PREFACE

Overview
The purpose of this manual is to provide New York State Department of Transportation Construction Inspectors with an overview of the operations involved in the construction of a Mechanically Stabilized Earth System (MSES) retaining wall, cautionary examples of poor construction practices, areas for troubleshooting, and a quick and easy-to-use set of inspection guidelines. The enclosed check lists are intended to serve as reminders to inspectors of important aspects for the successful construction of MSES.

Prior to using this manual, inspectors should become familiar with the general concepts of MSES. This information can be found in Chapters 1, 2 & 3 of the Federal Highway Administration Publication No. FHWA GEC-011 – Volume I, titled Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I, available at: https://www.fhwa.dot.gov/engineering/geotech/pubs/nhi10024/nhi10024.pdf

In addition, it is imperative that Engineers-In-Charge obtain from the Contractor and review copies of the MSES Designers/Suppliers Construction Manual. The MSES Designer/Supplier’s Construction Manual contains detailed information for the construction of a particular MSES and provides the necessary guidance during the construction inspection process.

The user of this manual is encouraged to make copies of the enclosed checklists as needed.

Acknowledgement
This manual is a result of research and review of other State Department of Transportation’s Inspector Manuals, along with the FHWA and various construction manuals from MSES Wall Systems appearing on the Department’s Approved List for Fill Type Retaining Walls (https://www.dot.ny.gov/divisions/engineering/technical-services/technical-services-repository/alme/pages/fillwall-1.html#A). The majority of information in this document was accumulated from Geotechnical Engineering Circular (GEC-011) Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes and Mechanically Stabilized Earth Wall Inspector’s Handbook published by Florida Department of Transportation.
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1. INTRODUCTION

The New York State Department of Transportation first used Mechanically Stabilized Earth System (MSES) in 1978. At that time, the Reinforced Earth Company and, to a much lesser extent, VSL Retained Earth, enjoyed the distinction of being the only Designers/Suppliers of this type of wall system for the Department. They were relatively new companies with a proprietary product, and they were able to provide knowledgeable personnel on-site to ensure that their system was constructed properly. The Department found that MSES were very cost effective, usually representing a cost saving of 20 to 40 percent over conventional reinforced concrete walls. A proprietary wall specification was developed for MSES walls and its use was encouraged by the Department.

Today, the situation is much different. The Department still reaps the benefits of cost-effective and well-designed MSES walls, but the number and types of proprietary wall systems has significantly increased since 1978. In response, Federal and State policies have changed regarding the use of proprietary wall specifications. The current policy of both the Federal government and State is to not use specifications which dictate a proprietary wall system since placing an unnecessary limit on the number of wall system options can potentially be unfair and may lead to unintentional, higher construction costs.

To allow competitive bidding between the various proprietary wall systems the Department has combined the following types of wall systems into one Approved List for Fill Type Retaining Walls:

- **Prefabricated Wall System (PWS).** A PWS is an externally stabilized fill wall structure consisting of prefabricated proprietary wall units which are stacked and effectively function as a gravity wall to “externally stabilize” the soil behind the wall units. The wall design also incorporates coping units, leveling pads, unit infill, earth backfill, joint filler material and geotextile, and a subsurface drainage system to reduce hydrostatic pressure on the wall system.

- **Mechanically Stabilized Wall System (MSWS).** An MSWS involves the addition of soil reinforcement elements into the backfill of a PWS. The wall units and soil reinforcement collectively function to “internally stabilize” the soil fill behind the wall units and greatly increases the range of wall heights and loads that would be allowed by the PWS wall units alone. The wall design also incorporates coping units, a specific soil backfill, an unreinforced concrete leveling pad, and a subsurface drainage system to reduce hydrostatic pressure on the wall system.

- **Mechanically Stabilized Earth System (MSES).** An MSES is a proprietary wall structure consisting of precast concrete face panels connected to soil reinforcement elements which collectively function to “internally stabilize” the soil fill behind the wall face panels. The wall design also incorporates coping units, a specific soil backfill, an unreinforced concrete leveling pad, and a subsurface drainage system to reduce hydrostatic pressure on the wall system.
The Fill Type Retaining Wall Approved List must be combined with essential notes and details in the contract documents to allow different proprietary wall systems, appropriate for the project’s goals, to be impartially considered by the Contractor.

Realistically, the term “proprietary” for many MSES walls is a misnomer because many of the wall designs no longer have patents to prevent use of their unique elements in other wall systems. In essence, innovative designs of retaining walls could incorporate component details from previously patented wall systems when utilizing proper design procedures.

Due to the increased competition and the continual arrival of innovative wall designs, it has become increasingly important for the Department’s field personnel to be more educated and to take a more active role in the construction control of an MSES wall. To that end, this Inspection Manual has been developed in an effort to make the job of construction inspection easier.

1.1 Construction Materials

Construction materials are the raw/processed components incorporated into the final structure. The components used to construct a structure have an impact on the schedule and cost, and will dictate the necessary construction techniques.

Prior to 1980, designs for the Departments permanent retaining walls typically involved gravity or cantilever concrete walls:

- **Gravity Poured Concrete Retaining Walls.** Gravity walls are monolithic, cast walls which depend on their own weight and any soil resting on the concrete in resisting lateral earth forces.
- **Cantilever Retaining Walls.** Cantilever retaining walls are constructed of reinforced concrete thereby using much less concrete than gravity walls but require more design and particular construction techniques to address the inclusion of the reinforcement.
- **Counterfort Retaining Walls.** Counterfort retaining walls are similar to cantilever walls except they have thin, vertical concrete webs at regular intervals along the backside of the wall (counterforts), adding to additional formwork and reinforcement layout.

These types of traditional retaining walls are typically constructed out of concrete. Concrete is a **bound** material that bonds together with other particles by means of a binder (i.e. cement). With this material, the retaining structures structural element is able to be batched, mixed, poured and cured in formwork to produce a finished façade that is straight and plumb. The performance of these types of walls relies on the significant weight and strength of the wall’s concrete and rebar. Concrete has long proven to be a durable material that is highly resistant to damage, but it commonly has high construction costs due to the time needed for its production, curing, and the formwork needed for its proper placement.
As with all consumer products and services, cost-competitiveness and addressing shortcomings are inspirations for the development of innovative designs. Soil reinforcement for retaining wall construction dates to the early 1960s. These walls are categorized as Mechanically Stabilized Earth System (MSES) and Mechanically Stabilized Wall System (MSWS), as defined previously, and are constructed out of earthen materials and steel or geosynthetic reinforcement. Earthen materials are *unbound*, as the aggregates are loose and do not bind or adhere to each other when laid and compacted, yet rely on the natural interlocking of adjacent solid stone particles and fines. Since the granular soil material and the soil reinforcement elements can have relatively low material costs and allow easy installation, and the volume of concrete is very limited, the overall cost of the wall system is significantly less than the construction costs of traditional concrete walls.

By using earthen material, the retaining structures structural element is not completed in a single (or relatively few, successive) pour(s) but must be tediously spread, graded, and compacted in thin layers after the outer face panel is meticulously laid-out and set with a specific back-batter to address the anticipated loading. This is continually repeated until the height of the wall is achieved, at which point the alignment of the finished façade is finally revealed. The success of the design depends on implementation of the Designer’s assumptions (i.e. the construction methods, progression of panel placement, compaction of reinforced volume, reinforcement placement elevations, sequence of panel loading, etc.). Therefore, it is necessary to monitor construction to ensure that appropriate equipment and construction methods are used.
2. GLOSSARY OF TERMS

1. **Backfill** – Any suitable material, meeting the requirements of §733-02 *Mechanically Stabilized Earth System Backfill Material* of the Standard Specifications, which, when placed in conjunction with the reinforcing strips or mesh and the facing panels, comprise the reinforced volume.

