Mechanically Stabilized Earth Wall Construction Inspection Manual

Peter J. Becker, PhD, PE
Division of Research & Development
1205 Montgomery Street, West Lafayette, IN, 47906

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1.0 Introduction

1.1 Purpose of Manual

This manual is intended for use by field personnel assigned to Indiana Department of Transportation (INDOT) construction projects that include mechanically stabilized earth (MSE) walls. The purpose of this manual is to provide an overview of MSE wall construction activities that field personnel may reference when inspecting MSE wall construction. MSE wall construction inspection guidelines are provided; however, they do not supersede road/bridge plans, standard specifications, and special provisions.

The MSE wall construction guidelines provided herein are representative of most circumstances. However, this manual cannot cover every contingency so field personnel are expected to use their best judgment in dealing with any specific or unusual situation that might arise on a project. Moreover, field personnel should contact their supervisor with specific questions about a procedure. Questions about this manual and suggestions for improvement should be directed to the Division of Geotechnical Engineering.

The use of this manual by others is solely at the risk of the user. The Department does not warrant the accuracy of the contents of the manual or any of its supporting material.

1.2 Role of Project Inspector

The primary role of the project inspector is to verify that construction complies with INDOT standard specifications and contract documents (plans and special provisions). When inspecting MSE wall construction, project inspectors should review site conditions, verify that all materials comply with specifications, verify that materials have been correctly placed, and verify that alignments are within their specified tolerances.

2.0 Components of MSE Walls

MSE walls are complex structures with many different components working together to maintain stability. Shown in Figure 1, the main MSE wall components include the following:

- Reinforced zone
- MSE wall facing
- Foundation soil
- Retained backfill
- Externally applied vertical loads
- Internal drain
- Embedment
- Miscellaneous components

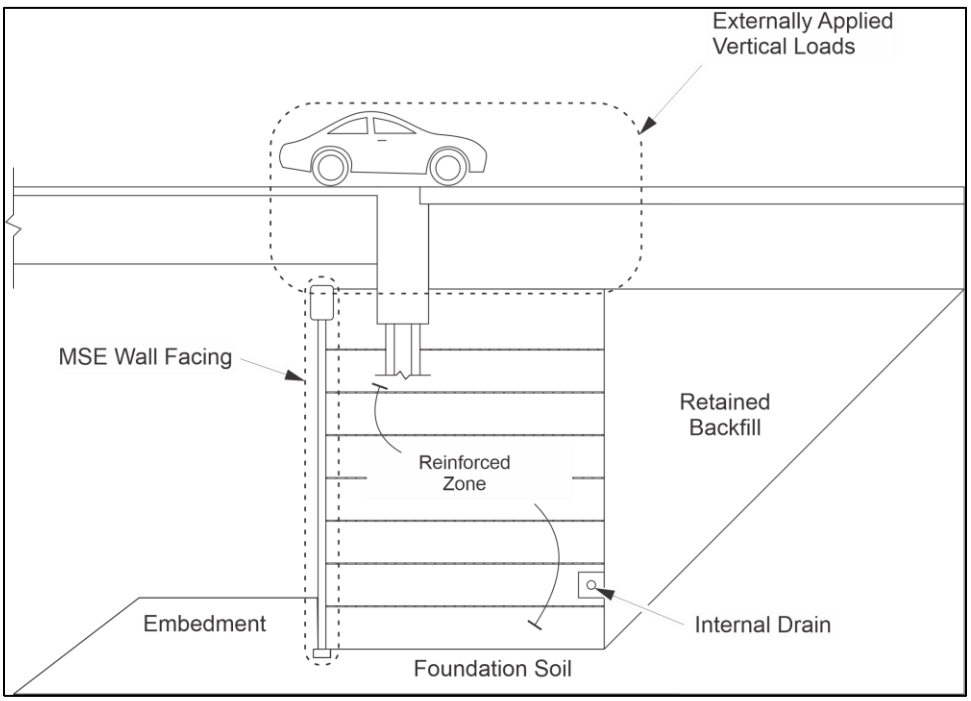


Figure 1. Main MSE wall components

The following sections provide an overview of each of these main MSE wall components.

2.1 Reinforced Zone

The MSE wall reinforced zone comprises the bulk of the MSE wall. Indeed, it is the reinforced zone that provides lateral earth retention. A high-quality structure backfill reinforced with approved MSE wall soil reinforcement can function as a stiff structure resistant to sliding, overturning, and excessive bearing pressures. Individual components of the MSE wall reinforced zone include:

- Structure backfill

- Soil reinforcement
- Obstructions
- Geotextile separator

The following sections provide an overview for the MSE wall reinforced zone components.

2.1.1 Structure Backfill

Structure backfill constituting the MSE wall must be of high-quality in terms of stability, drainage, and lack of aggressiveness. Because structure backfill is providing earth retention support, it must have adequate strength when compacted (i.e., stability). Moreover, water must be able to quickly drain through structure backfill so as to preclude buildup of water pressures in the MSE wall. Lastly, the structure backfill should not actively contribute to the degradation or corrosion of the soil reinforcements (i.e., electro-chemical processes).

Construction contractors shall furnish structure backfill materials for constructing INDOT MSE walls. Structure backfill used for MSE walls in INDOT contracts shall be structure backfill type 3 in accordance with ISS 211.03.1(c), though No. 30 aggregate is not permitted. Type 3 structure backfill shall be in accordance with ISS 904.05 that specifies aggregate compositions and gradations (ISS 904.03(e) and 904.05). In short, the following aggregate types are permitted for MSE wall construction:

- 1 in. aggregate
- ½ in. aggregate
- No. 4 aggregate
- No. 5 aggregate
- No. 8 aggregate
- No. 9 aggregate
- No. 11 aggregate
- No. 12 aggregate

Note: No. 4 aggregate shall not be allowed in the construction of MSE walls as part of contracts let on or after September 1, 2023 (i.e., contracts subject to 2024 standard specifications). INDOT removed No. 4 aggregate from the list of approved gradations for Type 3 structure backfill with the publication of the 2024 version of the standard specifications.

Aggregates used for MSE wall structure backfill shall be composed of crushed stone; however, No. 5 and No. 8 aggregates may be composed of air-cooled blast furnace (ACBF) slag. Figure 2 shows examples of aggregates commonly used as MSE wall structure backfill.

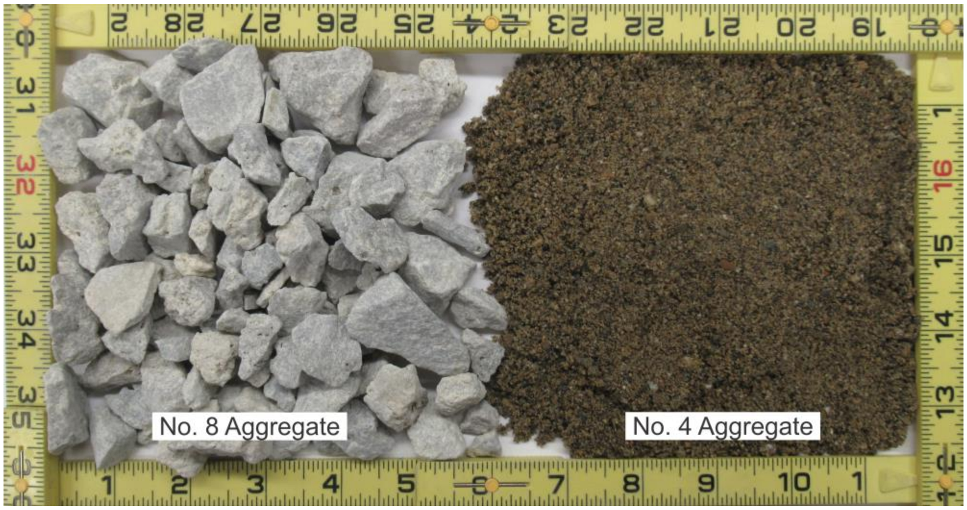


Figure 2. Common materials used as MSE wall structure backfills include No. 8 aggregate and No. 4 aggregate

Table 1. Minimum testing requirements for MSE wall structure backfill

Property	**Criteria**	**Test Method**
pH[a]	5 < pH < 10	AASHTO T 289
Organic Content[b]	≤ 1%	AASHTO T 267
Permeability[cd]	≥ 30 ft/day	AASHTO T 215
Chloride Content	< 100 ppm	AASHTO T 291
Sulfate Content	< 200 ppm	AASHTO T 290
Resistivity[ef]	≥ 3,000 Ω-cm	AASHTO T 288
Internal Friction Angle[dgh]	≥ 34°	AASHTO T 236 or T 297

Notes:

[a]One pH test is required for each bench of stone, each source of air-cooled blast furnace slag, and each source of gravel

[b]One organic content test is required for each source of gravel

[c]One permeability test is required for the smallest aggregate size from each source

[d]Testing shall be performed on the sample of material compacted to 95% in accordance with AASHTO T 99, Method C or D

[e]Resistivity shall be tested at 100% saturation

[f]Chloride and sulfate content testing requirements will be waived if measured resistivity exceeds 5,000 Ω-cm

[g]Sample shall be tested for internal friction angle under consolidated drained conditions

[h]Internal friction angle testing requirement will be waived if material is coarse aggregate No. 5, No. 8, or No. 9

MSE wall structure backfill materials must have Type A certification in accordance with ISS 916. Required tests for type A certification shall be performed by an approved geotechnical laboratory[1] with certification results being provided to the engineer prior to use. Table 1 lists the minimum testing requirements for MSE wall structure backfill, which shall all be conducted at a minimum frequency of once every 12 months per source.

Road/bridge plans may indicate that an MSE wall backfill material shall be composed of a particular material. For example, an MSE wall that is expected to be inundated during the course of its service life may be required to be constructed using an open-graded aggregate such as No. 8 aggregate.

2.1.2 Soil Reinforcement

Layered within wall backfill soils are the soil reinforcements that are responsible for providing the mechanical stabilization. Soil reinforcements restrain backfill soil deformations, which in turn improves the mechanical properties for the entire backfill soil mass. A properly designed reinforced soil backfill can then function as a vertical retaining wall (i.e., MSE wall).

Figure 3. Example of (a) steel strip type MSE reinforcement and (b) how it might be connected to facing panels

Steel materials are commonly used for soil reinforcements in MSE walls. Types of steel reinforcements include the strip type (Figure 3a) and the welded wire type (Figure 4a). Strip type reinforcements are commonly connected to MSE wall facing panels using a nut and bolt set (Figure

[1]A list of approved geotechnical laboratories can be found on the INDOT Geotechnical Engineering Division website (**https://www.in.gov/indot/engineering/geotechnical-engineering-division/**)

3b), while welded wire type reinforcements commonly use a pin connection (Figure 4b). Sections 910.07b and 910.07c of the Indiana Standard Specifications summarize all other minimum material specifications for soil reinforcements including:

- Dimensional requirements for both steel strip type and welded wire type soil reinforcements
- Metallurgic requirements for steel soil reinforcements
- Galvanization requirements for steel soil reinforcements
- Strength requirements for steel soil reinforcements
- Requirements for hardware connecting soil reinforcements to MSE wall facing panels

Figure 4. Example of (a) welded wire type MSE wall reinforcement and (b) how it might be connected to facing panels

Soil reinforcements are considered part of an MSE wall system so wall vendors are responsible for furnishing them. Just like the rest of the MSE wall system, soil reinforcements must have been approved with Type A certification per ISS 916 prior to their installation in any INDOT construction contract.

MSE wall designs are conducted by the wall vendor (or vendor's representative) after contract awarding, so only scant information pertaining to soil reinforcements will be available on road/bridge plans. Indeed, project plans typically only state that soil reinforcements shall be no shorter than 0.7 times the height of the wall as well as no shorter than 8 ft. MSE wall shop drawings will contain all relevant information for the MSE wall that should include the following:

- Soil reinforcement lengths[2] along the length of the wall
- Soil reinforcement steel grade and galvanization grade
- Specifications for hardware connecting soil reinforcements to MSE wall facing panels
- Drawings showing how soil reinforcements should be altered to accommodate vertical and horizontal obstructions (See Section 2.1.3)
- Drawings showing typical soil reinforcement—steel strip type (Figure 5) and welded wire type (Figure 6)—dimensions
- Drawings showing how reinforcements—steel strip type (Figure 7) and welded wire type (Figure 8)—should be connected to MSE wall facing panels

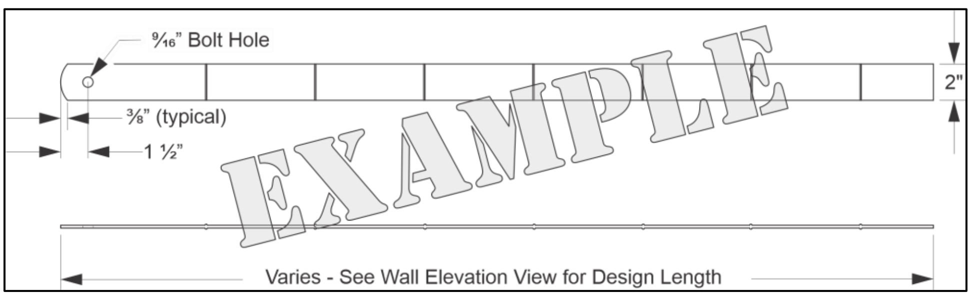


Figure 5. Example shop drawing for steel strip type MSE wall reinforcement

[2] INDOT requires that soil reinforcement shall be the same length from the bottom to the top of the wall regardless of the type of reinforcement used (ISS 731.03c)

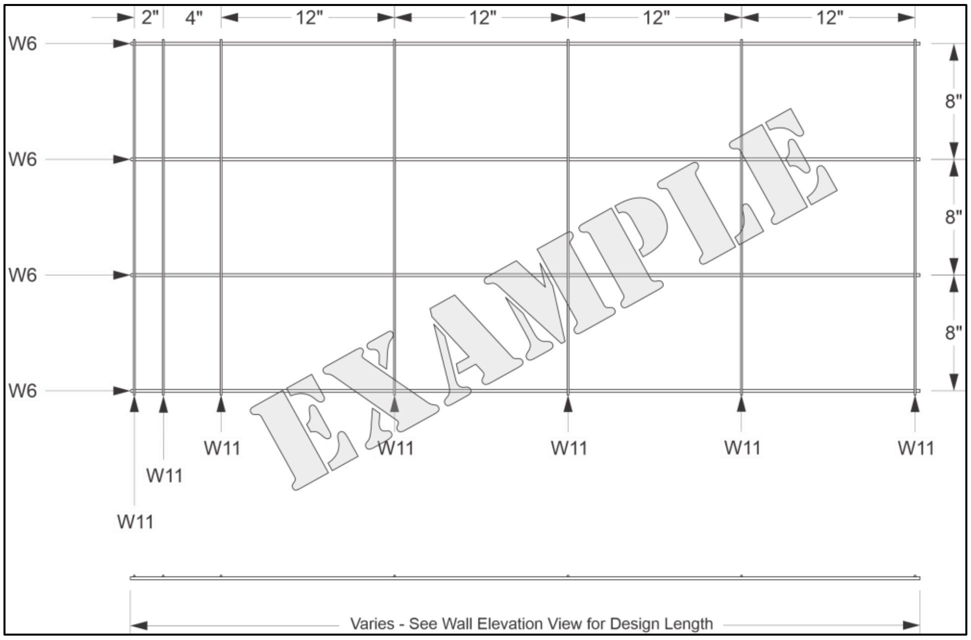


Figure 6. Example shop drawing for welded wire type MSE wall reinforcement

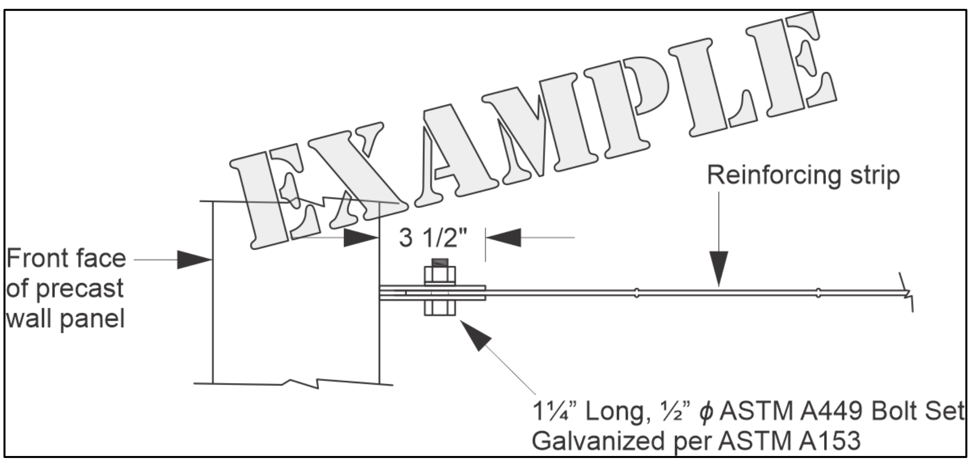


Figure 7. Example shop drawing for steel strip type reinforcement connection

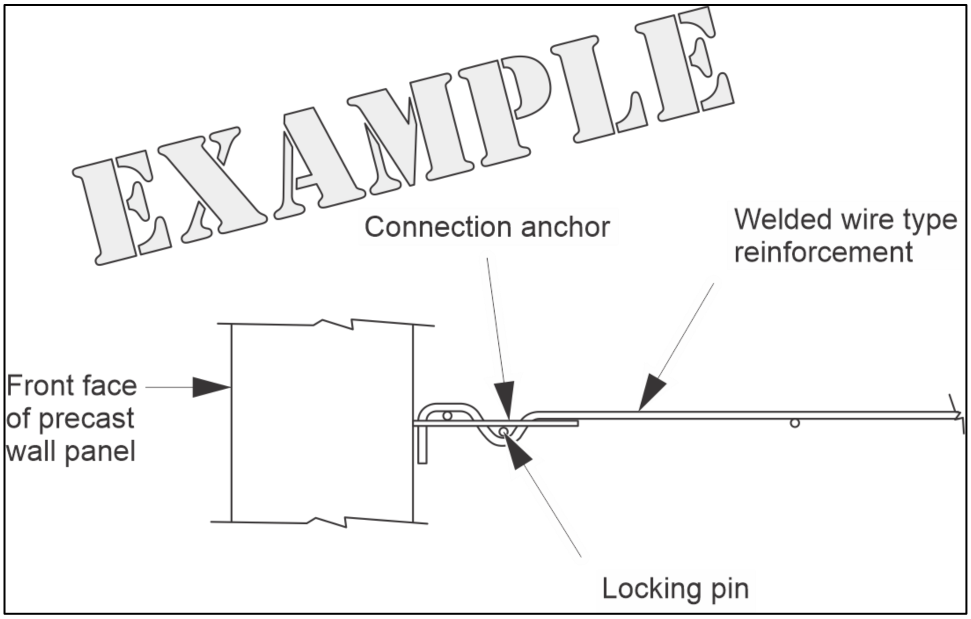


Figure 8. Example shop drawing for welded wire type reinforcement connection

2.1.3 Obstructions

In some instances, road/bridge plans require that external structures pass through the MSE wall reinforced zone. Such external structures are typically referred to as "obstructions" because they obstruct proper soil reinforcement placement. There are two general types of MSE wall obstructions—vertical obstructions and horizontal obstructions. As their names suggest, vertical obstructions extend vertically through MSE wall reinforced zones, while horizontal obstructions extend horizontally.

Examples of vertical obstructions include catch basins, grate inlets, sign foundations, light poles, guardrail posts, and culverts; however, bridge foundation piling (Figure 9) is the most common type of vertical obstruction encountered in MSE walls for INDOT contracts. When vertical obstructions are encountered within MSE walls, soil reinforcements must be placed so as to accommodate the obstructions. Shop drawings supplied by the MSE wall system vendor should detail procedures for placing soil reinforcements around vertical obstructions. Figure 10 shows an example MSE wall shop drawing detail for placing soil reinforcements around vertical obstructions. Typical MSE wall systems account for vertical obstructions by having soil reinforcements splayed around vertical obstructions. Splay angle, as shown in Figure 10, should not exceed 15° per ISS 731.03.

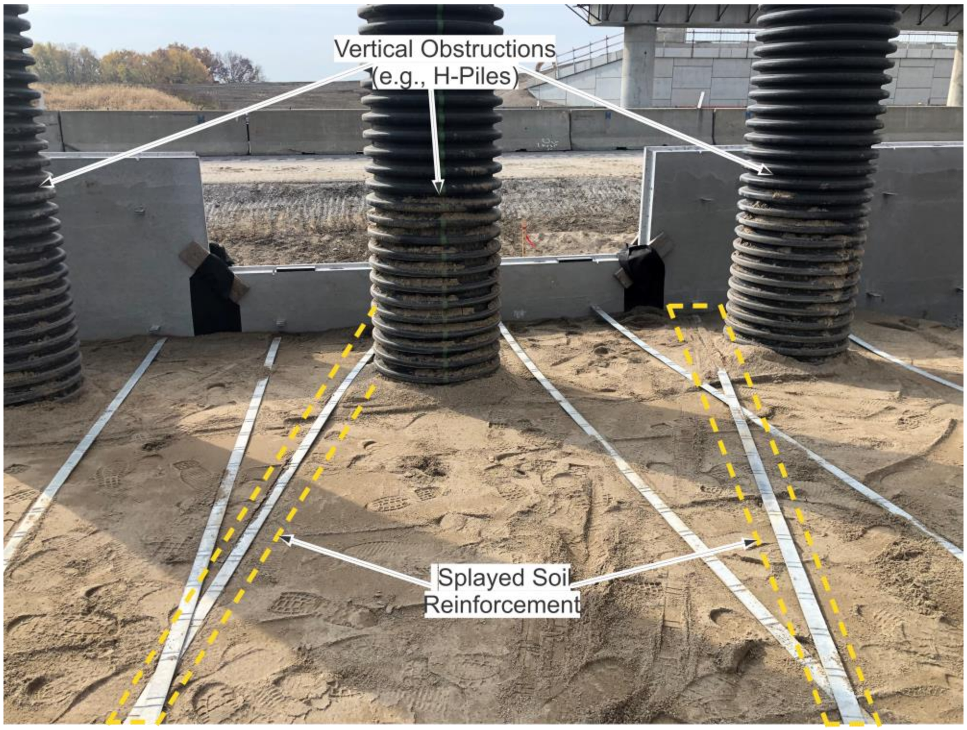


Figure 9. Vertical obstructions commonly encountered in MSE walls (e.g., H-Piles)

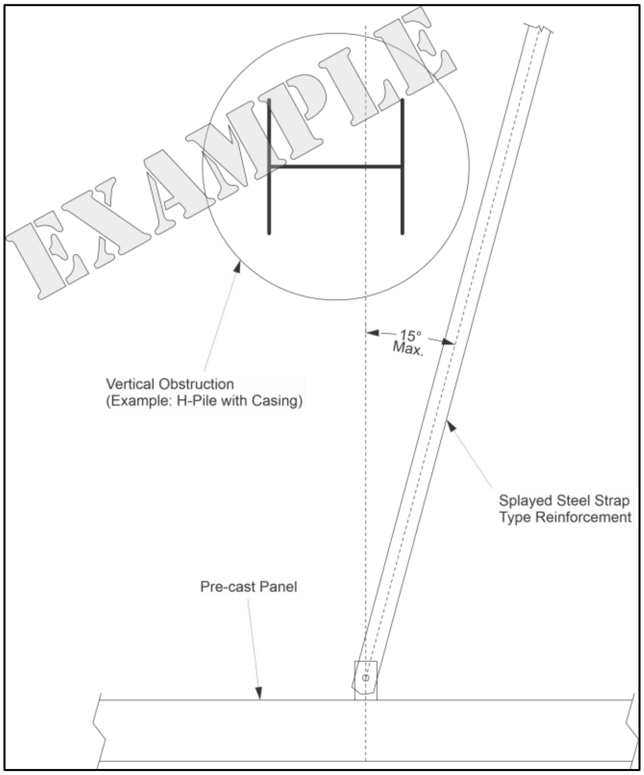


Figure 10. Example shop drawing detailing requirements for placing soil reinforcements to accommodate vertical obstructions

Storm drain pipes are the quintessential type of horizontal obstructions that may be encountered in MSE walls for INDOT contracts (Figure 11). Like with vertical obstructions, soil reinforcements must be placed so as the accommodate any horizontal obstruction. Moreover, shop drawings supplied by the MSE wall vendor should detail procedures for placing soil reinforcements around horizontal obstructions. An example of which is shown in Figure 12. In general, soil reinforcements are placed with vertically skewed angles to accommodate the obstructions. INDOT standard specifications do not prescribe a maximum vertical skew angle; however, MSE wall vendors generally require that skew angle not exceed 15°.

