight of the roller has performed satisfactorily at a trial section of the same type of wall. A smooth wheel or rubber tire roller is considered adequate. Ensure that the maximum lift thickness after compaction does not exceed 6 inches [150 mm]. Decrease the lift thickness if necessary, to obtain specified density.

Perform backfill compaction in a way that the compactor moves in a direction parallel to the wall face and proceeds from a distance not less than 3 feet [1 m] behind the wall face toward the end of the soil reinforcement element.

Ensure that the moisture content of the backfill material prior to and during compaction is uniformly distributed throughout each layer of material. Use backfill material having a placement moisture content at the dry side of the Optimum Moisture content. To achieve the required compaction moisture content, use water that meets the requirements of Section 923. Do not use saltwater. Do not transport

excessively moist backfill materials to the site for any reason. The Engineer will determine the Optimum Moisture Content in accordance with FM 5-521.

At the end of each day's operation, shape the last level of backfill to permit runoff of rainwater away from the wall face or provide a positive means of controlling run off away from the wall such as temporary pipe, etc.

548-7 Certification.

Furnish a copy of all test reports, which are necessary to document compliance with the Specifications, at least ten days prior to wall construction.

Also furnish the Engineer a Certificate of Compliance certifying that the retaining wall materials, backfill and construction practices comply with this Specification.

Acceptance of furnished material will be based on the Certificate of Compliance, accompanying test reports, and visual inspection by the Engineer.

548-8 Method of Measurement.

The quantity to be paid for will be the plan quantity, in square feet [square meters], completed and accepted, of the area bounded by the top of the traffic barrier, coping or parapet (or the top of the wall in areas with no top treatment), the top of the leveling pad, top of structural footings, bottom of walls which do not have footings or leveling pads, and the beginning and end wall limits as shown on the wall control drawings.

548-9 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section, including the design of the wall system, excavation and fill required specifically for wall construction below the normal roadway template, soil reinforcement, leveling pad, footings, traffic barriers, copings, parapets, fabric material, horizontal joint materials, alignment pins, repairs, labor, equipment, and other materials necessary to complete the wall in an acceptable manner as shown on the Contract drawings. The cost of granular fill for the normal roadway template will be included in the cost of embankment or borrow excavation, as applicable.

Payment will be made under:

Item No. 548-10-	Retaining Wall System (Permanent) - per square foot.
Item No. 2548-10-	Retaining Wall System (Permanent) - per square meter.
Item No. 548-11-	Retaining Wall System (Temporary) - per square foot.
Item No. 2548-11-	Retaining Wall System (Temporary) - per square meter.