2. **Connectors** – Galvanized metal tie strips or welded clevis loops cast into the back of a facing panel to which the reinforcing strips or mesh are attached.

3. **Coping** – Precast or cast-in-place concrete cap, which is placed on top of the MSES facing panels.

4. **Facing Panels** – Precast-reinforced-concrete units which are part of the reinforced volume that forms the outside face of the MSES and are attached by means of the connectors to the reinforcing strips or mesh.

5. **Fasteners** – Bolts, washer, and nuts or connecting rods used to attach the reinforcing strips or mesh to the connectors.

6. **Geomembrane** – An impermeable geosynthetic composed of one or more synthetic sheets used to isolate the backfill material from surface water and deicing salt infiltration as a means to prevent corrosion of the reinforcing elements.

7. **Geotextile** – A permeable, planar polymeric textile material used to promote drainage, prevent infill and/or backfill material from releasing through the joints, or separating dissimilar granular materials.

8. **Identification Markers** – Signs and marking tape, buried near the finished grade, to identify and prohibit excavation of the reinforced backfill.

9. **Joint Filler** – Material used to fill the vertical, angled and horizontal joints between the facing panels consisting of either polyether foam or geotextile for all joints to prevent soil migration and resin-bonded corkboard or rubber bearing pads for the horizontal and angled joints for bearing.

10. **Leveling Pad** – A concrete pad or footing, usually unreinforced, which serves as a flat starting surface for placing the initial coursed of facing panels.

11. **Reinforced Volume** – A system of facing panels, reinforcing strips or mesh and backfill, which, when constructed together according to specification, form one coherent mass.
12. **Reinforcing Mesh** – A system of longitudinal and cross galvanized steel wires or bars, spaced and welded together at specified intervals, forming mats of specified length, which are attached to connectors and internally reinforce and stabilize the backfill.
   Alternatively, a reinforcing geosynthetic or polymer grid mat, constructed either of coated yarns or a punched and stretched polymer sheet having high strength and stiffness.

13. **Reinforcing Strips** – Galvanized or epoxy-coated ribbed steel strips of a specified length, width and thickness, which are attached to connectors and internally reinforce and stabilize the backfill.
   Alternatively, a high-strength extensible geosynthetic reinforcing strips constructed of discrete channels of closely packed high-tenacity polyester fibers encased in a polyethylene sheath via extrusion coating.

14. **Retained Fill** – The fill material located behind the reinforced volume.

15. **Slip Joint** – A vertical joint specific to the wall system used as a stress relief at wall step locations.

16. **Subsurface Drainage System** – A system for removing water from behind the wall and channeling it to a point of positive drainage.
3. CONSTRUCTION OVERVIEW

An MSES wall is a retaining structure consisting of reinforcing elements installed in the backfill mass which are connected to a precast face panel. By installing tensile reinforcing elements in the backfill soil, the strength of the soil can be improved significantly such that the vertical face of the backfill soil mass is essentially self-supporting. When all these wall elements are installed per the requirements of the specification and manufacturer’s design, the resulting vertical structure will be able to provide significant load support with minimal settlement or lateral movement.

![Generic Cross Section of an MSES Wall](Ref: FHWA GEC-011)

The NYSDOT Standard Specifications Section 554 *Fill Type Retaining Walls* provides the requirements for the construction of an MSES retaining wall. The following sections outline the major construction activities with a description of the work.

### 3.1 Foundation Preparation

MSES walls, like any other structure, need a good foundation to build upon. Proper preparation of the site increases the potential for proper performance of the wall. NYSDOT Standard
Specifications §554-3.02 C. MSES Foundation provides the requirements for the preparation of the foundation area.

The area under the reinforced mass is to be graded level for a width equal to, or in excess of, the reinforcing element length. Prior to the wall systems construction, this area is to be compacted to a minimum of 90% of Standard Proctor Maximum Density. This foundation preparation establishes a clear and leveled area, at the required grade, so that the leveling pad may be installed to the proper alignment, grade, and elevation. The preparatory groundwork properly guides the panel installation and allows the reinforced volume to be placed on top of a uniform, firm base that is able to provide adequate foundational support for the reinforced volume.

To produce a uniform, firm base, all soils found to be unsuitable (incapable of supporting any significant load due to inherent material characteristics) or unstable (incapable of being satisfactorily compacted adequately because of high moisture content) will be treated in accordance with the recommendations of the Regional Geotechnical Engineer.

### 3.2 Leveling Pad

Usually, the leveling pad is not "structurally" important, since its primary purpose is to ensure the correct final position of the wall face panels. The leveling pad is typically an unreinforced, smooth finish concrete pad which is either cast-in-place or consists of precast sections set on a thin layer of cushion sand, if needed. Leveling pad dimensions are commonly 6 inches thick and 12 inches wide.

![FIGURE 2 Leveling Pad Installation](imageurl)
The leveling pad sets the initial horizontal and vertical alignment at the base of the wall facing. After the leveling pad is set, the Contractor shall create a layout line on the top surface to be used for accurately aligning the front edge of the wall. Extra care must be used in the placement of the leveling pad where steps occur along the base elevation of the wall face. Where steps do occur, leave a horizontal gap between the upper and lower leveling pads as per the manufacturer’s guidelines or as stated in the contract documents. Also, ensure that a concrete leveling pad contains open joints at all critical locations. NYSDOT Standard Specifications §554-3.02 F. *MSES Leveling Pad* and Standard Sheets 554-01 provide the requirements and guidelines for the installation of the leveling pad.

The leveling pad must be in the correct horizontal position, i.e. level, and at the correct elevation. Only rubber shims should be used between the leveling pad and the first course of wall panels. Shims shall not be used to level the surface of poorly installed leveling pads. If the wall face is not started on a level grade, the wall face panels will bind against each other which may result in spalling of the panel edges and corners. A leveling pad that is not placed accurately will create problems with wall panel alignment and joint spacing as the wall is progressively built higher. Experience has shown that if the wall is not started correctly, the finished product is seldom satisfactory.

### 3.3 Panel Placement

Correct placement of the first two levels of wall panels is the most critical portion of the effort needed to ensure a proper wall face final alignment. The first row of wall panels is placed on the leveling pad and braced into position. The bracing must remain in place until all the soil reinforcement is connected to the panel and the soil backfill is placed and compacted to a height which is above the highest reinforcement level on the panel. Spacer bars and temporary wooden wedges may be used to ensure the panel location, joint spacing, and face batter is set as required by the wall manufacturer. Prior to the installation of the second row of wall panels, ensure that the initial row is placed at the proper alignment and batter and provides a level, top edge for the entire length of the row. NYSDOT Standard Specifications §554-3.02 G. *MSES Erection* provides the requirements for the panel placement.
The correct vertical and horizontal joint spacing between wall facing panels is also very important. Without the correct spacing, panel corners will crack and spall with any wall settlement. Spacers (bearing pads) must be used between successive rows of facing units. These bearing pads maintain a consistent horizontal joint width for the entire row and provide a compressible material that prevents direct concrete-to-concrete contact between facing panels, thereby maximizing the flexibility of the facing and minimizing the amount of axial load transferred to the facing panels as the backfill compresses under its own weight.

Temporary wooden wedges are also used to help hold the vertical alignment of the panels. Wooden wedges may be temporarily placed in the vertical joints to maintain alignment until another panel is placed on top. 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.

During the initial stage of wall construction, no backfill should be placed or compacted against the externally braced panels, otherwise the panels will be pushed out of alignment. Once the bottom layer of soil reinforcing has been installed (and one lift of backfill has been placed and compacted over the reinforcements), placement and compaction of backfill directly against the panels can proceed.