Figure 11. Horizontal obstructions commonly encountered in MSE walls (e.g., pipe)

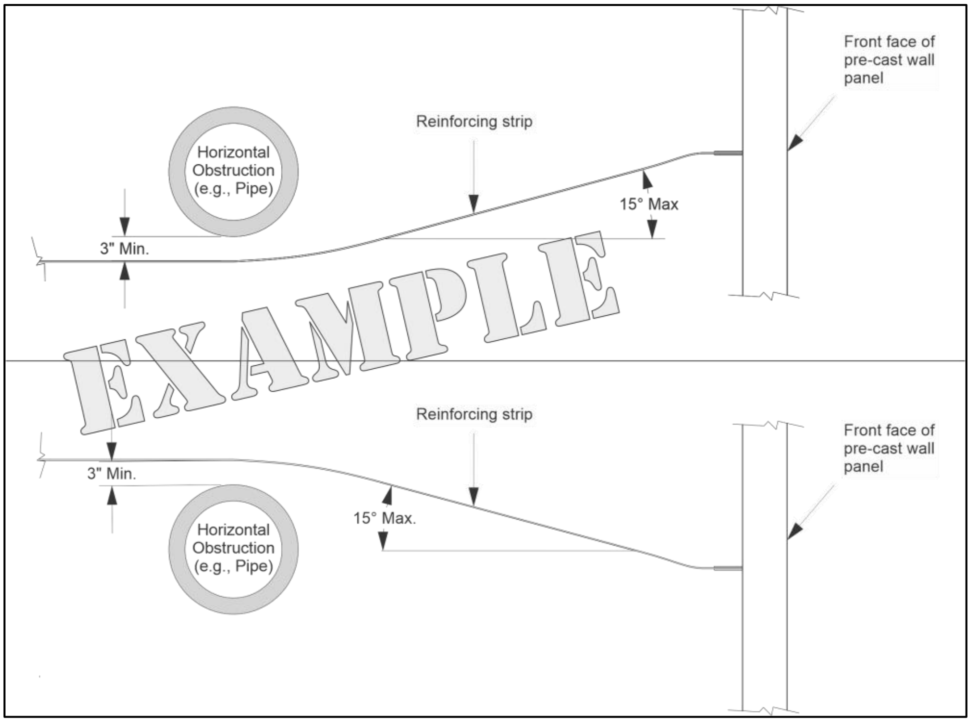


Figure 12. Example shop drawing detailing requirements for placing soil reinforcements to accommodate horizontal obstructions

2.1.4 Geotextile Separator

Over time, fine-grained particles (silts and clays) from retained backfill soils can seep into the structure backfill and degrade its quality. However, a geotextile separator will prevent any movement of fine-grained particles into the structure backfill.

Per ISS 731.05, a geotextile separator shall encapsulate the MSE wall structure backfill if the structure backfill constitutes any of the following materials:

- Coarse aggregate No. 5
- Coarse aggregate No. 8
- Coarse aggregate No. 9
- Coarse aggregate No. 11

The geotextile separator[3] shall be Type 2B in accordance with ISS 918.02(a) that specifies minimum requirements related to tensile strength, puncture strength, elongation, tearing strength, deterioration due to UV degradation, apparent opening size, and permittivity.

Geotextile separators are not considered part of the MSE wall system, so they should be supplied by the contractor assembling the MSE wall.

[3]A list of qualified geotextile materials can be found on the INDOT Division of Materials and Tests website (**https://www.in.gov/indot/div/mt/appmat/appmat.htm**)

2.2 MSE Wall Facing

The MSE wall facing is the exposed portion of the wall. Aesthetics is the primary function of wall facing elements; however, they also provide drainage paths and prevent backfill erosion. Individual components of MSE wall facings include the following:

- Pre-cast facing panels
- Corner elements
- Bearing pads
- Geotextile joint covering
- Leveling pad
- Coping

The following sections provide an overview for the MSE wall facing components.

2.2.1 Pre-Cast Facing Panels

Pre-cast facing panels constitute the bulk of the MSE wall facing. Figure 13 shows an example of a typical MSE wall pre-cast facing panel. Functions of pre-cast facing panels are twofold—(1) protect against backfill sloughing and erosion and (2) control aesthetics. Pre-cast facing panels come in different shapes, sizes, textures, and architectural treatments. Figure 14 provides examples of different pre-cast MSE wall facing panels.

Figure 13. Example MSE wall pre-cast facing panel

Figure 14. Examples of different MSE wall pre-cast facing panel architectural and textural treatments

Because pre-cast facing panels are part of the MSE wall system, they are to be furnished by the wall vendor. MSE wall panels installed as part of INDOT contracts shall conform to ISS 901.10 that summarizes the following minimum specifications and requirements:

- Approved pre-cast concrete sources
- Concrete compressive strength requirements
- Water to cement ratio requirements
- Requirements for concrete admixtures
- Requirements for setting soil reinforcement connections
- Production control testing and inspection requirements
- Casting requirements
- Curing time requirements
- Procedures for removing forms
- Finish requirements
- Tolerances (e.g., dimensions, squareness, etc.)
- Concrete compressive strength verification procedures

- Rejection criteria (e.g., chipped/cracked concrete, honeycombing, etc.)
- Marking (e.g., date, lot number, etc.)
- Handing, storage, and shipping requirements

Specific details on pre-cast facing panels shall be included in the MSE wall shop drawings prepared by the wall vendor. Figure 15 shows example shop drawings for a typical MSE wall pre-cast panel. Besides panel drawings, types of information made available on the shop drawings should include:

- Dimensions for all types of panels used in wall (with identifiers)
- Configuration of steel reinforcement in panel
- Grades of steel reinforcement
- Details for soil reinforcement connection
- Concrete compressive strength
- Details for lifting panels (e.g., lifting inserts)
- Texture and/or architectural finishing

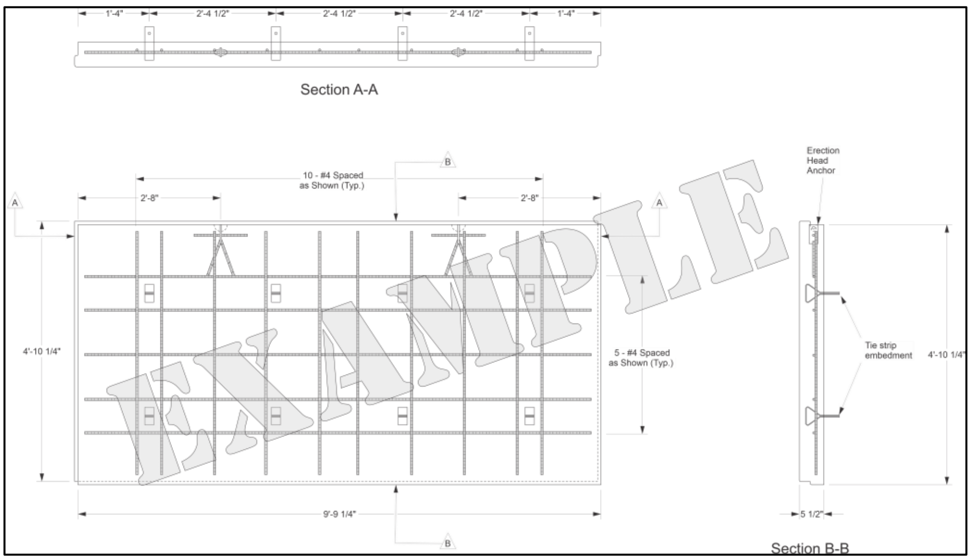


Figure 15. Example MSE wall pre-cast facing panel shop drawings

2.2.2 <u>Corner Elements</u>

In many instances MSE walls have corners where different wall sections intersect. For example, MSE walls placed at bridge end bents commonly have corners (Figure 16) so as to minimize the required right of way. In accordance with ISS 731.02, MSE wall corner elements are required when wall sections intersect at angles of 130° or less. Figure 17 shows an example of an MSE wall facing corner element—essentially a pre-cast panel allowing for wall bends. Just like with flat MSE wall pre-cast facing panels, corner elements constitute the MSE wall system so they are furnished by the wall vendor. Likewise, MSE wall corner element drawings (Figure 18 for example) are to be included in MSE wall shop drawings.

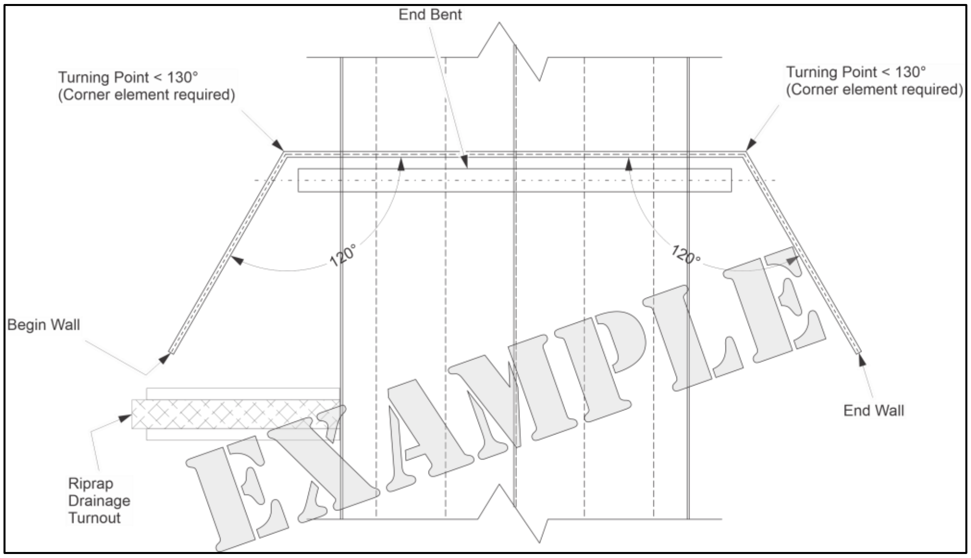


Figure 16. Example plan view of bridge end bent with MSE wall requiring corner elements

Figure 17. Example corner element installed in an MSE wall

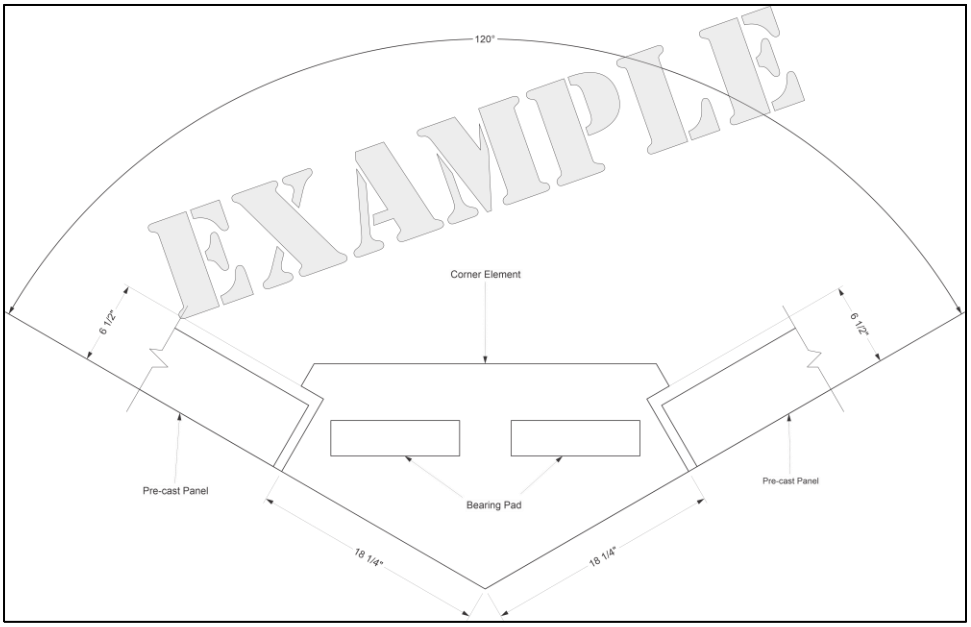


Figure 18. Example MSE wall corner element shop drawings

2.2.3 Bearing Pads

Bearing pads are placed within MSE wall facing horizontal joints to act as buffers between vertically adjacent panels. They prevent concrete to concrete contacts from occurring thereby precluding any cracking or spalling of pre-cast concrete facing panels. Moreover, bearing pads provide some compressibility and movement between panels during elastic compression and settlement of the reinforced fill. Bearing pads are typically made from either EPDM rubber or HDPE plastic (see Figure 19 for examples). ISS 901.10 specifies that only MSE wall manufacturer recommended bearing pads be used in MSE walls on INDOT contracts so wall vendors shall furnish them as part of wall systems. MSE wall shop drawings (see Figure 20 for example) should provide the following information:

- Composition material (e.g., HDPE plastic)
- Dimensions (i.e., length, width, and height)
- Instruction for placement (e.g., orientation, number of pads per horizontal joint)

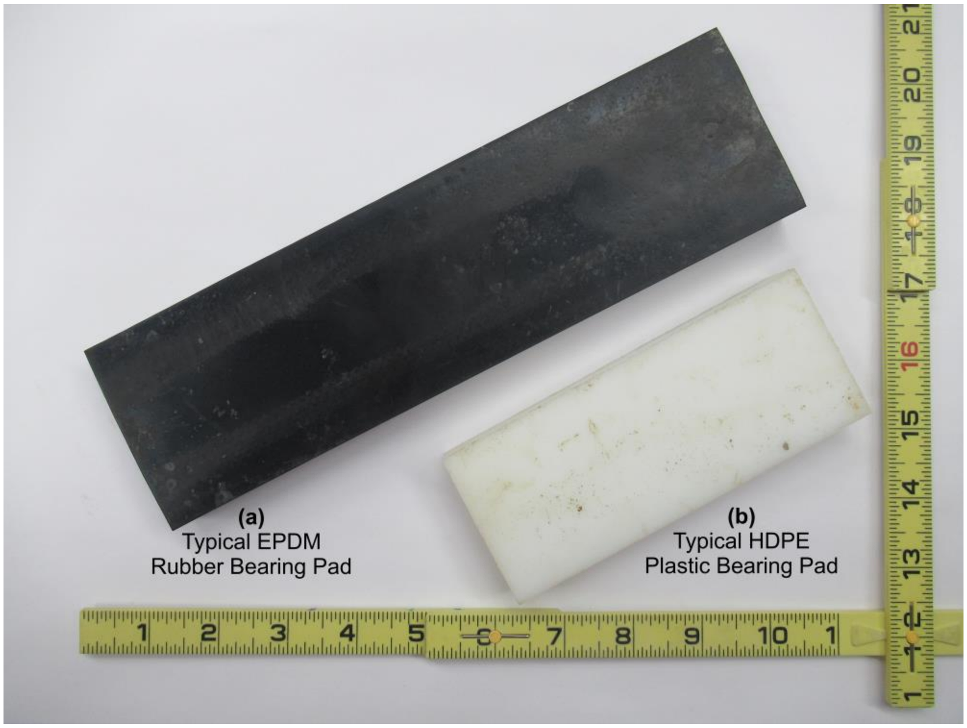


Figure 19. Bearing pad examples—(a) EPDM rubber bearing pad and (b) HDPE plastic bearing pad

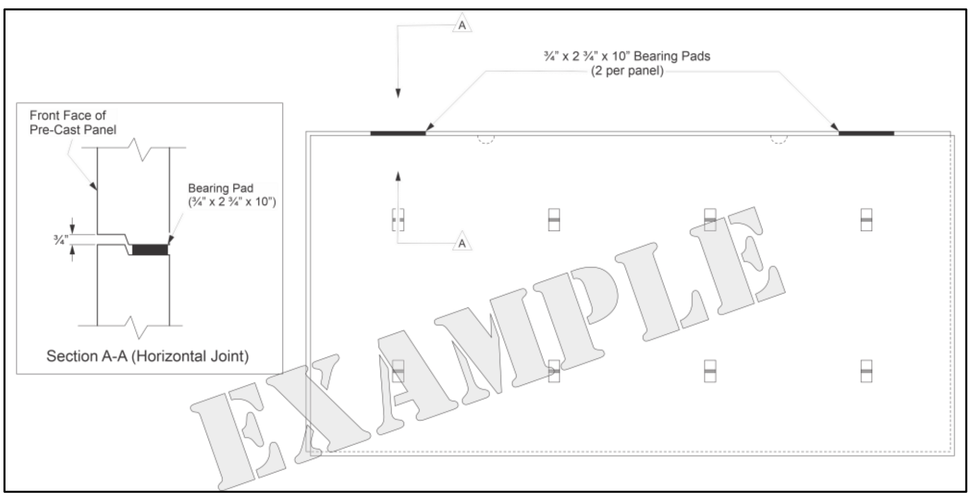


Figure 20. Example bearing pad shop drawings

2.2.4 <u>Geotextile Joint Covering</u>

Geotextile fabrics are placed over MSE wall panel joints to prevent structure backfill from leaking out from the MSE wall, while still allowing for water to escape. Figure 21 shows an example MSE wall panel joint geotextile covering installation. ISS 901.10(b) specifies that the geotextile shall be either a non-woven needle-punch polyester fabric or a woven monofilament polypropylene fabric, though section 731.10 of the 2024 INDOT specifications specify that join covering be Type 2B geotextile in accordance with ISS 918.02(a) (see section 2.1.4 of this manual). ISS 901.10(b) also specifies that geotextile joint coverings be attached to the rear of MSE wall facing panels using adhesives recommended by the MSE wall manufacturer.

Figure 21. Geotextile joint covering example

Geotextile joint coverings are considered part of the MSE wall system, so they are to be furnished by the MSE wall system vendor. Figure 22 provides example shop drawings for a geotextile joint covering. MSE wall shop drawings prepared by the MSE wall vendor should include the following information:

- Elevation view of placed geotextile joint coverings
- Instructions for attaching joint coverings (i.e., adhesive placement)
- Overlapping requirements (vertical over horizontal, vertical over vertical, horizontal over horizontal)
- Any additional requirements (e.g., whether geotextile is required at leveling pad)

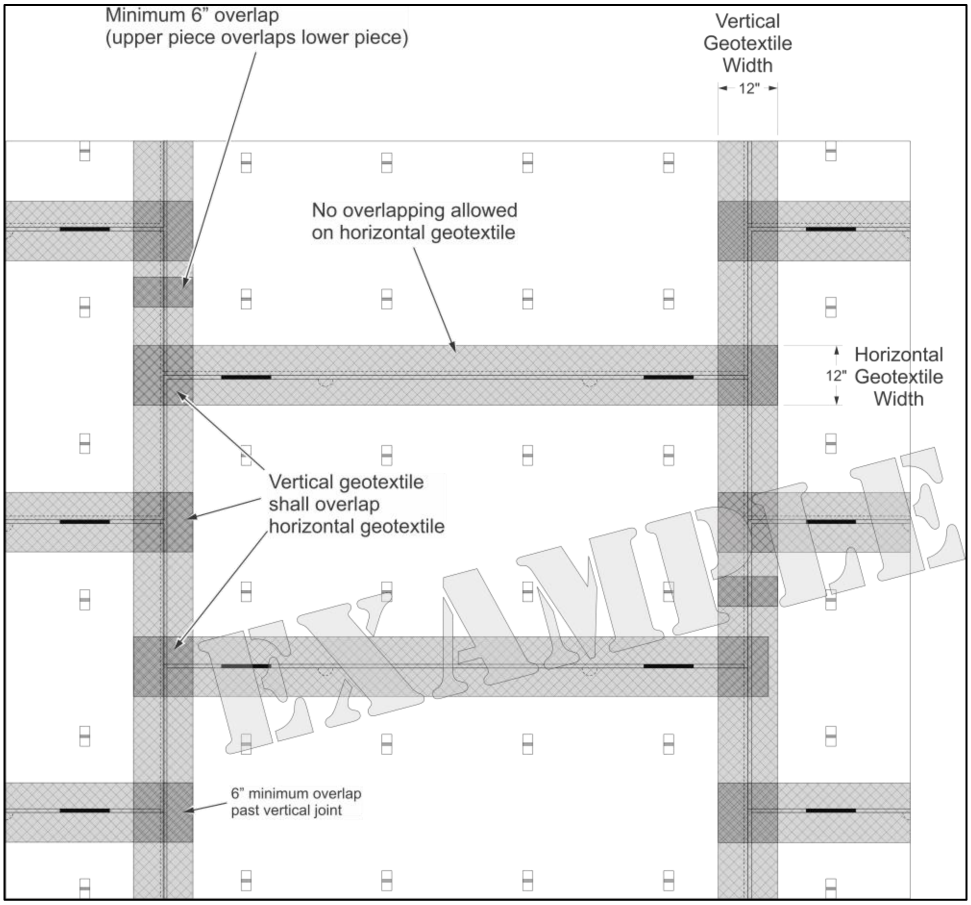


Figure 22. Example shop drawings for geotextile joint coverings

2.2.5 Leveling Pad

MSE wall leveling pads provide level surfaces for facing panel placement. They are not intended to be used for structural support. ISS 731.05 requires that leveling pads be constructed using at least class A concrete (i.e., 564 lb/CY cement content, maximum 0.450 water to cement ratio, minimum 0.380 water to cement ratio). Because leveling pads are not considered to be part of MSE wall systems they are to be furnished by construction contractors. Figure 23 shows an example MSE wall leveling pad.

Road/bridge plans for contracts that include MSE wall construction need to include the following information:

- Leveling pad thickness (generally 6 in.)
- Leveling pad width (generally 12 in.)
- Top-of-leveling-pad elevations

Figure 23. Example MSE wall leveling pad

MSE wall shop drawings supplied by the wall system vendor should provide information on the leveling pad that is consistent with road/bridge plans. Moreover, shop drawings shall adhere to the following requirements in accordance with ISS 731.02:

- Top-of-leveling pad elevations shown on the shop drawings shall be at or below those detailed on the road/bridge plans
- Leveling pad steps shall be in 2.5 ft increments.

2.2.6 Coping

The coping is placed atop MSE wall facing panels to provide a smooth, aesthetically-pleasing, and clean line at the top of the MSE wall. In accordance with ISS 901.10, MSE wall copings may be either pre-cast concrete (e.g., Figure 24a) or cast-in-place concrete (e.g., Figure 24b). ISS 731.05 specifies that copings shall be cast using class A concrete (i.e., 564 lb/CY cement content, maximum 0.450 water to cement ratio, minimum 0.380 water to cement ratio). INDOT Standard Drawing No. E 731-MSEW details requirements for pre-cast coping, cast-in-place coping, and cast-in-place coping with pedestrian fence. Road/bridge plans may detail typical coping dimensions (i.e., height and width) and preliminary elevations.

Figure 24. Example MSE wall copings: (a) pre-cast coping and (b) cast-in-place coping

Pre-cast copings are included in the MSE wall system, so they shall be furnished by the MSE wall vendor. Figure 25a provides example shop drawings for pre-cast coping. Shop drawings prepared by the MSE wall vendor should detail the following information related to pre-cast coping:

- Overall dimensions (length, width, and height)
- Layout of steel reinforcement
- Instructions for coping placement (e.g., leveling concrete)
- Finish work instructions (e.g., grouting lifting recesses)
- Elevations at top of placed copings

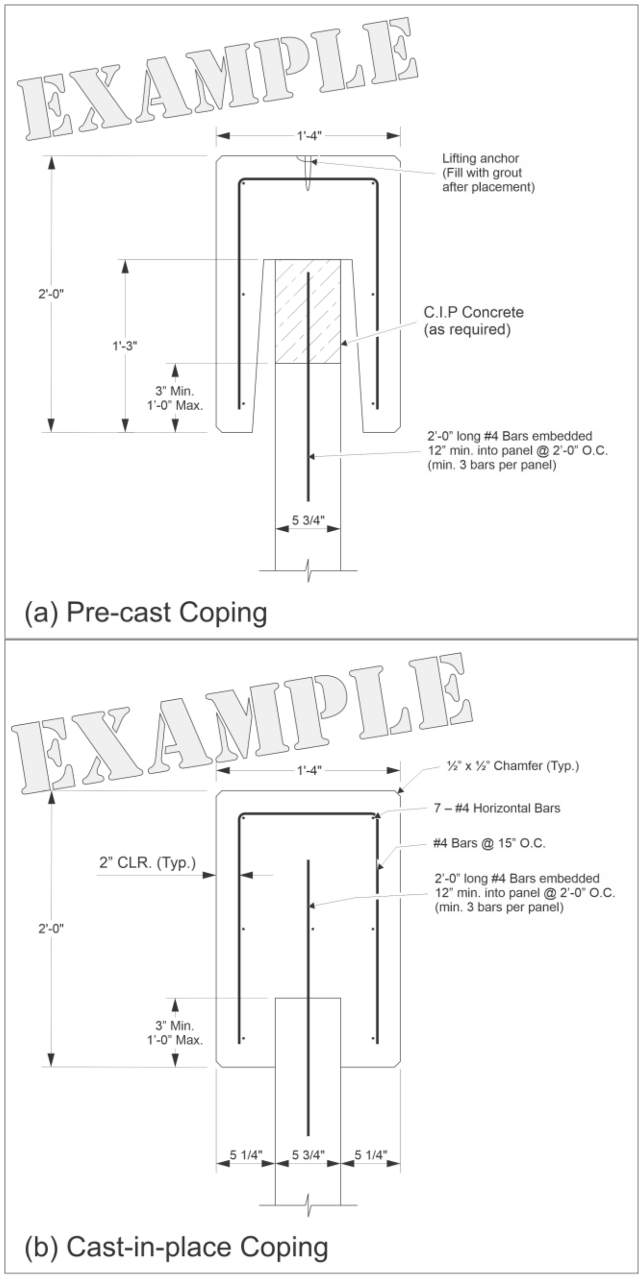


Figure 25. Example shop drawings for (a) pre-cast coping and (b) cast-in-place coping

Cast-in-place copings are generally used in locations that preclude pre-cast coping placement, such as at wall corners or at interfaces with cast-in-place structures (e.g., abutments). Cast-in-place copings are not included in the MSE wall furnished by the wall vendor, so such copings shall be constructed by the contractor. However, the MSE wall vendor should still include shop drawings for cast-in-place copings (example Figure 25b). Cast-in-place coping drawings should detail steel reinforcement sizes and locations, reinforcement clearances, and chamfers.