3.4 Backfill

The select granular backfill material should be placed in lifts parallel to the wall face and compacted to the required density in loose lifts no greater than 12 in. thickness. It may be helpful to mark the lift height on the back side of the wall panels. NYSDOT Standard Specifications §554-3.02 H. MSES Backfill provides the requirements for the backfill placement. The work performed within the area of 3 ft. from the back-face of the panels has a direct impact on the alignment of the wall. Therefore, this zone of the reinforced fill placement is treated with specific, augmented requirements (see Section 3.5 Compaction).

Backfill material is to be placed no closer than the 3-ft. zone from the back of the wall panels. The material 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. Once this has been accomplished, material is then placed within 3 ft. behind the wall panels by windrowing the material. The exception to this procedure is the initial placement of fill (noted in Section 3.3 Panel Placement) as the initial panels are only externally braced and may be pushed out of alignment.

(a) Backfill Placement   (b) Removing Slack

FIGURE 5 Backfill Placement – Removing Slack
Prior to placement of the reinforcing element, backfill material within the 3-ft. zone from the back of the wall panels is to be placed and compacted horizontally to 2 in. above the required reinforcing element elevation. The backfill material beyond the 3-ft. zone is to be placed and compacted horizontally to the reinforcing element elevation.

### 3.5 Compaction

A key to acceptable performance of an MSES wall is the consistent placement and compaction of the select backfill material. Moisture and density control are imperative for the proper construction of this type of wall system. NYSDOT Standard Specifications §554-3.02 H. *MSES Backfill* provides the requirements for the backfill compaction.

Compaction can be generally defined as the densification of soil by the removal of air and rearrangement of soil particles through the addition of mechanical energy. The energy exerted by compaction forces the soil to fill available voids, and the additional frictional forces between the soil particles improves the mechanical properties of the soil.

- Properties such as strength and bearing capacity increase with compaction. Furthermore, pavement response improves when the density of the materials (and consequently its stiffness), is increased
- Properties such as compressibility and permeability reduce with compaction.
At the time of placement, the moisture content of the backfill material shall be at or within 2% dry of the Optimum Moisture Content. During the wall’s construction, the moisture content of previously placed backfill should also be kept at acceptable levels to prevent undesirable movement or bulging along the wall facing panels. This is generally done by temporarily grading the wall backfill surface towards drainage swales or weeps beyond the far edges of the soil reinforced zone. This effort is critical when the gradation of the reinforced backfill typically contains more than 10% fine grained soil. In some cases, the contract plans will provide a wall design that includes filter stone drainage column at the end of the soil reinforcement area. This drainage column helps prevent excessive moisture levels within the reinforced backfill. Surface access to this drainage column should always be maintained during construction.

Moisture content of the soil is vital to proper compaction because moisture acts as a lubricant within soil, sliding the particles together.

- Too little moisture will result in inadequate compaction as the soil particles cannot move past each other to achieve density.
- Too much moisture will result in water-filled voids and subsequently weakens the load-bearing ability.

Backfill compaction is to be performed in such a way that the large, smooth-drum roller moves in a direction parallel to the wall facing panels and proceeds from the back of the reinforced soil mass, working towards the panels. This aids in locking the soil reinforcement in place before loading the panels.

(a) Initial Compaction    (b) Finalizing Compaction

FIGURE 7 Compaction – Locking Reinforcements In Place

- Roller compaction beginning at the back of the reinforced mass moving towards the panels and then finished with light, hand-operated equipment.

(modified, Florida DOT, 2012)
As noted in Section 3.4 Backfill, the zone of the reinforced fill within the area of 3 ft. from the back-face of the panels is treated differently. In this zone, small sized, walk-behind or hand-operated compaction equipment must be utilized. However, be aware that this type of equipment (in comparison to the large, smooth-drum roller used in the majority of the reinforced fill area):

- is slower and tends to lag behind,
- requires thinner lifts (6 in. loose lift thickness),
- requires more effort to obtain proper moisture and density, and
- requires intense inspection to identify and point out any panel movement, backfill gaps below the soil reinforcement, or any unintentional bending of the soil reinforcement.

Because of these factors, hand compaction is a source of irritation for all involved. This results in a tendency to point to the progress of the roller-compacted reinforced fill operation as a way to push forward or rush the advancement of the hand compaction zone, rather than to continue to maintain good construction techniques in both areas.

![Figure 8](image)

**FIGURE 8** Types of Compaction Equipment

Placement of the reinforced backfill material within the area of 3-ft. from the back-face of the panels should not lag behind the remainder of the reinforced fill area by more than one lift. Poor fill placement and compaction in this area has, in some cases, resulted in facing movement and/or down-drag on reinforcements, which increases connection stresses.

### 3.6 End of Each Day’s Operations

Inclement weather can seriously delay a project. Rather than being eternally optimistic, measures should be put in place to protect the portion of work that has been diligently installed. NYSDOT Standard Specifications §554-3.02 D. MSES Subsurface Drainage System and H. 3. Surface Drainage Control provides the minimum requirements for controlling runoff.

Weather disruptions are not only a direct time loss during the bad weather event but the event itself can cause damage to a partly completed MSES wall system (e.g. material washouts, panel
bulges, material saturation resulting in delays, material contamination, etc.). The Contractor is required to provide positive control and discharge of all surface drainage that will affect the installation of the MSES throughout the construction of the wall. Therefore, at the end of each day's operation, the Contractor should shape the last level of backfill to permit runoff of rainwater away from the wall face or provide a positive means of controlling runoff away from the wall (such as temporary pipes, etc.) to prevent ponding of water on surface of the reinforced soil mass.

3.7 Soil Reinforcement

Soil reinforcements are inclusions, incorporated in a soil to improve its behavior, where the soil-inclusion stress transfer occurs continuously along the inclusion. NYSDOT Standard Specifications §554-3.02 I. MSES Reinforcing Elements provides the requirements for reinforcing elements.

The soil reinforcement is used to create a reinforced-soil mass & physically ties the panel facing to the mass. Soil reinforcements are either inextensible (i.e., mostly metallic) or extensible (i.e., mostly polymeric materials). Inextensible reinforcements include reinforcing straps, welded bar mats, and reinforcing ladders. Extensible reinforcements include geogrids and geostraps.

![Soil Reinforcement Types](image)

**FIGURE 9** Soil Reinforcement Types

The integrity of the MSES wall system depends wholly on the integrity of the reinforcements. Reinforcements should not be bent, torn, galvanization chipped off, cut, left in the sun (polymer) or otherwise damaged. The reinforcement should be checked for the required length, size and supplier’s product designation. Typically, the reinforcement is placed perpendicular to the wall face and should be installed such that any slack in the reinforcement is removed (see Section 3.4 Backfill regarding the movement to work out any slack in the reinforcement).
3.8 Equipment Movement

In keeping with what is outlined in Section 3.6 End of Each Day’s Operations, measures should be put in place to continually protect the portion of work that has been diligently installed as the work proceeds. NYSDOT Standard Specifications §554-3.02 K. Equipment Movement provides the restrictions and precautions regarding the operation of equipment on the reinforced soil mass.

Movement of construction equipment and all other vehicles and loads over and adjacent to MSES is done at the Contractor's risk. Precautionary measures include:

- Vehicular equipment should be kept a minimum of 3 ft. from the panel units.
- As noted in Section 3.5 Compaction, the zone of the reinforced fill within the area of 3 ft. from the back-face of the panels is to be compacted with walk-behind or hand-operated compaction equipment.
- Rubber tired equipment may be operated on top of reinforcing elements only at low speeds (less than 5 mph) and without making sharp turns or braking sharply.
- Tracked equipment may not be operated directly on reinforcing elements. The reinforcement needs to be covered with a minimum 6 in. thick soil layer prior to operating tracked equipment over reinforced areas.

3.9 Geomembrane Installation

The key to long-term performance of an MSES wall is the durability of the reinforcing elements. The design of an MSES wall assumes a corrosion model which predicts a uniform maximum metal loss rate such that a sufficient cross section of steel remains at the end of the service life in order to ensure the original design criteria for strength are met. The corrosion model is predicated on the measurement of key index parameters of the reinforced fill as required by the specification. However, once installed, contamination may occur through salt intrusion from road de-icing salts infiltrating and affecting the controlled electrochemical properties in the reinforced zone. NYSDOT Standard Specifications §554-3.01.B.4ii. Geomembrane provides the requirement of a geomembrane barrier for an Internally Stabilized Fill Structure (either MSES or MSWS) which utilizes inextensible (metallic) reinforcing elements.

Accelerated or unanticipated corrosion of the reinforcements could cause sudden and catastrophic failure of MSES wall. The installation of a geomembrane isolates the reinforced mass from adverse elements. The geomembrane should be deep enough that it does not adversely affect the pavement performance and allows for installation of guiderail posts without puncturing the geomembrane. If reinforcements are designed to be situated above the geomembrane, they would be designed for an exaggerated service life and will be identified to the Inspector for proper installation locations.
4. IDENTIFYING POOR CONSTRUCTION PRACTICES

Most General Contractors want milestones to be completed on time and they want their employees, and Subcontractors, to know how to accomplish the task at hand. No Contractor sets out to build a substandard project. However, if construction management is poor, so will be the outcome. Bad management can affect workmanship and endanger both the success and completion of a project, as well as the safety of the workers.

The demands of construction are a result of various influencing factors including:
- inexperienced General Contractor creating an unrealistic, low-ball bid,
- an aggressive, impractical timeline,
- employing and scheduling second-rate Subcontractors,
- substandard day-to-day supervision, and
- poor planning.

When demands of construction put pressure on project personnel, the overworked, unhappy, and unproductive employees may revert to cutting corners, which lead to mistakes, embedded flaws, and accidents.

4.1 Improper Placement and Compaction of Fill Directly Behind the Panels

As noted in Section 3.5 Compaction, the placement of the reinforced backfill material within the area of 3 ft. from the back-face of the panels should not lag behind the remainder of the reinforced fill area by more than one lift and the compaction within that zone requires different methods (which slows down the operation). Rather than pointing to the progress of the roller-compacted reinforced fill operation as a way to push forward or rush the advancement of the hand compaction zone, the roller-compacted reinforced fill operation needs to adjust to the progress of the hand compaction zone.

As required by the specification, the backfill material within the 3-ft. zone from the back of the wall panels is to be placed and compacted horizontally to 2 in. above the required reinforcing element elevation while the backfill material beyond the 3-ft. zone is to be placed and compacted horizontally to the reinforcing element elevation. Therefore, in order to connect the reinforcement to the panel, the soil must be scooped out to allow mating and securing the connection mechanism. This process ensures the material directly underneath the reinforcement is properly compacted. As noted in Section 3.3 Panel Placement, the only exception to this procedure is during the initial stage of wall construction because the panels are only externally braced and may be pushed out of alignment. Once this initial step is completed, the panels will be sustained by the alternating supports of the soil reinforcement in a partially backfilled panel and shoulder clamps to the adjacent panels.

The Contractor should not cut corners by not placing and compacting the backfill material to 2 in. above the required reinforcing element elevation in order to allow easier access to the
connection mechanism and/or not adjusting the roller-compacted reinforced fill operation to the progress of the hand compaction zone.

Once the reinforcement connection is fastened, it is difficult to properly place and compact material within this zone. Poor backfill placement and compaction in this area will result in:

- Differential movement between the panel and the backfill. As the backfill soil compresses due to the increase in overburden pressure from the continuing fill placement, it generates unanticipated shear forces at the connections. Since the facing panels can be considered as essentially rigid, all the downward deformation resulting from the backfill soil compression causes the reinforcing elements to be dragged down with the backfill material, which in turn causes a strain and load increase in the soil reinforcement at its connection.

- A potential for corrosion due to differential aeration. It has been recognized (Siddharthan, R.V., Thornley, J., and Luke, B., 2010) that corrosion may occur at a significantly higher rate than anticipated in the reinforcements located in the differential compaction zone directly behind the facing (likely due to differential aeration through the development of macro cells). As stated in the report, aeration differentials across a metal inclusion, especially significant differentials over a short distance, can create an environment where an electron exchange can occur rapidly. Uniformity, both in material, gradation, and in-place density, is important for the long-term sustainability of the MSES wall.
4.2 Inconsistent Compaction, Under-Compaction by Insufficient Compactive Effort or Damage to Compacted Lifts

As noted in Section 3.5 Compaction, the key to acceptable performance of an MSES wall is the consistent placement and compaction of the select backfill material. Inconsistent compaction, under-compaction caused by insufficient compactive effort, or damage to compacted lifts will lead to gross misalignments and settlement issues.

The FHWA design manual notes that the internal stability of the reinforced soil zone is dependent on three fundamental characteristics:

- the soil-reinforcement interaction (resistance to pullout and to sliding, for sheet-type reinforcements);
- the tensile resistance of the reinforcement; and
- the durability of the reinforcing material.

With regard to the soil-reinforcement interaction, the soil-to-reinforcement relative movement required to mobilize the design tensile force depends mainly upon the load transfer mechanism, the extensibility of the reinforcement material, the soil type, and the confining pressure. At the time of construction, all design assumptions must be verified. Most of this task is addressed in the Shop Drawing review, where the reinforcement type is identified, and its parameters are utilized within the design calculations. In addition, the Contractor will identify the backfill material Supplier and the material is to be stockpiled and tested. As for the confining pressure, although the engineering properties of the reinforced soil volume have been assumed in design, it must be verified in construction. This is accomplished via compaction tests. Compaction is a mechanical process in which an earthen material is made more-dense. The densification of the various layers of materials achieved through compaction provides them the strength and stiffness necessary to provide the assumed soil-reinforcement interaction, withstand anticipated loading, and withstand some of the damaging effects of the environment.

Inconsistent or under-compaction may be a result of:

- A missed roller pass,
- Insufficient roller weight,
- A change in operating frequency or amplitude (if vibratory rollers are in use),
- A defective roller drum, or
- The use of an improper type of compaction equipment.

As noted in Section 3.8 Equipment Movement, measures should be put in place to continually protect the portion of work that has been diligently installed as the work proceeds.
FIGURE 11  Example of compaction damage due to abrupt panel level changes and haulage pathway

To avoid damage to the compacted lifts, the wall erection sequencing should begin on the leveling pad along the lowest elevational row of the wall system and proceed in horizontal lifts. Panel layout usually begins at the lowest leveling pad elevation or a fixed point (such as a corner or existing structure) proceeding towards the open end of the wall. The construction of the second row of panels must not start until backfill compaction has reached the top of the half-height base panels. Throughout construction, panels should only be set after backfilling and compaction to grade has been completed.

In instances where construction activities are focused on a specific section of a partially installed MSES system (e.g. abutment), a Contractor may lose appreciation for the delicate nature of the unbound granular backfill and impose concentrated loads and damage the installed, compacted lift. Haul roads, or paths, in areas of grade changes can impact a lift via displacement, rutting, or dislodging material. Excessive equipment movement (e.g. large loads, turns, tire spins) on a lift can also have damaging impacts.

Inconsistent compaction or under-compaction caused by insufficient compactive effort opens up the potential for rutting, as the lift material is not well compacted (Figure 12A). Furthermore, if the damage is not addressed and just buried, the potential remains. As equipment load stresses are applying on the subsequent lift, the low strength underlying lift will collapse and deform (Figure 12B).
4.3 Obstructions in the Reinforced Mass

As noted in Section 3.7 Soil Reinforcement, the integrity of the MSES wall system depends wholly on the integrity of the reinforcements. Reinforcements should not be bent, torn, galvanization chipped off, cut, left in the sun (polymer) or otherwise damaged.