2.3 Foundation Soil

In accordance with ISS 731.03, MSE walls shall be designed for external stability, which means that foundation soils must be able to support overlying wall structures. Road/bridge plans detail factored bearing resistance values for project foundations that wall designers must ensure is not exceeded. Likewise, MSE wall designs shall take into account resistance to sliding along the foundation and wall overturning. Foundation details on submitted MSE wall shop drawings should be consistent with road/bridge plans. If foundation improvements (e.g., undercutting) are required per contract documents and plans, then they should be included in the MSE wall shop drawings.

2.4 Retained Backfill

Retained backfill is located directly behind the MSE wall structure reinforced zone. ISS 731.05 specifies that backfill used for the retained zone be either B borrow or Type 3 structure backfill (see Section 2.1.1). ISS 211.02 provides the following description for B borrow:

> *The material used for special filling shall be of acceptable quality, free from large or frozen lumps, wood, or other extraneous matter and shall be known as B borrow. It shall consist of suitable sand, gravel, crushed stone, ACBF, GBF, or other approved material. The material shall contain no more than 10% passing the No. 200 (75 µm) sieve and shall be otherwise suitably graded. The use of an essentially one-size material will not be allowed unless approved.*

Road/bridge plans will detail the specified retained backfill limits. Retained backfill is not part of the MSE wall system, but shop drawings should include their required limits. Likewise, shop drawings should detail assumed retained backfill properties (friction angle and unit weight) used in the wall design. It is the responsibility of the contractor to furnish retained backfill.

2.5 Externally Applied Vertical Loads

MSE walls may need to support external loads applied to the top of the wall. Such loads typically arise from embankment backfill or traffic. Embankments backfilling MSE walls can either be sloping (Figure 26a) or adjacent to a bridge end bent (Figure 26c). In either case, elevations for the backfill will be detailed in the road/bridge plans. Moreover, sloping backfill slopes (e.g., 3H:1V) will be detailed in the road/bridge plans. Traffic on MSE walls can either travel parallel to walls (e.g., interstate on-ramps, Figure 26b) or perpendicular to walls (e.g., at bridge end bents, Figure 26c). ISS 731.03 specifies how embankment backfill loading and traffic loading shall be accounted for in wall design.

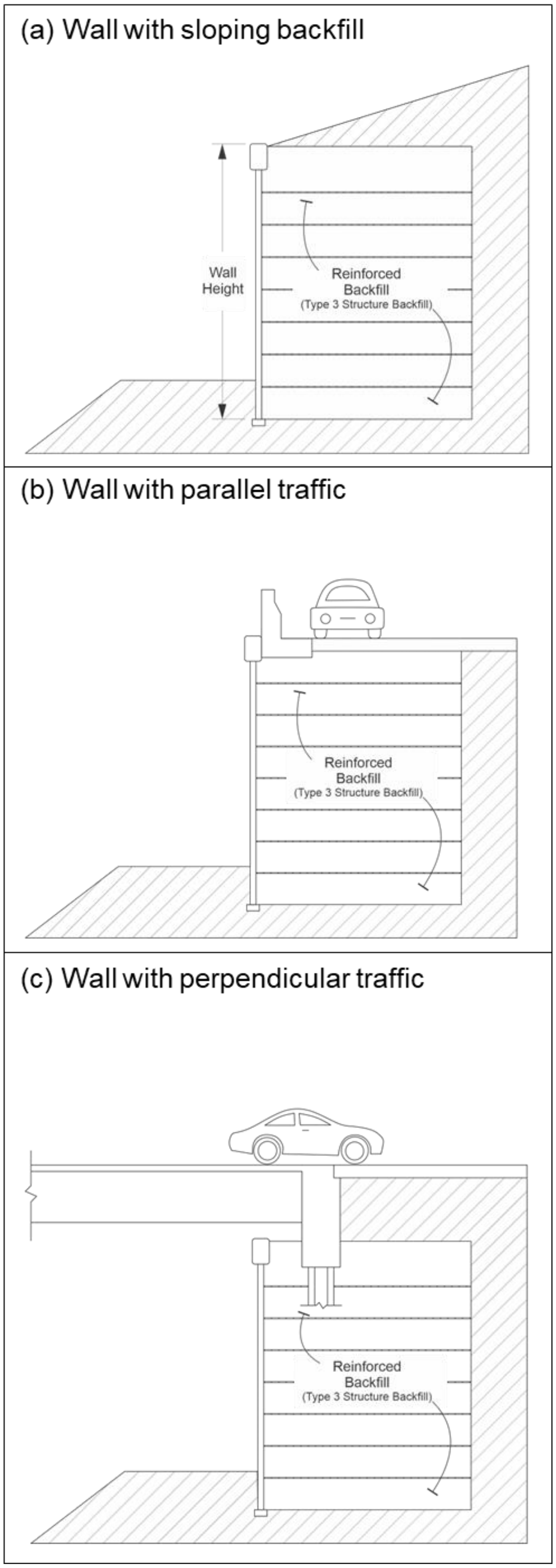


Figure 26. MSE wall configurations with externally applied vertical loadings: (a) sloping backfill, (b) parallel traffic, and (c) perpendicular traffic

2.6 Internal Drain

Internal drains provide conduit for quick removal of water from the MSE wall system. They are typically placed at the back of MSE walls so infiltration water flows away from wall facings. Figure 27 shows an example internal drain. ISS 718.03b specifies internal drain requirements. Per ISS 718, internal drains shall comprise 6 in. underdrain pipe in accordance with ISS 715.02d (i.e., Type 4 pipe), either No. 8 or No 9 aggregate, and geotextile for underdrains. Drain details will be provided in road/bridge plans with the following information:

- Pipe invert elevations
- Drain cross section (example Figure 28)
- Layout relative to the MSE wall

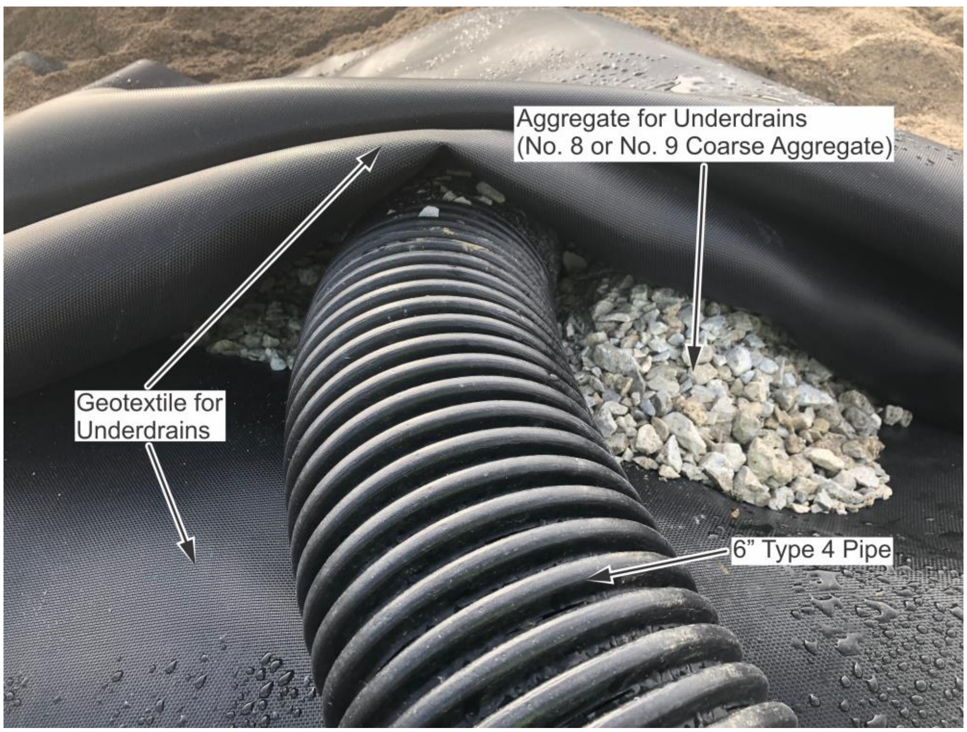


Figure 27. Example MSE wall internal drain

Internal drains are not considered part of the MSE wall system, so wall vendors will not provide the components. Rather, contractors shall furnish the required materials.

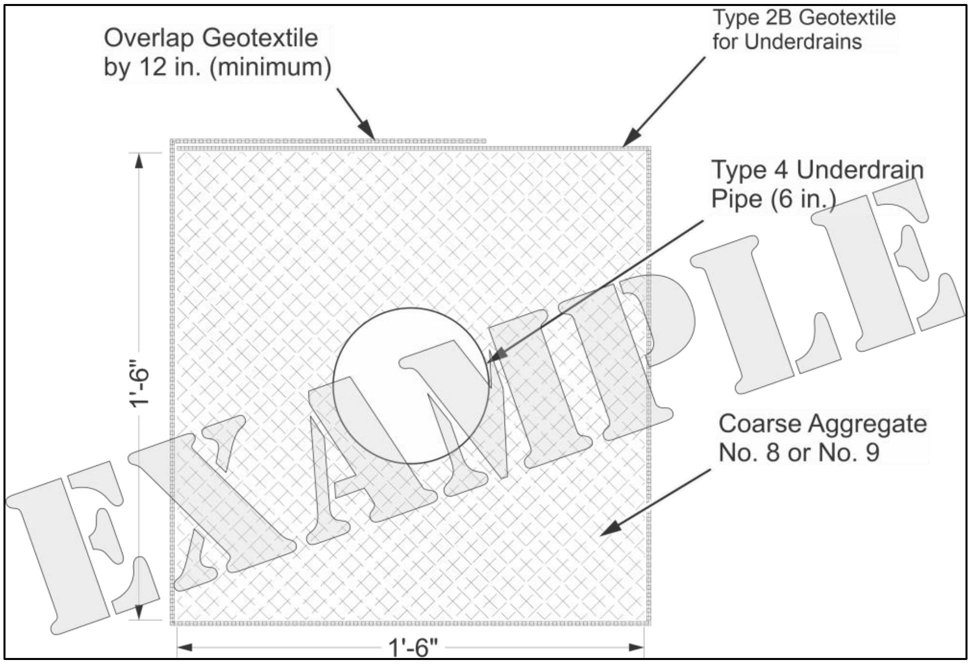


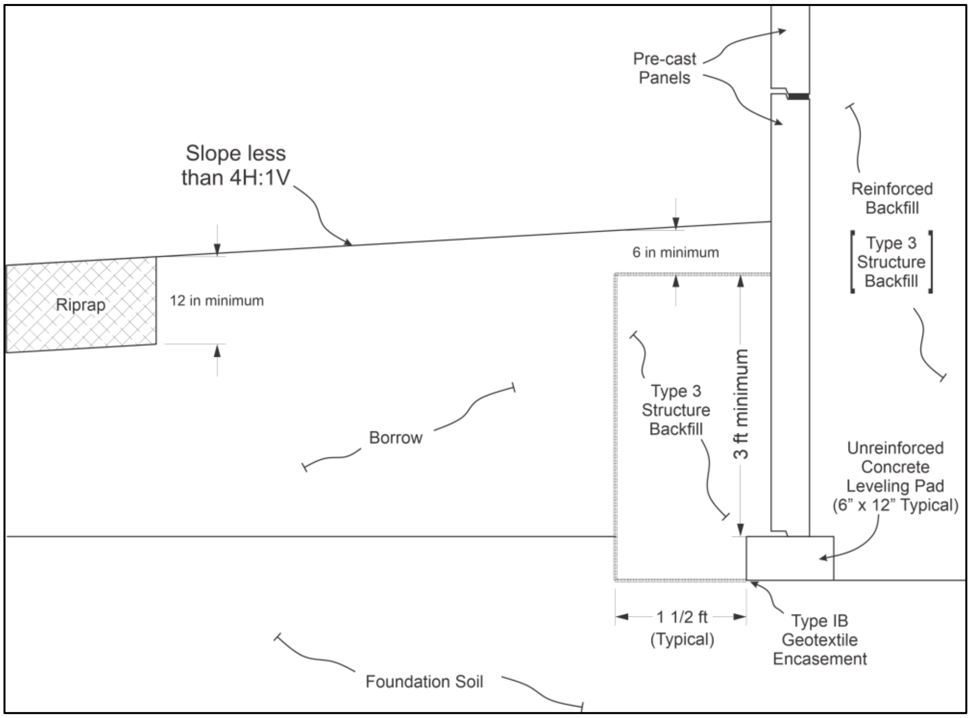
Figure 28. Example MSE wall internal drain cross section detail

2.7 Embedment

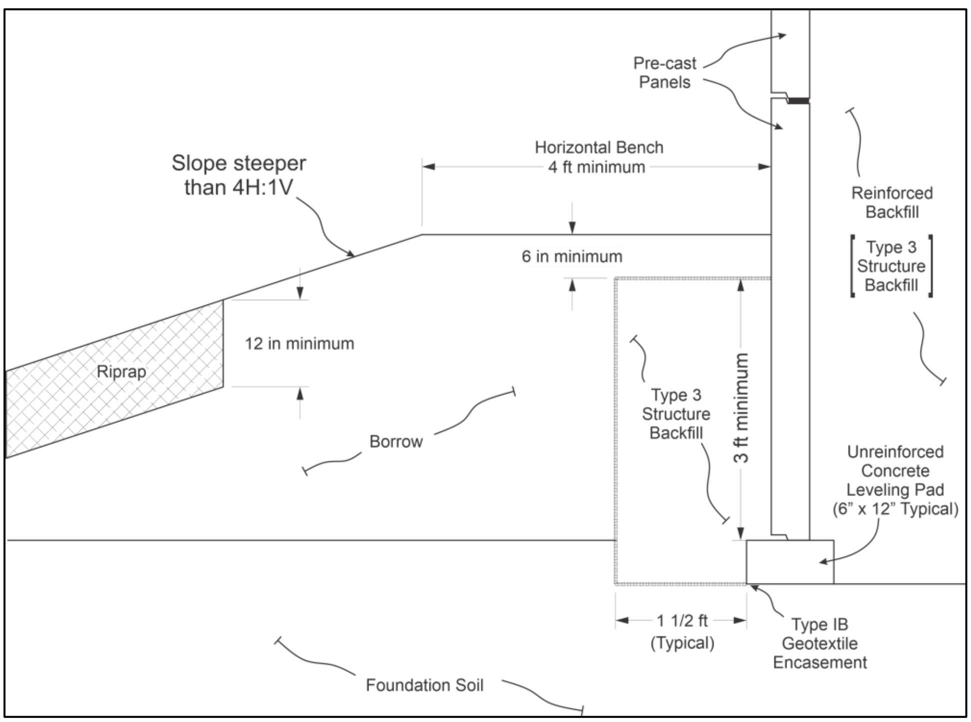
The embedment is the backfill placed in front of the MSE wall. Although its effects are not included in wall design, the embedment provides additional bearing resistance as well as passive lateral earth pressure resistance. Moreover, the embedment provides soil cover to insulate the foundation from frost.

ISS 731.03 specifies minimum requirements for MSE wall embedments such as dimensions and materials. Embedment depths (i.e., to the top of the leveling pad) shall be based off of maximum frost depths; however, embedment depths shall be no less than 3 ft, unless founded on rock. Figure 29a shows a typical MSE wall embedment layout. Shown in Figure 29b, Embedments steeper than 4H:1V shall include a 4 ft wide horizontal bench. Road/bridge plans will detail project specific requirements for MSE wall embedments.

Structure backfill, riprap, and geotextile materials constituting the embedment shall be furnished by the construction contractor.



(a) MSE wall embedments not requiring horizontal bench



(b) MSE wall embedments requiring horizontal bench (slope steeper than 4H:1V)

Figure 29. Typical MSE wall embedment layouts: (a) without horizontal bench and (b) with horizontal bench

2.8 Miscellaneous Components

2.8.1 Interfaces with Cast-in-place Structures

Road/bridge plans will detail how MSE wall components interface with cast-in-place structures such as bridge end bents. Interfaces will be designed to preclude concrete-to-concrete contacts that can cause concrete cracking, chipping, and spalling. One solution may be placement of an expanded polystyrene cushion. Such interface materials shall be furnished by the construction contractor.

2.8.2 Appurtenances

Appurtenances include any additional structures existing within the MSE wall reinforced zone, though unrelated to the wall itself. An appurtenance example may be a storm water pipe passing perpendicular through an MSE wall panel. Where concrete is required to accommodate appurtenances, ISS 731.05 requires that class C concrete (i.e., 658 lb/CY cement content, maximum 0.443 water to cement ratio, minimum 0.380 water to cement ratio) be used.

3.0 MSE Wall Procurement Process

3.1 Wall System Pre-Approval

Though there exist many different types of MSE wall systems, only systems receiving prior approval shall be constructed within INDOT contracts (ISS 731.02). Approved MSE wall systems are listed on INDOT's qualified products list (QPL) of approved retaining wall systems[4]. QPL approval is a standardized process that ensures only quality products are installed within INDOT contracts. MSE wall systems that have not been approved for use by INDOT should never be installed in INDOT contracts.

The following sections summarize the QPL approval process for MSE walls, as well as the process for maintaining standing on the QPL for retaining wall systems.

3.1.1 QPL Approval Process

The approval process for including MSE wall systems onto the INDOT QPL of approved retaining wall systems follows ITM 806, Procedure J that details the required submittals. Types of required submittals are dictated by whether the MSE wall system has already been approved by other state DOTs.

If an MSE wall system has already been approved by at least other state DOT, then the following documents must be submitted for QPA approval:

- A Technical Evaluation Report for the MSE wall system. The technical evaluation shall be performed under the authority of the FHWA Innovations, Developments, Enhancements, and Advancements (IDEA) Evaluation Review Panel and subsequently reviewed by the

[4] INDOT's QPL of retaining wall systems is located on the INDOT Division of Materials and Tests website (**https://www.in.gov/indot/div/mt/appmat/appmat.htm**)

FHWA IDEA Review Team. Report FHWA-16-006 outlines the protocol for MSE wall system IDEA evaluation.

- A sample set of shop drawings for the MSE wall system. Sample MSE wall shop drawings shall show all dimensions, reinforcing steel, ground reinforcement attachments, and any other information necessary to describe the retaining wall system.
- Any brochures, photographs, specifications, and other information on the wall system's use, applications, construction methods, etc.
- A list of all other states in which the wall system is currently approved.
- A list of at least five successful installations of the MSE wall system with varying wall heights. The following information shall be included with the list of previous successful installations: the states in which they are located, the contract they were installed on, the location of the project, the owner's name and contract information, the prime Contractor on the contract, and a description of foundation soil conditions.
- Type A certifications in accordance with ISS 916.02(a) for materials constituting the MSE wall system. Submitted Type A certifications shall include copies of certified laboratory reports that document results of specified tests in compliance with standard specifications. Tests may be conducted by a laboratory operated by the MSE wall system vendor or by another qualified laboratory. ISS 916.03 provides sample forms for Type A.
- A statement indicating that the MSE wall system has been checked against the appropriate current retaining wall specifications (i.e., AASHTO LRFD Bridge Design Specifications) and that the MSE wall system either satisfies the current specifications or identifies areas where the wall system does not satisfy the current specifications.

Vendors seeking QPA approval for MSE wall systems that have not been approved by any other state DOTs shall provide all the same submittals, less a list detailing prior other state DOT approval and a list of past successful installations. In addition, the following information shall be included with the QPL approval request:

- Applicant Identification—company or firm name; name and title of authorized representative; address; and phone number, fax number, and email address
- Product Identification—product or trade name, description of composition, and intended use
- Product function—the specific technological problem or need the product is intended to address and the innovative feature of the product intended to satisfy the identified problem or need
- Patents—product patents, copyrights, or other protections and a summary of the proprietary or protected features
- Performance criteria—technical criteria for determining whether product can fulfill intended purpose, pullout testing results conducted by an independent laboratory, and any additional information that may be of significant interest or concern to a potential user (e.g., environmental acceptability)

3.1.2 Maintaining Standing and Removal from QPL

MSE wall system vendors interested in maintaining standing in the QPL of approved retaining wall systems shall follow ITM 806, Procedure J. MSE wall system materials shall be sampled and tested in accordance with applicable standards. Moreover, vendors shall provide INDOT Geotechnical Engineering Division with written notification of any changes, revisions, or updates to the MSE wall system.

MSE wall systems may be subject to removal from the QPL of approved retaining wall systems shall include, but not be limited to, the following:

- Test failures, product changes, or changes to any component of the retaining wall system without notification to the Department's Geotechnical Engineering Division
- Performance of the retaining wall system failing to meet the intended purpose

It is the responsibility of the Director for the Department's Geotechnical Engineering Division to decide whether an MSE wall system shall be removed from the QPL of approved retaining wall systems. If the Director decides to remove an MSE wall system from the QPL, then the system vendor has the right to appeal the decision to the Department's Chief Engineer of Construction.

3.2 Wall System Submittals

Before an MSE wall system is installed as part of a contract, INDOT requires the Contractor to submit shop drawings and design calculations (i.e., submittals) for approval (ISS 731.04). Shop drawing submittals provide project specific details for proposed MSE walls such as wall height, soil reinforcement lengths, and panel dimensions. Design calculation submittals demonstrate that proposed MSE walls conform with both INDOT Standard Specifications and AASHTO LRFD Bridge Design Specifications. MSE wall submittals shall be in accordance with ISS 105.02 and ISS 731.04 that include the following pertinent specifications:

- Governing specifications for submittals—ISS 731.04 supersedes ISS 105.02 where discrepancies exist between the two specifications (e.g., beginning wall construction operations)
- Submission expediency and formatting—submittals shall be submittal as soon as practical after contract award in a format acceptable to the Engineer
- Inclusion of identifying information—contract number, name of Contractor, and contact person
- Approval from professional engineer—submittals shall be signed by and shall bear the seal of a professional engineer
- Submittal checks—submittals shall be checked for accuracy by a second qualified individual
- Reviewal process—submittals will be reviewed for design features only (the Contractor shall be responsible for dimensions, accuracy, and fit of work); submittals will be returned either approved or showing changes or corrections required within 14 calendar days of receipt
- Wall construction—wall construction operations shall not begin until the Contractor receives written notice that submittal documents have been approved

In additional to the aforementioned submittal requirements, MSE wall shop drawings shall include the following information in accordance with ISS 731.04:

- All details, dimensions, quantities, and cross sections necessary to construct the wall that include, though not limited to:
    - Plan view(s) depicting the following:
        - Final wall profile
        - All alignment points with stations and offsets
        - Offsets from the construction centerline to the face of the wall at all changes in horizontal alignment
        - Details for placement position and connection of all soil reinforcements in areas where vertical obstructions (e.g., piling) exist near the wall
    - Elevation view(s) depicting the following:
        - Final wall profile
        - All alignment points with stations and offsets
        - Elevations along the top of the wall at all horizontal and vertical breakpoints at least 50 ft intervals along the face of the wall
        - All leveling pad steps
        - Designations for pre-casting facing panels
        - Lengths of soil reinforcements
        - Wall-elevation envelope encompassing the wall envelope shown on the road/bridge plans
    - All general notes for constructing the wall
- Pre-cast facing panel details depicting all dimensions, types of reinforcing steel within the panels, and locations of reinforcing steel within the panels
- Details for constructing around drainage facilities
- Details for outletting internal drainage from the MSE wall
- Architectural treatment details
- Details for accommodating soil reinforcements around both vertical obstructions (e.g., piles) and horizontal obstructions (e.g., unpressurized pipe)
- Details for connecting soil reinforcements to pre-cast concrete panels

Likewise, MSE wall design calculations shall include the following information in accordance with ISS 731.04:

- Analysis results (either longhand or computer printout format) for each MSE wall design case that follow a systematic and logical methodology
- A summary sheet depicting design assumptions and their source, controlling parameters and load cases, and any other pertinent input and output information
- Determination of friction angle values for reinforced backfill (i.e., structure backfill) and retained backfill (i.e., B-borrow)
- Detailed differential settlement calculations for the MSE wall (Table 2)

Table 2. MSE wall standard summary sheet of design input values per ISS 731.04

Wall Detail		Design Value
Reinforcement	Life	
	Type	
	Configuration (Strip or grid)	
	Width, in.	
	E_c (Corroded Thickness), in.	
	Reinforcement Strength (F_y), ksi	
	Coverage Ratio (R_c)	
Reinforced Fill	Type	
	Unit Weight, pcf	
	Friction Angle, degrees	
Reinforcement Pullout Resistance	F*	
	α	
Retained Fill	Type	
	Unit Weight, pcf	
	Friction Angle, degrees	
Foundation Soil	Type	
	Unit Weight, pcf	
	Friction Angle or cohesion[A], degrees or lb/sq ft	
[A]Use only one value, whichever is applicable		

4.0 MSE Wall Construction

4.1 Preconstruction

MSE wall construction may begin after INDOT has provided written approval of working drawing submittals. During preconstruction, the MSE wall system vendor shall provide technical guidance and installation instructions to the Contractor as specified in ISS 731.06. Assistance from the vendor shall continue into the construction phase with on-site support to the Contractor as needed.

4.2 Components Delivery and Storage

The MSE wall system vendor typical delivers the following MSE wall components to the site in preparation for wall construction:

- soil reinforcements and fasteners;
- pre-cast facing panels and, if needed, corner elements;
- geotextile joint covering fabric and adhesive;
- bearing pads; and
- pre-cast copings.

The Contractor should handle and store all MSE wall components as directed by the wall vendor and in accordance with ISS 731.09. The following sections elaborate on proper handling and storage of pre-cast components, soil reinforcements, and appurtenant fasteners and joint materials.

4.2.1 Pre-Cast Components

Pre-cast MSE wall components—facing panels, corner elements, and copings—typically come delivered to the site from the wall vendors's selected precaster via flatbed truck. The Contractor should inspect all pre-cast components for potential defects including cracking, chipping, spalling, honeycombing, permanent staining, out-of-tolerance dimensions, and bent/misaligned soil reinforcement connections prior to accepting delivery. Likewise, the Inspector should also verify that the delivered pre-cast components are free from said defects. Some MSE wall vendors permit repairing damaged pre-cast components prior to installation; however, the Contractor shall obtain approval from the Engineer before attempting any repairs.

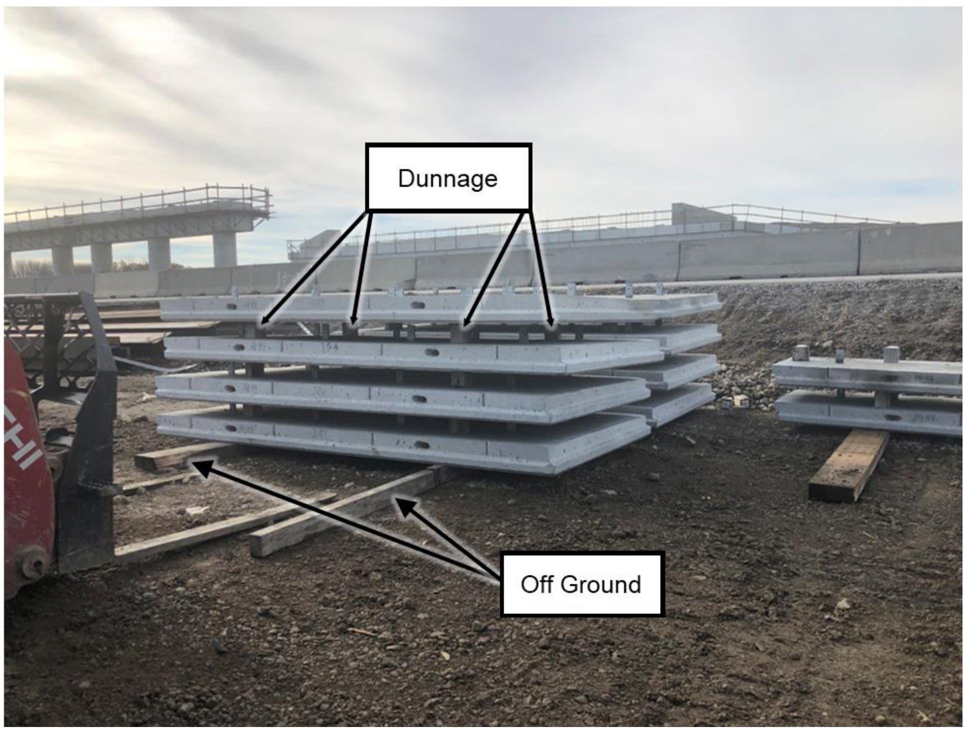


Figure 30. Pre-cast facing panels stored off of the ground with proper dunnage between panels

The Contractor may store pre-cast components outdoors, though they must be elevated off the ground. Pre-cast components stored outdoors should be placed on firm, level ground to provide stability and protection from staining. Figure 30 shows proper pre-cast facing panel storage in which panels had been placed atop blocking (e.g., 4 x 4 lumber) to preclude contact with the ground. If the Contractor stores pre-cast components directly on the ground surface resulting in stains and discolorations, then the Contractor shall clean the components using a chemical wash (ISS 731.09). Pre-cast facing panels may be stored in vertical stacks provided that there is proper dunnage (e.g., 4 x 4 lumber) separating each panel (Figure 30). Dunnage precludes damage due to concrete-to-concrete contact and bending of soil reinforcement connections. MSE wall vendors typically recommend that stacks not exceed five panels high. The Inspector should verify that pre-cast components are properly stored onsite.

4.2.2 Soil Reinforcement

Soil reinforcements may be stored outdoors, but they should be elevated off the ground. Improperly stored steel soil reinforcements could become bent or dented leading to accelerated corrosion rates. Figure 31 shows proper soil reinforcement storage in which reinforcing strips had been placed atop blocking (e.g., 4 x 4 lumber). The Inspector should verify that soil reinforcements are properly stored onsite.

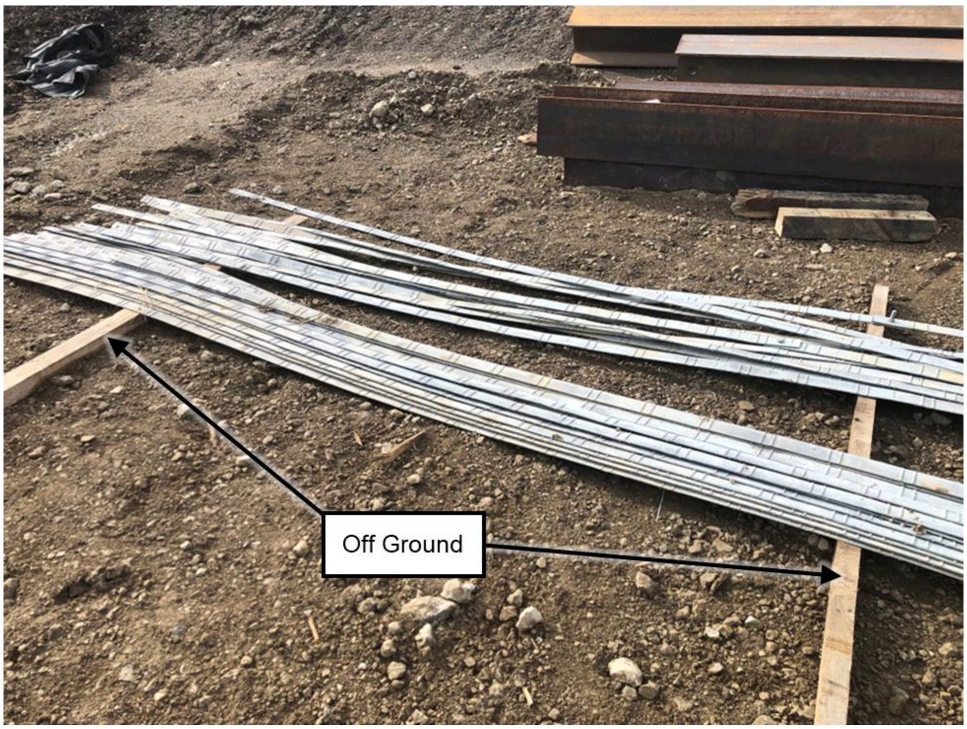


Figure 31. Soil reinforcements stored off of the ground

4.2.3 Fasteners and Joint Materials

Wall system vendors should provide specific instructions for handling and storing all other appurtenant MSE components—fasteners, bearing pads, and geotextile joint covering materials. MSE wall system vendors may have special requirements for storing such components (e.g., within a sheltered location). The Inspector should verify that these materials are stored in accordance with recommendations from the MSE wall system vendor.

4.3 Construction Process

4.3.1 Foundation Preparation

4.3.1.1 Excavation

INDOT's standard specifications for MSE wall excavation are detailed in ISS 731.08. Figure 32 depicts excavation operations leading up to the construction of an MSE wall.

Figure 32. Typical excavation operations for MSE wall foundation preparation

Shop drawings in accordance with 731.04 shall detail specified leveling pad elevations and reinforced zone widths along the length of the MSE wall, and the Contractor shall excavate and grade the site to those elevations and widths. However, excavation operations shall not begin until the Contractor has received notice that MSE wall shop drawings have been approved. Likewise, excavation operations shall not begin until the Contractor has cleared and grubbed the site to the wall limits detailed on the shop drawings. Clearing and grubbing shall be in accordance with ISS 201.03 and shall include removing and disposing of all timber, stumps, and debris. INDOT standard specifications also require that the Contractor notify the Engineer 7-calendar days, or other time as mutually agreed upon, before beginning excavation so that measurements can be taken of the undisturbed ground. The Inspector should verify that excavation operations begin in accordance with the procedures laid out in the standard specifications.

The Contractor shall conduct excavation operations abiding by State and local safety requirements, so some excavations may require a support system—shoring, sheeting, or bracing. MSE wall shop drawings shall indicate whether an excavation requires a support system. Moreover, shop drawings shall indicate the specified method of excavation support. Excavation support systems shall be removed at the end of excavation operations. The Inspector should verify that excavations are conducted safely and that excavation support systems are properly utilized where needed.

Excavation operations shall also include water removal—pumping, bailing, and draining. Moreover, excavation and related work shall be performed such that no portion of the MSE wall is endangered by subsequent construction operations. The Inspector should verify that water is appropriately removed from excavations where needed and that excavation operations pose no threat to future MSE wall stability.

Unsuitable soil encountered during excavation shall be removed and replaced with B Borrow in accordance with ISS 211.02 (see Section 2.4 of this manual). B Borrow shall be compacted in accordance with ISS 211.04, which specifies using mechanical tamps or vibrators in accordance with ISS 203.23 (i.e., compacted to 95% maximum dry density per AASHTO T 191). Compacted dry densities can be checked based on minimum dynamic cone penetrometer (DCP) blow count values provided in ISS 203.23. The Inspector should verify the following:

- That soils deemed unsuitable by the Engineer have been removed
- That unsuitable soils have been replaced with materials meeting B Borrow specifications
- That replacement soils have been compacted to at least 95% maximum dry density based on DCP blow count criteria in ISS 203.23

4.3.1.2 Compaction and Grading

INDOT standard specification 731.07 details requirements for foundation compaction and grading. The Contractor shall compact the MSE wall foundation in accordance with ISS 203 that specifies requirements for excavation and embankment. However, the Contractor need not compact foundations within rock. The foundation shall be graded for a width equal to or exceeding the length of the soil reinforcement or as shown on the plans. Likewise, the foundation shall be graded with a 1 in. per foot downward slope toward the back of the reinforced zone. However, the portion of the foundation beneath the leveling pad shall not be sloped. The Inspector should verify the following:

- That the foundation has been compacted in accordance with ISS 203 (if not founded on rock)
- That the width of the foundation grading equals or exceeds the length of the soil reinforcement
- That the foundation has been graded as detailed in the road/bridge plans
- That the foundation has been graded with a 1 in. per 1 foot downward slope toward the back of the reinforced zone
- That the portion of foundation below the leveling pad is level graded

4.3.1.3 Proofrolling

After compacting and grading the MSE wall foundation, the Contractor shall proofroll the foundation in accordance with ISS 203.26. Shown in Figure 33, proofrolling shall be conducted using an on-highway dump truck with a minimum 90 psi tire pressure and weighing at least 15 tons (i.e., proofrolling of original ground and embankment construction). Speed of the proofrolling truck shall not exceed 2 mph, and all proofrolled surfaces shall be covered completely with a single pass. Locations where deflections during proofrolling exceed ½ in. shall be remediated as directed by the Engineer. Likewise, Engineer directed remediation shall occur where proofrolling induces rutting deeper than ½ in. Locations where deflections or ruts exceed 3 in. shall require corrective remediation measures as directed by the Engineer and in consultation with INDOT Geotechnical Engineering Division. Proofrolling shall be conducted on locations that had received corrective remediation. The Inspector should verify the following:

- That the contractor has proofrolled the MSE wall foundation using an appropriately sized on-highway dump truck
- That locations failing proofrolling have been appropriated remediated as directed by the Engineer

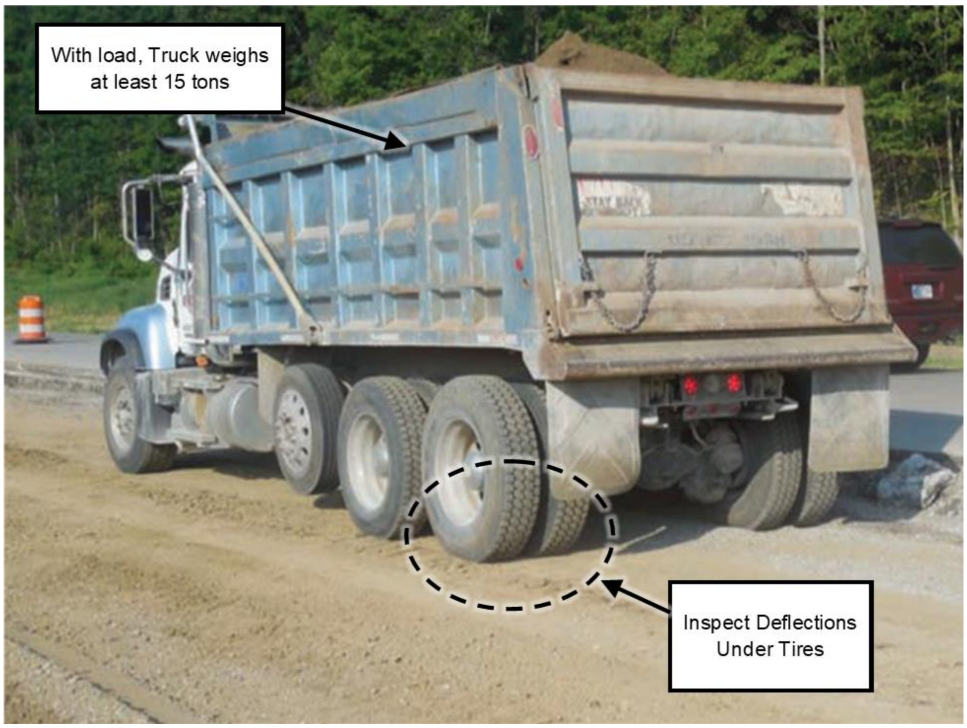


Figure 33. Proofrolling with an on-highway dump truck loaded weighing at least 15 tons

4.3.1.4 <u>DCP Verification Testing</u>

After proofrolling, the Inspector will verify MSE wall foundation construction using dynamic cone penetrometer (DCP) testing in accordance with ITM 509. Shown in Figure 34, DCP tests involve dropping a 17.6 lb weight from 22.6 in. onto a cone-tipped steel rod then measuring the subsequent penetration into the ground. DCP tests yield blow count measurements that equal the number of blows (i.e., DCP drops) required to penetrate 6 in. Each DCP test will penetrate a total of 30 in. into the ground, so five sets of DCP measurements are taken at each location. DCP blow counts at or exceeding 5 blows per 6 in. interval are considered acceptable. Foundation soils at locations failing DCP testing shall be removed and then replaced with compacted B Borrow (see Section 4.3.1.1 of this manual). The Inspector will conduct 1 DCP test per 500 square feet of MSE wall foundation. MSE wall foundations at bridge end bents will require 5 DCP tests per end bent. MSE wall foundations constructed as embankment sections in accordance with ISS 203 will not require DCP verification testing. The Inspector should verify the following:

- That DCP tests advanced to 30 in. deep yield blow count measurements equal to or greater than 5 blows per 6 in.
- That soils where DCP tests yield failing blow count measurements have been removed and replaced with compacted B Borrow

Figure 34. Conducting a dynamic cone penetration (DCP) test for acceptance testing of foundation soils and backfill compaction

INDOT Construction Memorandum 15-08 provides an MSE wall factored bearing resistance verification chart based on DCP blow count measurements (Figure 35). The chart converts DCP blow count measured over a 12 in. penetration to factored bearing resistance. Although, the chart is only applicable for cohesive soils (i.e., clayey and silty soils). The Inspector should verify that the DCP measured factored bearing resistances meet or exceed the factored bearing resistance detailed on the shop drawings. INDOT Geotechnical Engineering Division should be contacted if factored bearing resistances from DCP testing fail to exceed their specified values.

INDOT Construction Verification Chart

For Factored Bearing Resistance Based on DCP Blow Counts

DCP Blows for 12 inches	Factored Bearing Resistance (psf)	DCP Blows for 12 inches	Factored Bearing Resistance (psf)
10	4,000.00	21	7,600.00
11	4,300.00	22	8,000.00
12	4,600.00	23	8,300.00
13	5,000.00	24	8,600.00
14	5,300.00	25	9,000.00
15	5,600.00	26	9,300.00
16	6,000.00	27	9,600.00
17	6,300.00	28	10,000.00
18	6,600.00	29	10,300.00
19	7,000.00	30	10,600.00
20	7,300.00	31	11,000.00

Note: This table is applicable only for fine grained (cohesive) soils.
For sand & gravel, please contact the Office of Geotechnical Services.

Figure 35. INDOT Construction Memorandum 15-08 that provides a conversion from DCP blow count to foundation factored bearing resistance

4.3.2 Leveling Pad Placement

Leveling pad placement shall follow MSE wall foundation preparation. INDOT standard specifications 731.07 and 731.08 detail requirements for leveling pad construction. The Contractor shall compact soil underneath the leveling pad in accordance with ISS 203 (see Section 4.3.1.1 of this manual). The Contractor shall verify that the foundation is at the correct elevation as detailed in the shop drawings. The leveling pad shall not be placed until the Engineer has approved the leveling pad foundation elevations. The Inspector should verify the following:

- That soil underneath the leveling pad has been compacted in accordance with ISS 203
- That the Engineer has approved the elevations along the length of the leveling pad

The Contractor shall cast unreinforced concrete leveling pads at each foundation level as shown on the shop drawings (i.e., width and height). Figure 36 shows an example MSE wall concrete leveling pad placement operation. Leveling pad concrete shall be cured in accordance with ISS 702.22 for a minimum of 12 hours before placing pre-cast facing panels. After the concrete has set, the Contractor should establish a layout line on the leveling pad—a chalk line should suffice (Figure 37)—to provide a guide for placing the first course of pre-cast facing panels. The Inspector should verify the following:

- That the leveling pad has been placed as detailed on the shop drawings
- That the leveling concrete has been cured in accordance with ISS 702.22 for at least 12 hours

Figure 36. Typical MSE wall leveling pad construction operations that involve placing formwork and pouring concrete

An improperly placed leveling pad can lead to misaligned MSE wall facing panels. INDOT does not specify leveling pad tolerances, but some MSE wall system vendors do. Typical leveling pad tolerances range from ¼ in. below to ⅛ in. above design elevation. The Inspector should verify that the constructed leveling pad meets tolerances recommended by the MSE wall system vendor.

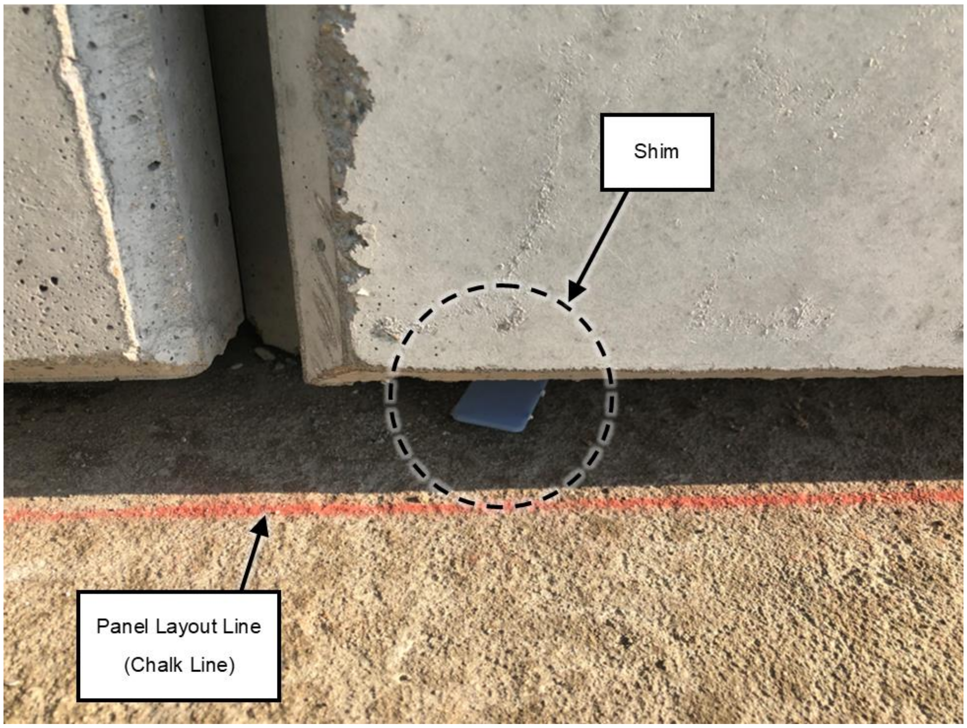


Figure 37. Pre-cast panels comprising the initial course are placed relative to a layout line that is typically drawn using a chalk line

Some MSE wall leveling pads may have multiple elevations that require step-ups, see Figure 38 for example. MSE wall system vendors typically recommend pouring the higher elevation leveling pad as detailed on the shop drawings, then leaving a 9 ± 3 in. gap between the higher and lower leveling pads. The gap provides some leeway when placing the first course of pre-cast facing panels at the leveling pad step-up. Figure 39 shows an example leveling pad step-up during MSE wall construction. The inspector should verify that leveling pad step-ups have been constructed in accordance with recommendations from the MSE wall system vendor.

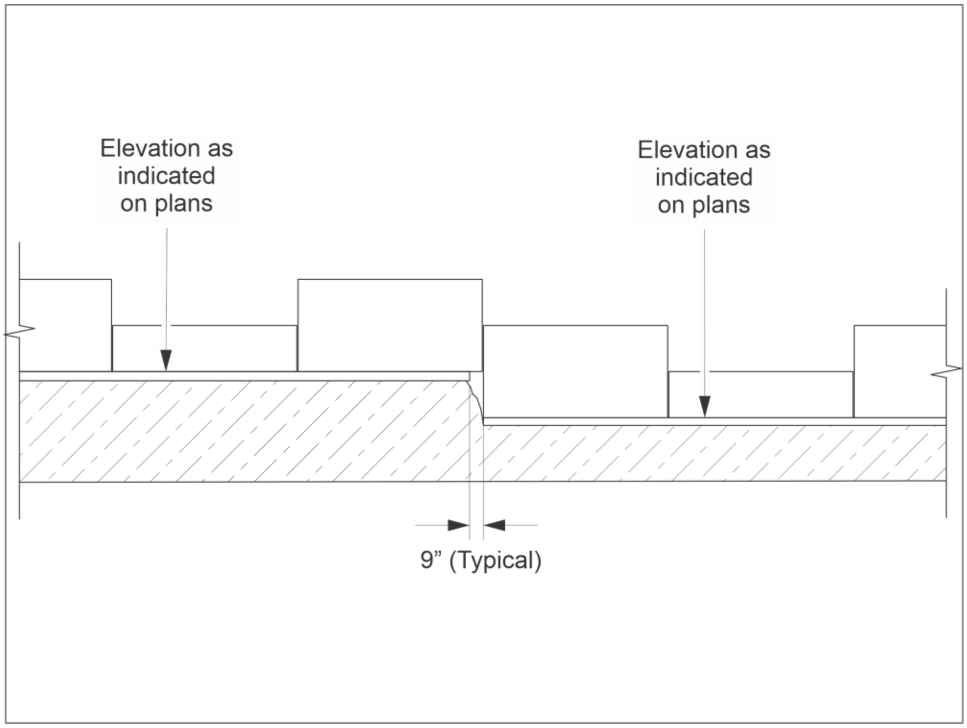


Figure 38. Example of how an MSE wall system vendor might recommend constructing leveling pads with step-ups

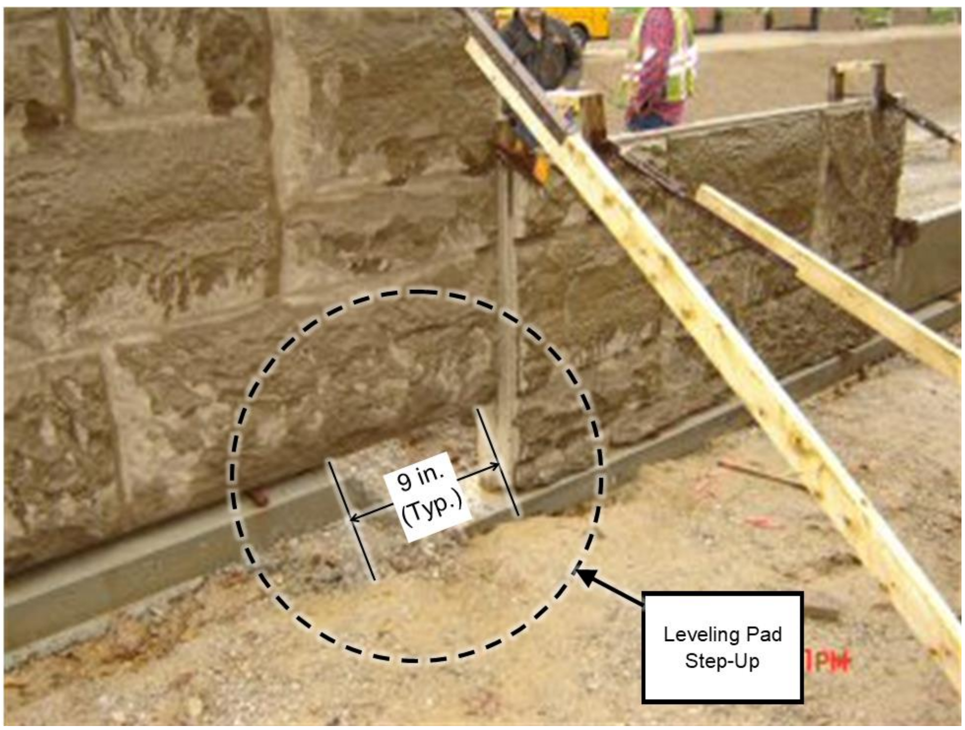


Figure 39. Example MSE wall leveling pad step-up

4.3.3 Place Initial Panel Course

After ISS 731.09, the Contractor shall place pre-cast facing panels in successive horizontal lifts (i.e., panel courses) as shown in the shop drawings. Proper alignment of the first panel course is paramount to MSE wall construction. Indeed, positioning of subsequent panel courses is directly linked to the alignment of the first panel course. Therefore, particular attention must be given to the placement and backfilling of the initial panel course.