Considering the variety of subsurface elements installed within a roadway section, there are bound to be conflicts with fully embedded reinforcements within the reinforced mass. Vertical obstructions are structures that are embedded in, or extend vertically through, the reinforced mass (e.g. catch basin, grate inlet, sign foundation, bridge foundation, light poles, guardrail post, or culvert). Horizontal obstructions are structures which are embedded in, or extend horizontally through, the reinforced mass for a substantial length along the wall (commonly due to utilities such as storm drain pipes).

The FHWA design manual provides potential alternatives for:

- **Addressing vertical obstructions:**
  - Fit the soil reinforcement around the obstruction without cutting the soil reinforcement. This can be accomplished by fitting the panels with extra facing
connections, such that soil reinforcing can be connected at locations away from the vertical obstruction, or splaying the reinforcements around the obstruction (the splay angle is defined as the angle measured from a line perpendicular to the wall face in a horizontal plane and shall be less than 15-degrees).

- Design and install the surrounding reinforcement layers to carry the additional load which would have been carried by the severed reinforcements.
- Install a structural frame around the obstruction, which is capable of carrying the load from the facing in front of the obstruction to reinforcement connected to the structural frame behind the obstruction.

**FIGURE 13** Circumventing Obstructions within the Reinforced Mass.

- Addressing horizontal obstructions:
  - Deflect the reinforcement in a smooth manner up to 15 degrees of vertical skew.
  - Incorporate the use of back-up panels.
  - Installation within a double wall design system with flexible connections at rigid interfaces, e.g. within a box culvert with inspection galleries or double-wall pipe, to address differential settlement issues.
During the design phase of the project, the Designer will identify any potential conflicts in the reinforced mass (e.g. drainage runs, catch basins, underdrain, utilities, etc.) in the contract details for the Fill Type Retaining Wall. These conflicts are to be addressed by the wall Designer and will be checked during the Shop Drawing review.

Under no circumstances, should any reinforcement be left unconnected to the wall face or arbitrarily cut/bent in the field to avoid the obstruction.

When clearing horizontal obstructions, the reinforcement should be smoothly curved around the obstruction. The reinforcement should not be kinked at any time. Deflections greater than 15 degrees tend to break the galvanization and may reduce the tensile and pullout resistance of the inextensible soil reinforcements.
4.4 Excessive Steps Adjusting to Contours

As noted in Section 3.5 *Compaction*, the key to acceptable performance of an MSES wall is the consistent placement and compaction of the select backfill material. Additionally, as noted in Section 3.1 *Foundation Preparation*, MSES walls need a good foundation such that the reinforced volume is placed on the top of a uniform, firm base that is able to provide adequate foundational support for the reinforced volume.

In an MSES wall installation that has been designed with an excessive number of steps to adjust to contours (i.e. a rise in the leveling pad elevation for an individual panel to tuck the wall into a sloping hillside), the foundation preparation and compaction elements in the construction installation process near this interface may be impaired. Although the step adjustment may be justified by meeting the minimum embedment requirements, constructability aspects are problematic. Benching into the hillside may tie the wall into the slope but it has its difficulties. Opening up the benches and placing the leveling pad and panel at each step may fit a Contractors schedule but may not allow for proper foundation preparation within the individual steps. Additionally, these open bench steps may be disturbed by weather effects or adjacent construction operations and, if not recompacted prior to backfill, may impact the performance of the wall.

Vertical steps in the leveling pad shall not be greater than half the standard panels height and the minimum length of wall between leveling pad elevation changes shall be the width of two standard panels.
FIGURE 16  Leveling Pad Elevation Change Restrictions:

FIGURE 17  Excessive steps adjusting to contours.
FIGURE 18  Panel slip.
5. TROUBLESHOOTING DESIGN DEFICIENCIES

An Inspector is the last person to address any deficiencies before it is incorporated into the MSES volume and accepted as the final product. The foremost goal of an Inspector is to assure a quality highway product. The Inspector has the responsibility of evaluating construction activities and procedures to assure that they are in accordance with the contract documents and Designer’s assumptions, and will result in the planned stable, sturdy MSES wall.

The previous sections of this manual provide an outline of the specification requirements and identify some poor construction practices in an attempt to reinforce the importance of the construction criterion for the proper performance of the MSES. Furthermore, this understanding can aid an Inspector in identifying issues with details of an MSES prior to installation to ensure the successful construction of the MSES.

5.1 Runoff Infiltrating Reinforced Mass

As noted in Section 3.5 Compaction, a critical component to the successful performance of an MSES wall is the consistent placement and compaction of the select backfill material. Any outside influences adversely affecting the installed reinforced mass will reduce the service life of the wall.

Inclement weather not only can seriously delay a project or damage a partly completed MSES wall system, it can also impact the service life of the wall. Severe rain runoff, isolated sumps/ponding, snow melt, etc. have the capacity to infiltrate and allow disturbance to the reinforced mass during subsequent construction work or after the wall’s completion. This is particularly relevant to MSES walls that are offset from the paved roadway section set on an embankment. This area between the road and wall face is typically permeable (e.g. turf establishment, stone fill), allowing infiltration of runoff and de-icing salts. Severe, permanent staining of the wall face panels is also likely.

To avoid detrimental infiltration of road de-icing salts into the compacted reinforced mass and affecting the controlled electrochemical properties in the reinforced zone, the design should address this service life concern and include a mechanism to protect against the potential for this post-construction change, which includes a full length, buried geomembrane isolating the reinforced mass.
FIGURE 19  Example of a movement in an MSES wall with the suspected cause from water infiltration
  - Top row of five MSES panels moving laterally away from structure;
  - Bridge contract corrected water infiltration issue;
  - Current survey monitoring indicates cessation of panel movement (survey to continue on periodic basis)

FIGURE 20  Example of MSES panel cracks
  - Possible movement of panel caused by surface water runoff infiltrating the reinforced mass
5.2 Acute Angles in Wall Layout

MSES corners can be difficult to construct due to the layering and skewing of the reinforcement, wall batter, and interference with obstructions such as piles or drainage structures. When two MSES wall segments intersect to form an “external” (e.g., 90 degree) or an “internal” (e.g., 270 degree) corner, both wall segments will tend to move laterally such that corners tend to open up. Corner elements are provided to accommodate differential movements by acting like slip joints, prevent fill from moving through the crack, and provide aesthetic treatment.

Furthermore, as explained in FHWA GEC-011, external wall corners with an angle of less than 70 degrees, i.e., acute angle, should be avoided because of construction difficulties, e.g., compaction in corners and placement of reinforcements. However, if such a situation cannot be avoided, then the wall corner should be designed based on following considerations:

- The acute angle corner should be designed as a bin wall for the extent of the wall where the full length of the reinforcement cannot be installed without encountering the opposite wall face. In the bin wall section, the reinforcing elements are either structurally connected to both wall faces forming the acute angle corner or overlapped if there is adequate space to develop the required pullout resistance.
- Full-height vertical slip joints should be provided at the interface of acute corner and after the last column of panels where full-length reinforcements can be placed.
- The soil reinforcement attached to the slip joints should be oriented perpendicular to the slip joint panels and shall be the full design length.
- Light weight concrete should be considered as an alternate to placing and compacting fill.
- Deformation compatibility between the bin wall section and the rest of the MSES structure should be carefully evaluated.