4.3.3.1 Lifting and Placing Panels

Facing panels shall be cast with lifting connections set into their upper edges in accordance with ISS 731.09. The embedded lifting connections (Figure 40) allow for panels to be quickly and easily lifted from storage stacks and then placed within MSE wall facing. The MSE wall system vendor typically provides special lifting equipment/rigging that quick connects to the embedded panel lifting connections. The Contractor may then secure the lifting equipment to their machinery (e.g., excavator) for lifting and transporting pre-cast panels, as shown in Figure 41. Some MSE wall system vendors provide guidelines for protecting pre-cast panels when lifting from storage stacks. For example, Figure 42 depicts proper panel lifting from storage stacks in which a wood block (e.g., 4 x 4 lumber) is used to provide cushioning between panels during lifting. The Inspector should verify the following:

- That panels have been cast with lifting connections set into their upper edges
- That panels are lifted and transported from onsite storage in accordance with recommendations from the MSE wall system vendor.

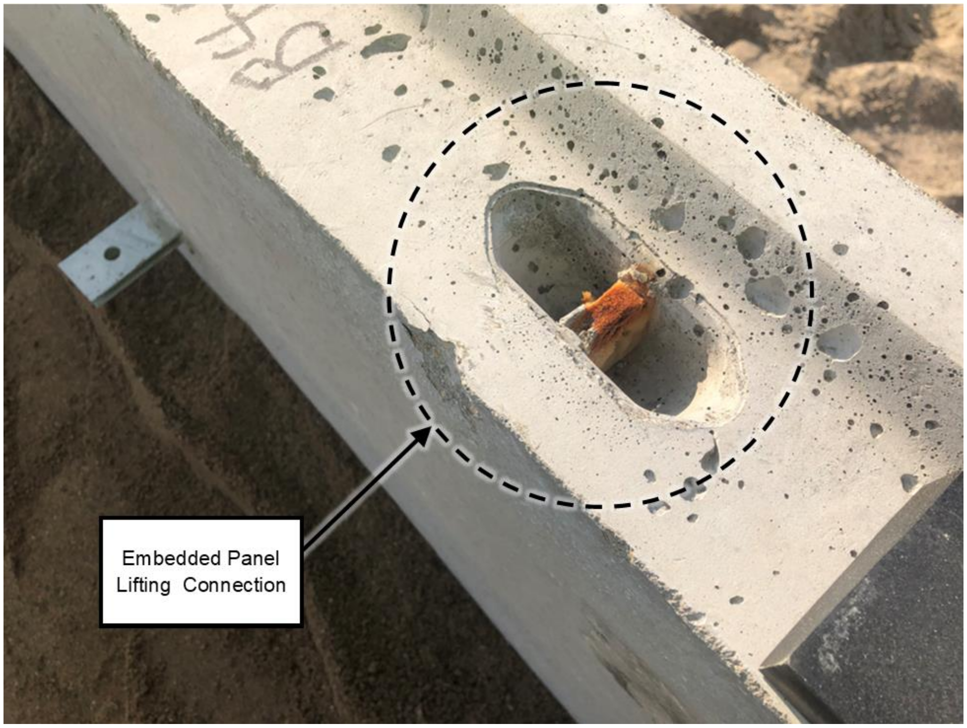


Figure 40. Example connection embedment for lifting pre-cast panels during placement

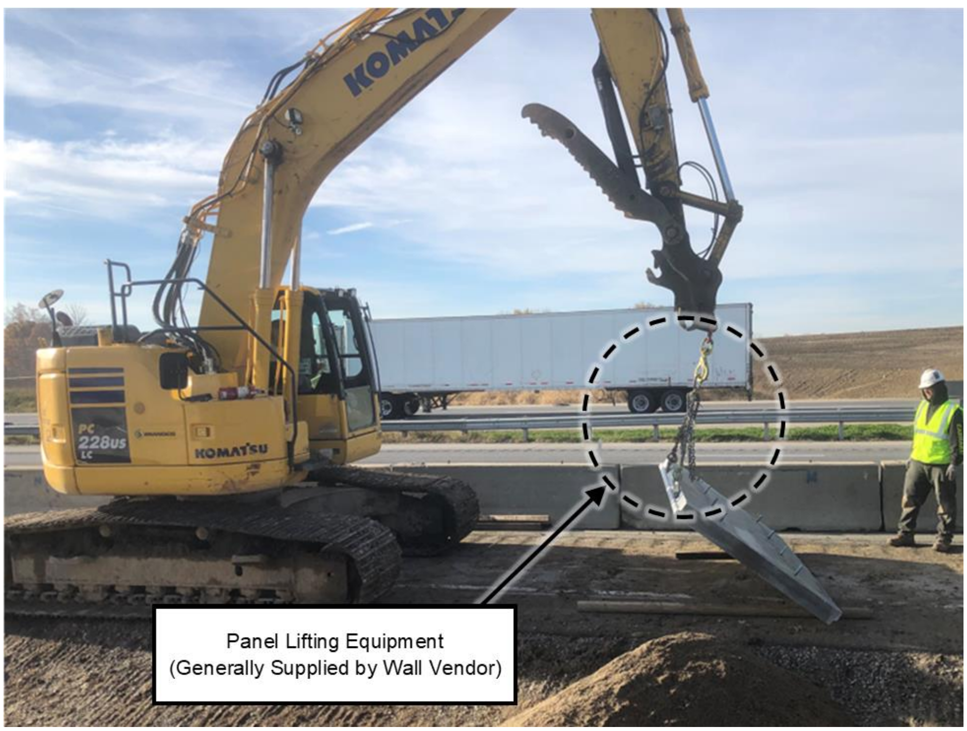


Figure 41. Typical pre-cast panel lifting and placement using MSE wall system vendor supplied panel lifting equipment and appropriate construction machinery

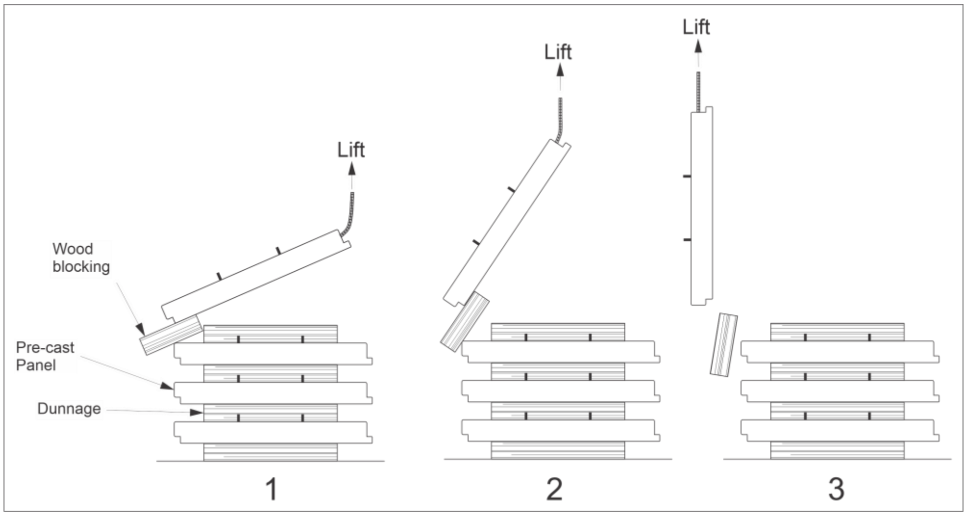


Figure 42. Recommended procedure for lifting pre-cast panels from stacks to minimize damage

Figure 43 depicts typical placement operations for the initial course of pre-cast facing panels onto the leveling pad. Panel placement typically begins at the lowest elevation leveling pad or at a fixed location—wall corner or existing structure. Initial course panels should be placed directly on top of the leveling pad. Bearing pads should not be placed beneath the initial course panels, unless specified on the wall shop drawings. Panels should be placed along the layout line that had been previously drawn on the leveling pad (see Section 4.3.2 of this manual). Panel positioning may be adjusted using a crowbar for leverage (Figure 44). Although, crowbar leveraging might cause concrete chipping or cracking, so the Contractor should avoid leveraging panels from the front (i.e., visible portion of the wall post-construction). The Contractor should check panel horizontal level using a 4-ft level and shim as needed (Figure 37). Permanent wood shims should never be used for leveling panels; instead, the Contractor should use plastic or rubber shims supplied by the MSE wall system vendor. Figure 45 shows examples of shims that may be used for leveling initial course panels. The Inspector should verify the following:

- That placement procedures are not causing undue damage to panels
- That panels are placed in alignment with the leveling pad layout line
- That panels are horizontally level
- That panels requiring shimming have been shimmed in accordance with the MSE wall system vendor guidelines

Figure 43. Typical initial course pre-cast panel placement operations

Figure 44. Using a crowbar from the backside of a pre-cast panel to adjust positioning

Figure 45. Examples of pre-cast panel shims supplied by an MSE wall vendor

4.3.3.2 Setting Panel Batter

Vertically upright pre-cast facing panels seldom remain plumb during construction. Rather, they tend to rotate away from the MSE wall due to horizontal pressures exerted by the backfill during its placement and compaction. Therefore, panels should be placed with a slight tilt (i.e., batter) toward the back of the MSE wall to compensate for their movements during construction. Although the degree to which panels should be battered depends on several factors (e.g., type of backfill), panel batter typically equals ½ in. horizontal to 4 ft vertical. Panel batter is typically set using a 4 ft level with a spacer sized for the target batter duct-taped to it (Figure 46). Batter shall be maintained using temporary wooden wedges placed beneath the front of panel (Figure 47). MSE wall system vendors typically provide guidelines for cutting out wooden wedges (Figure 48). Wooden wedges should not be removed until typically no more than 3-courses of panels overlying the wedges have been placed. During construction, the Contractor should monitor actual panel movement and adjust the degree of panel battering accordingly. The Inspector should verify the following:

- That panels have been battered toward the back of the MSE wall
- That temporary wooden wedges have been used to maintain panel batter
- That the contractor is monitoring panel movement during construction and adjusting the degree of panel battering accordingly

Figure 46. Using a 4 ft level with duct-taper spacer for setting panel batter

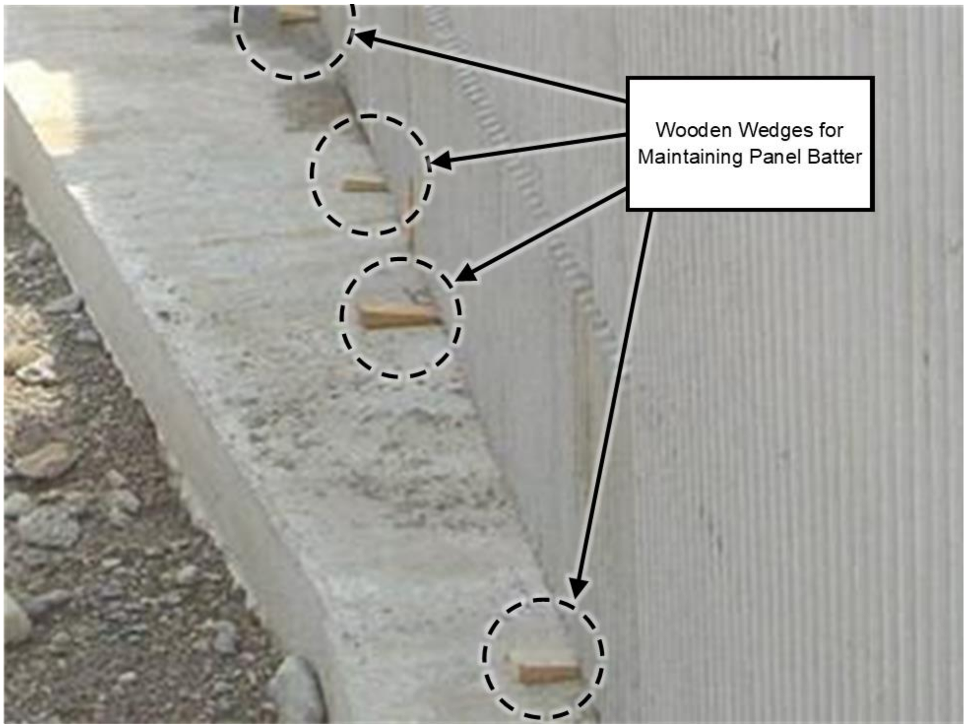


Figure 47. Example of wooden wedges maintaining pre-cast panel batter

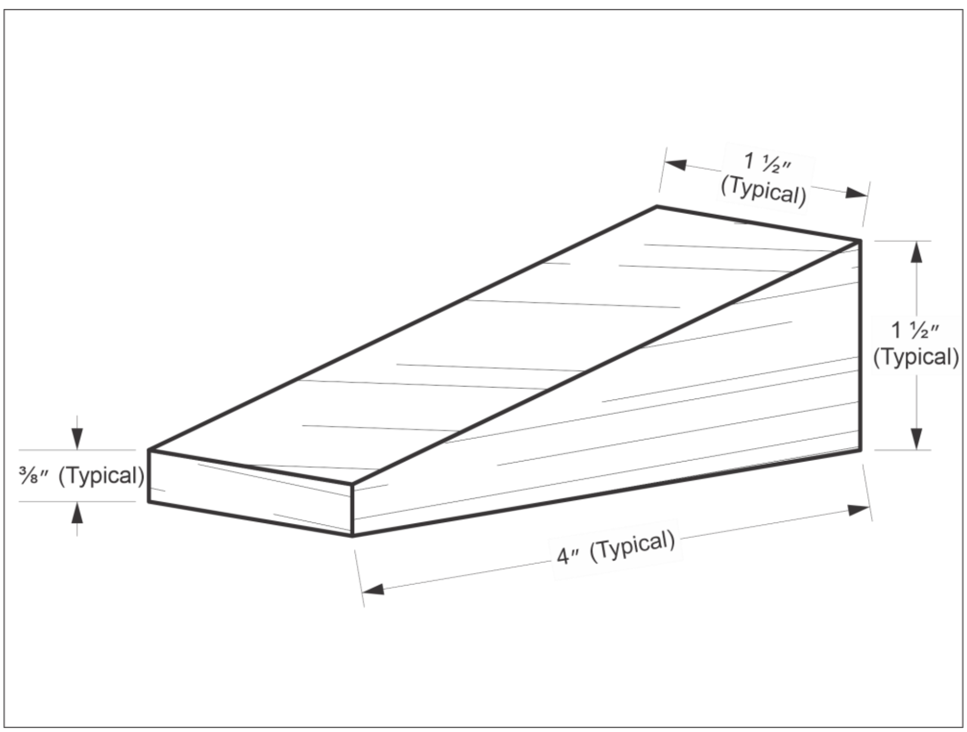


Figure 48. Typical wooden wedge used in MSE wall construction

4.3.3.3 Bracing Panels

Pre-cast facing panels will not stand on their own until soil reinforcements have been connected and backfilled over. So, the Contractor needs to temporarily brace panels during construction. Panel bracing should be fabricated by the Contractor following recommendations from the MSE wall system vendor. Figure 49 shows a typical panel bracing system that consists of 2 x 4 lumber clamped to a panel and staked to the ground. The bracing configuration depicted in Figure 49 uses one brace per panel; however, larger panels may require multiple braces. After bracing has been installed, the Contractor can detach the panel from lifting hardware. The Inspector should verify that initial course panels are braced following guidelines from the MSE wall system vendor.

Figure 49. Example panel bracing system used in MSE wall construction

4.3.3.4 Placing Adjacent Panels

In accordance with ISS 731.09, the Contractor shall place adjacent pre-cast facing panels with a minimum ¾ in. wide vertical joint separation. Vertical joints preclude concrete-to-concrete contacts that can cause panel distresses (e.g., cracking) over the life of the MSE wall. In general, vertical panel joints are ¾ in. wide, but MSE wall shop drawings should detail actual panel joint width. The Contractor sets vertical joints using typically at least one ¾ in. wide spacer placed in between adjacent panels (Figure 50). Vertical joint spacers are supplied by the Contractor based on recommendations from the MSE wall system vendor. Figure 51 depicts an example vertical joint spacer as-built drawing. Vertical joint spacers should remain in place until the next panel joint has been established by a spacer. The Contractor may fabricate vertical joint spacers from any material, including wood, because they are temporary fixtures. The Inspector should verify the following:

- That panels have been placed with ¾ in. wide vertical joints separating them per INDOT standard specifications
- Appropriate joint spacers using materials consistent with MSE wall shop drawings have been used

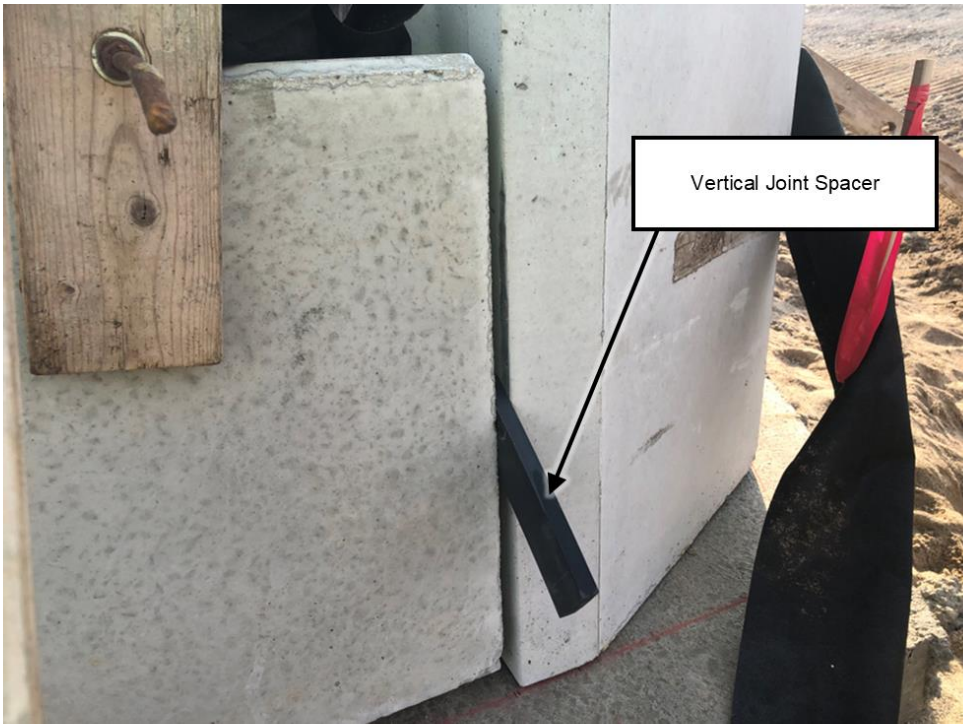


Figure 50. Example vertical joint spacer used in MSE wall construction

After battering and bracing the panels as discussed in Sections 4.3.3.2 and 4.3.3.3 of this manual, the Contractor should tightly clamp together adjacent panels as shown in Figure 52. Clamping together adjacent panels helps to maintain panel alignment during construction. Clamps are supplied by the Contractor and are typically fabricated from 2 x 6 lumber and ½ in. diameter threaded rod (Figure 53). The Inspector should verify that adjacent panels within the initial course are clamped together following recommendations from the MSE wall system vendor.

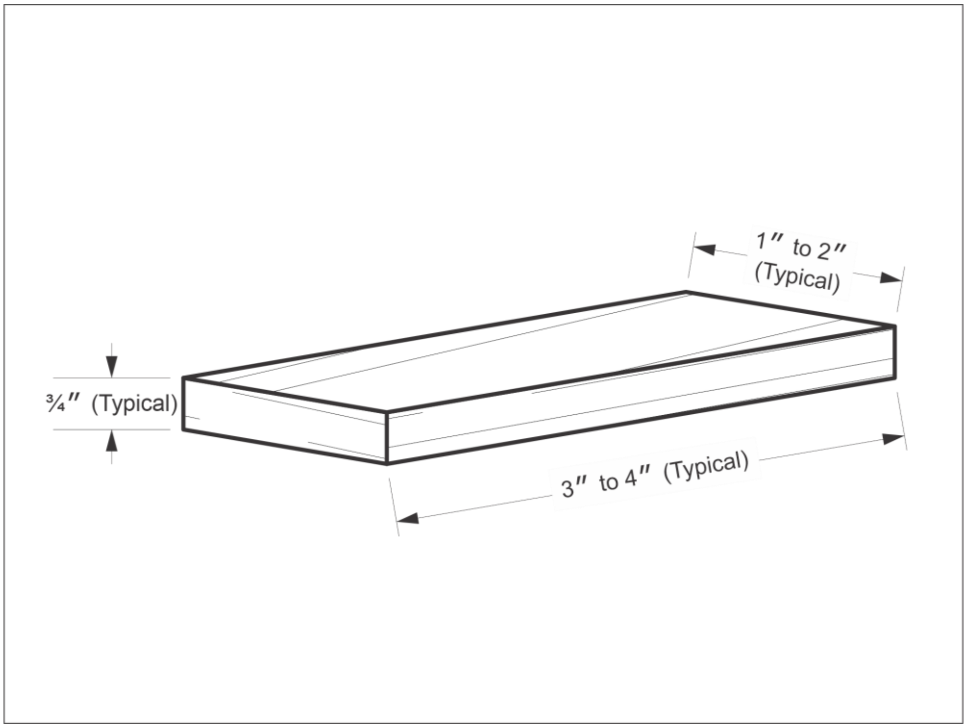


Figure 51. Typical vertical joint spacer used in MSE wall construction

Figure 52. Example of adjacent pre-cast panels clamped together for maintaining alignment during construction

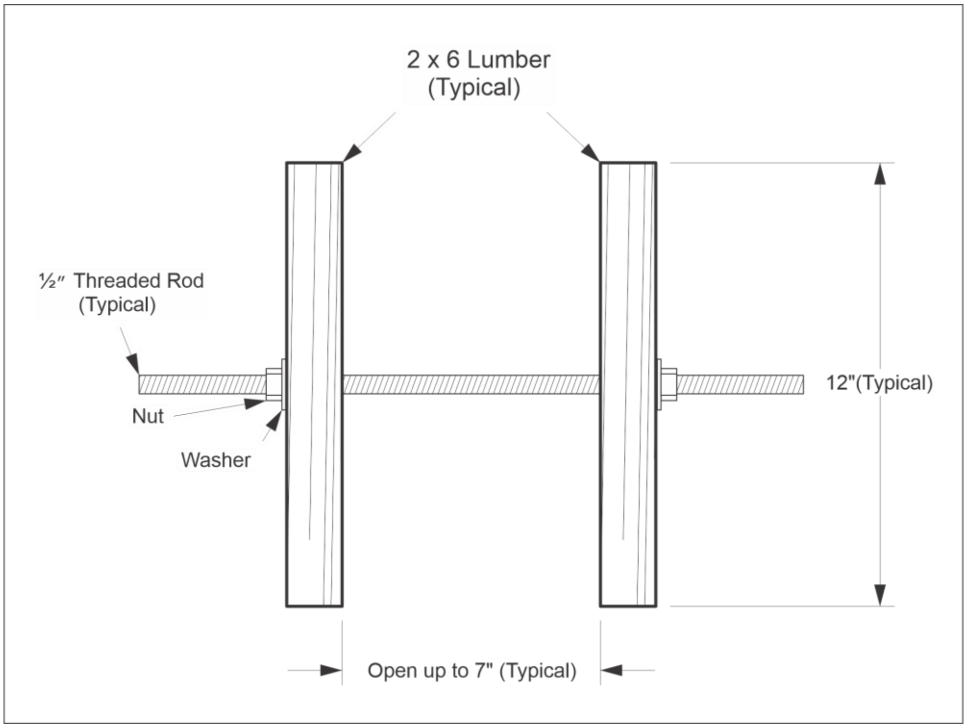


Figure 53. Typical panel clamp used in MSE wall construction

4.3.3.5 Checking Horizontal Panel Alignments

During placement of the initial course, the Contractor should periodically (e.g., after every 10 panels) check panel alignment by sighting along the wall face. ISS 731.09 specifies a maximum horizontal alignment tolerance of ¾ in. over a 10 ft length. Likewise, panels should be in-line with the leveling pad layout line (see Section 4.3.2 of this manual). The Contractor should promptly adjust any panels that are outside of horizontal alignment tolerance or are not in-line with the established layout line. Panel adjustments can be made using a crowbar leveraged from the fill side of the panel, as discussed in Section 4.3.3.1 of this Manual. Figure 54 shows an example initial course placement during MSE wall construction. The inspector should verify the following:

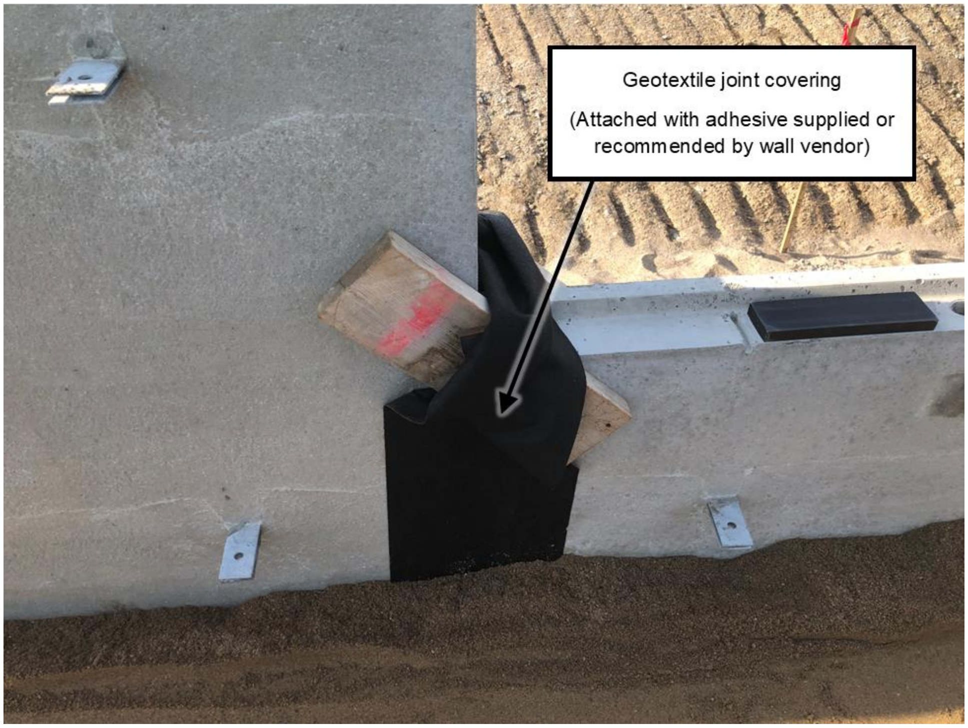
- That panels are within ¾ in. in 10 ft horizontal alignment tolerance
- That out-of-tolerance panels are properly adjusted following recommendations from the MSE wall system vendor

Figure 54. Example of a completed intial course of MSE wall pre-cast panels

4.3.3.6 Placing Geotextile Joint Covering

After placing an entire course of pre-cast facing panels, the Contractor should cover panel joints with a geotextile fabric supplied by the MSE wall system vendor, as shown in Figure 55. The geotextile fabric prevents backfill from seeping out through the joints, while still allowing for water to drain out. Geotextile joint coverings should be placed on the backfill side of pre-cast wall panels using adhesive supplied by the MSE wall system vendor. Shop drawings should detail additional considerations with placing geotextile joint coverings such as required minimum overlapping. In general, geotextile joint coverings are not required at the base of the wall where panels rest on the leveling pad. The Inspector should verify the following:

- That panel joints have been covered with MSE wall system vendor supplied geotextile fabric and adhesive
- That geotextile fabric has been affixed to the backside of wall panels as detailed in the shop drawings



- **Figure 55. Example of a vertical joint covered with geotextile**

4.3.3.7 Placing Initial Backfill Lifts

Structure backfill placement may begin after the first course of pre-cast facing panels have been set and their joints covered with geotextile fabric. INDOT standard specification 731.11 details requirements for MSE wall structure backfill placement. Backfill shall be placed so as to avoid damage or disturbance to the wall materials or misalignment of the concrete face panels. Most MSE wall system vendors recommend using the backfilling procedure shown in Figure 56 and Figure 57 to avoid potential panel misalignment. Structure backfill is placed and compacted in lifts up to the bottommost soil reinforcement level; however, no backfill is placed within 12 in. of the pre-cast panel. Backfilling should not occur next to the panel until the first course of soil reinforcements have been placed and backfilled over. Wall materials that become damaged or disturbed during backfill placement shall be removed and replaced or corrected as directed. Likewise, all misalignment or distortion of the concrete face panels due to placement of backfill outside the limits described herein shall be corrected as directed. The Inspector should verify the following:

- That backfilling operations are neither damaging nor disturbing pre-cast facing panels
- That pre-cast facing panels damaged or misaligned during backfilling are either corrected or removed and replaced, as directed by the Engineer

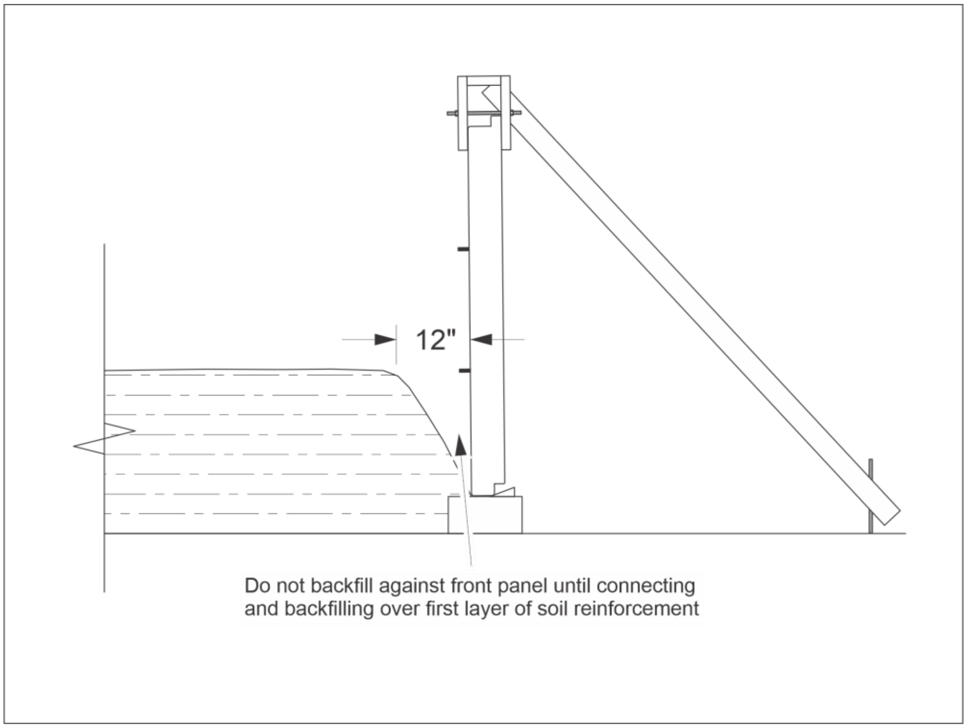


Figure 56. Procedure for backfilling behind the intial pre-cast panel course so as to minimize disturbances and misalignments of the panels

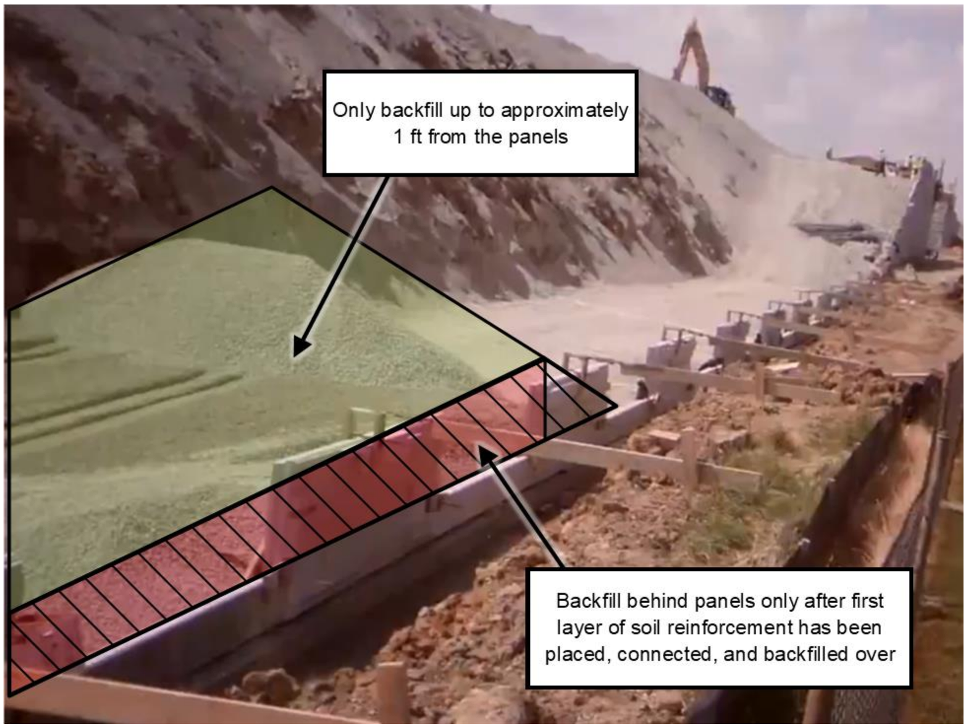


Figure 57. Example backfilling behind an initial pre-cast panel course

Structure backfill shall be compacted using equipment in accordance with ISS 409.03(d). The Contractor shall compact using a steel, smooth-drum vibratory roller equipped with a variable amplitude system, a speed control device, and a vibration frequency system with no less than 1,000 vibrations per minute, Figure 58 for example. Moreover, the compaction equipment shall be self-propelled, be in good condition, and be capable of reversing direction. However, the roller shall not be used for compacting structure backfill within 3 ft of the pre-cast facing panels. The Contractor shall instead use a lightweight compactor such as a vibratory plate compactor (example Figure 59) for compacting within 3 ft of pre-cast facing panels. The Inspector should verify that appropriate compaction equipment is being used to compact MSE wall structure backfill.

Figure 58. Typical steel, smooth-drum vibratory roller for compacting backfill outisde of 3 ft from pre-cast panels

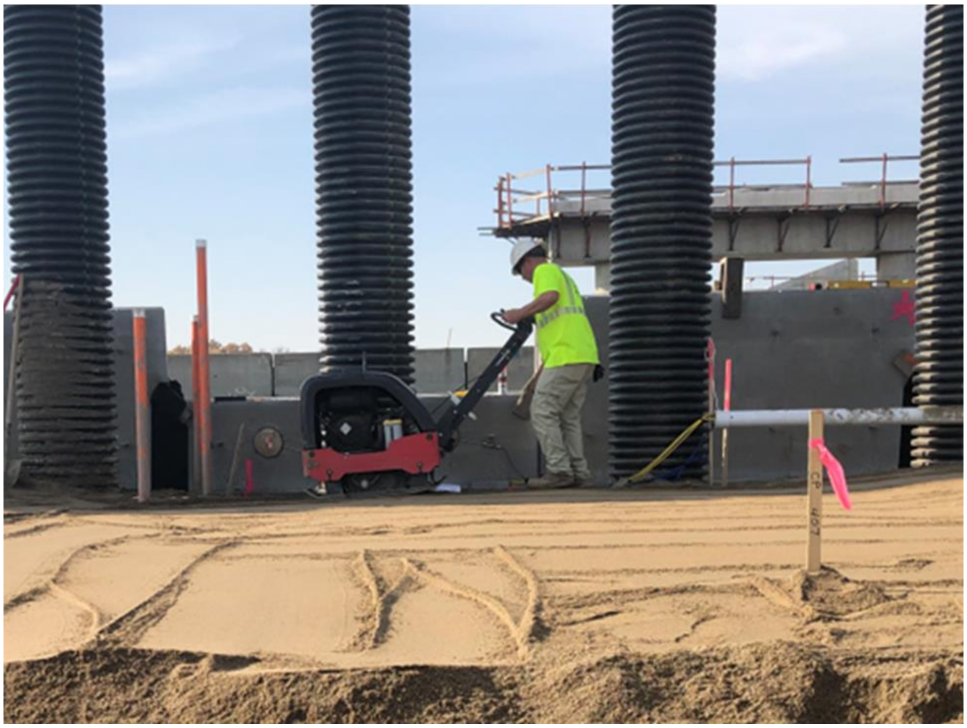


Figure 59. Typical vibratory plate compactor for compacting backfill within 3 ft of pre-cast panels

Structure backfill compacted using a full-sized vibratory roller shall be placed in loose lifts no thicker than 8 in, while structure backfill compacted using a lightweight compactor (e.g., vibratory plate compactor) shall be placed in loose lifts no thicker than 5 in. However, lift thicknesses for lightweight compactors shall be reduced as necessary to achieve target densities. Compaction operations with a full-sized vibratory roller shall consist of four passes in vibratory mode followed by one pass in static mode (i.e., no vibrations). Compaction operations with a lightweight compactor shall consist of no less than five passes. The Inspector should verify the following:

- That loose lift thicknesses do not exceed 8 in. where full-sized vibratory rollers will be used for compaction operations
- That loose lift thicknesses do not exceed 5 in. where lightweight compactors (e.g., vibratory plate compactors) will be used for compaction operations
- That compaction operations using full-sized vibratory rollers consist of four passes in vibratory mode followed by one pass in static mode
- That compaction operations using lightweight compactors consist of no less than 5 passes

Structure backfill compaction is assessed in terms of relative compaction (i.e., percentage of compacted dry density relative to maximum dry density). Maximum dry density for a structure backfill is determined from laboratory testing in accordance with AASHTO T99 (Standard Method of Test for Moisture-Density Relations of Soils Using a.5-lb Rammer and a 12-in. Drop). AASHTO T99 yields a moisture-density curve with a maximum dry density at a corresponding optimum moisture content, Figure 60 for example. Structure backfill shall be compacted to at least 95% relative compaction. Inspectors will verify structure backfill compaction in accordance with either ISS 203.23 or ISS 203.24.

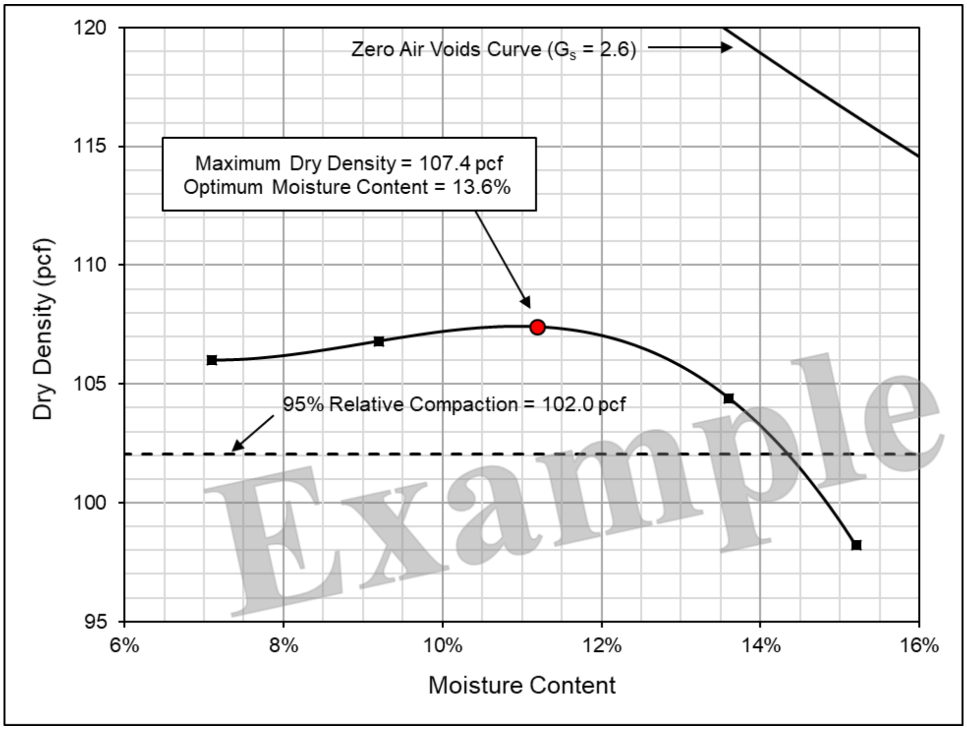


Figure 60. Example moisture density curve for an MSE wall structure backfill

INDOT standard specification 203.23 specifies that dynamic cone penetrometer (DCP) in accordance with ITM 509 be used for compaction acceptance. Refer to Section 4.3.1.4 of this manual for detailed information on DCP test procedures. DCP-based compaction acceptance testing is applicable for structure backfill soils consisting of No. 4 aggregate, ½" aggregate, or 1" aggregate. Acceptable minimum DCP blow count values for No. 4 aggregate, ½" aggregate, and 1" aggregate are provided in ISS 203.23. If using DCP tests for compaction acceptance, the Inspector should verify that DCP blow counts on compacted backfill meet or exceed minimum criteria per ISS 203.23.

INDOT standard specification 203.24 specifies that sand cone testing in accordance with AASHTO T 191 (Standard Method of Test for Density of Soil In-Place by the Sand-Cone Method) be used for compaction acceptance. Inspectors can measure in situ density with a sand cone test (Figure 61) by removing a known weight of wet soil then backfilling the void with a geomaterial of known density (e.g., silica sand). Dry density can be determined after measuring soil unit weight in accordance with ITM 506. If using sand cone tests for compaction acceptance, the Inspector should verify that dry densities meet or exceed 95% relative compaction.

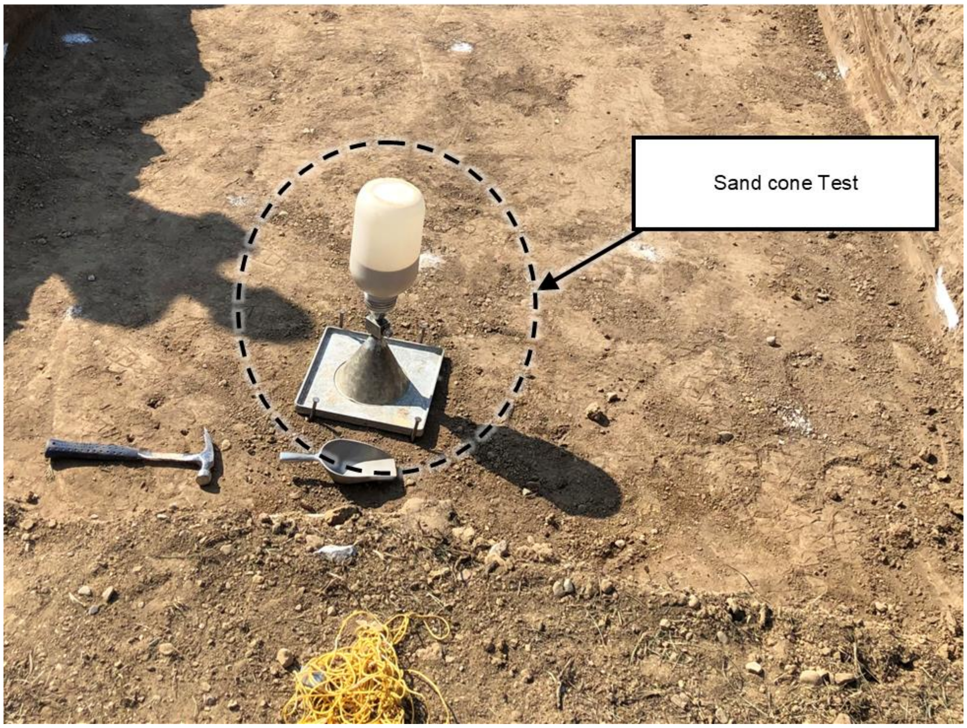


Figure 61. Typical sand cone test setup

In between lifts, the Contractor shall repair all structure backfill displacements and rutting prior to placing subsequent material. Structure backfill will settle during and shortly after construction, so MSE wall system vendors recommend bringing backfill up to about 2 in. above soil reinforcement levels (Figure 62). The Inspector should verify the following:

- That structure backfill displacements and rutting are repaired before placing subsequent lifts
- That structure backfill placement follows recommendations from the MSE wall system vendor

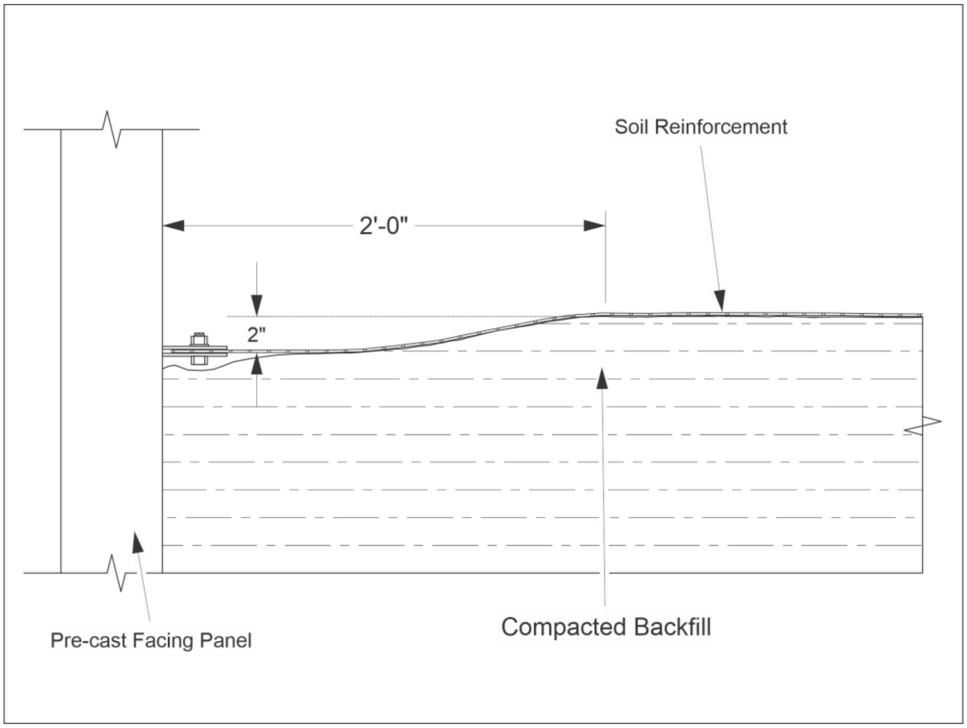


Figure 62. Recommended compacted backfill height relative to soil reinforcement connection to account for backfill settling shortly after construction

4.3.3.8 Placing First Course of Soil Reinforcements

INDOT Standard Specification 731.09 details requirements for placing MSE wall soil reinforcements. In general, soil reinforcements shall be placed normal (i.e., both horizontally and vertically perpendicular) to MSE wall facings. However, obstructions within reinforced zones (e.g., bridge foundation piling) may prevent normal reinforcement placement. Shop drawings shall detail requirements for placing reinforcements near and around such obstructions. Soil reinforcements are typically skewed around obstructions where necessary, as shown in Figure 63 (vertical obstructions) and Figure 64 (horizontal obstructions). However, skewing might not be applicable for some reinforcement types, such as welded-wire mats. Maximum skew angle typically equals 15°, though shop drawings should indicate specific reinforcement skewing requirements. The Inspector should verify the following:

- That unobstructed soil reinforcements are placed normal to the MSE wall facing
- That soil reinforcements are placed around vertical and horizontal obstructions in accordance with the submitted MSE wall shop drawings
- That reinforcements requiring skewed placement are not skewed more than 15° (typical)

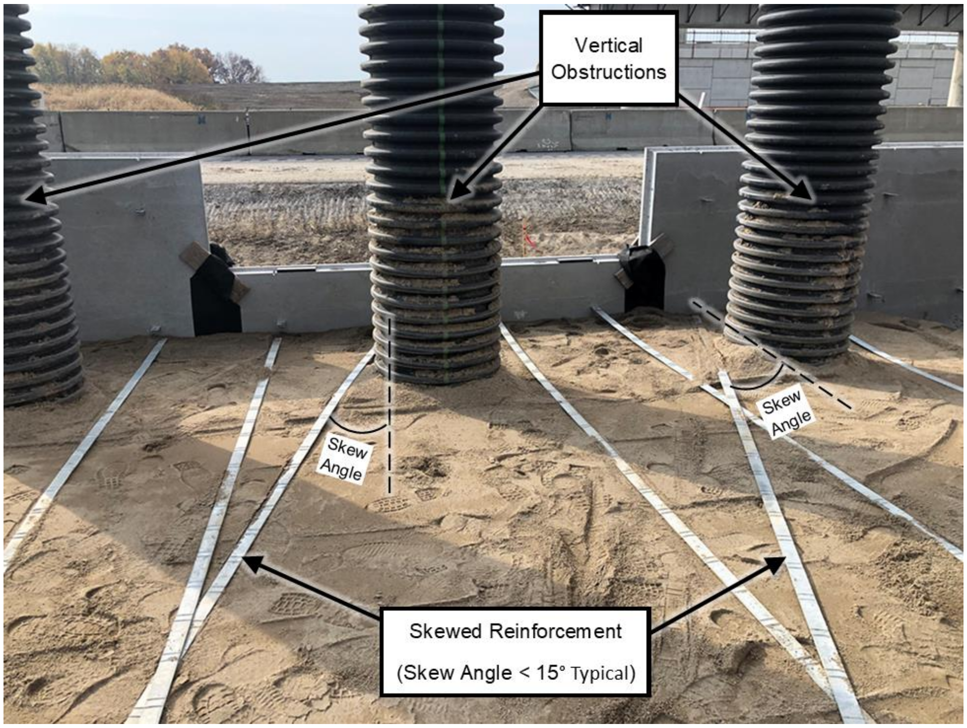


Figure 63. Example soil reinforcement skewing around vertical obstructions

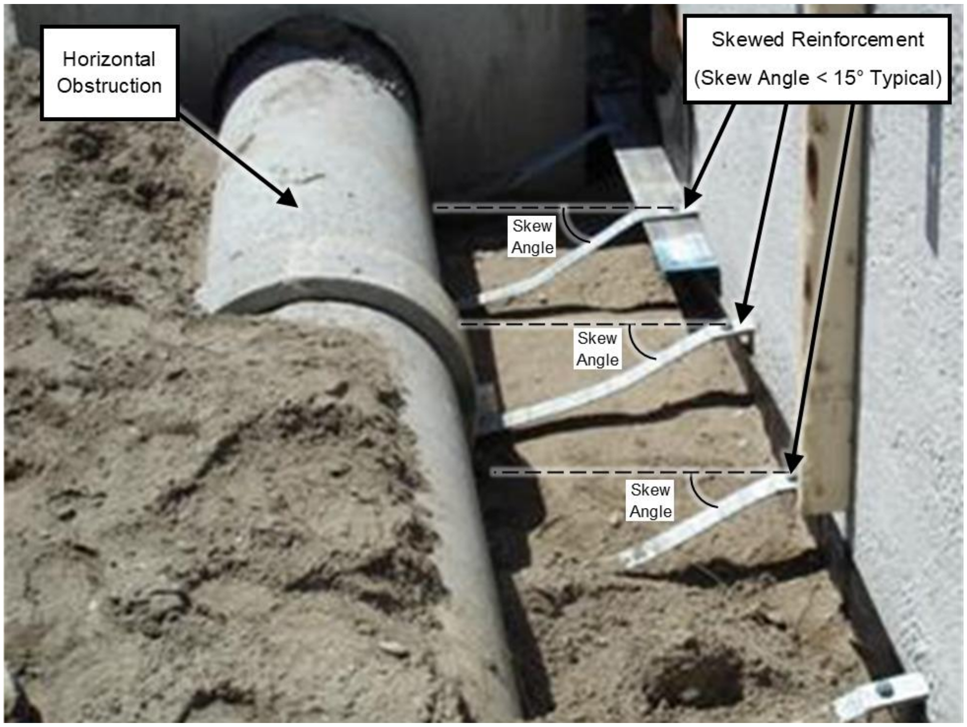


Figure 64. Example soil reinforcement skewing around horizontal obstruction

The basic structural sections of soil reinforcements shall not be cut or altered onsite, unless such cuttings or alterations are preplanned and detailed on the approved shop drawings. Structural sections of reinforcements might be cut or altered if an obstruction is too large for conventional obstruction accommodation procedures. In which case, adequate additional soil reinforcement shall be provided to produce the required strength shown in the approved calculations. Cut ends shall be covered with a galvanized paint or coal tar to prevent corrosion of the metal. The Inspector should verify the following:

- That soil reinforcements have not been cut or altered unless approved by the Engineer
- That, if soil reinforcement cuts or alterations have been approved, then the approved amount of additional soil reinforcements has been provided
- That any soil reinforcement cuts have been covered with a galvanized paint or coal tar

Soil reinforcements should be connected to pre-cast facing panels as detailed in the MSE wall system shop drawings. Strip-type soil reinforcements are typically connected using a single nut and bolt connection. Shown in Figure 65, reinforcement strips are inserted in between two exposed embedded panel tie strips with a nut and bolt tightly securing them together. MSE wall system vendors typically recommend that bolts be inserted from the bottom because it simplifies construction inspection. Indeed, Inspectors can easily verify whether the nut and bolt connections have been properly installed and whether they need to be tightened. Welded-wire-type soil reinforcements are typically secured to pre-cast facing panels using a locking pin. However, specific locking pin connection procedures tend to vary amongst different MSE wall systems using welded-wire reinforcements. For example, Figure 66 shows a welded-wire-type connection that requires driving a wooden wedge between the panel and the reinforcement to lock the reinforcement in place. In any case, the Inspector should verify that soil reinforcements are connected to pre-cast facing panels as detailed in the MSE wall shop drawings.

Soil reinforcements are easily damaged by construction equipment, so the Contractor should exercise care when backfilling over reinforcements by following guidance from the MSE wall system vendor. Many MSE wall system vendors recommend using the backfilling process shown in Figure 67. Structure backfill is placed parallel to the wall approximately 3 ft from the back of the pre-cast panels (Steps 1 and 2). The structure backfill is then spread toward the back of the reinforced zone (Step 3). Finally, the remaining backfill is spread toward the wall facing (Step 4). Figure 68 shows an example of appropriate backfilling of soil reinforcements operations. The Inspector should verify that soil reinforcements have not been damaged during backfilling operations.

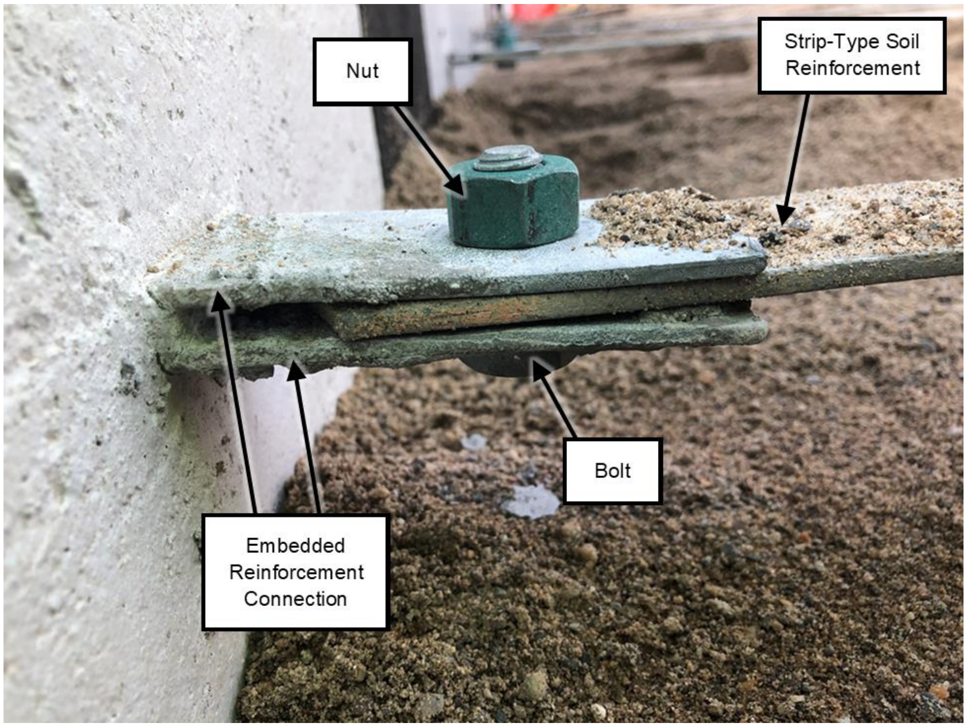


Figure 65. Example connection for strip-type soil reinforcements

Figure 66. Example connection for weld-wire-type soil reinforcement

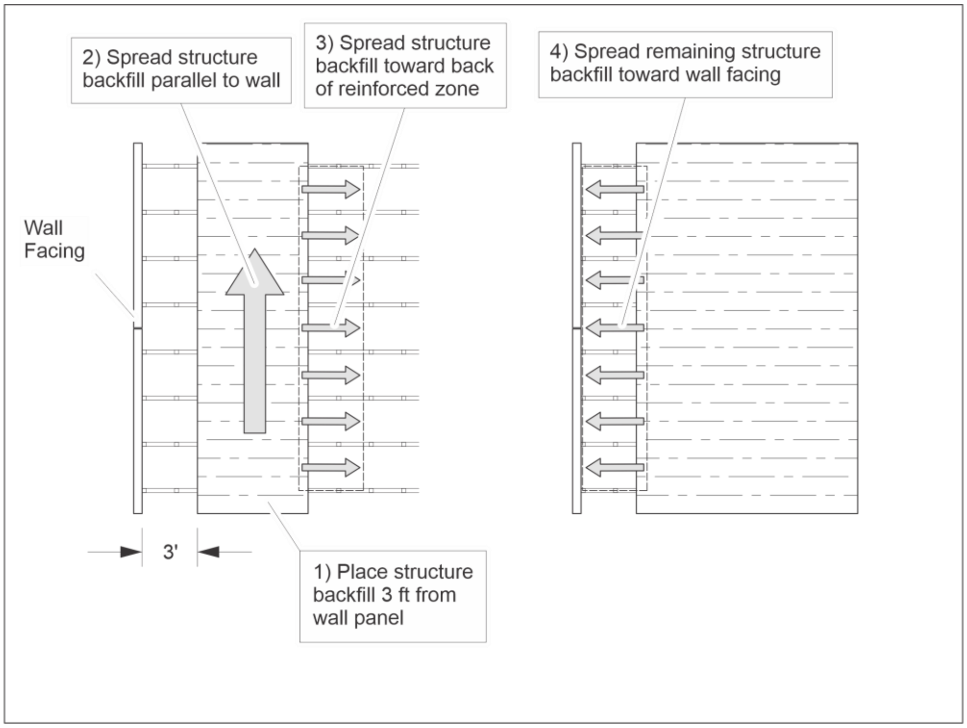


Figure 67. Typical procedure for placing backfill over soil reinforcements

Figure 68. Example of appropriate backfilling over soil reinforcements

Following its placement, backfill shall be compacted in accordance with ISS 731.11 (see Section 4.3.3.7 of this manual). Figure 69 provides guidance for appropriate backfill compaction over soil reinforcements. The compaction roller should travel parallel to the MSE wall beginning approximately 3 ft from the wall facing (Step 1). As compaction operations progress, the roller should move closer toward the back of the reinforced zone continuing to travel parallel with the wall facing (Step 3). Finally, the remaining 3 ft of structure backfill behind the pre-cast panels should be compacted using lightweight compaction equipment (e.g., vibratory plate compactor). With the first layer of reinforcements secured and backfilled, the initial panels course is stabilized, so the Contractor may place backfill within 12 in. of the back of the pre-cast panels (Figure 56). The Inspector should verify that backfill over soil reinforcement has been placed and compacted in accordance with ISS 731.11 (see Section 4.3.3.7 of this manual).

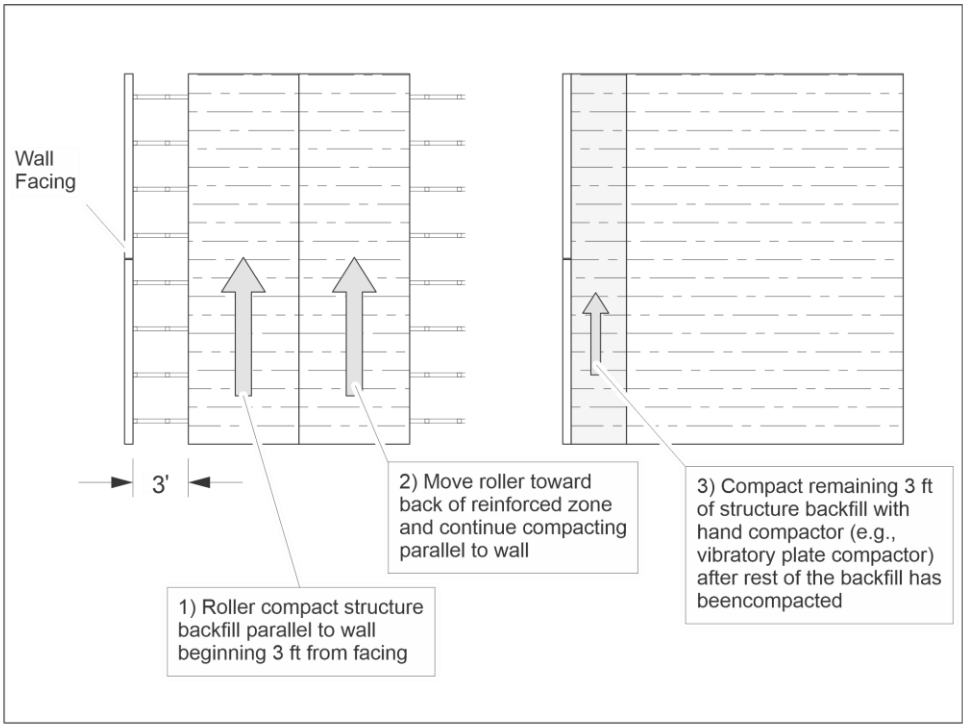


Figure 69. Typical procedure for compacting backfill place on top of soil reinforcements

4.3.4 <u>Placing Subsequent Panel Courses</u>

MSE wall system installation guidelines typically require that structure backfill reach the top of a pre-cast panel before placing its overlying panel. Indeed, placing a panel atop a panel that has not been completely backfilled can destabilize the MSE wall and induce panel misalignment. Because initial panel courses typically consist of alternating full- and half-panels, placement of the second panel course should be allowed to begin once the structure backfill level has reached the top of the half-panels. The Contractor should begin placing the second panel course and all subsequent panel courses from the same location where placement of the initial panel course began. The Inspector should verify that the Contractor has followed guidelines from the MSE wall system vendor for placing subsequent courses of panels.

4.3.4.1 Placing Bearing Pads

Before placing additional panel courses, the Contractor shall place bearing pads on top of each already placed panel as detailed in the shop drawings. Figure 70 shows an example placement of EPDM rubber-type bearing pads. Bearing pads prevent concrete-to-concrete contacts at horizontal panel joints and allow for panels to move during elastic compression and settlement of the reinforced fill. Shop drawings should indicate the number of bearing pads required for each horizontal joint as well as their required positioning (e.g., how far from the edge of the panel). Moreover, shop drawings might require different quantities or thicknesses of bearing pads at various levels within the MSE wall facing. Because bearing pads are designed to compress during the construction process, horizontal joints created by bearing pads might narrow during construction. The Inspector should verify that bearing pads have been placed at each horizontal panel joint in accordance with the MSE wall shop drawings.

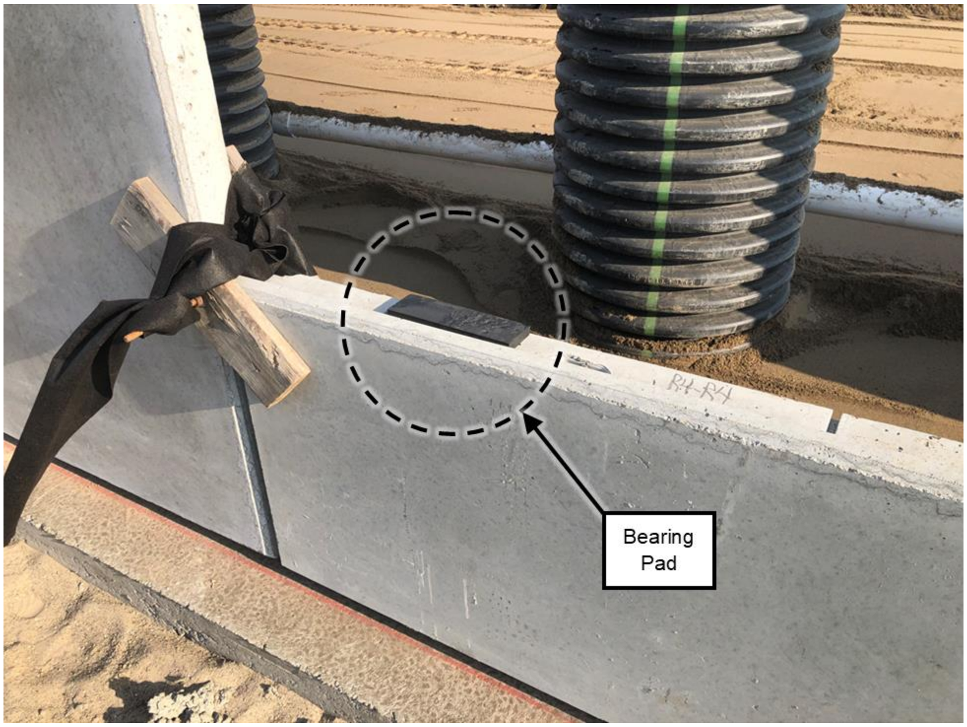


Figure 70. Example bearing pad placement

4.3.4.2 Placing Subsequent Panel Courses

Panels constituting the subsequent courses should be lifted, transported, and placed in accordance with section 4.3.3.1 of this manual. Though, panel clamps and bracing should be removed before placing the subsequent course of panels. Only a single pair of clamps over an entire panel course should be removed at a time. With panel clamps and bracing out of the way, the Contractor can place additional panels, as shown in Figure 71 for example. Proper panel positioning may be adjusted using a crowbar from the backfill side of the MSE wall. Panels should also be placed with an adequate amount of batter in accordance with 4.3.3.2 of this manual. Once panel position and batter has been set, the Contractor should secure the panel with a new pair of panel clamps before finally disconnecting the panel from rigging (Figure 72). Though INDOT standard specifications only specify bracing for panels in the initial course, MSE wall system vendors might recommend, or even require, bracing for subsequent panel courses (Figure 73 for example). Panel joints should be covered with geotextiles (Figure 74 for example) as required by the shop drawings (see 4.3.3.6 of this manual). The Inspector should verify that subsequent panel courses are placed following recommendations from the MSE wall system vendor (see Sections 4.3.3.1, 4.3.3.2, and 4.3.3.6 of this manual).

Figure 71. Example placement of subsequent panel course

Shop drawings will specify different panel types (sizes and aesthetics) across the MSE wall that are denoted by an identification number. The different panel types must be placed in accordance with MSE wall shop drawings. Pre-casters will typically etch the identification numbers into panels during casting (Figure 75 for example). The Inspector should verify that panel positioning (row and column) follows shop drawing details.

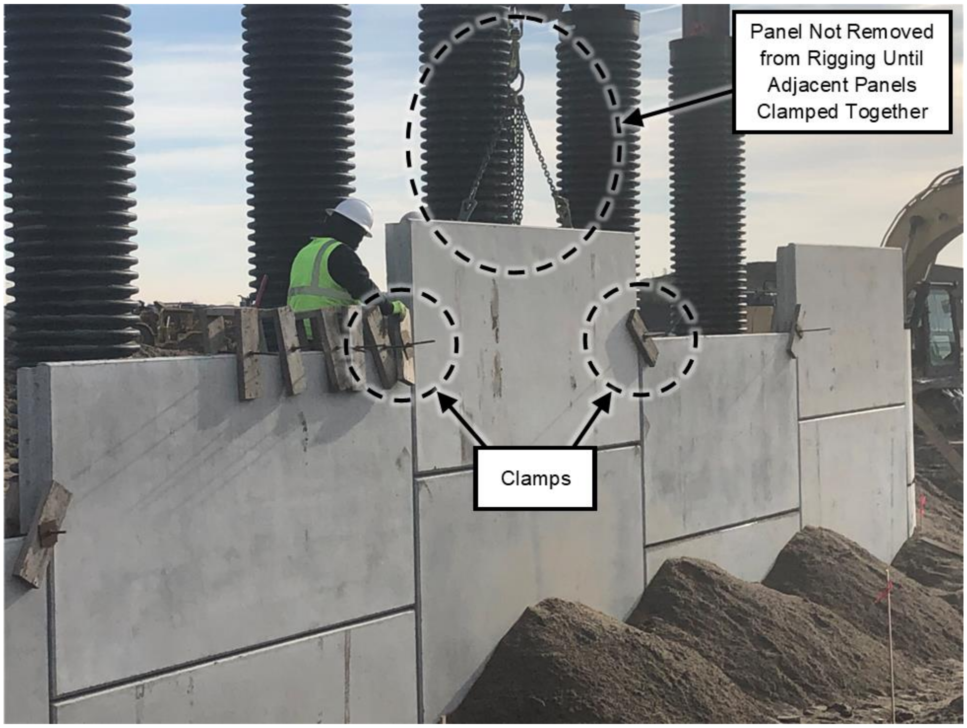


Figure 72. Securing adjacent panels with panel clamps

Figure 73. Example bracing of subsequent panel courses

Figure 74. Example of subsequent panel coures joints covered with geotextiles

Figure 75. Example panel identification number etched into concrete

4.3.4.3 <u>Placing Subsequent Backfill and Soil Reinforcements Courses</u>

Placement of structure backfill and soil reinforcement continues with the placement of pre-cast facing panel courses. Subsequent lifts of structure backfill should be placed and compacted in a similar manner with the initial lifts of structure backfill (see Section 4.3.3.7 of this manual). Figure 76 shows an example of compacted structure backfill placement during MSE wall construction. Likewise, subsequent courses of soil reinforcements should be placed and connected in a similar manner with the initial course of soil reinforcements (see Section 4.3.3.8 of this manual). Figure 77 shows an example of soil reinforcement placement during MSE wall construction. The Inspector should verify that subsequent courses of structure backfill and soil reinforcements are placed in accordance with INDOT standard specifications and following recommendations from the MSE wall system vendor (see Sections 4.3.3.7 and 4.3.3.8 of this manual).

At the end of each day's operation, ISS 731.11 requires that the Contractor shall grade the structure backfill away from the MSE wall facing. The sloped structure backfill prevents surface water from accumulating at the MSE wall facing, which can cause panels to move out of alignment. Moreover, ISS 731.11 requires that surface runoff from adjacent areas shall not enter the wall MSE wall construction site. The Inspector should verify that MSE wall structure backfill and facing are protected from surface water runoff during construction.