Design should address these constructability concerns by avoiding acute angles. As noted in NYSDOT Bridge Manual, a retaining wall adjacent or abutting a bridge abutment is commonly referred to in bridge plans as a wingwall and inline wingwalls cantilevered from the abutment are the preferred arrangement.
FIGURE 21   Example of a 90° corner in an abutment application with:
- Significantly under-backfilled yet reinforcement connection has been fastened; and
- Vertically adjacent layers of reinforcement not separated by a minimum of 3 in. of wall backfill material.

5.3 On-Site Consultation by Wall Designer/Supplier

The specification requires the MSES wall Designer-Supplier to provide technical assistance, by a Professional Engineer from the designated Wall System, for consultation throughout the installation of the wall. The technical assistant is to be on-site during the initial installation of the wall panels, during critical installation phases designated at the Pre-Operation Meeting, and as requested by the Engineer. In addition to the Inspection Manual as a technical resource, the requirement of an on-site technical assistant is provided to ensure the intricacies of a particular MSES wall system may be directly explained to assure that they are in accordance with the Designer’s assumptions and will result in a successful installation.

Subsequent to the completion of the wall but before the start of the work elements above the final top of wall elevation, the technical assistant is to conduct an engineering survey of the wall and provide a report to the Engineer. The report will contain the following elements:
- A summary of the work procedures used to construct the wall, including backfill material moisture content, compactive effort/equipment specifications, lift thicknesses, initial panel back-batter, initial bracing techniques.
- A description of any procedures that deviated from the designer’s Installation Manual, including the reasoning for the change.
- An inspection of the wall joints, including offset per panel, gap tolerance, spacers (appropriate use of, and subsequent removal of, temporary wooden wedges, bearing pad placement), and joint fillers/geotextile.
- An inspection of the wall system, including alignment and overall plumbness of the wall.
- An account of the wall reinforcing elements, including storage and handling methods, procedures used to attach and fasten reinforcements, methods used to minimize disturbance to compacted material at attachment locations, and technique employed to remove slack.
- A summary of the field conditions and drainage control, including installation of subsurface drainage system, methods for positive control and discharge of all surface drainage during the walls construction, and any adverse weather impacts to the wall system.
- An account of the geomembrane installation, including the elevation in relation to the reinforced mass, placement technique, details/materials used at connections to vertical projections extending through the geomembrane, seam sealing method/equipment specifications, installation of subsurface drainage system.
- Identification of any approved field changes.
- Remarks on the construction procedure and a conclusion regarding whether or not the completed wall construction has met the designated Wall Systems design and installation requirements.
6. CHECKLISTS

The following checklists are provided as an aid to the Inspector to help ensure consistency and completeness in each phase of construction, as a means of organization for the day’s events, and an initial documentation of tasks.

For any task marked “NO”, the Inspector shall record on DWR in SiteManager a thorough explanation of the reasoning for failure of completion.

6.1 Preconstruction

YES NO
☐ ☐ Review and become familiar with the State plans and specifications and the MSES working drawings, including the construction sequencing.

☐ ☐ Check to make sure that all required manuals and directives for the construction of the wall(s) have been supplied. This includes:

YES NO
☐ ☐ Standard Specification Section 554 Fill Type Retaining Walls,

☐ ☐ MSES Construction Manual, supplied by the MSES Designer/Supplier,

☐ ☐ The current NYSDOT Geotechnical Control Procedure (GCP) issued for the Control of Granular Material, supplied by the Regional Geotechnical Engineer,

☐ ☐ The current NYSDOT Directive for the Acceptance/Rejection Procedure MSES Backfill, supplied by the Regional Geotechnical Engineer.

☐ ☐ Preliminary evaluation for potential source(s) of backfill material for electrochemical properties may be undertaken by the State at the discretion of the Regional Geotechnical Engineer.

☐ ☐ Preconstruction Meeting:

A preconstruction meeting with the Regional Geotechnical Engineer and/or the Geotechnical Engineering Bureau representative is encouraged. This meeting should be used by the Engineer-In-Charge and his inspectors to discuss and clarify any items of concern about the proposed MSES. See Appendix A Pre-Operation Meeting.
6.2 Materials, Handling and Storage

YES  NO

☐  ☐ Ensure that the Contractor has an area to store and/or stockpile materials supplied by the MSES Designer/Supplier. This area should be clean, dry and capable of being covered.

☐  ☐ Ensure that all component materials necessary to construct the wall(s) supplied by the MSES Designer/Supplier have been shipped to the site. This includes:

☐  ☐ Facing panels, marked as to their type and stamped as being inspected by the NYSDOT Materials Bureau. Facing panels which are not being directly unloaded form a truck and placed in the structure must be restacked and stored in accordance with the Construction Manual.

☐  ☐ Reinforcing strips or reinforcing mesh, bundled, labeled and of the length specified by the Designer/Supplier. Reinforcing strips and reinforcing mesh are to be stored off the ground.

☐  ☐ Fasteners, bundled or boxed and labeled.

☐  ☐ Joint fillers, consisting of:

For all Joints:

YES  NO

☐  ☐ Polyether foam strips, properly sized and shipped in bags.

- or-

☐  ☐ Geotextile, shipped in rolls.

In addition, for bearing surfaces:

☐  ☐ Preformed bearing pads, boxed and labeled.

- or-

☐  ☐ Resin-bonded corkboard, properly sized and shipped on pallets.

☐  ☐ Check the items that must be fabricated by the Contractor as shown in the appropriate Construction Manual. Make sure there are sufficient quantities to perform the work.

6.3 Construction

6.3.1 Site Preparation:

YES  NO

☐  ☐ Concrete leveling pad area is excavated to the proper dimensions and compacted according to Section 554, Mechanically Stabilized Earth System, of the Standard Specifications.
Underdrains, where required, are installed.
Concrete leveling pad is poured within tolerance.
Concrete leveling pad is cured properly.
Control line for the front face of the MSES is established on the leveling pad.

6.3.2 Initial Course Construction:

Proper layout and setting of the initial course of panels for any MSES is crucial. Extra effort by the Contractor at the beginning of wall construction should result in trouble-free and rapid construction of a wall. The inspector should ensure that the Contractor is paying close attention to vertical and horizontal alignments, batter and centering when placing each panel.

Initial course construction is straightforward and consists of setting a series of alternating half-height and full-height panels along the proper alignment and to the proper batter. The general construction procedure is as follows and is repeated throughout the initial course construction:

Setting a Half-Height Panel:
- Set the first half-height panel at its proper location.
- Align the panel with the control line.
- Space the next half-height panel the proper lateral distance from the previous half-height panel using the spacing tool.
- Spacing tool left in place, ensuring proper distance.
- Batter of the half-height panel is set with wedges.

Setting a Full-Height Panel:
- Remove the spacing tool.
- Center the full-height panel between the half-height panels to ensure equal vertical or angled joint spacing.
- Batter of the full-height panel is set with wedges.
- Clamp the full-height panel to the half-height panels on each side.

For ease of inspection, checklists have been provided which break the initial course construction into Phases 1, 2 and 3. This is done so that there are breaks at critical junctures to ensure the construction of the wall is proceeding properly.
## Initial Course Construction – Phase 1 Checklist

<table>
<thead>
<tr>
<th>Construction Activity</th>
<th>Half-Height Panel Number*</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B1</td>
<td>B2</td>
<td>B3</td>
</tr>
<tr>
<td><strong>Set Half-Height Panel</strong></td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>• Align the panel with the control line.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>• Space half-height panel proper distance from the previous half-height panel using spacer bar.</td>
<td>NA</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>• Spacer bar left in place.</td>
<td>NA</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>• Batter is set with wedges.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Construction Activity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Set Full-Height Panel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Remove spacer bar.</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>• Center full-height panel between the half-height panels to ensure equal vertical joints.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>• Batter is set with wedges.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>• Clamp full-height panel to the half-height panels.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

* Numbers in the Table represent the order of placement of the half- (“B”) and full-height (“A”) panels.
Upon completion of Phase 1, the horizontal alignment of the completed wall section is checked and adjusted accordingly.
## Initial Course Construction – Phase 2 Checklist

<table>
<thead>
<tr>
<th>Construction Activity</th>
<th>Half-Height Panel Number*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B4</td>
</tr>
<tr>
<td>Set Half-Height Panel</td>
<td>YES</td>
</tr>
<tr>
<td>• Align half-height panel with control line.</td>
<td>☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐</td>
</tr>
<tr>
<td>• Space half-height panel proper distance from the previous half-height panel using spacer bar.</td>
<td>☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐</td>
</tr>
<tr>
<td>• Spacer bar left in place.</td>
<td>☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐</td>
</tr>
<tr>
<td>• Batter is set with wedges.</td>
<td>☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construction Activity</th>
<th>Full-Height Panel Number*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A3</td>
</tr>
<tr>
<td>Set Full-Height Panel</td>
<td>YES</td>
</tr>
<tr>
<td>• Remove spacer bar.</td>
<td>☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐</td>
</tr>
<tr>
<td>• Center full-height panel between the half-height panels to ensure equal vertical joints.</td>
<td>☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐</td>
</tr>
<tr>
<td>• Batter is set with wedges.</td>
<td>☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐</td>
</tr>
<tr>
<td>• Clamp full-height panel to the half-height panels.</td>
<td>☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐</td>
</tr>
</tbody>
</table>

* Numbers in the Table represent the order of placement of the half- (“B”) and full-height (“A”) panels.
Upon completion of Phase 2, the horizontal alignment of the completed wall section is checked and adjusted accordingly. Bracing of panels begins (See Construction Manual). Backfilling of panels begins (See Checklist).
### Initial Course Construction – Phase 3 Checklist

<table>
<thead>
<tr>
<th>Construction Activity</th>
<th>Half-Height Panel Number*</th>
<th>B13</th>
<th>B14</th>
<th>B15</th>
<th>Repeat to end</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set Half-Height Panel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Align the panel with the control line.</td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Space half-height panel proper distance from the previous half-height panel using spacer bar.</td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Spacer bar left in place.</td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Batter is set with wedges.</td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Construction Activity</strong></td>
<td><strong>Full-Height Panel Number</strong>*</td>
<td><strong>11</strong></td>
<td><strong>12</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Set Full-Height Panel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Remove spacer bar.</td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Center full-height panel between the half-height panels to ensure equal vertical joints.</td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Batter is set with wedges.</td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Clamp full-height panel to the half-height panels.</td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

* Numbers in the Table represent the order of placement of the half- (“B”) and full-height (“A”) panels.
During Phase 3, the horizontal alignment of the completed wall section should be checked frequently and adjusted accordingly until the entire initial course has been completed.
Bracing of panels continues (See Construction Manual).
Backfilling of panels continues (See Checklist).
6.3.3 Backfilling – Phase I:

YES NO

☐ ☐ Backfill is properly evaluated and documented in accordance with the current NYSDOT Directive titled “Acceptance/Rejection Procedure, MSES Backfill”.

☐ ☐ Backfill is properly stockpiled and documented in accordance with the current NYSDOT Geotechnical Control Procedure titled “Procedures for Control of Granular Materials”.

Backfilling of the structure can commence, along with the remainder of the initial course construction, once 10 full-height panels have been installed, battered, aligned, braced, and the joints filled. The first backfill lift proceeds as follows:

YES NO

☐ ☐ Backfill is placed up to the bottom row of facing-panel connectors and in the same direction as the wall construction. Backfill is sloped so that the toe of the slope originates at the back of the facing panel.

☐ ☐ Backfill is compacted as required. Large compaction equipment is kept a minimum of 3 ft. (1 m) away from the panels. Compaction within 3 ft. (1 m) of the wall is accomplished using small hand operated equipment.

☐ ☐ Check wall alignment, adjust accordingly and continue.

Once the first backfill lift has commenced, the reinforcing strips or mesh can be placed and the second backfill lift can be placed. These two operations can run concurrently but must not interfere with one another.

YES NO

☐ ☐ Reinforcing strips or mesh are placed on the compacted backfill and into the facing-panel connectors. The reinforcing strips or mesh must be perpendicular to the facing panels, unless otherwise specified.

☐ ☐ Reinforcing strips or mesh are attached to the facing-panel connectors in accordance with the Construction Manual.

☐ ☐ Backfill is placed up to the next row of facing-panel connectors and in the same direction as the wall construction. Backfill is spread parallel to and windrowed toward the facing panels and the free end of the reinforcing strips or mesh. Backfill is sloped so that the toe of the slope originates at the back of the facing panel.
Backfill is compacted as required. Large compaction equipment is kept a minimum of 3 ft. (1 m) away from the panels. Compaction within 3 ft. (1 m) of the wall is accomplished using small hand operated equipment.

Check the wall alignment, adjust accordingly and continue.

### 6.3.4 Subsequent Course of Construction:

Subsequent course construction can commence only after the backfill has been placed and compacted to the top of the half-height panels from the previous course. Subsequent course construction must begin at the wall end where the initial construction began. The construction procedure for subsequent courses is identical to that which was followed for initial course construction.

Set a full-height panel:

- Remove the two clamps securing the two initial course full-height panels to the half-height panel.
- Joint filler is placed on the horizontal surface where the next panel is to be placed.
- Place the full-height panel onto the underlying panel, centering the panel to ensure equal joints.
- Panel batter is set with the wedges.
- Joint filler is placed into the horizontal and angled joints.
- Clamp the panel to the two adjacent initial course panels.

### 6.3.5 Subsequent Backfilling and Wall Completion:

Backfilling of subsequent courses can only commence once that course has been completed. The backfill procedure followed during initial course construction applies here. That is:

Backfill is placed up to the next row of facing panel connectors and in the same direction as the wall construction. Backfill is not placed against the panels themselves but is spread parallel to and windrowed toward the facing panels and the free end of the reinforcing strips or mesh.

Backfill is compacted as required.
Check the wall alignment and adjust accordingly.

Reinforcing strips or mesh are placed on the compacted backfill and aligned with the panel connectors.

Reinforcing strips or mesh are attached to the connectors as recommended in the Construction Manual.

Backfill is placed to the top of the full-height panels from the previous course.

- YES
- NO
  - Toe of the backfill is placed approximately 3 ft. (1 m) from the facing panel.
  - Backfill is spread parallel to the facing panels and windrowed toward the facing panels and the free ends of the reinforcing strips.
  - Backfill is compacted as required.
  - Bracing from the initial course is removed after the second course has been placed.

Backfilling in front of the wall or berm construction commences. Backfilling must be completed before wall reaches 50 percent of its height or 15 ft. (4.5 m), whichever is less.

- YES
- NO
  - Hardwood wedges are removed. This should be done prior to there being no more than three courses of panels above the level of any wedge.

This procedure continues until the wall is complete.

- YES
- NO
  - Remaining hardwood wedges and clamps are removed from wall.
  - Coping is installed.
7. REFERENCES


APPENDIX A

Pre-Operation Meeting:
In accordance with §554-3.02 A., a Pre-Operation Meeting will be held between the Engineer, Contractor, Regional Geotechnical Engineer, Geotechnical Engineering Bureau and other appropriate Department representatives. This meeting should be used by the Engineer-In-Charge and his inspectors to discuss the Contractors proposed construction methods and to clarify any items of concern about the proposed MSES.