Figure 76. Example structure backfill placement

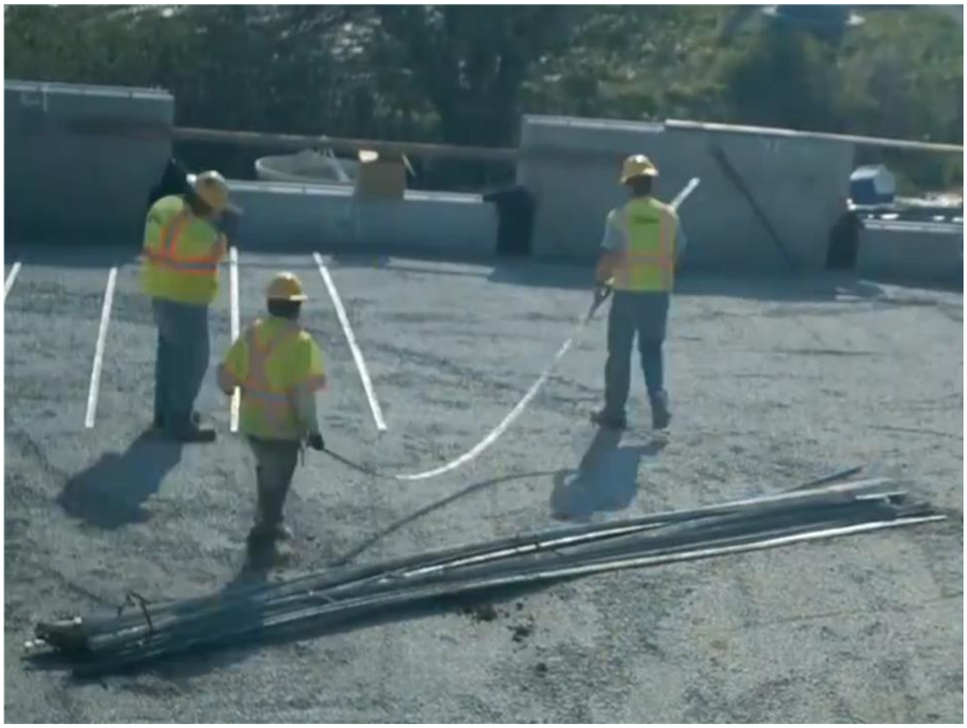


Figure 77. Example soil reinforcement placement

4.3.4.4 Installing Internal Drain

Some MSE walls will require installation of an internal drainage system (for example Figure 78) as detailed on road/bridge plans. ISS 731.08 requires that internal drainage systems consist of 6 in. type 4 underdrain pipe placed in accordance ISS 718. Though INDOT allows for different type 4 pipe materials, Contractors typically elect to use thermoplastic pipe. Only qualified thermoplastic pipe materials shall be used for internal drainage systems[5]. Drainage pipe shall be installed within either No. 8 or No. 9 class E (see ISS 904.03(a)) course aggregate. Road/bridge plans will detail the required limits for drainage system aggregate (example Figure 28). Aggregate shall be compacted in accordance with ISS 302.06(b) that requires using a roller in accordance with ISS 409.03(d)4 or, where large equipment is inaccessible, specialty equipment in accordance with ISS 409.03(d)7. The internal drainage system shall be encapsulated using a geotextile meeting the requirements specified in ISS 918.02(b) (i.e., geotextiles for underdrains and drainage applications). Road/bridge plans will detail the required geotextile type for the internal drainage system. Only qualified geotextile materials shall be used for internal drainage systems[6]. Video inspection is not required for internal drainage systems. The Inspector should verify the following:

- Whether the road/bridge plans require installing an internal drainage system for the MSE wall
- That the internal drainage system is constructed as detailed on the road/bridge plans and in accordance with INDOT standard specifications

[5]A list of qualified thermoplastic pipe can be found on the INDOT Division of Materials and Tests website (**https://www.in.gov/indot/div/mt/appmat/appmat.htm**)

[6]A list of qualified geotextile materials can be found on the INDOT Division of Materials and Tests website (**https://www.in.gov/indot/div/mt/appmat/appmat.htm**)

- That only qualified materials have been used for internal drainage system pipe and geotextiles

Figure 78. Example internal drainage system

4.3.4.5 Placing Wall Embedment

The Contractor should place the MSE wall embedment (for example Figure 79) as soon as feasibly possible to minimize the risk of erosion beneath the leveling pad. Though INDOT standard specifications do not specify requirements for embedment construction, MSE wall system vendors typically recommend that embedments be placed before walls reach one-half their total height or 20 ft tall, whichever is less. Road/bridge plans will detail embedment requirements including backfill material and backfill limits. All temporary construction materials (e.g., wooden spacers) should be removed from MSE wall facing panels before placing the embedment. The Inspector should verify that the embedment has been placed in accordance with the road/bridge plans and with guidelines from the MSE wall system vendor.

Figure 79. Example wall embedment

4.3.4.6 Removing Wooden Wedges

Wooden wedges for maintaining panel batter (see Section 4.3.3.2) should remain in place for as long as possible during MSE wall construction. MSE wall system vendors typically recommend that no more than one or two full-height panels be placed atop wooden wedges at any time during construction (Figure 80 for example). Indeed, removing wooden wedges without damaging pre-cast panels becomes more difficult as more courses of panels are placed (i.e., more weight pressing down on wedges). Typically, 2 to 3 rows of panel wedges should remain in place at all times during MSE wall construction. All wooden wedges must be removed when wall construction is complete (i.e., coping has been placed). If the Contractor has elected to use wooden wedges in MSE wall construction, then the Inspector should verify that the wedges are removed following guidelines from the MSE wall system vendor.

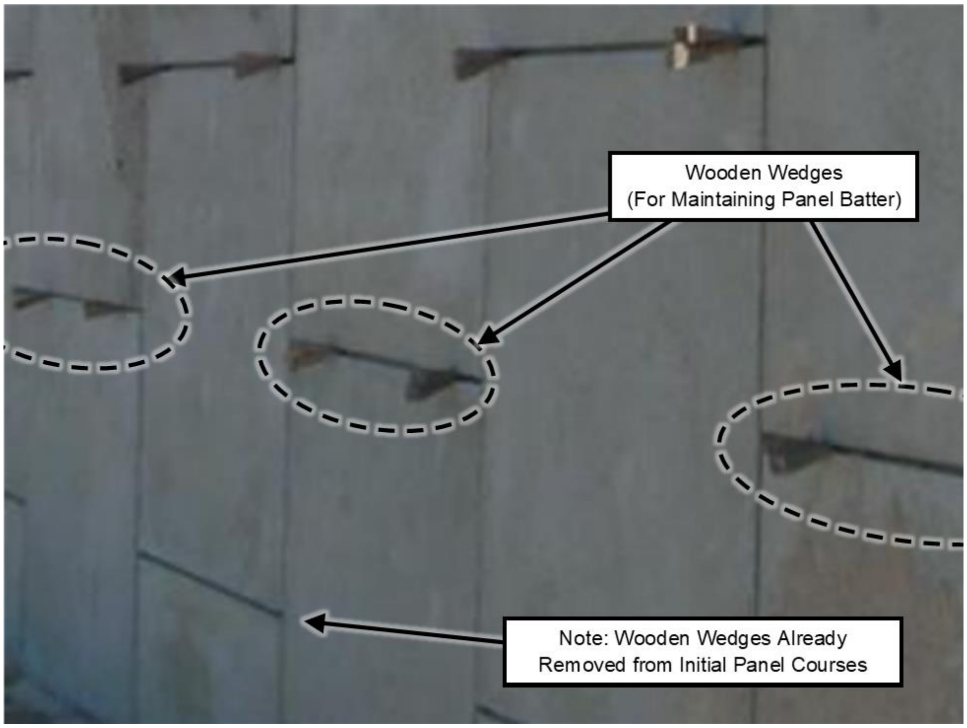


Figure 80. Removing wooden wedges during construction

4.3.4.7 Checking Panel Alignments and Joint Spacing

ISS 731.09 requires that the Contractor shall regularly check panel alignments—vertical (i.e., plumb) and horizontal (i.e., level)—during MSE wall construction (Figure 81). Alignment shall be checked at each layer of panels after the backfill behind the panels has been compacted, and the results shall be recorded. Plumb, vertical alignment tolerances, and horizontal alignment tolerances shall not exceed ¾ in. as measured with a 10 ft straightedge. The maximum allowable offset in panel joints shall be 3/4 in. For a wall of over 10 ft height, the overall plumb from top to bottom of the wall shall not exceed 0.05 in./ft of wall height. Corrective action should be taken immediately when any of the specified tolerances are exceeded. The Inspector should verify the following:

- That the Contractor is regularly checking and recording panel alignments—plumb, vertical, and horizontal—and joint spacings
- That panel alignments do not exceed tolerances specified in ISS 731.09

Figure 81. Checking panel alignments

4.3.5 <u>Final Panel Course and Coping</u>

MSE wall construction is completed with the placement of the final panel course and the coping. Pre-cast coping must be placed atop flat panel surfaces. In many cases, the flat surface will need to be formed using pre-cast concrete, as shown in Figure 82. Cast-in-place coping is placed at locations where pre-cast coping cannot be accommodated, such as at wall corners or adjacent to cast-in-place structures. Figure 83 provides an example of cast-in-place coping formwork. The inspector should verify the following:

- That the tops of panels constituting the final panel course are flat and level prior to placing coping
- That pre-cast coping sections are placed atop the final course of panels where appropriate
- That cast-in-place coping is placed atop the final course of panels where pre-cast coping cannot be accommodated

Figure 82. Example of using cast-in-place concrete to flatten and level out the final panel course

Figure 83. Example of formwork for pouring cast-in-place coping

5.0 Additional Construction Considerations

Inspectors should be aware of the following considerations—construction loads, wall-adjacent excavations, and temporary walls—that have implications on MSE wall construction and performance. Though they are not exclusive to all MSE wall construction contracts, they are not uncommon to occur.

5.1 Construction Loads

Fully installed MSE walls may need to support heavy temporary loadings during construction operations for nearby assets. For example, an MSE wall located at a bridge end bent may need to support a crane for placing bridge beams. Such temporary MSE wall loadings might already be identified in road/bridge plans, though more likely they will not be identified until the Contractor has performed their construction engineering after contract awarding. For either case, the Contractor and MSE wall system vendor should verify that the MSE wall can safely support any temporary construction loadings.

5.2 Walls-Adjacent Excavations

Excavating adjacent to existing MSE walls can destabilize foundations leading to excessive wall settlements and possibly even catastrophic wall failures. An engineer should approve any excavation adjacent to an existing wall before beginning excavation operations.

5.3 Temporary Walls

Road/bridge plans might require constructing temporary MSE walls. Such walls are typical in phased construction to allow for traffic to travel atop walls before the end of construction. Temporary walls typically have facings consisting of welded-wire or geotextile fabric wrapping. The temporary wall facings are covered up at a later date with a permanent facing (e.g., pre-cast facing panels). MSE wall shop drawings should provide details for installing temporary walls and ultimately covering them up.

Appendix A: MSE Wall Inspection Checklist

		Yes	No	NA
MSE Wall System Procurement				
1.1	The Contractor has selected a pre-approved MSE wall system from INDOT’s qualified products list (QPL) of approved retaining wall systems			
1.2	The Contractor has submitted project specific MSE wall shop drawings and design calculations that satisfy ISS 105.02 and ISS 731.04 (see Section 3.2 of this Manual)			
1.3	INDOT Engineers, including INDOT Division of Geotechnical Engineering, have provided written notice approving MSE wall submittals			
MSE Wall Construction: Preconstruction Activities				
2.1	Pre-cast components (facing panels and copings) have been properly stored onsite in accordance with INDOT specifications and MSE wall system vendor recommendations (see Section 4.2.1 of this Manual)			
2.2	Soil reinforcements have been properly stored onsite in accordance with INDOT specifications and MSE wall system vendor recommendations (see Section 4.2.2)			
2.3	Fasteners, bearing pads, and geotextile joint covering materials have been properly stored onsite in accordance MSE wall system vendor recommendations (see Section 4.2.3 of this Manual)			
MSE Wall Construction: Foundation Preparation				
3.1	Excavation operations are being conducted in accordance with ISS 201.03 and ISS 731.04 (see Section 4.3.1.1 of this Manual)			
3.2	Excavation operations abide by State and local safety requirements (see Section 4.3.1.1 of this Manual)			
3.3	Excavations requiring support systems have been properly shored or braced (see Section 4.3.1.1 of this Manual)			
3.4	Water has been appropriately removed from excavations (see Section 4.3.1.1 of this Manual)			

		Yes	No	NA
3.5	Excavation operations do not endanger stability of the future MSE wall (see Section 4.3.1.1 of this Manual)			
3.6	Foundation soils deemed unsuitable by the Engineer have been removed and replaced with B Borrow (see Section 4.3.1.1 of this Manual)			
3.7	Replacing B Borrow has been compacted to at least 95% maximum dry density based on DCP blow count criteria in ISS 203.23 (see Section 4.3.1.1 of this Manual)			
3.8	The foundation has been compacted in accordance with ISS 203 (see Section 4.3.1.2 of this Manual)			
3.9	The width of the foundation equals or exceeds the length of prescribed soil reinforcement units (see Section 4.3.1.2 of this Manual)			
3.10	The foundation has been graded as detailed in the road/bridge plans (see Section 4.3.1.2 of this Manual)			
3.11	The foundation has been graded with a 1 in per 1 foot downward slope toward the back of the reinforced zone (see Section 4.3.1.2 of this Manual)			
3.12	That the portion of foundation below the leveling pad is level graded (see Section 4.3.1.2 of this Manual)			
3.13	The contractor has proofrolled the MSE wall foundation using an appropriately sized on-highway dump truck in accordance with ISS 203.26 (see Section 4.3.1.3 of this Manual)			
3.14	Locations failing proofrolling have been appropriated remediated as directed by the Engineer (see Section 4.3.1.3 of this Manual)			
3.15	DCP tests of the foundation advanced to 30 in. deep yield blow count measurements equal to or greater than 5 blows per 6 in. (see Section 4.3.1.4 of this Manual)			
3.16	Foundation soils where DCP tests yielded failing blow count measurements have been removed and replaced with compacted B Borrow (see Section 4.3.1.4 of this Manual)			
3.17	DCP measured factored bearing resistances (see INDOT Construction Memorandum 15-08) meet or exceed the factored bearing resistance detailed on the shop drawings Borrow (see Section 4.3.1.4 of this Manual)			

		Yes	No	NA
Leveling Pad Placement				
4.1	Soil underneath the leveling pad has been compacted in accordance with ISS 203 (see Section 4.3.2 of this Manual)			
4.2	The Engineer has approved the prepared foundation elevations along the length of the leveling pad (see Section 4.3.2 of this Manual)			
4.3	The leveling pad has been cast using unreinforced concrete as detailed on the shop drawings (see Section 4.3.2 of this Manual)			
4.4	The leveling pad has cured in accordance with ISS 702.22 for at least 12 hours (see Section 4.3.2 of this Manual)			
4.5	Leveling pad top elevations meet tolerances recommended by the MSE wall system vendor (see Section 4.3.2 of this Manual)			
4.6	Leveling pad step-ups (i.e., where leveling pad elevation changes) have been constructed in accordance with recommendations from the MSE wall system vendor (see Section 4.3.2 of this Manual)			
Placement of the Initial Panel Course				
5.1	MSE wall pre-cast components (facing panels and copings) have been cast with lifting connections set into their upper edges (see Section 4.3.3.1 of this Manual)			
5.2	Panels are being lifted and transported from onsite storage in accordance with recommendations from the MSE wall system vendor (see Section 4.3.3.1 of this Manual)			
5.3	Procedures for placing panels on the leveling pad are not causing undue damage to the panels (see Section 4.3.3.1 of this Manual)			
5.4	Panels placed on the leveling pad are in alignment with the wall layout line detailed on the shop drawings (see Section 4.3.3.1 of this Manual)			
5.5	Panels placed on the leveling pad are horizontally level determined using a 4-ft level (see Section 4.3.3.1 of this Manual)			

		Yes	No	NA
5.6	Panels place on the leveling pad that require shimming have been shimmed in accordance with guidelines from the MSE wall system vendor (see Section 4.3.3.1 of this Manual)			
5.7	Panels place on the leveling pad have been battered toward the back of the MSE wall in accordance with recommendations from the MSE wall system vendor (see Section 4.3.3.2 of this Manual)			
5.8	Where needed, temporary wooden wedges have been used to maintain the batter for panels placed on the leveling pad (see Section 4.3.3.2 of this Manual)			
5.9	The Contractor is monitoring panel movement during construction and adjusting the degree of panel battering accordingly (see Section 4.3.3.2 of this Manual)			
5.10	Panels within the initial panel course have been braced following guidelines from the MSE wall system vendor (see Section 4.3.3.3 of this manual)			
5.11	Panels have been placed with ¾ in. wide vertical joints separating them per INDOT standard specifications (see Section 4.3.3.4 of this Manual)			
5.12	Appropriate joint spacers using materials consistent with MSE wall shop drawings have been used (see Section 4.3.3.4 of this Manual)			
5.13	Adjacent panels within the initial course have been clamped together following recommendations from the MSE wall system vendor (see Section 4.3.3.4 of this Manual)			
5.14	Panels have been placed within a ¾ in. in 10 ft horizontal alignment tolerance (see Section 4.3.3.5 of this Manual)			
5.15	Any panels deemed to be out-of-tolerance have been properly adjusted following recommendations from the MSE wall system vendor (see Section 4.3.3.5 of this Manual)			
5.16	Panel joints (both horizontal and vertical) have been covered with MSE wall system vendor supplied geotextile fabric and adhesive (see Section 4.3.3.6 of this Manual)			
5.17	Geotextile fabric has been affixed to the backside of wall panels as detailed in the shop drawings (see Section 4.3.3.6 of this Manual)			
5.18	Structure backfill backfilling operations are neither damaging nor disturbing pre-cast facing panels (see Section 4.3.3.7 of this Manual)			

		Yes	No	NA
5.19	Pre-cast facing panels that are damaged or misaligned during backfilling are either corrected or removed and replaced, as directed by the Engineer (see Section 4.3.3.7 of this Manual)			
5.20	Appropriate compaction equipment is being used to compact the structure backfill, i.e., full-sized rollers are not compacting within 3 ft of the pre-cast facing panels (see Section 4.3.3.7 of this Manual)			
5.21	Loose lifts of structure backfill do not exceed 8 in. thick where full-sized vibratory rollers will be used for compaction operations (see Section 4.3.3.7 of this Manual)			
5.22	Loose lifts of structure backfill do not exceed 5 in. thick where lightweight compactors (e.g., vibratory plate compactors) will be used for compaction operations (see Section 4.3.3.7 of this Manual)			
5.23	Compaction operations using full-sized vibratory rollers consist of four passes in vibratory mode followed by one pass in static mode (see Section 4.3.3.7 of this Manual)			
5.24	Compaction operations using lightweight compactors consist of no less than 5 passes (see Section 4.3.3.7 of this Manual)			
5.25	Either DCP testing (ISS 203.23) or sand-cone testing (ISS 203.24) has been selected for structure backfill compaction acceptance (see Section 4.3.3.7 of this Manual)			
5.26	DCP blow counts on the compacted structure backfill meet or exceed minimum criteria per ISS 203.23 (see Section 4.3.3.7 of this Manual)			
5.27	Compacted structure backfill dry densities meet or exceed 95% relative compaction (see Section 4.3.3.7 of this Manual)			
5.28	Structure backfill displacements and rutting are repaired before placing subsequent lifts (see Section 4.3.3.7 of this Manual)			
5.29	Structure backfill placement follows recommendations from the MSE wall system vendor (see Section 4.3.3.7 of this Manual)			
5.30	Unobstructed soil reinforcements are placed normal (perpendicular) to the MSE wall facing (see Section 4.3.3.8 of this Manual)			
5.31	Soil reinforcements are placed around vertical and horizontal obstructions in accordance with the submitted MSE wall shop drawings, i.e., skewed (see Section 4.3.3.8 of this Manual)			

		Yes	No	NA
5.32	Skewed soil reinforcements are not skewed more than 15° (see Section 4.3.3.8 of this Manual)			
5.33	Soil reinforcements have not been cut or altered unless approved by the Engineer (see Section 4.3.3.8 of this Manual)			
5.34	The approved amount of additional soil reinforcements has been provided to compensate for Engineer approved cut or altered soil reinforcements (see Section 4.3.3.8 of this Manual)			
5.35	Cut or altered soil reinforcements have been covered with a galvanized paint or coal tar (see Section 4.3.3.8 of this Manual)			
5.36	Soil reinforcement have been connected to pre-cast facing panels as detailed in the MSE wall shop drawings (see Section 4.3.3.8 of this Manual)			
5.37	Soil reinforcements have not been damaged during backfilling operations (see Section 4.3.3.8 of this Manual)			
5.38	Structure backfill over soil reinforcements has been placed and compacted in accordance with ISS 731.11 (see Section 4.3.3.8 of this Manual)			
Placement of Subsequent Panel Courses				
6.1	Bearing pads have been placed at each horizontal panel joint in accordance with the MSE wall shop drawings (see Section 4.3.4.1 of this Manual)			
6.2	Subsequent panel courses are placed following recommendations from the MSE wall system vendor (see Section 4.3.4.2 of this manual)			
6.3	Locations for different pre-cast panel types (size and texture) are in accordance with MSE wall shop drawings (see Section 4.3.4.2 of this manual)			
6.4	Subsequent panel courses and soil reinforcements have been placed and backfilled in accordance with items 5.8 to 5.38 of this checklist			
6.5	Before concluding work for the day, the Contractor has graded the structure backfill away from the MSE wall facing (see Section 4.3.4.3 of this manual)			

		Yes	No	NA
Ancillary construction—internal drain, wall embedment, removing wooden wedges				
7.1	The internal drainage system is constructed as detailed on the road/bridge plans and in accordance with INDOT standard specifications (see Section 4.3.4.4 of this manual)			
7.2	Only qualified materials (e.g., geotextiles) have been used for internal drainage system pipe and geotextiles (see Section 4.3.4.4 of this manual)			
7.3	The wall embedment has been placed in accordance with the road/bridge plans and with guidelines from the MSE wall system vendor (see Section 4.3.4.5 of this Manual)			
7.4	Wooden wedges used for maintaining panel batter are being removed following guidelines from the MSE wall system vendor (see Section 4.3.4.6 of this manual)			
Checking Panel Alignments and Joint Spacing				
8.1	The Contractor is regularly checking and recording panel alignments—plumb, vertical, and horizontal—and joint spacings (see Section 4.3.4.7 of this manual)			
8.2	Panel alignments (plumb, vertical alignment, and horizontal alignment) do not exceed the tolerances specified in ISS 731.09 (see Section 4.3.4.7 of this manual)			
Final Panel Course and Coping				
9.1	The tops of panels constituting the final panel course are flat and level prior to placing coping (see Section 4.3.5 of this manual)			
9.2	Pre-cast coping sections are placed atop the final course of panels where appropriate (see Section 4.3.5 of this manual)			
9.3	Cast-in-place coping is placed atop the final course of panels where pre-cast coping cannot be accommodated (see Section 4.3.5 of this manual)			

Appendix B: Out-of-Tolerance Conditions and Possible Causes

Reference:

Berg, R. R., Christopher, B. R., & Samtani, N. C. (2009). *Design and Construction of Mechanically Stabilzed Earth Walls and Reinforced Soil Slopes, Volume II (FHWA-NHI-10-025).* Washington, D.C.: Federal Highway Administration.

MSEW 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.

OUT-OF-TOLERANCE CONDITION	**POSSIBLE CAUSE(S)**
1. Distress in wall (differential settlement or low spot in wall)	• Foundation (subgrade) material too soft or wet for proper bearing • Fill material of poor quality or not properly compacted
2. Distress in wall (overall wall leaning beyond vertical alignment tolerance)	• Foundation (subgrade) material too soft or wet for proper bearing • Fill material of poor quality or not properly compacted
3. Distress in wall (spalling, chipping, or cracking of facing units, e.g. from panel to panel contact)	• Foundation (subgrade) material too soft or wet for proper bearing • Fill material of poor quality or not properly compacted • Inadequate spacing in horizontal and vertical joints • Use of improper bearing pads • Stones or concrete pieces between facing units (e.g., units not clean or used level to face units)
4. First panel course difficult (or near impossible) to set and/or maintain level	Leveling pad not level

OUT-OF-TOLERANCE CONDITION	**POSSIBLE CAUSE(S)**
5. Wall out of vertical alignment tolerance (plumbness), or leaning out	• Panel not battered sufficiently • Oversized compaction equipment working within 3 ft (1 m) of wall facing panels • 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) • Backfill materials pushed against back of facing panel before being placed and compacted above reinforcing elements • Excessive compaction of uniform, medium-fine sand (more than 60% passing the No. 40 sieve) **Note:** If the fill material has greater than 60% passing the No. 40 sieve, then it likely does not meet INDOT specifications for type 3 structure backfill • Backfill material dumped close to free end of reinforcing elements, then spread toward wall face, causing displacement of reinforcements and pushing panel out • Panel wedges not seated securely • Panel clamps not tight • Slack in reinforcement to facing connections
6. Wall out of vertical alignment tolerance (plumbness), or leaning in	• Excessive batter set in panels for structure backfill type being used • Inadequate compaction of backfill • Possible bearing capacity failure
7. Wall out of horizontal alignment tolerance, or bulging	• 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) • Backfill materials pushed against back of facing panel before being placed and compacted above reinforcing elements • Excessive compaction of uniform, medium-fine sand (more than 60% passing the No. 40 sieve) **Note:** If the fill material has greater than 60% passing the No. 40 sieve, then it likely does not meet INDOT specifications for type 3 structure backfill • Backfill saturated by heavy rain or improper grading of backfill after each day's operations

OUT-OF-TOLERANCE CONDITION	**POSSIBLE CAUSE(S)**
8. Panels do not fit properly in their intended locations	• Panels are not level due to differential settlement (see causes for out-of-tolerance conditions 1 and 2) • Panel cast beyond tolerances **Typical Tolerances for Pre-cast Panels** ○ Overall dimensions: ± ½ in. ○ Connection device locations: ± 1 in. ○ Clevis loop embeds: ± ⅛ in. horizontal alignment ○ Element squareness: ± ½ in. difference between diagonals ○ Surface finish (smooth surface): ± ⅛ in. in 5 ft ○ Surface finish (textured surface): ± 5/16 in. in 5 ft
9. Large variations in movement of adjacent panels	• Backfill material not uniform • Backfill compaction not uniform • Inconsistent setting of facing panels

Appendix C: List of Additional Resources

INDOT Standard Specifications

INDOT General Instructions to Field Employees

INDOT Design Manual

INDOT Qualified Products List and Qualified Sources Lists

INDOT Geotechnical Engineering Division

INDOT Division of Research & Development

Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Volume I (FHWA-NHI-10-024) and Volume II (FHWA-NHI-10-025)