Items of discussion include:

1. Technical Assistance from the designated Wall System:
The specification requires a Professional Engineer from the designated Wall System to provide technical assistance during the construction of the wall.
   - Available for consultation throughout the installation of the wall.
   - Shall be on-site during:
     ◊ initial installation of the wall panels, including:
       ➢ oversight of initial panel bracing and subsequent panel back-batter,
       ➢ guidance on alignment and spacing of panels, and techniques to remove slack in reinforcements,
       ➢ explanation on proper use of bearing pads and wooden wedges,
       ➢ inspection of the Contractors compaction operations, and
       ➢ explanation of proper procedures used to attach and fasten reinforcements and methods used to minimize disturbance to compacted material at attachment locations.
     ◊ critical installation phases designated at the Pre-Operation Meeting, and
     ◊ if requested by the Engineer.
   - Critical installation phases may include:
     ◊ steps in the leveling pad, affording wall construction operations to advance in horizontal lifts (beginning at the lowest elevation),
     ◊ corners, or angles, requiring reinforcement overlaps,
     ◊ obstructions, such as drainage structures, requiring splaying or circumventing via a structural frame,
     ◊ penetration through the wall face panels, such as drainage outlets, requiring special panels, inline precast headwall, or augmented reinforcements,
     ◊ geomembrane installation to isolate the reinforced mass.

Subsequent to the completion of the wall but before the start of the work elements above the final top of wall elevation, the technical assistant is to conduct an engineering survey of the wall and provide a report to the Engineer. The report will contain the following elements:
   - A summary of the work procedures used to construct the wall, including backfill material moisture content, compactive effort/equipment specifications, lift thicknesses, initial panel back-batter, initial bracing techniques.
- A description of any procedures that deviated from the designers Installation Manual, including the reasoning for the change.
- An inspection of the wall joints, including offset per panel, gap tolerance, spacers (appropriate use of, and subsequent removal of, temporary wooden wedges, bearing pad placement), and joint fillers/geotextile.
- An inspection of the wall system, including alignment and overall plumbness of the wall.
- An account of the wall reinforcing elements, including storage and handling methods, procedures used to attach and fasten reinforcements, methods used to minimize disturbance to compacted material at attachment locations, and technique employed to remove slack.
- A summary of the field conditions and drainage control, including installation of subsurface drainage system, methods for positive control and discharge of all surface drainage during the walls construction, and any adverse weather impacts to the wall system.
- An account of the geomembrane installation, including the elevation in relation to the reinforced mass, placement technique, details/materials used at connections to vertical projections extending through the geomembrane, seam sealing method, installation of subsurface drainage system.
- Identification of any approved field changes.
- Remarks on the construction procedure and a conclusion regarding whether or not the completed wall construction has met the designated Wall Systems design and installation requirements.

2. Sampling & Testing MSES Backfill Material:
The Department’s approval and acceptance of MSES backfill material is outlined in Geotechnical Control Procedure (GCP-17) Procedure for Control and Quality Assurance of Granular Materials.
- GCP-17 stresses the significance of controlling, tracking, and maintaining quality material on a project.
  ◊ It establishes statewide control, quality assurance (QA), and documentation procedures for evaluating granular and recycled materials used for construction items. The intent of the manual is to assure that the Department receives a product that meets the specifications for the item for which it is used. The procedures in the manual have been developed to assure that sampling is representative of the entire source or stockpile.
  ◊ The Supplier/Producer assumes full responsibility for all quality control (QC) activities for the production of the material. QC activities include assuring the material meets the specification requirements for which it is manufactured, as well as a plan to manage the inventory.
- Backfill for MSES structures must have consistent physical, and, for systems utilizing metal reinforcing straps or mesh, electro-chemical properties to ensure that the overall structure is constructable, and meets predicted, long-term performance requirements.
• The Department has instituted material controls and will perform QA tests on the final product to ensure that it meets specification requirements.
  ◊ “Chain of Custody” - This describes the documentation process by which the Department ensures that the material being placed in the work is from a given approved stockpile. This process is the responsibility of the Contractor and Supplier, and it may include the employment of Contractor staff at the stockpile source, and the use of delivery tickets.
  ◊ If the EIC observes material being placed on the grade that appears to be outside of the specification requirements or observes a visual difference in the material, the EIC may request the RGE to obtain QA samples at any location and reject all material not conforming to the specification requirements.

3. QA Sampling MSES Backfill Material:
Acceptance of MSES backfill material includes meeting the requirements of the specification under the Department’s Quality Assurance (QA) program.
• It is the responsibility of the Contractor/Supplier to make sure that the methods used for delivering and handling the material does not result in a significant change in the material’s properties, such that the material goes “out of spec” due to segregation of particles. The Department will employ QA procedures, such as sampling material placed on the grade, to ensure that the material placed still meets specification requirements.
• Sampling and testing material on the contract site includes from behind an MSES Structure after placement by the Contractor or at any other location where the material is being stored or used.
  ◊ The Department may elect to take samples from the grade at any time as part of the overall QA process. Note that because of the critical importance of backfill placed for MSES applications, the Department will always take additional samples from behind the new structure for additional testing. The frequency of these additional samples will be determined by the GEB’s General Soils Laboratory Supervisor, or representative, based on a history of the source and the quantity of material being placed.
  ◊ The Department will always take additional samples from behind the new structure for additional testing even if material "looks" the same - Resistivity is not visual.

4. Testing Timeframe for MSES Backfill Material:
There are time requirements for the testing of MSES material.
• Laboratory tests includes
  ◊ Gradation,
  ◊ Plasticity Index,
  ◊ Soundness,
  ◊ Resistivity,
  ◊ pH,
  If resistivity: 1000 ohm-cm ≤ ρ ≥3000 ohm-cm, additional tests on soluble salts are required:
    ◊ Sulfide Ions,
◊ Sulfates Ions, and
◊ Chlorides Ions.

Note that the typical turn-around time for these test results is two weeks. Every effort will be made to expedite this testing. GCP-17 includes references to these tests, including T288 Soil Resistivity, T290 Sulfate Ion Content, T291 Chloride Ion Content, NYSDOT Materials Bureau Test Method 711-12C, Sulfide Content.

5. Moisture Content of MSES Backfill Material:
The Department’s recent history in the construction of MSES walls has included bulging of partially constructed walls after heavy rain events.

- MSES backfill material can be very sensitive to moisture content.

◊ Moisture and density control are imperative for construction of MSES and RSS systems. Even when using high-quality granular materials, problems can occur if compaction control is not exercised. Reinforced wall fill material should be placed and compacted at or within 2 percent dry of the optimum moisture content.
◊ Placement moisture content can have a significant effect on reinforcement-soil interaction. Moisture content wet of optimum makes it increasingly difficult to maintain an acceptable facing alignment, especially if the fines content is high. Moisture contents that are too dry could result in significant settlement during periods of precipitation.

6. Geomembrane Installation:
If the Contractor elects to provide an MSES wall which utilizes inextensible (metallic) reinforcing elements, the specification requires the installation of a geomembrane to isolate the reinforced mass.

- The geomembrane needs to drain away from the MSES face panels to a subsurface drainage system to be collected and drained to a positive outlet.
- Care must be exercised by workers when walking or working on the geomembrane.
  ◊ Take time when unloading and placing rolls to avoid damage. Verify the location of a sheet before unrolling and placement to avoid improper alignment.
- Sealing seams and connections to vertical projections extending through the geomembrane are critical in isolating the reinforced mass.
  ◊ Seams shall be sealed as per the manufacturer’s recommendations. Field welding equipment for extrusion fillet welding consists of a bead of molten resin along the edge of a panel lapped on top of another panel. The polyethylene rod used for welding must be compatible with the geomembrane material.
  ◊ Connections to attach to structures may be mechanical (batten strip with caulk, cushioning pads, and gaskets), embedment strip (same material as geomembrane...
placed in concrete during casting) or boot method (a boot apron welded to the geomembrane liner with the boot sleeve sealed to the protrusion).